Advanced Technology
Distribution Market Demonstration and Analysis
Final Project Report

Developed by
SCE Transmission & Distribution, Advanced Technology
Organization

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Preface

1 Executive Summary

SCE, in its recently released whitepaper “The Emerging Clean Energy Economy,” outlined a vision to accelerate the transition to a clean, reliable energy future that includes a high penetration of distribution energy resources (DERs), by facilitating customer choice of new technologies, creating opportunities for DERs to provide grid services, and modernizing the grid to ease integration and optimization of DERs.

As customers connect increasing amounts of DERs to the electric grid, the grid has been rapidly evolving. However, in order to facilitate and accommodate a high penetration of DERs, a modernized grid is needed, both technically and business-wise.

On one hand, a modernized grid needs to support multi-directional power flows from these DERs, while being resilient enough to mitigate voltage and power quality issues resulting from these DERs. To facilitate the design and planning of this evolving grid, SCE has identified the need for new advanced distribution circuit modeling tools as a necessary foundational technology solution. SCE leveraged EPIC funds allocated to Distribution Planning Tool project to conduct two sub-projects that have related objectives. The first sub-project focused on developing advanced modeling functions by leveraging GridLAB-D, an open-source research simulation software with the ability to model behind-the-meter resources and demands, created by the U.S. Department of Energy’s Pacific Northwest National Lab, GridLABD (GLD). SCE contracted, Battelle, a non-profit, Federally Funded Research and Development Corporation (FFRDC), to develop new GLD modules and to assist SCE with developing new distribution models.

This sub-project was partially successful with Battelle completing approximately 50% of the planned work. In total, Battelle developed four of the originally 8 planned GLD modules and assisted SCE with successfully developing 30 distribution models. The original project scope called for Battelle to define, implement and validate 8 new GLD modules, enhance SCE’s ‘CYME to GLD’ conversion tool and to support SCE with developing 30 GLD distribution models.

The GLD modules that were completed include:

- Commercial module capable of simulating commercial loads and commercial demand response
- Valuation framework to calculate locational value of DERs
- Enhancements to Energy Storage module
- Enhancements to Electric Vehicle module.

The planned features that were not developed included:

- Volt/VAR module
- Advanced inverter modules
- Cloud cover modules
- Modified Market Module,
- Energy Management System/ Distributed Resource Energy Management System, (EMS/DREMS).

Of the four modules developed, only the Commercial module was validated. The validation results show that the Commercial model predicts monthly usage to within 20% of actual usage. SCE validated the demand response portion of the Commercial module and results show that the demand response function performs poorly and is not currently suitable for planning purposes. The other modules, the Valuation Framework, Energy Storage and Electric Vehicle were not validated.

Both technical and human resource issues negatively affected the outcome of this project. The development of some modules proved more technically challenging than originally anticipated, resulting in project delays. SCE ultimately terminated the contact with Battelle after the lead developer, working on this project, resigned from Batelle. SCE concluded that the risk of the remaining portions of the sub-project not be properly implemented was too great.

The valuation pipeline tool can help to develop incentive structures that would compensate customers based on the locational value of their DER. This also supports the legislative requirement in AB 327 to capture the locational values of DERs. The Electric Vehicle and Energy Storage modules will also help to enhance planning capabilities by simulating more realistic charging schedules. The 30 distribution models have already provided value as they were used in a core research project to study the impacts of high PV penetration and to determine the optimal set of mitigation strategies to enable 100% PV penetration using representative circuits used in the research study.

On the other hand, a modernized grid also needs to provide transparent information for customers to understand the system condition and their options for easy and economic DER adoption and development. SCE has identified the need of sharing the hosting capacity information to the public for this purpose.

In this second sub-project, SCE demonstrated a fully dynamic DER hosting capacity analysis which would determine the hosting capacities at circuit nodes based on limiting categories of thermal rating, power quality and voltage criteria, protection coordination requirements, safety and reliability, as well as substation limitations. The demonstration evaluated two different methodologies using the existing distribution planning tool CYMDIST but with newly developed function modules, within two distinct distribution planning areas and under various power flow scenarios and loading conditions.

The first methodology, referred to as the Streamlined Method, was to perform one power flow simulation for each scenario and then extract quantities from the power flow simulation and insert them into the streamlined equations to determine the hosting capacities for each of the limiting categories. The second methodology, referred to as the Iterative Method, was to utilize iterative power flow simulations to determine the hosting capacities for each of the limiting categories. Considering the balance of accuracy of results and computational time requirements, SCE proposed a Blended Method for initial implementation of hosting capacity calculations across the SCE service territory. This method would use the Iterative Method on the typical 24-hour, light-load day in an annual period, which yields the necessary information required under the existing Rule 21 process, while developing a full 576 hourly (typical high load day and typical light load day for each month) calculation utilizing the Streamlined Method to provide information for planning purposes.

This sub-project successfully implemented all the planned tasks including area selection, model development, methodology implementation and simulations. The hosting capacity results, which indicated the maximum amount of DERs that can be connected without adversely impacting SCE's distribution system functions, were published on SCE's Distributed Energy Resource Interconnection Map (DERiM) to share with the public.

In this EPIC project, the tools developed under the first sub-project will provide great value by informing SCE's future investments towards a modernized grid, the methodologies demonstrated in the second sub-project will provide valuable information for both customers and planning engineers to move towards a grid with a high penetration of DERs. More immediately, these capabilities can help to satisfy regulatory requirements for utilities to identify locational net benefit of DERs, incorporate DERs into grid planning activities and support demonstration projects such as the Integrated Grid Project which satisfies requirements under the Distribution Resource Plan (DRP) Demo D.

2 Sub-project 1: Distribution Planning Tool

2.1 Project Summary

This project involves the development and validation of advanced modeling capabilities necessary for the planning of the future distribution system. SCE contracted Battelle to develop new capabilities within GLD, develop an export tool from Cyme to GLD, and assist SCE in developing 30 distribution models.

2.1.1 Project Objective

The primary goal of this project was to develop advanced modeling capabilities and distribution models necessary to inform SCE's future distribution system. To achieve this goal, SCE contracted Battelle, a non-profit, Federally Funded Research and Development Corporation (FFRDC), to modify and enhance the existing GLD software. SCE developed a list of 8 core functional requirements to be developed under this project. Additionally, the project involved the development of 30 distribution circuit models in GLD format and a tool to convert Cyme models to GLD.

The capabilities to be developed under this project included (1) a framework to determine true cost of DERs (2) a module to simulate SCE specific Commercial customer loads and demand response (3) enhancements to the Energy Storage module, (4) improvements to the Electric Vehicle module, (5) implementation of a SCE specific Volt/VAR scheme, (6) a Distributed Energy Resource Managing System to coordinate all DER functions, (7) an asynchronous Cloud cover module and others, and (8) revisions to the demand response functions to include SCE specific Demand Response programs.

2.1.2 Problem Statement

The electric industry is being transformed due to advances in technology; regulatory requirements and increased customer demand for choice. The success of this transformation will depend largely on the distribution planning tools available to that will inform this new grid. There are currently large gaps between the modelling capabilities available in the electric industry today and those that are needed to help plan this future grid. This project seeks to bridge some of these gaps by identifying and implementing new functionalities within the existing open source power simulation tool, GLD. Some of these new functionalities were guided by regulatory requirements under AB 327, such as the development of a framework to help determine the locational net benefit of DERs.

2.1.3 Scope

Originally the project scope involved only the services defined under the Phase 1 scope and this included the development and validation of 8 GLD modules, a 'CYME to GLD' conversion tool and support services to help SCE develop GLD distribution models. Approximately 6 months into the project, a new project phase was developed, the 2nd project phase, to align with SCE's changing priorities and due to some of technical difficulties with the development of some modules. Three of the modules scheduled for phase 1 were moved into phase 2. Below is a summary of the scope of works defined under both phases.

Phase 1 Scope:

Phase 1 tasks represent the total scope as defined at the start of the project. The three main tasks are:

1) Define, implement and validate 8 new modules within GLD. Below is a listing of these modules.
    - Commercial & Industrial Load Models

- Advanced Inverter Module
- Electric Vehicle Charger Module
- Energy Storage Module
- Market Module (Demand Response)
- Solar Irradiance Module (Cloud Cover)
- Volt/VAR module
- Distributed Energy Renewable Management System (DERMS)

2) Enhance SCE's 'CYME to GLD' conversion tool to include features
3) Support SCE with model building and fix bugs that SCE may encounter while building the distribution models.

Phase 2 Scope:

The 2nd phase was developed, during the phase 1 execution stage, to capture some of the challenges and changing priorities of the project. Three of the four modules defined in the 2nd phase were originally to be developed during the 1st phase. The main tasks included in the 2nd phase are:

1) Define, implement and validate 4 new modules within GLD. These include:
    - Solar Irradiance Module (From 1st phase)
    - Volt/VAR module (From 1st phase)
    - Distributed Energy Renewable Management System (From 1st phase)
    - Valuation Pipeline Framework (New in 2nd phase)
2) PV adoption script which places new PV devices at locations based on a PV adoption methodology.

2.1.3.1 Phase 1 & 2 Module Description:

Below is a brief description of each planned module:

2.1.3.1.1 Commercial & Industrial Load Models

The purpose of the Commercial module is to model SCE specific commercial load types and to enable demand response simulations on the HVAC components of the commercial loads. GLD has built in capability to model residential homes, which are generally single zone buildings between 500 and 4000 sq. ft, and the major devices within the homes such as HVAC, ovens, water heaters, pool pumps. There was no module available, capable of modeling and simulating commercial buildings which are multi-zonal and diverse in size and business functions. The Commercial module was built to fill this gap. This module should simulate SCE specific commercial loads and HVAC demand response.

2.1.3.1.2 Volt-VAR Control Module

The Volt-VAR module is a control algorithm that simulates the Distributed Volt/VAR control system currently in operation at SCE. It attempts to minimize average circuit voltage while ensuring that voltages, as measured throughout a circuit, remain within specified limits. The AVVC module will be designed to execute optimization both at regular intervals and in the event that measured voltage is outside set limits. As part of the optimization procedure, the module will attempt to find capacitor switching configurations that minimize both voltage and reactive power while ensuring that both remain within set limits. The module will also have the ability to detect which capacitors are available for use in optimization at execution time, to flag unresponsive or poorly-performing capacitors as failed, and to determine if previously failed capacitors are functional again.

2.1.3.1.3 Advanced Inverter Module

The existing inverter module in GLD would be extended to include additional smart capabilities. Some of these capabilities include:

- Adjusted power factor control based upon PCC voltage
- Adjusted power factor control based on time of day
- Adjusted power factor control based on predetermined modes for the day (eg a once a day SCE control system communicates with the inverter to notify of weather conditions)
- Inverter control communications based upon a delay setting (eg 1 minute).
- Develop, Implement, Test, Validate and Refine support for the “FOUR_QUADRANT” inverter type and control modes “CONSTANT_PQ” and “VOLT_VAR”

2.1.3.1.4 Electric Vehicle Charger Module

The existing Electric Vehicle module would be enhanced to allow more flexible schedules. In the standard build of GLD the schedules of EV usage defined by the user is equally applied to all seven days of the week. Changes to the module would allow for more flexible scheduling so that more realistic usage patterns could be applied to the electric vehicle usage.

2.1.3.1.5 Market Module (Demand Response)

The existing Market Module would be enhanced to simulate SCE specific Demand Response Programs and to add functionality that would incorporate wholesale market prices and behavior to devices.

2.1.3.1.6 Energy Storage

The existing Electric Storage module would be enhanced to include (1) a MW size (Sodium Sulfur – NaS) battery object, (2) a Community Energy Storage (CES) controller object which coordinates operation of multiple energy storage devices and (3) enhanced inverter object which includes 4 quadrant controls. The CES controller coordinates energy storage devices to achieve (1) peak shaving, (2) load following, and (3) islanding functions

2.1.3.1.7 Solar irradiation stochastic variance (cloud cover)

The Solar Irradiance module would simulate the effects of cloud cover by varying the irradiance detected by nearby PV objects on the same circuit. The standard version of GLD does not support this. Some of the new features include:

- Turn the stochastic feature on/off
- Set bandwidth for variance
- SCE would analyze/provide irradiance data

2.1.3.1.8 EMS/DERMS

An Energy Management System (EMS)/Distributed Energy Resource Management System (DERMS) module would model a central control mechanism to optimize the usage of multiple DER resources based on a user defined objective function. The objects to be controlled by the DERMS include (1) photovoltaic (PV) inverters, (2) Energy Storage device controllers, (3) Electric Vehicle Chargers, and (4) demand response of residential and commercial HVAC and pool systems.

The DERMS module coordinates the behavior of the subsystems to achieve system-wide goals, possibly by modifying or overriding independent goals of the individual subsystems. Upgrades would be made to the DER classes (PV, Demand Response, Electric Vehicle and Energy Storage) to enable participation with the DERMS during simulation. The DERMS would have the following characteristics.

- An independent objective function
- A scheduling feature
- A list of points to monitor to use for its state estimation
- A generic stochastic failure of communication

2.1.3.1.9 VALUATION PIPELINE:

The Valuation Pipeline framework is needed to help understand the true cost of installing technology on the circuit. It performs a cost-benefit analysis from installing technologies to the circuit and it evaluates cost from the perspective of the customer, utility and society.

The technologies included are energy storage, demand response (HVAC & pool pumps), renewable generation (specifically solar PV), electric vehicles, and conservation voltage reduction (utility controlled capacitors). The tasks to develop the tool include the following:

- Modification of GridCommand Distribution
- Apply organized recorder methodology to track relevant simulation values

2.1.3.2 Phase 1 CYME import tool

This task would make improvements to a ‘CYME to GLD’ conversion tool originally developed by SCE. SCE’s conversion tool does not currently model line capacitance and cannot handle single-phase center tapped transformers. Battelle was tasked with implementing these features and also make changes ensuring that CYME spot loads can be validated against GLD loads.

2.1.3.3 Phase 2: Scripting Services

The Scripts to be developed will accomplish the following functions:

- Distribute solar to house and commercial objects based on usage bin parameter and inputs from SCE PV Adoption model
- Distribute EVs and PHEVs in a similar method to Solar PV, with SCE forecasts as input
- Distribute Energy Storage based on total installed capacity

2.1.4 Schedule

The initial project schedule involved the development of eight modules to be completed within 8 months. The project commenced in May 2014 and was scheduled to be completed by the end of Jan 2015. At the end of January, only the EV Charger and the Energy Storage modules were completed while the Commercial Model was still being developed. Due to the project delays and shifting priorities a 2nd phase of the project was implemented in the early part of 2015. The scheduled tasks for Phase 1 and Phase 2 of the project are shown in Tables 1 and 2 below respectively.

Table 1: First Phase Project Schedule (9/19/14)

Updated Schedule of tasks as of (9/18/14)				
#	Task	Duration (Days)	Start Date	End Date
1	Kickoff meeting	3	5/12/2014	5/14/2014
2	Commercial Model	105	5/19/2014	10/10/2014
3	EV Charger	73	6/16/2014	9/24/2014
4	Energy Storage	73	6/16/2014	9/24/2014
5	Commerical Demand Response	40	9/15/2014	11/7/2014
6	Cloud Cover	41	10/10/2014	12/5/2014
7	Solar PV Inverter (enhanced)	30	10/24/2014	12/4/2014
8	Generic Residential Demand Response	46	10/17/2014	12/19/2014
9	Volt VAR Control	56	9/26/2014	12/12/2014
10	EMS/DERMS	80	9/19/2014	1/8/2014
11	Monthly Reports	155	6/30/2014	1/30/2014

Table 2: Second Phase Project Schedule

Phase 2 Schedule		
#	Task	Duration (Days)
1	EMS/DERMS	120
2	Volt VAR Control	90
3	Cloud Cover	30
4	Valuation Pipeline	120
5	Scripting Support	Duration of project

2.1.5 Milestones and Deliverables

Battelle was required to provide a document defining module functionality, source code, and Validation results for each module developed. Table 3 below shows the final status of the planned modules and table 4 shows the milestones of the supporting tasks.

Table 3: Module Development Status

Milestone/Deliverables (Module Development)	Source Code	Requirement Document	Validation	Project Phase
Commercial Model with Demand Response	Complete	Complete	Complete	1,2
EV Charger	Complete	Complete	Incomplete	1
Energy Storage	Complete	Complete	Incomplete	1
Valuation Pipeline	Complete	Complete	Incomplete	2
Volt VAR Control	Incomplete	Complete	Incomplete	1,2
EMS/DERMS	Incomplete	Complete	Incomplete	2
Cloud Cover	Incomplete	Incomplete	Incomplete	1
Solar PV Inverter (enhanced)	Incomplete	Incomplete	Incomplete	1
Generic Residential Demand Response	Incomplete	Incomplete	Incomplete	1

Table 4: Additional Tasks Status

Milestone/Deliverables (Additional Services)	Status	Project Phase
Training on new and existing GridLABD modules	Complete	1,2
Scripting Services for distribution model buidling	Complete	1,2
General support for SCE distribution model building efforts	Complete	1,2
Import Tool from Cyme to GridLAB-D	Incomplete	1
Fix Bugs encountered by SCE modeling effort	Complete	1,2

Much of the originally planned project scope was not completed. In total only four of eight planned modules were implemented with only one of these, the Commercial module, also being validated.   The remaining four modules were either not completed or cancelled during the course of the project.   There were unforeseen difficulties with the development of some modules, especially the Commercial module, and this resulted additional time being spent on these modules and thus other modules could not be developed.

The contract with Battelle was based on the “time” spent on the project. Both SCE and Battelle acknowledged that all the works may not be completed within the planned schedule due to uncertainties regarding the exact amount of time that would be needed.   The project was ultimately cut short and cancelled after one of the key developers working on the project had resigned from Battelle.

2.2 Test Set-Up/Procedure

Battelle wrote specification documents defining the various functionalities and features to be included in each module.   Battelle then wrote software code to implement the modules in GLD. Below is a description of the functions, features and methods used to develop the four completed GLD modules and a description of the additional tasks performed by Battelle.

2.2.1 Commercial Module Development and Validation

The Commercial module was developed to simulate SCE commercial loads and demand response events. It consists of two major components. The first component is a model of the building’s HVAC system and the second component is a model of the commercial customer’s load profile due to their typical business processes and HVAC.   The Implementation procedure of these two components is described below

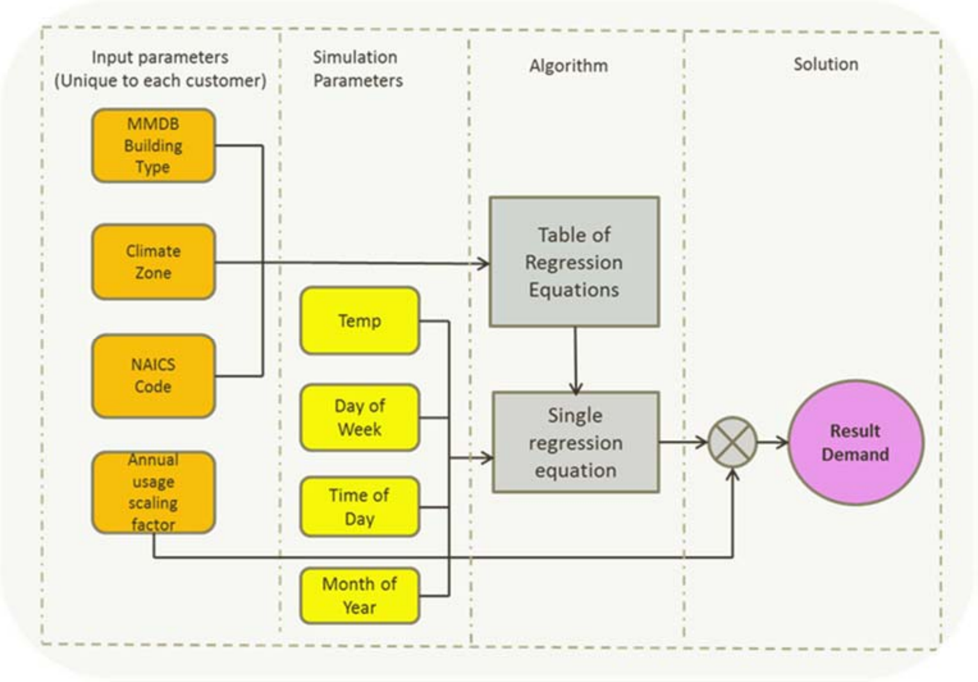
Commercial load component:

The underlying behavior of the Commercial Load Module is governed by a regression equation that considers the customer’s building type, climate zone, North American Industry Classification System (NAICS) code, and average daily energy usage, as well as the current date, time, and outdoor temperature to compute a load value. The building type, climate zone, and NAICS code are used to select a set of coefficients that describe the time- and temperature-dependent behavior of the customer’s load. The average daily usage serves to scale the calculated load value. SCE provided Battelle with masked customer historical usage and AMI data along with other customer characteristics such as the customer’s NAICS code and the climate zone they are situated in.

The major steps to create the commercial models involved (1) defining 33 Building types and map each of the North American Industry Classification System (NAICS) code to one of the 33 Building Types, (2) groups customers into cohorts based on similar characteristics (Building Type, North American Industry Classification System (NAICS) code and Climate Zone and (3) perform a regression on each cohort using historical customer usage data, to build a statistical model that predicts the customer's scaled usage based on Temperature, Hour of the Day, Day of the Week and Month of the Year

To run the model, the user enters the customer's Building Type, NAICS, Climate zone and average annual usage. A set of regression coefficients is then selected and the customer's demand is calculated, at each time step, as the solution to the regression equation.

Figure 1: Commercial Module Process Flow



Commercial HVAC Demand Response Component:

The ultimate goal of the commercial module was to simulate demand response events on the HVAC component of the commercial load. Battelle's initial approach was to model a simplified HVAC system using a set of differential equations that models energy exchange between the HVAC and the outside of the building. This model did not perform well. Battelle then attempted a more simplified method using the temperature dependent nature of loads to affect change by simply adjusting the outside temperature during a demand response event. This method also did not provide good results.

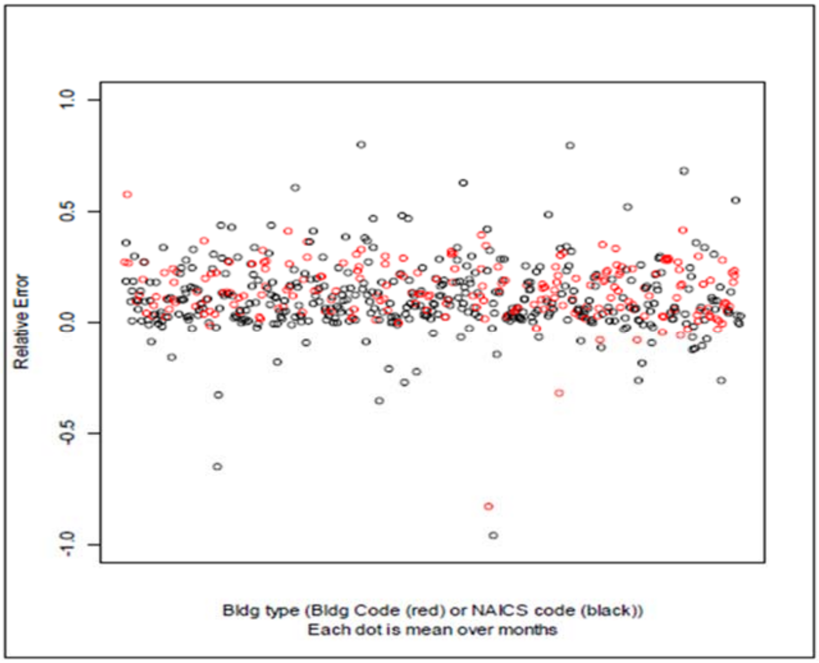
Table 5: Commercial Building Types

ID	MMDB-Building Type
1	Agricultural
2	Assembly
3	Education - Primary School
4	Education - Secondary School
6	Education - Community College
7	Education - University
8	Grocery
9	Food Store
10	Health/Medical - Hospital
11	Health/Medical - Nursing Home
12	Health/Medical - Clinic
13	Lodging - Hotel
14	Lodging - Guest Rooms
15	Lodging - Motel
17	Manufacturing - Light Industrial
18	Industrial
19	Misc. Commercial
20	Office - Large
21	Office - Small
23	Residential - Multifamily
25	Restaurant - Fast-Food
26	Restaurant - Sit-Down
27	Retail - Multistory Large
28	Retail - Single-Story Large
29	Retail - Small
31	Storage - Unconditioned
32	Transportation - Communication - Utilities
33	Warehouse - Refrigerated

Commercial Module –Validation (Load model component):

Battelle validated the module's ability to model usage. Actual monthly usage data was compared against the predicted hourly data for the same month and the same ambient temperature profile for that month. Figure 2 below shows the results of this prediction with the y axis representing the relative error. The model is over predicting usage generally below 30%

Figure 2: Commercial Load Model Validation Results



Note: The y axis shows the relative error. The error is generally below 30%

Commercial Module – Validation (Demand Response Component):

As part of a CSI high PV penetration study, SCE considered traditional demand response to mitigate the impact of high solar PV penetration. SCE intended to utilize the commercial modules developed by Battelle to simulate commercial demand response events. However, unlike the residential load modules which are fully developed, the result of the validation performed as part of this effort showed the new GridLAB-D commercial models developed by Battelle are not ready to accurately simulate commercial demand response events to assess demand response potential of temperature sensitive loads mainly HVAC systems. The team heavily leveraged AMI data to develop the modules used in the study; more detailed data about commercial load are needed to develop more accurate commercial models.

In addition, the study showed traditional demand responses is not well suited to mitigate the vast majority of operational violations which involve high voltage conditions during periods of high solar. This can be exacerbated by the reduction of load which also has the effect of raising voltage across the circuit. Under these conditions, what would be required is a demand response scheme that incentivizes load to turn *on*; or directly energizes load through a direct load control system. Therefore, the commercial module further development work need to ensure capability is built in the commercial modules to simulate turning load on contrary to traditional demand response schemes which are designed to reduce load.

2.2.2 Energy Storage Module Enhancements

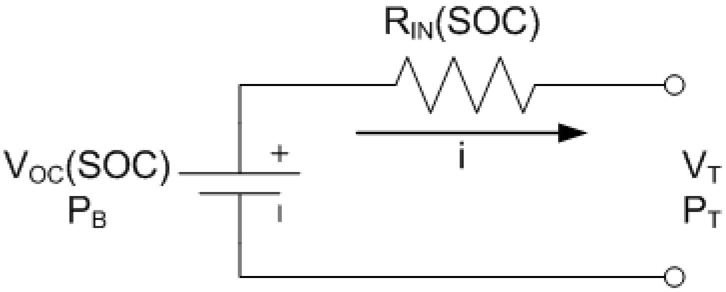
Battelle implemented new features enhancing the capabilities of the existing Energy Storage module. These features include (1) a MW size (Sodium Sulfur – NaS) battery object, (2) a Community Energy Storage (CES) controller object which coordinates operation of multiple energy storage devices and (3) enhanced inverter object which includes 4 quadrant controls.

Inverter Object:

One of the most significant updates to the inverter object was the inclusion of four quadrant control, which is upgraded from the previous single quadrant control, which provided only real power. A four quadrant inverter can provide power across all four quadrants of the power unit circle, which allows the inverter to supply or sink real power while also providing positive or negative reactive power support to the electric grid. These updates allow the inverter to function with the updates to the battery object, and to accommodate the control functionality required by NaS and CES.

Sodium Sulfur (NaS) object:

The battery object in GLD was updated to support the electrical and chemical characteristics of the NaS battery type. The battery object uses a simple model to simulate the battery losses by taking into account the internal resistance and the voltage curve with respect to state of charge (SOC). Parameters provided by the user along with the characteristics of the battery type are used to calculate the internal efficiency of the battery. The round trip efficiency is used to determine an internal efficiency based on the open circuit voltage (V_{OC}) curve of the battery. The simplified circuit used in the battery object to represent the efficiency of the battery is shown in **Error! Reference source not found.**.



For each battery type, there is a specific voltage vs. SOC curve. Using this curve, as well as a specified round trip efficiency, an internal resistance can be found that is assumed constant for all battery loading. Given the round trip efficiency, the rated power into and out of the battery is found by equations 3.1 for charging and 3.2 for discharging.

Charging:
$$P_{BR} = P_R\sqrt{\eta_{RT}} \qquad (3.1)$$

Discharging:
$$P_{BR} = \frac{P_R}{\sqrt{\eta_{RT}}} \qquad (3.2)$$

Where:

- P_{BR} is the actual rated power out of the battery
- P_R is the rated power of the inverter into the inverter on the DC side
- η_{RT} is the round trip efficiency of the battery at rated power

Community Energy Storage Controller:

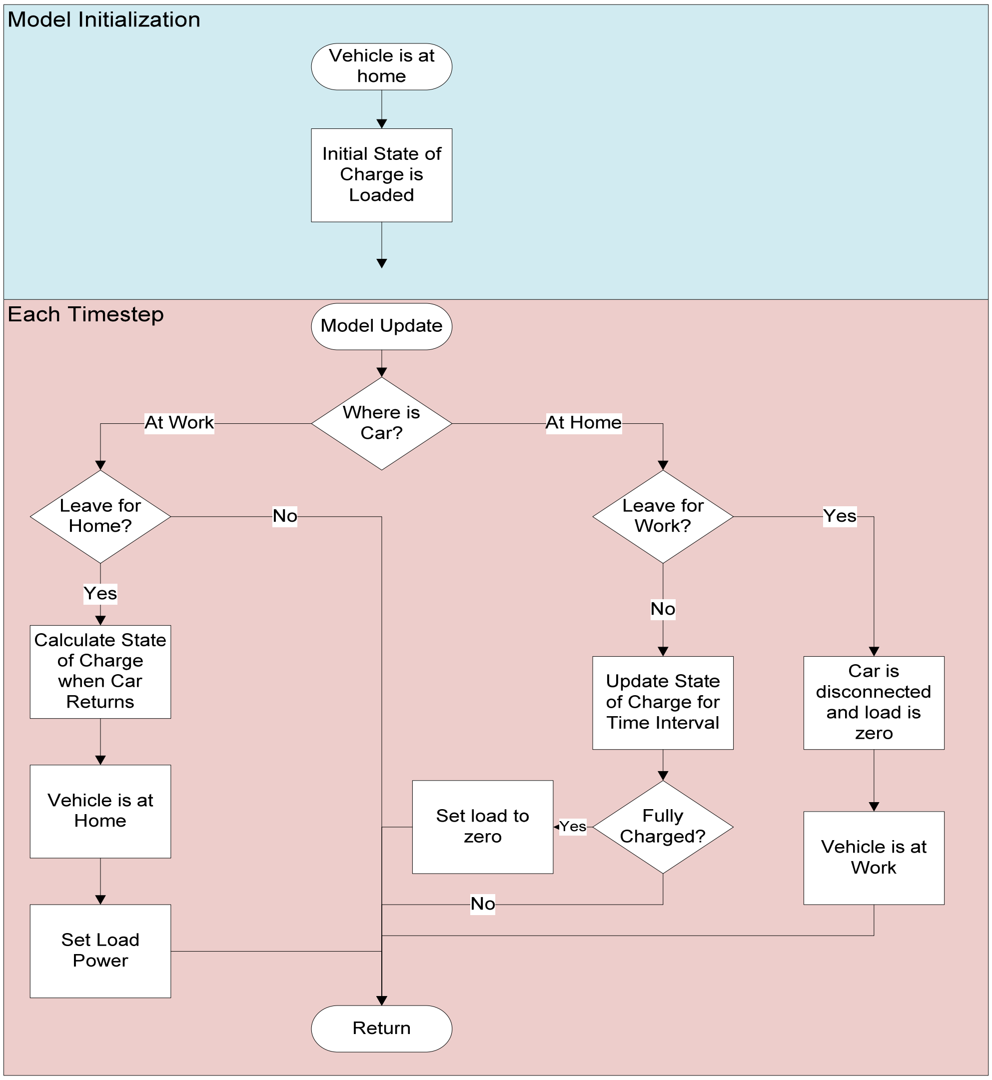
The Community Energy Storage (CES) controller is used to control/coordinate CES, which consists of multiple independent batteries and associated inverters. The CES controller can coordinate energy storage units to achieve one of three functions including (1) Var support, (2) Islanding and (3) Peak shaving (scheduled or load-following).

The controller looks at power measurements for each phase on a given sense node and then determines whether the measurements are within a specified bound. Depending on these criteria, the controller instructs all of the CES and NaS units (battery and inverter objects) under its control to output a certain power level up to, but not exceeding, the rated inverter power for each unit.

2.2.3 Electric Vehicle Module Development

An existing Electric Vehicle (EV) module is available with GLD. The standard version only supports scheduling trips from home to work and back and it is not able to distinguish between weekdays and weekends. The goal of this effort was to provide more scheduling flexibility allowing for more realistic EV use patterns. Battelle initially anticipated that changes were needed to the EV module source code, however they later proposed that GLD's scheduling functions could be leveraged in innovative ways to achieve the desired outcomes. Ultimately no change to the source code was needed. Figure 3 below is a diagram of how the EV module operates.

Figure 3: Electric Vehicle Module Operation



2.2.4 Valuation Pipeline Framework

The Valuation Pipeline tool was built to be a flexible cost-benefit framework to capture the value streams (benefits and burdens) of DERs from the perspective of the Customer, Utility and Society. From the customer perspective, the value streams include (1) cost of technology and (2) the savings from change in consumption, rebates and incentives. GLD directly calculates the change in customer energy consumption while the user inputs values for the cost of energy, technology and rebates into a configuration file. The total customer value stream is calculated from the below formula:

Customer value streams = Cost of Technology + Energy Savings

From the Utility perspective, value streams can be attributed to Generation, Transmission and Distribution. Since GLD is limited to distribution level simulations, the Generation and Transmission value streams are not directly computed by GLD but can be provided by the user via a configuration file. The Distribution value streams include (1) Deferred Distribution Upgrade

Project Costs, (2) Required Distribution Upgrade costs and (3) Net energy losses. The total distribution value stream is calculated as:

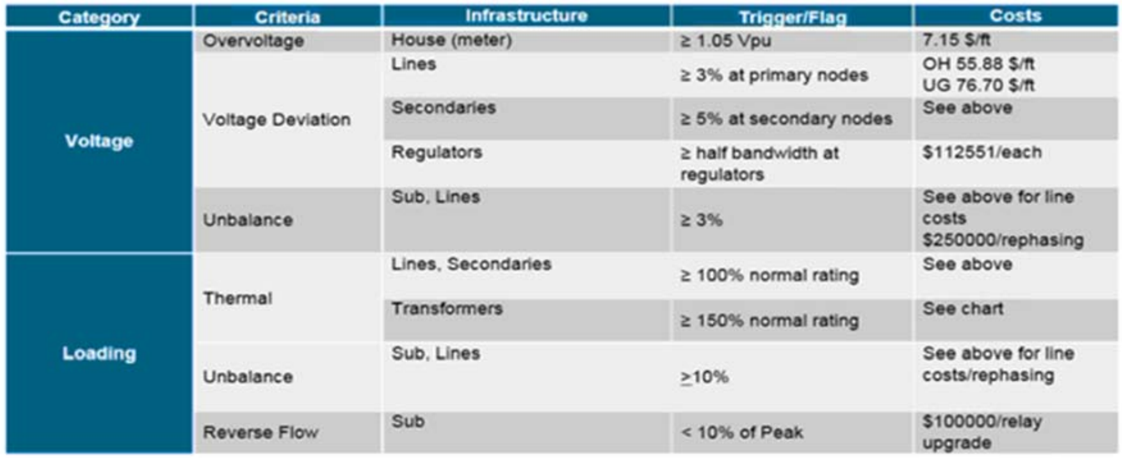
Utility Distribution Value Streams = Costs of deferred projects + required distribution upgrades + Net energy loss

To perform the cost benefit analysis on the distribution circuit certain measurements are made to help quantify the cost of the distribution system and to flag equipment that need to be upgraded. These measurements include:

1. Feeder head (Power Factor, Reverse Power Flow and Load imbalance
2. Capacitor switching operations
3. Bill dumps which includes detailed customer usage
4. Violation records to record (Line voltages, transformer loading, line thermal limits, load imbalances and reverse power flow

Both the trigger flags and the costs of the infrastructure to mitigate these issues are provided by the user. An example of the distribution value stream configuration file is given in Figure 5 below:

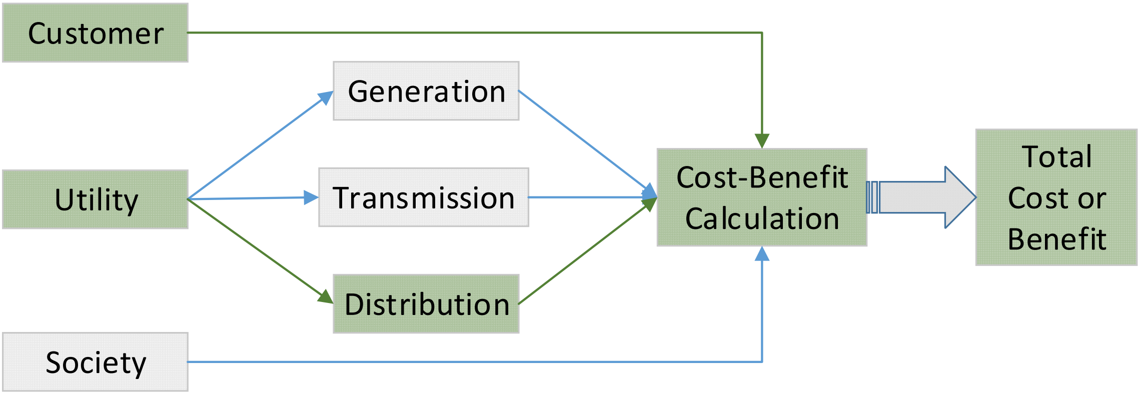
Figure 4: Example of Distribution Upgrade Triggers & Costs



Category	Criteria	Infrastructure	Trigger/Flag	Costs
Voltage	Overvoltage	House (meter)	≥ 1.05 Vpu	7.15 $/ft
	Voltage Deviation	Lines	≥ 3% at primary nodes	OH 55.88 $/ft UG 76.70 $/ft
		Secondaries	≥ 5% at secondary nodes	See above
		Regulators	≥ half bandwidth at regulators	$112551/each
	Unbalance	Sub, Lines	≥ 3%	See above for line costs $250000/rephasing
Loading	Thermal	Lines, Secondaries	≥ 100% normal rating	See above
		Transformers	≥ 150% normal rating	See chart
	Unbalance	Sub, Lines	≥10%	See above for line costs/rephasing
	Reverse Flow	Sub	< 10% of Peak	$100000/relay upgrade

The value streams from the society perspective can be defined by the user. This can include costs associated with reductions of carbon emissions or any other benefit that can be attributed to society. Figure 5 below shows the three main value streams. In the current framework, the streams colored in green are directly calculated via GLD simulations. The other value streams must be manually entered by the user.

Figure 5: Value Stream Calculation Process Flow



Valuation Framework Development:

The development of the Valuation framework required modifications to the existing GridCommand Distribution software. GridCommand Distribution is a front end addition to GridLAB-D providing a user interface to streamline and simplify the model building process easier. For the valuation framework, new functionalities were implemented in GridCommand Distribution which allowed recorders and collectors to be automatically placed at strategic locations throughout the distribution circuit. A configuration file to enter cost information and criteria for flagging upgrades is also provided via GridCommand Distribution.

2.3 Project Results

Battelle developed new pieces of source code and compiled this with the rest of the core GridLAB-D source code to make one executable. The following is a list of the modeling features and additional tasks that were provided by Battelle under this project.

- New Commercial module including Validation works
- New Valuation pipeline tool
- Enhanced Electric Vehicle module
- Enhanced Energy Storage module
- Documentation describing module development logic and functions
- Support services to develop 30 distribution models
- Training provided to SCE employees

There were some functions that were not implemented. The Contractor required more time than originally anticipated to develop some of the module and since the contract was “time based”, these delays put a strain on the project budget and some of the planned modules could not be developed. SCE ultimately decided to cut the contract short after one of the main software developers working on the project resigned from Battelle.

2.3.1 Technical Results, Findings, and Recommendations

Battelle validated the Commercial module and the results how that the Commercial load model is able to predict the customer’s monthly usage to within approximately 20% of the actual monthly usage. SCE validated the demand response features of the Commercial module and found that the commercial demand response features performs poorly and should not be used for planning purposes in its current state. The Valuation Framework, Energy Storage and Electric Vehicle modules were not validated.

Improvements need to be made to the Commercial module to properly simulate commercial AC/Heater demand response events. The Commercial load model predicted monthly usage to roughly 20% of the actual value. It is likely however that the predictions at smaller time scales, than 1 month, will be less accurate. The Valuation Pipeline framework seems to be promising tool. SCE will conduct validation tests on the valuation pipeline tool to determine if it can be leveraged for planning.

2.3.2 Technical Lessons Learned

The development of certain modeling features using GLD proved to be more challenging that initially anticipated. This was especially true with the development of the Commercial demand response functions. The difficulty was not so much with regards to the programming aspect of it, but with regards to the mathematical work necessary to properly fit the model and to decompose the customer AMI data into theoretical load components.

Potential factors that may have contributed to the poor performance of the HVAC model include (1) the number of distinct commercial customer groups defined, (2) the sample size of the historical demand customer usage information provided and (3) the validity of coefficients used to perform the multiple regression analysis to predict usage and the cooling and heating load components. For example the customer demand sample size was 6,700 customers, which represents approximately 1% of the total commercial customer base. This sample size may not have been large enough to extract meaningful data.

2.3.3 Value Proposition

SCE has identified the need for new advanced distribution circuit modeling tools as one of the foundational technology solutions necessary to help realize a modernize grid. The tools developed under this project help to satisfy this need and will provide great value as it guides SCE's future investments towards a modernized grid. More immediately, these capabilities can help to satisfy regulatory requirements for utilities to identify locational net benefit of DERs, incorporate DERs into grid planning activities and support demonstration projects such as the Integrated Grid Project which satisfies the requirement to perform Distribution Resource Plan Demo D.

The 30 distribution models developed were used in a core research project to study the impacts of high PV penetration and to determine the optimal set of mitigation strategies to enable 100% PV penetration on the circuits studied. Additionally the results from this simulation were used to compare SCE's initial DRP Integrated Capacity Analysis (ICA), which determined the hosting capacity on the same set of 30 distribution circuit, but using a different set of criteria and a different power simulation tool, CYME.

The modeling functionalities developed under this project support the primary and some of the secondary EPIC guiding principles. The valuation pipeline tool is used to determine the locational value of DERs. This information can help the utility align incentives with DER value thus promoting increased DER adoption in areas where there is most benefit to the grid. Likewise the Commercial, Electric Vehicle, and Energy Storage modules will all help to enhance the accuracy of the simulations. This will help to optimize DER resource deployments and thus reduce cost and reduce emissions.

2.3.4 Technology/Knowledge Transfer Plan

SCE will work with Battelle to ensure that the specific changes made to GLD, the work done collaboratively on this project and the reasoning behind the major decisions made during the project are made publically available, drawing conclusions about the realized and expected societal benefit from this work.

2.4 EPIC Metrics

List of Proposed Metrics and Potential Areas of Measurement (as applicable to a specific project or investment area in applied research, technology demonstration, and market facilitation)	
2. Job creation	
a. Hours worked in California and money spent in California for each project	See 5.1
3. Economic benefits	
a. Maintain / Reduce operations and maintenance costs	See 5.2
c. Reduction in electrical losses in the transmission and distribution system	See 5.3
4. Environmental benefits	
a. GHG emissions reductions (MMTCO2e)	See 5.4
7. Identification of barriers or issues resolved that prevented widespread deployment of technology or strategy	
b. Increased use of cost-effective digital information and control technology to improve reliability, security, and efficiency of the electric grid (PU Code § 8360);	See 5.5
c. Dynamic optimization of grid operations and resources, including appropriate consideration for asset management and utilization of related grid operations and resources, with cost-effective full cyber security (PU Code § 8360);	See 5.6

2.4.1 Hours worked in California:

Labor costs were supported for the engineers working at Southern California Edison. This included time spent on the project management, validation works, and works done in developing 30 distribution circuit models.

2.4.2 Reduce O&M costs:

The valuation pipeline framework will help determine the burdens that Distributed Energy Resources will have on the system. This tool automatically flags equipment that need to be upgraded as a result of new DERS and thus giving the planner greater visibility into potentially issues before they occur. This can help prevent equipment from prematurely failing. The Energy Storage controller will help inform actual energy storage coordination schemes to regulate extreme circuit loading conditions and also regulate VAR flow which can help reduce capacitor operations.

2.4.3 Reduction in electrical losses:

Each of the new features developed will play a role in informing the planning and design of the future distribution system. These planning activities routinely revolve around making the distribution system more efficient. The Energy storage module can be used to help smooth out peaks in circuit load, the Electric Vehicle module can help inform the planner about potential overloading issues due to EV adoption. The valuation pipeline tool likewise can be used to help incentive customers to utilize DERs in a way that can reduce losses on the transmission and distribution lines.

2.4.4 Reduction in GHG emissions:

The tool developed will be used to help design the distribution system so that it can safely and reliably support increasing amounts of DERs. The more DERs are connected to the grid the less GHG emissions can be expected.

2.4.5 Increased use of digital information and control technology:

The Energy Storage controller can be used to coordinate the operation of multiple energy storage devices to achieve various objective functions such as VAR support, peak shaving and load following. These capabilities can help to provide insight on the best mix of objective functions to inform future control schemes and technology.

2.4.6 Dynamic optimization of grid operations:

The 30 distribution models were used to perform numerous high PV penetration scenarios. These included scenarios to determine the optimal mix of traditional upgrades and support services from DERs to enable up to 100% PV penetration levels. SCE developed the 30 distribution models, in part by leveraging the Commercial module and using support services and training provided by Battelle.

3 Sub-project 2: Hosting Capacity Analysis

3.1 Project Summary

This project demonstrated the methodology to determine the level of DERs that could be interconnected to the distribution system without adversely affecting the critical distribution system components and developed the process of sharing the hosting capacity results to the public in order to facilitate DER adoption economically.

3.1.1 Project Objective

The primary goal of this project was to demonstrate a dynamic hosting capacity methodology, within selected study areas, that could be used to determine the capacity of distribution system to integrate DERs down to a line section or node level.

3.1.2 Problem Statement

SCE, in its recently released whitepaper "The Emerging Clean Energy Economy," outlined a vision to accelerate the transition to a clean, reliable energy future that includes a high penetration of DERs, by facilitating customer choice of new technologies, creating opportunities for DERs to provides grid services, and modernizing the grid to ease integration and optimization of DERs.

The expected high levels of DERs on SCE's distribution system will have significant impacts on all critical distribution system functions. These include: maintaining distribution system electrical components within thermal limits, maintaining power quality within applicable industry standards, and maintaining the necessary level of protection to provide safe and reliable electrical service to customers. The determination of the maximum amount of DERs that can be connected without adversely impacting SCE's distribution system functions (referred to as the hosting capacity) involves rigorous engineering analysis and review.

3.1.3 Scope

The project was planned to demonstrate a fully dynamic analysis which would determine the DER hosting capacity at line sections and/or nodes within the distribution system.

The demonstration was to be performed in two distinct areas that represent the wide variety of distribution systems within SCE's diverse service territory, such as a typical urban service area and a typical rural service area. Through this analysis, the project was to investigate and demonstrate the impact of the characteristics of local distribution systems the level of DERs that can be interconnected to the distribution grid without adversely affecting the critical distribution system components.

The demonstration would examine 576 hours over a 12-month period, which composed of one day per month of typical high-load conditions and one day per month of typical light-load conditions.

The project was to examine the hosting capacities under two power flow scenarios: a) power does not flow towards the transmission system beyond the distribution substation bus; b) the technical maximum amount of interconnected DERs that the system is capable of accommodating irrespective of power flow direction.

The demonstration was planned to examine the hosting capacity based on limiting categories of thermal rating, power quality and voltage criteria including steady state voltage and voltage fluctuation, protection coordination requirements, safety and reliability, as well as substation limitations.

Two different methodologies of calculating the DER hosting capacities would be demonstrated. The first methodology, referred to as the Streamlined Method, was to perform one power flow simulation for each scenario and then extract quantities from the power flow simulation and insert them into the streamlined equations to determine the hosting capacities for each of the limiting categories. The second methodology, referred to as the Iterative Method, was to utilize iterative power flow simulations to determine the hosting capacities for each of the limiting categories.

The hosting capacity results would be published on SCE's Distributed Energy Resource Interconnection Map (DERiM) to share with the public.

All the above scopes were completed in this project.

3.1.4 Schedule

The project was officially commenced in May 2016, with necessary preparations carried out earlier, and was scheduled to complete by the end of 2016.

Table 6: Project Schedule

Project Schedule				
#	Taks	Duration (Days)	Start Date	End Date
1	Area Selection	34	5/2/2016	6/16/2016
2	Circuit Model Development	31	6/17/2016	7/29/2016
3	Load Shape Development	31	6/17/2016	7/29/2016
4	DER Portfolio Development	54	6/17/2016	8/31/2016
5	Script Development	31	6/17/2016	7/29/2016
6	Hosting Capacity Simulation	55	8/1/2016	10/14/2016
7	Comparative Assessment	54	9/1/2016	11/15/2016
8	Map Development	121	7/15/2016	12/30/2016
9	Project Report	50	10/17/2016	12/31/2016

3.1.5 Milestones and Deliverables

The project deliverables were composed of 1) an implementation plan outlining the detailed project plan including area selection and scenario development; 2) an intermediate status report presenting the project status and the final methodology; 3) a final project report summarizing the project activities and results; and 4) an online map presenting the results to public. All the milestones and deliverables have been completed on time.

Table 7: Project Milestones and Deliverables

Milestone/Deliverable	Status	Date
Implementation Plan	Completed	6/16/2016
Intermediate Status Report	Completed	9/30/2016
Final Project Report	Completed	12/23/2016
Online Map Display	Completed	12/23/2016

3.2 Test Set-Up/Procedure

3.2.1 Area Selection

SCE's service territory covers a wide area varying in electrical and physical characteristics. Two areas were selected to represent a broad range of physical and electrical conditions within SCE's distribution system as presented in Table 8. The selected distribution planning areas (DPAs) are an urban and a rural DPA, as their geographic locations shown in Figure 4.

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Figure 4: Geographic Locations of Selected Areas

Table 8: Overview of Area Characteristics

	Urban DPA	Rural DPA
Area	Orange County	Central Valley
Service Area Size	18 mi^2	120 mi^2
No. Feeders	38	44
No. Customers	25,100	49,700
2016 Projected Load	217 MVA	314 MVA
No. Service transformers	2,375	9,617
Load types	Mixture of residential, commercial, and light Industrial loads	Mixture of residential and commercial, with significant agricultural loads
Substations	Johanna 66/12, Camden 66/12, Fairview 66/12, Edinger 12/4.16	Goshen 66/12, Hanford 66/12, Mascot 66/12, Octol 66/12, Tulare 66/12
Special Notes:	Within PRP region	Load growth driven by drought conditions

3.2.2 Methodology

Figure 5 illustrates the general process of the hosting capacity calculation. After the system model data and load data are extracted from various databases, the distribution feeder models are developed in the power flow analysis tool CYMDIST. The applicable power system criteria are examined based on 1) pre-defined equations in the Streamlined Method and 2) iterative power flow simulations in the Iterative Method. Each of these two methods identify the maximum DER integration capacity at each node. The DER hosting capacity for each criterion is calculated independently and the most limiting value is used to establish the final hosting capacity limit.

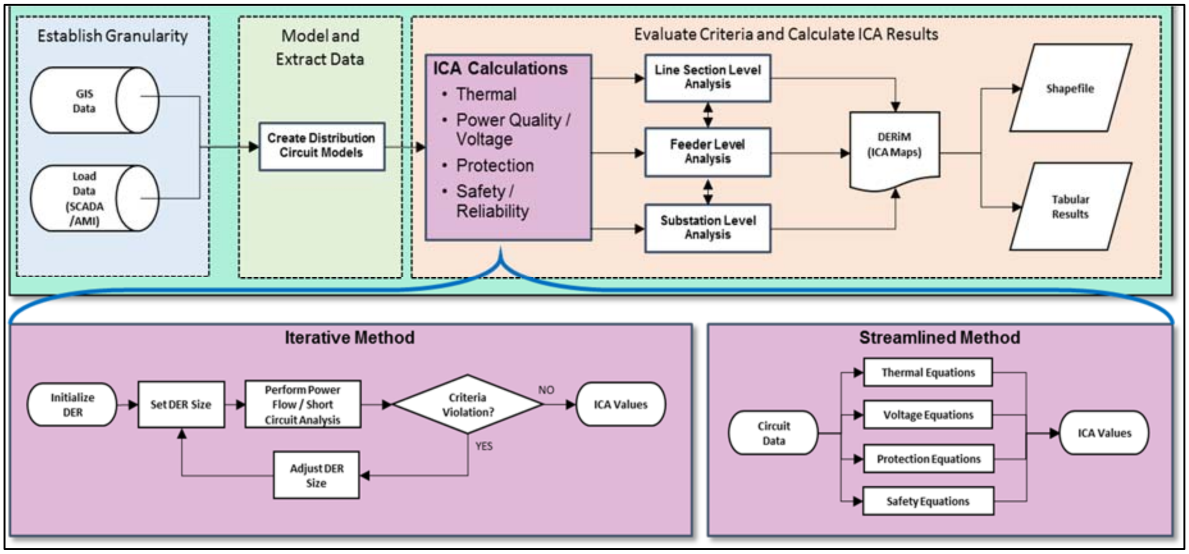


Figure 5: Process Diagram

The hosting capacity methodology composed of four general steps:

- Establish distribution system level of granularity;
- Model and extract power system data;
- Evaluate power system criterion to determine DER capacity;
- Calculate ICA results and display on online map.

The Streamlined Method applied a set of streamlined algorithms for each power system limitation category/sub-category to evaluate the DER capacity limit at each node of the distribution feeders. Figure 6 illustrates how each power system limitation criterion is evaluated at each node though power flow or short circuit duty (SCD) analyses and how the final hosting capacity values are established at each node based on the most limiting individual values. For the scenario that is to evaluate the maximum integration of DER irrespective of direction of power flow, the safety/reliability criterion (i.e., operational flexibility) will be excluded so that the maximum DER can be studied irrespective of power flow direction

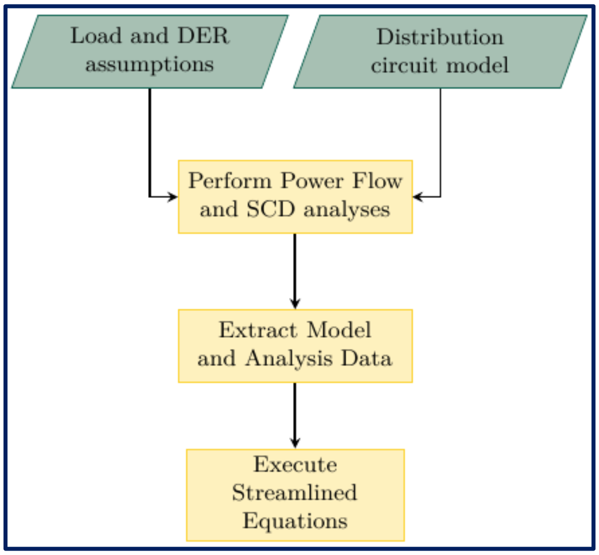


Figure 6: Criterion Evaluation Process

The Iterative Method is the direct modeling of new resources and performing iterative simulations for determining the hosting capacity at each node. Each analysis uses power flow calculation engines to compute the phase currents and voltages at every node on the network given the load and generation levels in the model. Figure 7 illustrates how each power system limitation criterion is evaluated at each node though power flow or short circuit analyses and how the final hosting capacity values are established at each node based on the most limiting individual values.

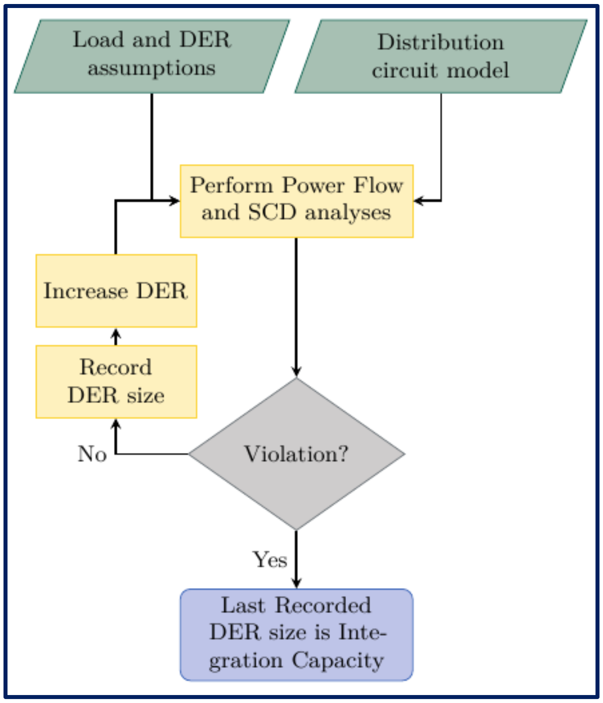


Figure 7: Simplified High-Level View of Iterative Methodology

3.2.3 Limitation Category

This section shows the equations and flags used to evaluate different limitations in the Streamlined Method and the Iterative Method, respectively.

3.2.3.1 Thermal Criteria

Streamlined	$\text{kW Load Limit [t]} = \left(\text{Thermal Capability} - \left(\text{Load[t]} - \text{Generation [t]}\right)\right)$ $\text{kW Generation Limit [t]} = \left(\text{Thermal Capability} + \left(\text{Load[t]} - \text{Generation [t]}\right)\right)$
Iterative	Power flow determines maximum DER without exceeding device thermal rating

3.2.3.2 Steady State Voltage Criteria

Streamlined	$\text{kW Limit [t]} = \frac{\left(\text{Voltage Headroom [t] (per unit)} * {V_{LL}}^2\right)}{(R * PF_{DER} + X * \sin(\cos^{-1}(PF_{DER})))} * PF_{DER}$ $\text{Voltage Headroom [t]} = \frac{\lvert\text{Rule 2 Limit} - \text{Node Voltage[t]}\rvert}{\text{Base Voltage}}$
Iterative	Power flow tool flags a steady state over-voltage condition when simulated voltage at any node exceeds 126V and flags an under-voltage condition when simulated voltage drops below 114V at any node.

3.2.3.3 Voltage Fluctuation Criteria

Streamlined	$\text{kW Limit} = \frac{\left(\text{Deviation Threshold (per unit)} * {V_{LLnom}}^2\right)}{(R * PF_{DER} + X * \sin(\cos^{-1}(PF_{DER})))} * PF_{DER}$
Iterative	a. Record voltage at node b. Simulate generation at node c. Vary generation levels until deviation threshold is surpassed d. Generation level closest to but under the allowed deviation value is the limit e. Compare node voltages with DER on and off f. Highest value recorded before deviation threshold is surpassed

3.2.3.4 Protection Criteria

Streamlined	$\text{kW Limit} = \dfrac{\text{Reduction Threshold Factor} * I_{\text{Fault Duty}} * \text{kV}_{\text{LL}} * \sqrt{3}}{\left(\dfrac{\text{Fault Current}_{\text{DER}}}{\text{Rated Current}_{\text{DER}}}\right)} * \text{PF}_{\text{DER}}$
Iterative	Power flow tool flags when the DER connected at a node causes the relay to detect less than 2.3*relay's phase minimum trip value (SCE's typical practice of applying minimum trip settings)

3.2.3.5 Operational Flexibility Limits

Streamlined	$\text{kW Limit [t]} = \left(\text{Load[t]} - \text{Generation [t]}\right) \mid \text{where limit} > 0$
Iterative	Power flow tool calculates the downstream load at the SCADA or VR devices and equates that load value to be the DER value which can be installed without causing reverse power flow. .

3.2.4 Map Display

The results of the calculated hosting capacity have been published as additional layers within SCE's existing Distributed Energy Resource Interconnection Map (DERiM) at http://on.sce.com/derim. DERiM is an interactive web map developed on ESRI's ArcGIS online platform. It performs calculations by collecting data from a variety of sources, such as cGIS (line routes and substation locations), Generation Interconnection Tool (interconnection queue), and Master Distribution Interface (forecast and equipment capacity). Users click on map features to obtain a variety of results, including the hosting capacity results. A sample map is shown in Figure 8.

In addition, an ArcGIS Online Web Application has been launched to publish interactive load profiles for circuits, substations, and DPAs (http://on.sce.com/derimwebapp). Lastly, SCE published comprehensive downloadable result files, by circuit, to a new webpage referred to as the DRP Demo Results Library (http://on.sce.com/drpdemos). Among all the downloadable files, there is a translator tool which interested parties may use to convert the agnostic hosting capacity values to a technology specific value, as shown in Figure 9.

All of the information published to the map or downloadable files will be subject to Personal Identifiable Information (PII) or Critical Energy Infrastructure Information (CEII) compliance requirements.

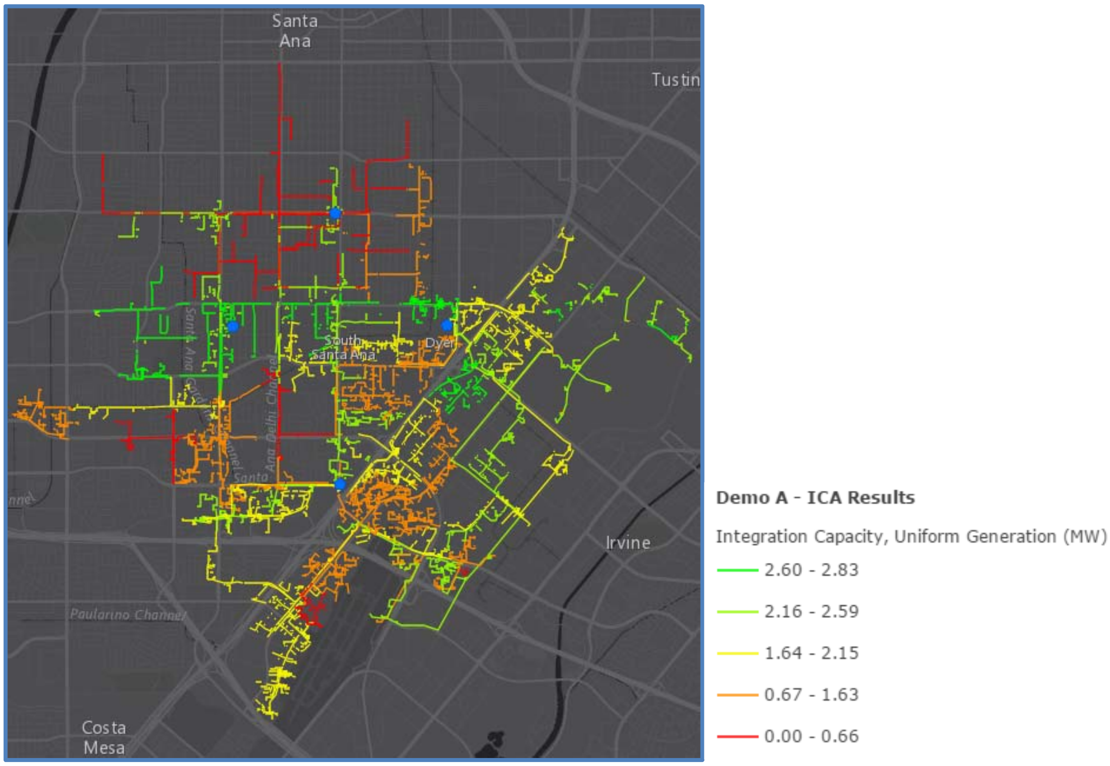
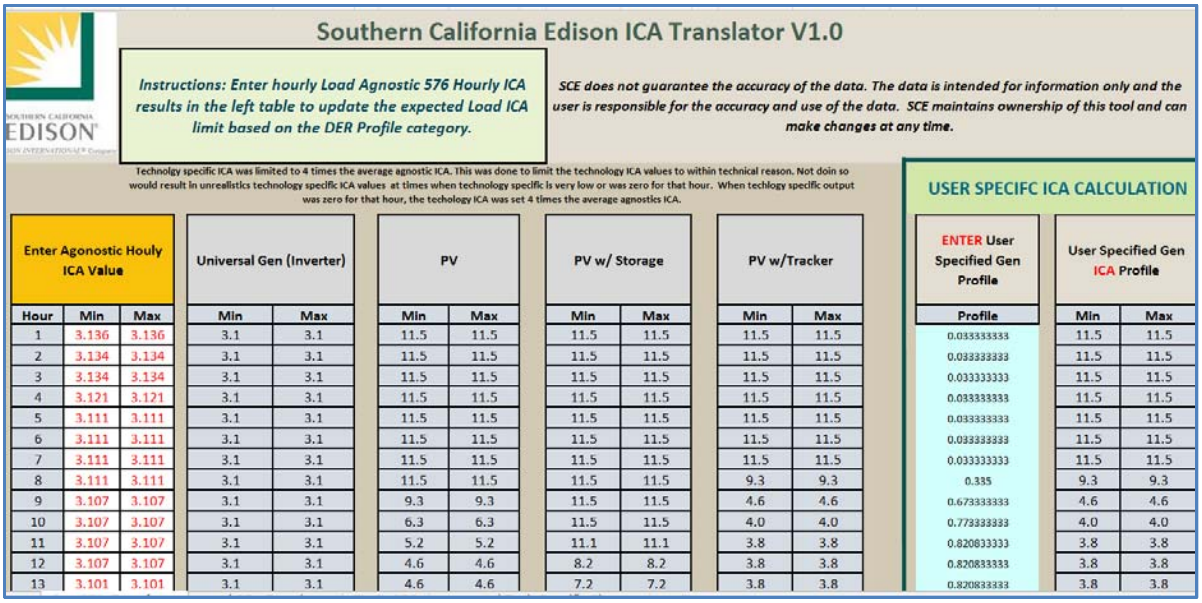


Figure 8: Hosting Capacity Sample Map


Southern California Edison ICA Translator V1.0

Instructions: Enter hourly Load Agnostic 576 Hourly ICA results in the left table to update the expected Load ICA limit based on the DER Profile category.

SCE does not guarantee the accuracy of the data. The data is intended for information only and the user is responsible for the accuracy and use of the data. SCE maintains ownership of this tool and can make changes at any time.

Technolgy specific ICA was limited to 4 times the average agnostic ICA. This was done to limit the technology ICA values to within technical reason. Not doin so would result in unrealistics technology specific ICA values at times when technology specific is very low or was zero for that hour. When techlogy specific output was zero for that hour, the techology ICA was set 4 times the average agnostics ICA.

USER SPECIFC ICA CALCULATION

Enter Agonostic Houly ICA Value			Universal Gen (Inverter)		PV		PV w/ Storage		PV w/Tracker		ENTER User Specified Gen Profile	User Specified Gen ICA Profile	
Hour	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Profile	Min	Max
1	3.136	3.136	3.1	3.1	11.5	11.5	11.5	11.5	11.5	11.5	0.033333333	11.5	11.5
2	3.134	3.134	3.1	3.1	11.5	11.5	11.5	11.5	11.5	11.5	0.033333333	11.5	11.5
3	3.134	3.134	3.1	3.1	11.5	11.5	11.5	11.5	11.5	11.5	0.033333333	11.5	11.5
4	3.121	3.121	3.1	3.1	11.5	11.5	11.5	11.5	11.5	11.5	0.033333333	11.5	11.5
5	3.111	3.111	3.1	3.1	11.5	11.5	11.5	11.5	11.5	11.5	0.033333333	11.5	11.5
6	3.111	3.111	3.1	3.1	11.5	11.5	11.5	11.5	11.5	11.5	0.033333333	11.5	11.5
7	3.111	3.111	3.1	3.1	11.5	11.5	11.5	11.5	11.5	11.5	0.033333333	11.5	11.5
8	3.111	3.111	3.1	3.1	11.5	11.5	11.5	11.5	9.3	9.3	0.335	9.3	9.3
9	3.107	3.107	3.1	3.1	9.3	9.3	11.5	11.5	4.6	4.6	0.673333333	4.6	4.6
10	3.107	3.107	3.1	3.1	6.3	6.3	11.5	11.5	4.0	4.0	0.773333333	4.0	4.0
11	3.107	3.107	3.1	3.1	5.2	5.2	11.1	11.1	3.8	3.8	0.820833333	3.8	3.8
12	3.107	3.107	3.1	3.1	4.6	4.6	8.2	8.2	3.8	3.8	0.820833333	3.8	3.8
13	3.101	3.101	3.1	3.1	4.6	4.6	7.2	7.2	3.8	3.8	0.820833333	3.8	3.8

Figure 9: Hosting Capacity Translator

3.3 Project Results

3.3.1 Technical Results, Findings, and Recommendations

SCE generated hosting capacity using a “technology-agnostic uniform generation and uniform load” approach so that the results are independent of the type of DER technology. SCE also developed a translator to translate the technology-agnostic uniform generation or load hosting capacity values into a desired, specific technology or portfolio of technologies.

Through this demonstration, SCE strived to find the proper balance of accuracy of results and computational time requirements, to produce meaningful hosting capacity values that would be useful for near-term use-cases while also allowing for continued refinements of the methodologies and calculations for long-term applications. SCE proposes that a Blended Method should be adopted for initial implementation of hosting capacity calculations across the SCE service territory. This method would use the Iterative Method on the typical 24-hour, light-load day in an annual period, which yields the necessary information required under the existing Rule 21 process, while developing a full 576 hourly (typical high load day and typical light load day for each month) calculation utilizing the Streamlined Method to provide information for planning purposes and to produce technology-specific hosting capacities. SCE believes this blended approach would establish a solid baseline for the development of a more complex, long-term hosting capacity analysis.

SCE believes that as the hosting capacity calculation methodologies continue to evolve, as tools become more effective, and as network models become more accurate through use of enhanced SCADA data, the efficiency of producing the hosting capacity values and the accuracy of the hosting capacity values will increase. Therefore, SCE recommends that for the initial phases, the proposed Blended Method should be adopted with the understanding that continuous improvements will occur based on technology improvements, tariff modifications, and improvements in network models.

Long-term, more complex hosting capacity applications would include the applicability of smart inverters and transmission-level evaluations. The most immediate use of the hosting capacity values would be in expediting the interconnection process through modifications of SCE’s Rule 21 tariff filed with the California Public Utility Commission. Other likely use cases include the application of hosting capacity information by SCE in its annual planning processes to aid in forecast development.

3.3.2 Technical Lessons Learned

The calculated hosting capacity results showed significantly different patterns between the urban area and the rural area. Circuits in the rural arear tend to have lower hosting capacities. Therefore, it is necessary to study different feeder characteristics in order to obtain a complete understanding of the hosting capacity pattern.

Typically, in most rural feeders, the steady state voltage and the operational flexibility criteria are the most limiting factors for nodes towards the end of the feeders; on the other hand, in most urban feeders, the operation flexibility limitation would be the most limiting factor for nodes near the substation while the steady state voltage would commonly be the most limiting factor for nodes further away from the substation.

The Streamlined Method performs one power flow simulation per hour of analysis to extract initial circuit electrical parameters to input into external equations. This method yields results quickly, is highly efficient in terms of the computational time required to produce hosting capacity values. However, for areas with voltage regulation schemes, areas distant from the substation, or systems with low short-circuit duty values, this method may not detect violations of voltage or thermal limitations accurately. In contrast, the Iterative Method performs multiple power flow simulations with varying levels of DERs connected. This method can produce the most accurate results that could be applied more seamlessly in the interconnection process. However, thousands of simulations for each feeder are needed, which significantly increases computational time.

3.3.3 Value Proposition

Through this demonstration, essential information is provided to the public to enable strategic DER siting which could help not only expedite the interconnection process but also avoid unnecessary system upgrade in order to accommodate the DER interconnection. This will lower costs while promoting enhanced environmental sustainability.

In the long term, this information can be integrated in SCE's annual planning process so that the possible impacts and benefits of DERs can be considered during the distribution planning process in order to develop cost effective system upgrade plans to safely and reliably supply electricity to all the customers. It can put ratepayers' money in efficient use.

3.3.4 Technology/Knowledge Transfer Plan

SCE has provided detailed project reports explaining the methodologies and the equations. The reports and detailed study results were made publicly available through the online map display so that users can not only access the overall hosting capacity results but also download the detailed results for in-depth analysis. SCE also performed benchmark analysis on IEEE 123-node feeder which is publicly available so that third party users or other utilities can perform the same analysis on the test feeder to understand the process, examine the results, and even perform additional analysis.

3.4 Metrics

List of Proposed Metrics and Potential Areas of Measurement (as applicable to a specific project or investment area in applied research, technology demonstration, and market facilitation)	
2. Job creation	
a. Hours worked in California and money spent in California for each project	See 5.1
3. Economic benefits	
a. Maintain / Reduce operations and maintenance costs	See 5.2
c. Reduction in electrical losses in the transmission and distribution system	See 5.3
4. Environmental benefits	
a. GHG emissions reductions (MMTCO2e)	See 5.4
7. Identification of barriers or issues resolved that prevented widespread deployment of technology or strategy	
b. Increased use of cost-effective digital information and control technology to improve reliability, security, and efficiency of the electric grid (PU Code § 8360);	See 5.5
c. Dynamic optimization of grid operations and resources, including appropriate consideration for asset management and utilization of related grid operations and resources, with cost-effective full cyber security (PU Code § 8360);	See 5.6

3.4.1 Hours worked in California:

Labor costs were supported for the engineers working at Southern California Edison. This included time spent on the project management, model and algorithm development, hosting capacity simulation and results analysis, and online map development.

3.4.2 Reduce O&M costs:

The methodologies developed, demonstrated, and recommended in this project will help DER developers to design the most economic project plans, and help SCE to expedite the interconnection process through modifications of SCE’s Rule 21 tariff filed with the California Public Utility Commission. This project can also help integrate the hosting capacity information in SCE’s annual planning processes to aid in forecast development.

3.4.3 Reduction in electrical losses:

Not Applicable

3.4.4 Reduction in GHG emissions:

The project will provide DER developers the available hosting capacity on the distribution system without system upgrade, this information can help developers design cost effective project and expedite the interconnection process therefore encourage and facilitate the integration of clean energies and to reduce the GHG emission.

3.4.5 Increased use of digital information and control technology:

Not Applicable

3.4.6 Dynamic optimization of grid operations:

Not Applicable.

4 Appendix

List of Acronyms

ARRA	American Reinvestment and Recovery Act
AT	Advanced Technology (the organization)
ATP	Advanced Technology Procedure, or Authority to Proceed
BOM	Bill of Materials
CCB	Change Control Board
CMO	Compliance Management Office
COTS	Commercial Off-The-Shelf
CPUC	California Public Utilities Commission
DBE	Disadvantaged Business Enterprise
DOE	Department of Energy
eDMRM	electronic Data Management/Records Management
EPIC	Electric Program Investment Charge
FY	Fiscal Year
GRC	General Case
IAW	In Accordance With
ICC	Integrated Change Management
IO#	Internal Order Number
IP	Intellectual Property
O&M	Operations and Maintenance
PDF	Portable Document Format (Acrobat file)
PfMP	Portfolio Management Plan
PM	Project Manager
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PMO	Portfolio Management Office
PMP	Project Management Plan
PMR	Portfolio Management Review
PO	Purchase Order
PPM	PMO Process Matrix
PPP	PMO Procurement Plan
PRR	PMO Risk Register
PSR	Project Status Review
SCE	Southern California Edison

SME	Subject Matter Expert
TFC	Termination for Convenience
TL	Technical Lead
Ts&Cs	Terms and Conditions

Glossary

Term to define	Definition here

Also see glossary's available for the electric utility industry available on the internet like this one: http://www.nwppa.org/advertise_sponsor/Facts_Figures_Glossary_of_Terms.aspx)