Final Scientific/Technical Report

Project Title:	Integrated Simulation Development and Decision Support Tool-Set for Utility Market and Distributed Solar Power Generation
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1 EXECUTIVE SUMMARY

This project will enable utilities to develop long-term strategic plans that integrate high levels of renewable energy generation, and to better plan power system operations under high renewable penetration. The program developed forecast data streams for decision support and effective integration of centralized and distributed solar power generation in utility operations. This toolset focused on real time simulation of distributed power generation within utility grids with the emphasis on potential applications in day ahead (market) and real time (reliability) utility operations.

The project team developed and demonstrated methodologies for quantifying the impact of distributed solar generation on core utility operations, identified protocols for internal data communication requirements, and worked with utility personnel to adapt the new distributed generation (DG) forecasts seamlessly within existing Load and Generation procedures through a sophisticated DMS.

This project supported the objectives of the SunShot Initiative and SUNRISE by enabling core utility operations to enhance their simulation capability to analyze and prepare for the impacts of high penetrations of solar on the power grid. The impact of high penetration solar PV on utility operations is not only limited to control centers, but across many core operations. Benefits of an enhanced DMS using state-of-the-art solar forecast data were demonstrated within this project and have had an immediate direct operational cost savings for Energy Marketing for Day Ahead generation commitments, Real Time Operations, Load Forecasting (at an aggregate system level for Day Ahead), Demand Response, Long term Planning (asset management), Distribution Operations, and core ancillary services as required for balancing and reliability. This provided power system operators with the necessary tools and processes to operate the grid in a reliable manner under high renewable penetration.

2 ACCOMPLISHMENTS

2.1 What was done? What was learned?

Green Power Labs has successfully adapted its state of the art solar generation forecast to enable production forecasts at any service transformer within SDG&E's service area. Compared to point power generation forecasts this work required significant changes in IT architecture design, as well as in physical modeling approach. Further, this project has provided strong insight into how high penetration DG-PV will impact adjacent circuits, how this impact can be mitigated via NMS use cases, and what forecast data is required to enable the enhanced NMS capability critical to ensuring safe and reliable operation of the distribution grid.

The significance of the work conducted by Green Power Labs within this project is immediately relevant to SDG&E, and directly applicable to electric utilities throughout the US. The work conducted under this project has identified how electric utilities can facilitate and sustain increased DG-PV growth, while ensuring safe, reliable operation of the distribution grid and delivering cost benefits to US ratepayers. Specifically, this project has made fundamental advances that have identified potential utility operations, use cases, and ancillary services that can be adapted to effectively optimize, control, and automate safe and reliable operation of the distribution grid. This project has focused on which data, its format, and structure is immediately required to enable utility Network Management System (NMS) tools (comprised of Distribution Management Systems (DMS) and Outage Management Systems (OMS) components) to properly execute utility use cases for reliable electric distribution operations.

2.2 What are the major goals of the project?

Electric utilities throughout the United States and globally are currently experiencing one of the largest infrastructure and technology shifts in the industry's history. Historically, electric utilities and related independent system operators have developed, maintained, and operated electrical transmission and distribution systems based on the premise that major generation would be placed onto transmission systems with the necessary rules and regulations in place to ensure optimal safety and reliability. This included data access, and control mechanisms for large scale generation. The rise of Distributed Generation - specifically, distributed solar PV generation (DG-PV), changes the landscape for electric utilities. With the scale of DG-PV deployment, and foreseeable exponential growth of DG-PV in the years to come, the immediate risk to electric utilities resides in the lack of data, connectivity controls, operational technologies, and infrastructure required to operate the distribution grid in a cost-effective, efficient, safe, and reliable manner.

The goals of this project were to Assess Potential Levels of Penetration of Renewables; Determine Impacts and Mitigation Measures and Develop Simulation and Forecasting Toolset to enable production forecasts at any service transformer within SDG&E's service area.

The project team set out to identify all existing distributed solar photovoltaic generation (DG PV), and large-scale solar PV capacity within SDG&E service area, and as of the first quarter of project performance, the team identified 20,869 PV installations. Distribution circuits in SDG&E's service territory have been reviewed, with 165,230 service transformers identified and 250 service transformers initially selected for pilot analysis based on circuit and penetration of DG PV. Revision to GPL's SolarSatData solar power prediction engine has begun. Changes required to accommodate 'Big Data' (ex: 165,230+ potential service transformer location point forecasts) have been determined. The ability to forecast DG PV at any of 165,230 service transformers within Green Power Labs' SolarSatData solar power prediction engine has been completed.

Key ADMS Phase 2 Functional Requirements were identified in the first quarter of program performance. Green Power Labs initiated contact with senior Distribution Operations personnel at SDG&E to establish technical components related to each use case. During the second quarter of program performance, the project team made progress to identified Key Phase 2 functional requirements in respect to DG integration.

Lessons learned thus far include level of detail required for various DMS vendors may vary, however, this project has identified at what circuit level solar asset forecast data must be provided for ingestion compatibility within any DMS products. The team also learned that highly technical IT and complex engineering expertise is required for quality production of solar asset forecasts at circuit-level granularity; GPL's experience and solar asset forecast base-product is a major enabler.

2.2.1 What was accomplished under these goals?

BUDGET PERIOD 1 (Months 1-12)

Task 1: Assess Potential Levels of Penetration of Renewables

The deliverable for Task 1 is:

- Summary Report to include a list of and number of DG sites and service transformers successfully adapted to SDG&E distribution assets profiled within the study area.

DOE's Acceptance Criteria Metric for Task 1 is:

- SDG&E has successfully integrated GPL data stream into a file location accessible by the NMS test environment.
- The work was completed in 2013.

Subtask 1.1*: Identify all existing distributed solar photovoltaic generation (DG PV), and large-scale solar PV capacity within SDG&E service area.*

SDG&E provided GPL data identifying, characterizing and locating all sub-stations, distribution circuits, distribution service transformers and distributed generation sites in the service territory. A total of 27,715DGPV installations were identified as of November 2013.

SDG&E and GPL geographic information system (GIS) teams related each DGPV site to its respective service transformer. Figure 1 below locates the 20,869 service transformers in the SDG&E service territory with attached DGPV.

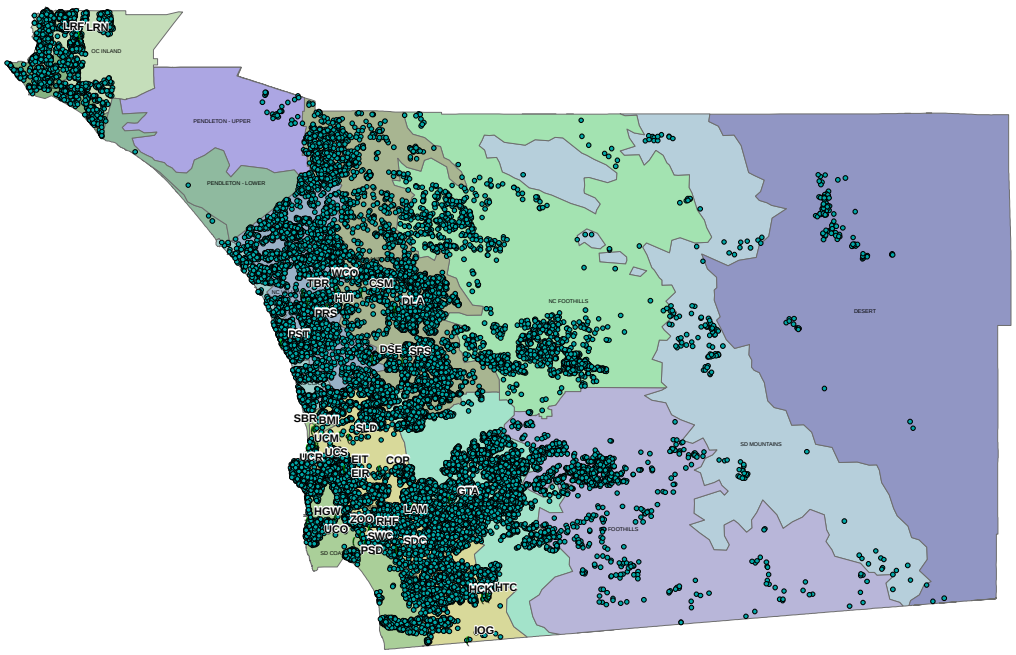


Figure 1: Current DG Forecast Locations at Transformer Level

The nameplate capacity of installed DGPV was 262.8 MW.

SDG&E monitors the solar power generation at 38 of the DG sites through a system which permits access by GPL.

Figure 2 below shows the micro-climatic classifications in the territory and distribution of the sites where generation data is available. The near real time data from twelve (12) of these sites are used by GPL to calibrate generation forecasts and monitor forecast performance for various forecasting methodologies.

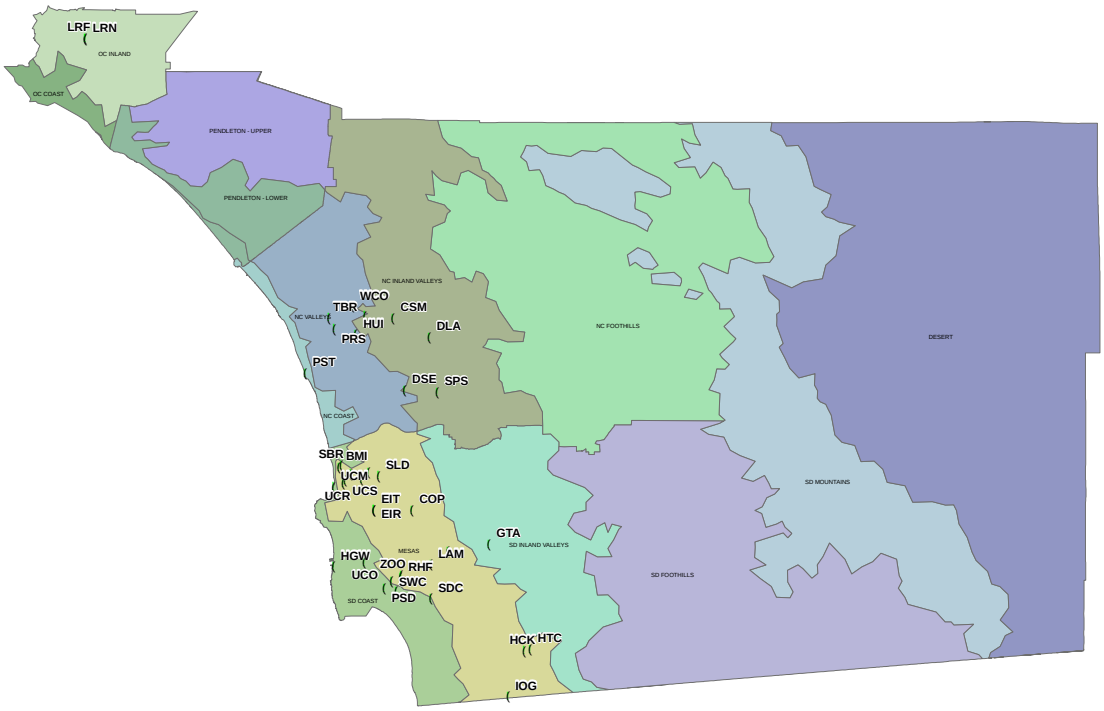


Figure 2: Monitored PV Locations

Subtask 1.2*: Distribution circuits in the SDGE service territory with High Penetration DG PV will be identified, chosen and utilized for this project SDG&E will provide Green Power Labs with 250 service transformer, location, transformer ID, GPS and, premise IDs, and installed solar generation associated with those premise IDs. The exact number of solar PV installations will be determined following the identification of the service transformers.*

The data provided by SDG&E was analyzed by GPL to identify the total nameplate capacity within each circuit and at each substation. SDG&E has provided GPL with all 165,000+ service transformer locations and identifications, and all DG premise IDs and locations, and the installed solar generation associated with those premise IDs.

The impact of DGPV on load profiles was examined at the substation level. At the time (2013), the level of DGPV penetration was relatively low. Five substation sites were selected based on varying load types, climate types, and DGPV penetration. The load and DG level was

characterized using three years of historical load data and the then-current DG assets. Table 1 below identifies the selected sites.

Table 1: Substation summary data

Name	No. of Feeders	Peak Load Observed (MW)	Peak Month	PV Max Nameplate Capacity (MW)	PV Penetration (%)[1]
Site 1	**6**	34.09	September	1.73	5.07%
Site 1	**3**	10.5	July	0.899	8.56%
Site 3	**4**	19.6	December	1.74	8.88%
Site 4	**5**	46.49	September	4.8	10.3%
Site 5	**9**	57.7	September	2.08	3.6%

Subtask 1.3*: Identified premise(s) with installed PV and associated name plate data will be entered into the SolarSatData™ Power Prediction engine. The output data (PV generated power flow data) will be rolled up to the service transformer, where an aggregated PV generated power flow value will be provided. The SolarSatData output will be aggregated at the service transformer level and will be then feed into SDG&E's Network Management System (NMS – comprised of both DMS and OMS). The SolarSatData power prediction involves a process to optimize power prediction output data by removing inherent bias. Bias relates to a peak over-prediction or under-prediction, which can be removed by feeding site observations into the prediction feedback models. Once bias is removed, the total system error is subsequently reduced to optimize power prediction data. While this is a process that was initially described in task 1.4, subtask 1.4 was omitted as it is an embedded process within the existing SolarSatData power prediction engine.*

Preliminary Revision to GPL's SolarSatDataTM Solar Power Prediction Engine

Forecast Data Management

Solar power forecasting requires considerable resources for real-time storage of weather data and for processing the solar resource forecasting models.

In contrast, the size of results files of solar power forecasts are small: for example, a file containing intra-hour forecasting at 15 minute increments for three hours and hourly forecasting for five days for 20,000 service transformer locations, in CSV format, is 100 MB, +/- 5%.

Methodology

A process was developed to use all available data in forecasting DGPV, and to evaluate accuracy relative to forecasts at individual sites. The major steps are:

- Determine power generation relative to solar resource at each site based only on location and nameplate capacity.

[1] PV Penetration = (Peak PV Power) / (Peak Load Apparent Power) - Anderson Hoke, Rebecca Butler, Joshua Hambrick, and Benjamin Kroposki; Maximum Photovoltaic Penetration Levels on Typical Distribution Feeders; NREL/JA-5500-55094; July 2012.
For the purpose of this study, PV Penetration is taken to be:
PV Penetration = (PV Power nameplate capacity) / (Peak Load Apparent Power)

- Capture solar resource forecasts in an aerial grid format at 1 km (0.6 miles) resolution
- Determine the generation forecast in terms of nameplate capacity from the gridded solar resource forecast
- Apply the generation forecast to each service transformer using the known location and related DG nameplate capacity.

Generation Forecast at each Service Transformer

The SolarSatData program has been adapted to store a database of service transformers, connected DG capacity and related circuit and transformer IDs. The SolarSatData program functions in real time to respond to queries for forecast generation at individual or multiple service transformer sites: it polls the service transformer database for installed DG capacity and the gridded irradiance forecast runs the load response routines for the respective locations and times of forecast.

The adapted SolarSatData program operates in real time to provide forecasts for any or all service transformers – or levels of aggregation – in the SDG&E service territory.

As noted above, a composite DG PV response model is necessary for residential-scale assets where the orientation and system details are unknown. The use of a composite model does not add a considerable error to the overall DG forecast. However, further work is recommended to determine probable errors at individual service transformers and circuit bus points.

The operating time to process all of the service transformers in the territory and to generate and upload a results file is currently less than five minutes. The current file size is 100 MB. The file is readily adapted to network management system use.

The process is scalable to include all service transformers in the territory as DG assets are added, and is readily updated as changes to the assets and service transformers are made.

The process is also readily adapted to combine forecasts for individual assets where the site configuration may be known, e.g., larger scale commercial installations, with residential-scale assets.

While not detailed in this report, calibration routines are established for solar resource utilizing 31 weather stations operated by SDG&E which include solar irradiance measurement. Performance monitoring is carried out routinely utilizing near real time data from 12 DG sites.

Task 2: Determine Impacts and Mitigation Measures

The Task 2 deliverable is:

- Summary Report to include prioritized mitigation measures for simulation and simulation outline; NMS data inputs required, and impacts of DG on SDG&E's grid.

DOE's Acceptance Criteria Metric is:

- Completed simulation outline.

Progress: The key design elements of the NMS simulation have been identified. All distributed generating forecasting procedures are in place. The simulation outline documentation, to be completed, will be consistent with existing processes.

Subtask 2.1*: Identify and document utility use cases (The "use cases" will utilize the circuits identified for this project with High Penetration PV defined as up to 30% solar) and software*

functionality required to provide SDG&E utility operations with improved power flow simulation modeling and related operations support to be implemented in SDG&E's Network Management System - NMS (OMS/DMS) using GPL's adapted data streams.

All substation, circuit, service transformer and DG assets were identified and included in SDG&E's and GPL's databases. This data is used to identify the extent of DG development throughout SDG&E's territory.

The impact of high penetration DGPV on load profiles was examined at the substation level. Five substation sites were selected based on varying load types, climate types and their significant levels of DGPV penetration. The load and DG level was characterized using three years of historical load data and the then-current DG assets.

As detailed in GPL's Task 1 report, the analysis determined:

- Load and DG profiles vary considerably between substations, and
- The impact of increasing DG penetration varies considerably between substations

The report used the Artesian Substation as an example. At this substation, as the nameplate capacity of DG increases to 50% of the peak hourly load in the circuits connected to the substation, the hourly PV production may exceed the load consumed in the circuits for approximately 1% of daylight hours, and would peak at 119% of the consumption. These results are summarized in Table 2 below.

Table 2: P99 and maximum values of generation-to-consumption by DG penetration, Artesian

DG Penetration (%)	Hourly PV/Consumption Ratio (%)	
	Maximum value	P99 value
5	12	9.9
25	60	49
50	119	99
75	179	147

The profile for the Artesian substation may be considered to be a typical example. Two of the substations may be considered to be relatively extreme cases, both in size of substation – with maximum hourly values of 10.5 MWh and 57.7 MWh respectively - and in the variability in load.

The distributed generation varies from zero to the nameplate capacity, net of generating system losses. Accordingly, for systems in which distributed generation is non-dispatchable and the net load at the substation transformer must be greater than zero.

Also, instantaneous conditions may occur in which the minimum consumption level is considerably less than the recorded hourly value.
Consequently, to determine the minimum load which may coincide with high levels of distributed generation, it is important that circuit-level or – depending on substation design – substation-level load records are available for a number of years.

High Penetration PV Data Integration – NMS Use Cases

The Network Management System (NMS) functions which may be enhanced through distributed generation forecasting include:

- Optimal Power Flow (OPF)
- Feeder Load Management (FLM)
- Suggested Switching
- Volt/VAr Optimization

These functions utilize estimates of real-time and/or forecast loads as inputs in their analyses. The NMS models circuit load conditions over a 24-hour time window; the load data is derived from basic loading assigned to specific equipment, profiling loads by time of day, day of week, season, holidays, etc., and load class, and/or from metered data at bus points on the circuits.

High penetration distributed generation alters the loads throughout the circuits from the primary bus at the substation through to individual service transformers. By modeling the net load (loads due to power consumption less power generated) at each point in the circuits, the existing NMS functions are unchanged.

A major consideration is determining the net load values that are required for a particular NMS function at specific locations and time horizons. The PV forecast integration may require minimum and/or maximum probable values for generation as well as load to maintain the safety criteria and reliability of the NMS function.

Summary - Sub-task 2.1

- All substation, circuit, service transformer and DG assets are identified.
- The circuits with the existing highest penetration PV may be readily obtained from the information which is available.
- A key consideration to the DG capacity of a circuit is the variability of load during periods of peak solar generating potential.
- The NMS use cases for which DG forecasting may be applied are identified

Subtask 2.2*: Identify the SolarSatData data stream outputs, file structure, and IT requirements for SDG&E's NMS functional enhancements and integration.*

The SolarSatDataTM power prediction engine was reviewed and it was determined that it will need to operate in real time to provide generation forecasts for any or all service transformers – or levels of aggregation – in the SDG&E service territory.

A composite DGPV response model is necessary for residential-scale assets where the orientation and system details are unknown. The use of a composite model does not add a considerable error to the overall DG forecast. However, further work is recommended to determine probable errors at individual service transformers and circuit bus points.

The forecasts were developed under Subtask 3.2 below to include solar generation forecasts in five-minute increments for the first two hours and in hourly increments for five days. Delivery is in

CSV format and, on a query basis, in graphic format at sites which are accessible to SDG&E. Forecasts are currently refreshed every 30 minutes.

The operating time to process all of the service transformers in the territory and to generate and upload a results file is currently less than five minutes. The current file size is 100 MB. The file is readily adapted to network management system use.

The process is scalable to include all service transformers in the territory as DG assets are added, and is readily updated as changes to the assets and service transformers are made.

The process is also readily adapted to combine DG forecasts with forecasts of individual assets where the site configuration may be known, e.g., larger scale commercial installations, with residential-scale assets.

Subtask 2.3*: Identify utility objectives for NMS-based simulations that will help determine the operational impacts of DG on SDG&E's distribution grid. New NMS feature/functionality components will be analyzed and prioritized for integration with SDG&E grid operations. Such distribution impacts may include operational issues such as customer and system impact of DG caused dynamic voltage swings, dynamic phase imbalance, intermittent power flow changes and reverse power flows on approximately five circuits.*

Utility Objectives for NMS-based Simulations
General Considerations

The ultimate objective is increasing DG while maintaining or improving the safety, reliability and cost-effectiveness of operations. A number of factors determine the extent to which distributed generation capacity may increase without impairing the reliability of the distribution system. A partial list includes:

- System design for individual circuits to feed other circuits on the low-side bus at the substation
- Variation in customer loads on individual circuits
- Predictability of the circuit loads
- Assets available or added for voltage regulation on the distribution circuit
- Assets available of added for power factor control, e.g., capacitors
- Network management

Future considerations - not part of this study - include:

- Smart invertors deployed with DG systems for voltage and/or frequency control and/or dispatch ability
- Energy storage
- Demand-side management

Task 3: Develop Simulation and Forecasting Toolset

Subtask 3.1*: SDG&E will provide enhanced NMS simulation outline.*

Simulation
The simulation intended to validate DG forecasting integration with NMS should include running the NMS with historical DG data and with real time DG forecasting data. Selected circuits will be run with and without DG forecast data to compare performance of the following NMS functions:

- Optimal Power Flow (OPF)
- Feeder Load Management (FLM)
- Suggested Switching
- Volt/VAR Optimization

Summary – Subtask 3.1
The key design elements of the NMS simulation outline have been identified.

SDG&E has extensive experience in adapting distribution management systems in response to changing requirements and opportunities. The simulation outline will be consistent with existing processes.

Subtask 3.2*: Green Power Labs development of required forecast data outputs, update frequency, and detailed time horizon from simulation outline.*

The requirements identified in Subtask 2.2 above have been developed and implemented in GPL's solar generation forecasting software.

To best enable efficient data ingestion within the NMS, GPL has recommended and implemented segregated csv files, grouped by substation. This enables the NMS to identify which service transformers/circuits are required for a specific model routine, without ingesting unnecessary forecast data. Ultimately, this will improve the processing time for the NMS.

Summary Subtask 3.2
GPL development of required forecast data outputs, update frequency, and detailed time horizon from simulation outline.

The data is available in a fully operational mode.

Subtask 3.3*: SDG&E will implement modified application on SDG&E vendor host environment. SDG&E will confirm implementation of modified application on SDG&E vendor host environment.*

GPL's modified solar generation forecast application was adapted to produce a generation forecast at each service transformer within SDG&E's service territory. The modified application was implemented on GPL's host environment and can produce data files which are populated to a SDG&E host file location that is available for ingestion into the utility's NMS.

Task 4: Provide DOE and Public Accessible Data Created from Budget Period 1 of this Project

The timeline for this deliverable is 30 days after the conclusion of Budget Period 1, at which time non-proprietary data will be made available.

Task 7: Project Management and Reporting
The Electricore project team participated and presented at the SunShot Grand Challenge Summit 2014 and Peer Review in May 2014. The poster and abstract presented are attached as an appendix to this report.

Electricore submitted a revised SOPO on May 12, 2014 for DOE consideration and review. The subcontract budget justifications were revised by SDG&E and GPL to reallocate federal and cost

share funds from Oracle to SDG&E and GPL per the revised SOPO. The following documents were submitted to DOE on May 23, 2014:

- Revised SOPO draft v.3
- Revised Budget Justifications for:
  - Electricore, Inc. (Prime Contractor)
  - San Diego Gas & Electric (Subcontractor)
  - Green Power Labs (Subcontractor)
- Revised Letter of Cost Share Commitment for:
  - San Diego Gas & Electric (Subcontractor)
  - Green Power Labs (Subcontractor)

Electricore received an Agreement Modification on July 15, 2014.

3 PROJECT ACTIVITIES SUMMARY

The following information resulted from the revised SOPO submitted to DOE and incorporated into Agreement Modification 1 dated July 15, 2014.

BUDGET PERIOD 1 (Months 1-12)

Task 1: Assess Potential Levels of Penetration of Renewables

- **Subtask 1.1**: Identify all existing distributed solar photovoltaic generation (DG PV), and large-scale solar PV capacity within SDG&E service area.
- **Subtask 1.2**: Distribution circuits in the SDGE service territory with High Penetration DG PV will be identify, chosen and utilized for this project SDG&E will provide Green Power Labs with 250 service transformer, location, transformer ID, GPS and, premise IDs, and installed solar generation associated with those premise IDs. The exact number of solar PV installations will be determined following the identification of the service transformers.
- **Subtask 1.3**: Identified premise(s) with installed PV and associated name plate data will be entered into the SolarSatData™ Power Prediction engine. The output data (PV generated power flow data) will be rolled up to the service transformer, where an aggregated PV generated power flow value will be provided. The SolarSatData output will be aggregated at the service transformer level and will be then feed into SDG&E's Network Management System (NMS – comprised of both DMS and OMS). The SolarSatData power prediction involves a process to optimize power prediction output data by removing inherent bias. Bias relates to a peak over-prediction or under-prediction, which can be removed by feeding site observations into the prediction feedback models. Once bias is removed, the total system error is subsequently reduced to optimize power prediction data. While this is a process that was initially described in task 1.4, subtask 1.4 was omitted as it is an embedded process within the existing SolarSatData power prediction engine.

Milestone 1.1: GPL will have adapted SDG&E's NMS requirements into the SolarSatData model and will supply outputs for review by SDG&E. Acceptance of those outputs by SDGE will be the first milestone.

Milestone 1.2: SDG&E and GPL will successfully upload the SolarSatData output into a file location which can be accessed by SDG&E's NMS.

Milestone 1.3: GPL will have adapted the SolarSatData model to the chosen 250 service transformers and will be delivering a real time data stream that meets SDG&E's NMS requirements. Success is acceptance by SDG&E.
Deliverable 1.1: Summary Report to include a list of and number of DG sites and service transformers successfully adapted to SDG&E distribution assets profiled within the study area.

DOE Acceptance Criteria Metrics: SDG&E has successfully integrated GPL data stream into a file location accessible by the NMS test environment.

Task 2: Determine Impacts and Mitigation Measures

- **Subtask 2.1**: Identify and document utility use cases (The "use cases" will utilize the circuits identified for this project with High Penetration PV defined as up to 30% solar) and software functionality required to provide SDG&E utility operations with improved power

flow simulation modeling and related operations support to be implemented in SDG&E's Network Management System - NMS (OMS/DMS) using GPL's adapted data streams.

- **Subtask 2.2**: Identify the SolarSatData data stream outputs, file structure, and IT requirements for SDG&E's NMS functional enhancements and integration.
- **Subtask 2.3**: Identify utility objectives for NMS-based simulations that will help determine the operational impacts of DG on SDG&E's distribution grid. New NMS feature/functionality components will be analyzed and prioritized for integration with SDG&E grid operations. Such distribution impacts may include operational issues such as customer and system impact of DG caused dynamic voltage swings, dynamic phase imbalance, intermittent power flow changes and reverse power flows on approximately five circuits.

Milestone 2.1: Prioritized mitigation measures for simulation. Mitigation measures can range from operator alarms to fully automated distribution automation processes and procedures derived in NMS to proactively mitigate the impacts, as much as possible, before they become serious problems.
Milestone 2.2: GPL and SDG&E reach agreement on requirement for output of forecast data

Deliverable 2.1: Summary Report to include prioritized mitigation measures for simulation and simulation outline; NMS data inputs required, and impacts of DG on SDG&E's grid.

DOE Acceptance Criteria Metrics: Completed simulation outline.

Task 3: Develop Simulation and Forecasting Toolset
This task will develop an advanced simulation toolset with an integrated solar power forecasting engine will be developed to suit SDG&E operations with an eye toward sector-wide application. The focus is on applying the forecasts to Distribution Operations for scenario optimization at the circuit level (power flow management), outage management, and long term planning.

The team will conduct integration of data from SDG&E's existing SolarSatData Solar Prediction Engine to SDG&E's NMS. SDG&E employs a rigorous testing process to ensure new OMS/DMS functionality is free of major defects prior to migrating code to the test environment. Prior to code being delivered to SDG&E, the utility requires proper unit and factory testing to occur by the software vendor. Once code is received by SDG&E, it is migrated to the utility's Integration and Quality Assurance (QA) test environments. The integration environment is primarily by SDG&E integration developers to ensure that integrations are working properly. The QA environment is used for functional and performance testing. The code has to be free of any significant defects that may cause a functional or performance issue prior to migrating to the test environment.

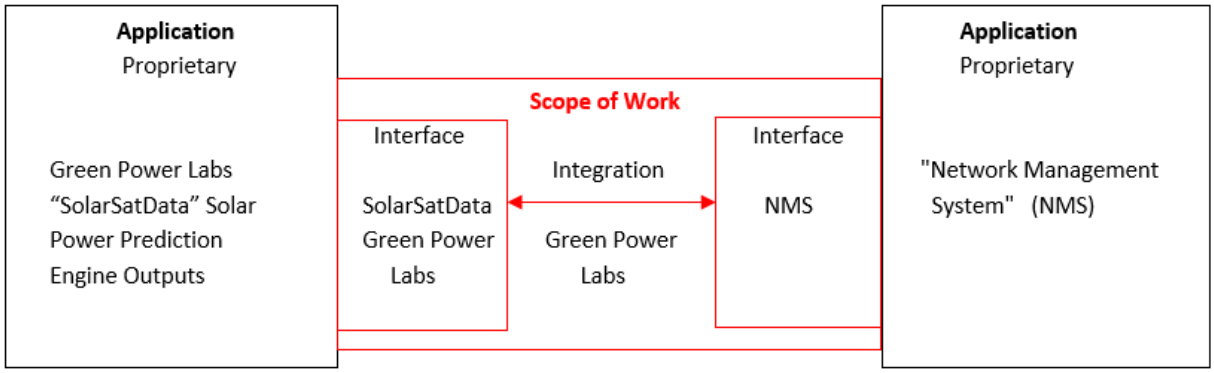
The test strategy document to reference: 07 10_OpEx_2020_OMS DMS_Test_Strategy_v6.doc. There are also detailed plans available for string, end to end, and technical testing. These are SDG&E internal documents, so they would need to be reviewed and scrubbed for sensitivity prior to release to a 3rd party Specific actions that will be taken by SDG&E in incorporating the enhanced DMS into their real time operations.

Data points will be comprised of aggregate data pulled from the approximately 165,000 transformers in SDG&E territory. Each transformer aggregates approximately nine (9) residential homes. Transformers with high penetration of solar will be prioritized for prediction and transmission through the interface designed and implemented by the Sunrise program. A range of implementation goals is anticipated:

- ✓ Basic project success = 40 transformers currently experience voltage attenuation from high penetration of solar
- ✓ Strong project success = 100 transformers in high penetration affected areas
- ✓ Outstanding project success = 200 transformers

- **Subtask 3.1**: SDG&E will provide enhanced NMS simulation outline.
- **Subtask 3.2**: Green Power Labs development of required forecast data outputs, update frequency, and detailed time horizon from simulation outline.
- **Subtask 3.3**: SDG&E will implement modified application on SDG&E vendor host environment. SDG&E will confirm implementation of modified application on SDG&E vendor host environment.

Milestone 3.1: Green Power Labs and SDG&E's review and acceptance of SDG&E's vendor adapter specification design document.



Green Power Labs will integrate output data from their "SolarSatData" into the "Network Management System" (NMS) software.

The NMS software is used for distribution outage management and distribution power flow management.

Task 4: Provide DOE and Public Accessible Data Created from Budget Period 1 of this Project

Deliverable 4.1: Data that was generated as part of the scope of this project in Budget Period 1 in easily viewed and downloadable format no later than 30 days after the conclusion of Budget Period 1.
GO/NO GO Decision: At the end of BP1, DOE's decision whether or not to proceed into BP2 with this award will be based on the successful completion of 85% of the subtasks and deliverables in BP1, and in accordance with program and budget requirements.

Task 5: Install and Utilize Enhanced Power System Hardware and/or Software
This task will install and utilize enhanced power system hardware and/or software that can test operational changes under high solar penetration scenarios to simulate the impact of high

penetration of renewables. The advanced simulation toolset will be installed and tested in a pre-production environment with representative operating conditions reflecting high penetration of variable generation.

Task 5 Deliverable: Summary Report to include summary of test scenarios of project simulation in test environment.

Subtask 5.1*: Install enhanced NMS on SDG&E pre-production test environment.*

Budget Period 1 succeeded in achieving a number of critical advances required to proceed with making necessary changes to the NMS use case functionality, and subsequent testing of the generation forecast data at the service transformer level during budget period 2. Specifically, the required forecast data granularity and format is now available for initial ingestion and testing within a utility NMS. Budget period 2 will facilitate the configuration and adaptation of the NMS functionality and subsequent testing within a pre-production environment.

Subtask 5.2*: Run test scenarios to analyze and validate test results.*

The configuration and format of the DG-PV forecast generation files developed in budget period 1 will be used to feed the NMS during budget period 2. NMS use case test scenarios will be run to validate test results, and to make any necessary changes to file format, and/or ingestion process. Details of the identified use cases are further defined in Section 5.0 above.

Task 6: Disseminate Lessons Learned
This task will disseminate lessons learned through case studies and manuals developed during the course of the program. In addition, roundtables and webinar presentations will be held to disseminate the results of the project to a broader audience. Case studies and informational materials will be developed to allow dissemination of lessons learned from the project. Project results will be woven into discussions, and presentations to advise the stake holder community of the results of the project.

Deliverable 6.1: All data that was generated as part of the scope of this project for both Topic A-1 and A-2 will be delivered in an easily viewed and downloadable format no later than 30 days after the conclusion of the grant.
Deliverable 6.2: Utility roundtable delivered
Deliverable 6.3: Public webinar delivered
Deliverable 6.4: Presentation of results at DOE Workshop delivered
Deliverable 6.5: Final Report delivered

Subtask 6.1*: (1) One utility roundtable; and (1) one public webinar program/agenda to be developed and agreed by SDG&E, and GPL.*

Results from budget period 1 will be compiled and made available to advise the stakeholder community. Following successful testing and validation from Task 5 in budget period 2, (1) one utility roundtable; and (1) one public webinar program/agenda will be developed and agreed by SDG&E and GPL. The agenda, schedule, and format will be presented in the corresponding quarterly report for DOE approval prior to proceeding.

***Subtask 6.2**: Provide DOE and Public Accessible Data Created from this Project*

This task will collect and make available in the public domain free of charge to be easily viewed and downloaded all data that was generated as part of the scope of this project, including data generated using federal and cost-share funds, such as, but not limited to, synthesized solar irradiance and power output together with name of city as a minimum location, electricity grid/feeder models developed in this project, strategic plans developed for solar integration, databases of feeder characteristics and results of clustering, composite load levels and outputs from screening tool. All data will be thoroughly checked for any errors and other quality issues corrected before making it available for download. Exceptions for redaction of proprietary information may be made on a case-by-case basis before posting the data in public domain for compliance to this task.

***Subtask 6.3**: Peer presentations developed and agreed by SDG&E, GPL, and DOE at a DOE High Penetration workshop (to be coordinated).*

Results from budget period 1 and 2 will be compiled and made available for presentation at a DOE High Penetration workshop, if so desired by DOE. The presentation outline will be presented in the corresponding quarterly report for DOE approval prior to proceeding.

***Subtask 6.4**: Final Report with results of benefits and applicability for broad-scale adoption/deployment amongst US electric utilities.*

All results from budget period 1 and 2 will be compiled and made available in the Final Report, with clear reporting on non-proprietary data, challenges, recommendations for industry adoption, and potential benefits.

Task 7: Project Management and Reporting

This task will focus on the overall project management and reporting required for this project. Electricore will lead this activity and obtain approval from the DOE regarding program goals, objectives, milestones, decision points, deliverables, success metrics and program plans. The project manager will report the achievement of all major milestones for the project. Reports and other deliverables will be provided in accordance with the Federal Assistance Reporting Checklist following the instructions included therein.

Program Management and Reporting in accordance to DOE F 4600.2:
Deliverable 7.1: Management Reporting
Deliverable 7.2: Scientific/Technical Reporting
Deliverable 7.3: Financial Reporting
Deliverable 7.4: Closeout Reporting
Deliverable 7.5: Other Reporting

4 FINAL PRODUCTS

4.1 What has the project produced?

TASK #	MILESTONE #	MILESTON DESCRIPTION	Due Date	Status
BUDGET PERIOD I				
Task 1: Assess Potential Levels of Penetration of Renewables	Milestone 1.1	GPL will have adapted SDG&E's preliminary NMS requirements into the SolarSatData model and will supply outputs for review by SDG&E. Acceptance of those outputs by SDG&E will be the first milestone.	Q4 2013	Complete
Task 1: Assess Potential Levels of Penetration of Renewables	Milestone 1.2	SDG&E and GPL will successfully upload the SolarSatData output into a file location which can be accessed by SDG&E's NMS.	Q4 2013	Complete
Task 1: Assess Potential Levels of Penetration of Renewables	Milestone 1.3	GPL will have adapted the SolarSatData model to the chosen 250 service transformers and will be delivering a real time data stream that meets SDG&E's NMS requirements. Success is acceptance by SDG&E.	Q4 2013	Complete
DOE ACCEPTANCE METRIC: *SDG&E has successfully integrated GPL data stream into a file location accessible by the NMS test environment.*				
Task 2: Determine Impacts and Mitigation Measures	Milestone 2.1:	Prioritized mitigation measures for simulation. Mitigation measures can	Q4 2013	Complete All substation, circuit, service transformer and

		range from operator alarms to fully automated distribution automation processes and procedures derived in NMS to proactively mitigate the impacts, as much as possible, before they become serious problems.		DG assets are identified. The circuits with the existing highest penetration PV has been reviewed from the information which is available. The NMS use cases for which DG forecasting may be applied have been identified
Task 2: Determine Impacts and Mitigation Measures	Milestone 2.2:	Summary Report to include prioritized mitigation measures for simulation and simulation outline; NMS data inputs required, and impacts of DG on SDG&E's grid.	Q4 2013	Complete Summary Report Delivered. Preliminary use cases identified. GPL's Simulation Operation Outline included in Summary Report.
DOE ACCEPTANCE METRIC: Completed simulation outline.				
Task 3: Develop Simulation and Forecasting Toolset	Milestone 3.1:	SDG&E's review and acceptance of adapter specification design document.	Q3 2014	In Progress The key design elements of the NMS simulation outline have been identified. SDG&E has extensive experience in adapting distribution management systems in response to changing

				requirements and opportunities. The simulation outline will be consistent with existing processes.
	End of Year 1 Go/No Go Milestone:	*GO/NO GO Decision: At the end of BP1, DOE's decision whether or not to proceed into BP2 with this award will be based on the successful completion of 85% of the subtasks and deliverables in BP1, and in accordance with program and budget requirements.*	***Q4 2014***	As of Q2 2014, 8/9 BP1 Subtasks are completed, with the final BP1 Subtask scheduled for completion by end of Q4 2014. Currently the project has completed 89% of subtasks plus deliverables in accordance with program budget requirements.

5 PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Partner	Key Personnel	Qualification	Role
Electricore	Deborah Jelen Executive Director	Ms. Jelen has twenty-six years of management and engineering experience with major companies including Electricore, Inc, AeroVironment, Olin Aerospace, Rocket Research Company, Eldec (now Crane Aerospace) and Hughes Aircraft Company. Her background includes leadership roles in the development and manufacture of electric and hybrid vehicles, unmanned air vehicles, solid rocket systems, infra-red detection products and a broad array of associated land and airborne electronics.	Prime Contractor, Program Management and Administration
Electricore	Kodie Arnold Program Manager	Ms. Arnold joined Electricore in 2008. As a Program Manager, she is responsible for Program Management and Administration for research and development projects with the Department of Transportation, Defense and Energy, US Military, and California Energy Commission. Ms. Arnold holds a Masters in Public Administration with special focus on Management and Leadership from California State University, Northridge and B.A., English from California State University, Northridge.	Prime Contractor, Program Management and Administration
SDG&E	Dallas Cormier Senior Engineer	Dallas is a Senior Engineer in the Smart Grid Projects Group. His present responsibilities involve renewable power generation prediction, understanding and modeling weather impacts to solar photovoltaic power generation on the distribution system, smart grid project implementation, strategic project design, and development of new technologies to manage Solar Photovoltaic power generation impacts to the transmission and distribution systems. Dallas is currently managing and leading the development of the following strategic smart grid projects at SDGE.	Host Utility Partner
SDG&E	Sherwin Edra PE	Project Manager of Advance Distribution Management System (ADMS) – Test and implement Fault Location Analysis, Feeder Load Management, Power Flow, Volt/VAR Optimization and Fault Location, Isolate and Restore tools to the existing NMS; Create and manage budget, business case, and project schedule	Host Utility Partner

SDG&E	Michael Espinoza PE	Project Manager - Special Projects Electric Distribution Operations Distribution Smart Grid, Weather, Renewable Energy, Touch Technologies, Situational Awareness, GIS, Cloud Technologies..	
Green Power Labs	Tony Daye, Vice President, Smart Grid Operations / PI	As a senior member of Green Power Labs' Leadership Team, Mr. Daye brings extensive senior management, strategic planning, and leadership experience from both the public and private sectors. A recognized authority in renewable energy, Mr. Daye has been a key contributor to the global solar industry, including cutting-edge advances in smart grid and solar energy management technologies. Reporting directly to the President of one of North America's largest engineering firms, Mr. Daye was the lead on numerous renewable energy projects across the U.S., including principle contributor to the Bay of Fundy Strategic Environmental Assessment for Tidal Energy demonstration and commercial development; Model Bi-Law development for Wind Energy deployment; and solar generation integration for IOU and municipal utilities. Currently, as Vice President, Smart Grid Operations with Green Power Labs, Mr. Daye continues to work closely with many of North America's largest utilities, business leaders, government, and academic partners in the integration of solar generation within utility operations to enable operational cost savings for utilities and their ratepayers.	Simulation Tools Development / PI
Green Power Labs	Dr. Vladimir Kostylev, Principal Investigator	Green Power Labs is a leading provider of solar power forecasting services, with major operations in US, Canada, and Australia. Green Power Labs' SolarSatDataTM Monitoring and Forecasting software provides electric utilities and system operators with advanced operational forecasting of variable solar power generation for utility-scale and distributed generation facilities, Net-Load, Demand Response, Distribution Operations, Energy Marketing & Trading, and Real Time Ops. As Principal Investigator with Green Power Labs, Dr. Vladimir Kostylev has 24 years of experience in environmental research and integrated geomatics applications. He received his Ph.D. degree from Gothenburg University (Sweden). Dr. Kostylev has an extensive background in	Simulation Tools Development

		environmental assessment and GIS, linking physical and ecological modeling to digital mapping projects, and use of remote sensing technologies for automated capture and analysis of spatial data. Dr. Kostylev is a member of various national and international committees on integrated environmental management, mapping, and solar forecasting including International Energy Agency (IEA) Task 46 on Solar Resource Assessment and Forecasting.	
Green Power Labs	Dr. Alexandre Pavlovski, Senior Power Systems Engineer/Advisor	Dr. Pavlovski is a professional engineer with over 30 years of expertise in renewable energy field. He holds a Master of Science, Applied Physics and a Ph.D., Power Conversion degrees from St. Petersburg Polytechnic University, diplomas and certificates in Environmental Policy and Innovations Management from St. Petersburg Polytechnic University – Institute for Innovations, Suffolk University – Sawyer School of Management (Boston) and Central European University - Department of Environmental Sciences and Policy (Budapest). Dr. Pavlovski began his professional activities in 1981 as an environmental researcher with High Voltage Direct Current Power Transmission Research Institute. His engineering expertise has been focused on alternative/renewable energy applications: magnetohydrodynamic energy conversion, solar and wind power generation. He has also gained successful managerial experience running companies in the field of power engineering. His excellent international reputation as an entrepreneur and wide personal contacts in the energy industry greatly contribute to the success of the company and utility partners.	Simulation Tools Development

5.2 Have other collaborators or contacts been involved?

Electricore was awarded the subject contract with San Diego Gas & Electric (SDG&E), Green Power Labs and Oracle.

Electricore provided a draft subcontract to Oracle upon award notice and followed up with a visit to San Diego and then in weekly email and phone calls in order to complete the subcontracting effort. Initially, Oracle negotiated on several terms, some of which were flow downs from the DOE prime contract, thus Electricore was unable to negotiate any change.

In January 2014, Oracle took the position that the only acceptable contract method was the standard Oracle contract. Oracle's position was identified as firm and no further compromise available. Electricore convened a team meeting several times during the week in an attempt to find an alternative approach. SDG&E offered a compromise in which they would accept the scope of work and deliverables for the DOE contract, consuming the budget with SDG&E team members. SDG&E has an extensive program underway with Oracle on their own private funding and agreed to cover any necessary Oracle activities out of the non-federal budget. This compromise provides a good alternative to the original SOPO and would allow all program initiatives to be completed and shared with industry as planned. Electricore conveyed the alternative approach to DOE in the quarterly report on January 30, 2014.

6 CHANGES/PROBLEMS

As discussed during the October 14, 2014 conference call, it was mutually determined to close Award DE-EE-0006332 upon completion of Budget Period 1 scope of work and budget commitments.

The project team participated in the Phase Review meeting with DOE on September 17, 2014 in Washington, DC to discuss Budget Period 1 accomplishments and Budget Period 2 path forward. During this meeting, the project team also discussed the risks associated with moving forward with Budget Period 2. These risks included the following:

- SDG&E did not receive a commitment from their vendor, Oracle, in the time frame necessary to move forward with Budget Period 2 scope.
- SDG&E and Green Power Labs are working to execute their internal agreement which allocates the remaining Budget Period 1 non-federal funds. The remaining non-federal share from SDG&E will be captured and invoiced to DOE.

Following the September 17, 2014 meeting with DOE, the project team's primary objective to proceed with Budget Period 2, was to either:

- Secure Oracle's involvement, or
- Replace Oracle's tasks with another DMS vendor. The risk/challenge with replacing Oracle, is that any new DMS must be able to replicate the utility's Distribution system.

To mitigate this risk, Green Power Labs identified a DMS vendor that SDG&E currently uses as its SCADA provider, and that also has existing SDG&E distribution system information in their DMS and simulator. This would enable the project to proceed, completely replacing the need for Oracle.
The first week of October, Electricore and Green Power Labs received initial notification from its utility partner, SDG&E that they will not be participating in Budget Period 2. SDG&E will fulfil its participation for Budget Period 1 activities and cost share.

Electricore and Green Power Labs held a teleconference with DOE on October 14, 2014 to discuss Budget Period 2 options. Electricore and Green Power Labs proposed to replace the utility partner and DMS vendor but it was explained by DOE that this option would not be considered. During this meeting, it was mutually determined to close Award DE-EE-0006332 upon completion of Budget Period 1 scope of work and budget commitments.

7 SPECIAL REPORTING REQUIREMENTS

None.