Energy Research and Development Division

FINAL PROJECT REPORT

Borrego Springs: California's First Renewable Energy-Based Community Microgrid

California Energy Commission

Gavin Newsom, Governor

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- Microgrid Energy Solutions

PREFACE

The California Energy Commission's Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solution, foster regional innovation and bring ideas from the lab to the marketplace. The Energy Commission and the state's three largest investor-owned utilities – Pacific Gas & Electric Company, San Diego Gas & Electric Company and Southern California Edison Company – were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The Energy Commission is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and flexible load, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Borrego Springs: California's First Renewable Energy Based Community Microgrid is the final report for the Borrego Springs: A Future Photovoltaic Based Microgrid project EPC-14-060 conducted by San Diego Gas & Electric Company. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

The mission of the Borrego Springs Microgrid project was to build a primarily renewable energy based microgrid that could independently provide power to an entire substation and the approximately 2,500 residential and 300 commercial and industrial customers it serves in the community. Borrego Springs has a history of numerous outages because of severe environmental conditions and is located at the end of a single transmission line. The microgrid project provides a direct and significant benefit to a real-world community and has a positive effect on the environment because it increases the community's energy resilience while reducing its carbon footprint by using renewable energy resources. The microgrid consists of San Diego Gas & Electric Company's 69 kilovolt to 12 kilovolt air-insulated substation; a 26 megawatt photovoltaic system located in the community; approximately 3 megawatts of customer-owned rooftop photovoltaic systems, two 1.8 megawatt distributed generation resources; two substation batteries; and three community energy storage batteries to provide electricity to the entire community during the day and, when necessary, dropping to critical loads at night.

During the project period, San Diego Gas & Electric Company and project team members upgraded the existing microgrid facility and developed an advanced microgrid controller, enabling successful and reliable islanding of the entire Borrego Springs community and its customers. San Diego Gas & Electric Company controlled the microgrid both locally (in Borrego Springs) and from its Distribution Control Center more than 80 miles away. Besides the immediate benefit to the Borrego Springs community of having non-interrupted energy resources, this project has significantly increased the microgrid knowledge base, particularly regarding advanced microgrid controllers and implementing non-utility owned resources.

Keywords: advanced microgrid controller, renewable energy, Borrego Springs microgrid, island testing, third-party solar integration

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EXECUTIVE SUMMARY

Introduction

California's energy policies focus on promoting affordable energy supplies, improving energy reliability, and enhancing health, economic well-being, and environmental quality. Reliability in this context means delivering energy at the quantity and with the quality required by users. A closely related concept is energy resilience, which refers to the ability of the energy system to recover from crisis events such as hurricanes, floods, and other weather-related situations. Microgrids are an important tool to help increase the reliability and resilience of California's electricity system. A microgrid is an independent electric grid with onsite energy generation or storage or both that can operate while connected to or when islanded (disconnected) from the larger utility grid. When in island mode, the electrical power generation in the microgrid must exactly match the electrical loads within the microgrid.

Microgrids are not a new concept. Several modern microgrids have been used in California during the past decade, typically using a variety of fossil fuel-based power generation or energy storage or both. These microgrids, however, have operated at a small scale and do not apply to real-world fluctuations in customers' energy consumption. More importantly, there has been limited success in demonstrating the ability of a microgrid to comply with California's mandated renewable energy policies and goals, or to manage large amounts of renewable energy (up to 100 percent) to meet facility or community electricity needs while avoiding adverse impacts to the electric grid from the unpredictability of renewable resources. Most of these also microgrids lack a sophisticated microgrid controller or energy management system that could automatically enhance the performance of systems that use more than one renewable energy resource.

Microgrid technology that uses renewable energy resources, such as solar photovoltaic (PV), and energy storage technologies, such as batteries, can improve resiliency and reliable energy distribution for communities with energy volatility. Until now, the ability to develop a community microgrid powered by renewable energy and controlled by software has been a challenge. The Borrego Springs Microgrid, the subject of this report, is California's first renewable energy-based microgrid that can provide a sustainable, stable, software-controlled power solution for a California community during planned or unexpected electric outages.

San Diego Gas & Electric Company (SDG&E) recognized the importance of demonstrating a microgrid at a larger scale than previous versions. Specifically, SDG&E believed that a large enough microgrid, with renewable energy resources, could increase the energy resilience and reduce the carbon footprint of an entire community. Such a microgrid could also increase the community's energy reliability and support California's goals to reduce greenhouse gases that contribute to climate change.

SDG&E recognized, however, that renewable resources are intermittent, technologically complex, and costly, which may be why most utilities have shied away from such projects. SDG&E proposed improving the limited function and scale of most microgrids by including renewable energy while simultaneously developing a reliable advanced microgrid controller. The goal was to develop, use, and manage a microgrid that provided a direct and significant benefit to a real-world community, while also supporting environmental sustainability.

For this project, SDG&E chose to improve its already established microgrid in Borrego Springs, California, to include the entire Borrego distribution substation, incorporate third-party owned solar PV resources located within the community, and develop an advanced microgrid controller. For flexibility and responsiveness, SDG&E developed the controller so that the microgrid could be operated both remotely from its Distribution Control Center and locally at the site.

The Borrego Springs community was originally chosen for the microgrid site because it is located in a remote area that has historically experienced many outages due to extreme and volatile weather conditions. The community also has a single transmission line feeding the substation, which makes it more vulnerable. The Borrego Springs community was also chosen because it already had a high concentration of private solar energy systems on resident's homes, as well as two commercial PV production plants in the vicinity (although only one commercially owned plant chose to be included in the project). For the privately owned solar resources, particularly rooftop PV, their lack of uniform energy flow made them difficult to account for and control during microgrid operations. SDG&E was determined, however, to take advantage of the substantial presence of these resources within the microgrid to generate the necessary energy to the community while reducing greenhouse gas emissions.

Project Purpose

The focus of the Borrego Springs project was developing a renewable-based microgrid that would island (disconnect from the grid) the entire substation, which serves approximately 2,500 residential and 300 commercial and industrial customers. In addition to the substation, SDG&E used a third-party commercial 26 megawatt (MW) PV system located in the community, approximately 3 MW of customer-owned rooftop PV systems, two 1.8 MW distributed generation resources, two substation batteries, and three community energy storage batteries to island the entire community during the day and, when necessary, dropping to critical loads at night.

The project team believed that the geographically remote community of Borrego Springs could benefit from its environment. SDG&E also believed that the benefits from this project would not be limited to Borrego Springs, and that the knowledge gained could be transferable to other communities. Other electrical utilities can also benefit from development of renewable energy microgrids that which can provide stable energy to communities when off the electric grid and help reduce greenhouse gas emissions.

The team already had the two primary assets necessary for the project in Borrego Springs: a base microgrid and indigenous and significant renewable energy resources. These individual assets, however, were never originally designed to work in unison. From the onset, this project had to overcome the hurdle of incorporating and reliably controlling third-party assets that were never intended to be managed by the utility. Furthermore, this had to be accomplished using a microgrid controller that had yet to be developed.

Project Process

SDG&E led the project from its Kearny Mesa headquarters in the City of San Diego, California. SDG&E decided at the onset that this project needed a broad range of participants. Besides working with its top engineers and microgrid experts, SDG&E wanted to have external engineering review and input as well as involvement from the community the microgrid would service. With this in mind, SDG&E created its microgrid team: the National Renewable Energy Laboratory (laboratory testing); Spirae (software design); University of California, San Diego (academia); OSIsoft (open enterprise infrastructure); Borrego community members with the Anza-Borrego Desert Natural History Association; and NRG (renewable energy production). SDG&E chose these partners because of their unique experience and expertise.

The project team first created goals, objectives, and scopes of work for each aspect and phase of the project. With these in mind, the team created a detailed project plan, devised time lines, and determined individual and group responsibilities and success requirements. The project stakeholders and a technical advisory committee were involved in the overall process including defining requirements, system design, advanced microgrid controller development, testing, demonstration, analysis, and reporting. The project plan allowed for adjustments based on feedback and real-world results. Since this was a community-based project, the team included the Borrego Springs residents in every decision and phase of the project. The researchers also considered project cost, and performed tasks in the most economically efficient way possible.

After preparing the project plan, the team immediately started testing the concepts and plans in SDG&E's Integrated Test Facility. Once ideas proved true in the laboratory setting, they were passed on to SDG&E System Protection and Control Engineering to ensure the plan did not violate any system regulatory requirements or safety factors. For plan phases that involved external systems or components, such as the NRG solar plant, SDG&E either solicited assistance from or subcontracted with the entities that developed those components (as in the case of SunPower and Versus with the NRG controllers). Throughout the venture, the project team revised the plan as needed.

Project Results

The project team successfully accomplished most of its desired results, including effectively developing a system to island the Borrego Springs community and eliminate much of its vulnerability to interruptions of the electric grid. At the project conclusion, SDG&E and project team members:

- Expanding the existing microgrid facility boundaries to energize all the Borrego Springs customers by adding synchronizing relays, integrating third-party PV systems, hardening of electric overhead structures, and field automation.
- Developed an advanced controller that could successfully island the entire Borrego Springs community and all of its customers.

- Controlled the microgrid locally and from SDG&E's Distribution Control Center more than 80 miles away.

The project team successfully islanded the community on multiple occasions during daylight and nighttime conditions. The microgrid islanded the community using distributed power generation and energy storage, and incorporated the local third party 26 MW PV facility into the microgrid. The project results increased the ability to support the customers in the Borrego Springs community through a renewable energy based microgrid. The project also furthered the research of including multiple assets originally designed to work independently to instead work harmoniously together within a microgrid. All these actions are remarkable in that they were not previously accomplished at this scale, within an active community, and with non-utility energy producing assets, while simultaneously developing a microgrid controller/energy management system to manage the microgrid.

Some of the key lessons learned included:

- Dedicated subject matter experts are critical for each task area (system protection, distributed generation, testing, and so on), as well as for integration of each component of the microgrid.
- While each microgrid asset works as expected when run independently, the challenge with an advanced renewable-based microgrid is when the assets are combined together to island the load. When there are multiple assets, one resource becomes the "master" while all others become "slaves." This configuration requires an advanced microgrid controller with custom programming about each asset's capabilities are to allow the system to dispatch the right asset at the right time and maintain all assets in the optimum state.
- There are difficulties associated with islanding in a low-inertia environment that requires modification of protection setpoints and ride-through settings. ("Inertia" maintains electric system stability, and is provided through the spinning mass provided by rotating turbines in large electricity generating facilities which allows the system to "ride through" deviations in power frequency.)
- There are challenges associated with controlling third-party assets whose owners have no obligation to participate.
- The impact of 3 MW of customer rooftop solar, which has older inverters and protection settings, quickly results in removal of that generation resource from the grid.
- It is necessary to include additional fast response devices such as the Maxwell Ultracapacitor into the operating environment. The Maxwell Ultracapacitor was not funded by this grant, and was installed at SDG&E's expense.

As with any project, there is always more to learn. Although the Borrego Springs Microgrid project is completed, SDG&E and the project team members are committed to continuing the research to further incorporate the commercially owned and operated third-party renewable energy resources into the microgrid. Additional testing is scheduled for later in 2018, and there are continuing discussions about the possibilities of increased energy storage at the microgrid and other improvements that could enhance the microgrid's overall stability and its ability to supply dependable, reliable energy to the community when the microgrid is needed for islanding purposes. The project team intends to continue to improve on its concepts and developments to improve the microgrid for the benefit of the community. Furthermore, the project team hopes to transfer the knowledge gained through this project through this report, public meetings, community events, and published fact sheets.

Benefits to California

The Borrego Springs Microgrid project has already benefitted Borrego Springs residents and promises to be even more beneficial in the future. The benefits of the project team's research and testing for the further development of the microgrid were experienced by ratepayers firsthand. During the previous demonstration project, the microgrid met the energy needs of the Borrego community for both planned and unanticipated situations in which the community would have otherwise been without energy. These past island events were performed manually and required significant prior planning, used limited renewable resources, required substantial human manual intervention, and could only occur while the microgrid was operating locally. The improved microgrid has been successfully used on multiple occasions to meet energy needs for the entire community during compliance and emergency maintenance work to the substation and its power delivery components. In these situations, unlike the previous demonstration project, events were executed locally and from SDG&E's control center, located more than 80 miles away, using the new advanced microgrid controller developed during this project. Without the improved microgrid and the advanced microgrid controller, the Borrego Springs community, including many senior citizens who rely on energy-dependent life support systems, would have had to endure long power outages, day and night, under extreme desert conditions. The microgrid project also provided economic benefits to the community by allowing storefronts, restaurants, and other local businesses to stay open during what would ordinarily be a power outage. This improved support to a vulnerable community was one of the primary reasons for developing the microgrid in Borrego Springs.

Besides the immediate benefit to the Borrego Springs community of uninterrupted energy supplies, this project has also significantly increased the microgrid knowledge base, particularly in the areas of software controllers and implementation of third-party resources. Through the project team's efforts, including significant research and testing by independent partners like the National Renewable Energy Laboratory, large amounts of data and investigation results have provided technical information needed to develop more efficient and effective microgrids and software controllers. This information provides benefits not only to the Borrego Microgrid, but also to almost all current and future microgrids throughout California.

The Borrego Springs Microgrid is not a temporary experiment for SDG&E, but instead, it is a commitment by SDG&E to its customers of Borrego Springs. The longer-term goal is to further leverage renewable resources for more dependable, resilient energy, while minimizing negative impacts to the environment.

CHAPTER 1: Introduction

Problem Statement

The town of Borrego Springs is fed by a single, radial 69 kilovolt (kV) transmission line which is approximately 30 miles long and experiences an elevation change of approximately 5,000 feet. As part of the Colorado Desert sub-region of the Sonoran Desert, the area experiences high winds and monsoonal storms which can lead to long duration outages during periods of high temperatures. San Diego Gas & Electric Company (SDG&E) has been actively developing a microgrid to provide energy resiliency for the approximately 2,800 year-round residents of Borrego Springs.

Due to technology advancements in communications, controls, and computers, microgrids have emerged as a new tool for a possible alternative service delivery model. The California Energy Commission has invested in the research, development, demonstration, adoption, and commercialization in support of development of microgrids. The United States Department of Energy (USDOE) defines the microgrid as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in grid-connected or island mode."

Microgrids have also been deployed that integrate traditional fossil fuel-based generation (in limited deployments) along with the renewable energy resources (such as solar photovoltaic and energy storage systems). SDG&E, with funding from the Energy Commission and USDOE in 2013, developed one such microgrid at Borrego Springs, in San Diego County. The previous "Borrego Springs Microgrid Demonstration Project" focused on the design, installation, and operation of a community scale "proof-of-concept" microgrid demonstration. The site of the microgrid was an existing utility circuit that had a peak load of 4.6 megawatts (MW) serving 615 customers within a remote area of the service territory. The key aspects of that microgrid demonstration project were integrating and operating the following types of equipment and systems:

- Distributed generation.
- Advanced energy storage.
- Price-driven load management.
- Fault location, isolation, switching, and restoration.
- Integration with outage management system/distribution management system and microgrid controls.

This project attempted to demonstrate the viability of a microgrid to manage high amounts (up to 100 percent) of renewable energy to meet the facility/community load, while avoiding adverse grid impacts, using a microgrid controller/energy management system.

SDG&E expanded the scope of its existing Borrego Springs Microgrid using the local, large 26 MW third-party solar photovoltaic (PV) system to enable the islanding of the entire Borrego substation during the day and to maintain critical loads as solar output drops. This project demonstrated a high-penetration, renewable energy-based microgrid in a California community.

Project Goals and Objectives

Goals

The goals of this project were to:

- Support the deployment of high-penetration, renewable energy based microgrids in California's industrial, commercial, and/or mixed-use facilities and communities.
- Demonstrate that microgrids can provide value to customers and the grid by enabling higher penetrations of renewable energy than the existing distribution infrastructure supports, while avoiding adverse grid impacts through the use of a microgrid controller/energy management system.
- Demonstrate that microgrids can operate with up to 100 percent renewable energy supply, and/or export renewable energy during periods of high renewable energy production or low demand.
- Encourage energy efficiency upgrades and flexible load to maximize the impact of renewables and avoid the need to export power during periods of over-generation.
- Produce technical and economic microgrid performance data, including documentation of installation issues, operational constraints, and operational performance (such as the number of hours a microgrid can operate independently off the grid).
- Identify barriers to deployment of high-penetration, renewable energy based microgrids (such as financing and regulatory requirements) for specific facility/community types, and solutions to the barriers.
- Determine microgrid configurations comprised of renewable generation, energy efficiency, flexible load, and energy storage that provide the highest value to owners, customers, and utilities.
- Create a replicable microgrid model by developing lessons learned and best practices.
- Develop use cases that maximize the daily operating value of high-penetration, renewable energy based microgrids for customers and the grid, including management of energy storage and flexible load to avoid exporting power when the grid experiences periods of over-generation.
- Use automation and communication strategies that optimize reliability, safety, customer savings, and environmental benefits.

Objectives

The overall objectives for this microgrid project were to:

- Develop microgrid technologies, including a controller that is commercially available and by having the controller to identify, isolate, and efficiently serve critical loads, and test phasor measurement unit-based control algorithms.
- Island the entire community of Borrego Springs during the day and to drop non-critical loads during the night. Additionally, the project would coordinate generation and loads, control storage, prevent export of power during over-generation, and limit other grid impacts such as harmonics, VAr imbalances,[1] and steep ramp rates consistent with SDG&E's requirements.
- Develop a microgrid that meets or exceed USDOE's 2020 goals of commercial-scale microgrid systems capable of reducing the outage time of required loads by more than 98 percent at lowest cost while reducing emissions by more than 20 percent compared to a backup distributed generator set.
- Enable the "smart inverter" functionality that meets the requirements of Institute of Electrical and Electronics Engineers (IEEE) 1547.1 or IEEE 1547.8 by working with SMA, the manufacturer of the 26 MWac PV array inverters.
- Use renewable resources to supply 100 percent of the community's load.
- Reduce energy use by using energy efficiency and flexible load where appropriate.
- Include engineering and interconnection infrastructure for additional energy storage devices.

[1] Volt-ampere reactive or VAr is a unit by which reactive power is expressed; reactive power exists in an alternating current circuit when current and voltage are not in phase, and is important in maintaining voltage in the power system.

CHAPTER 2: Project Approach

Task List

The overall project approach included the development and deployment of multiple technologies within Borrego Springs to meet the desired project objectives. The project plan was organized into the following tasks:

- Task 2: Advanced Microgrid Controller
  - This task included the deployment of a control platform that served as a microgrid controller for Borrego Springs. SDG&E selected Spirae's Wave™ control platform to be the Advanced Microgrid Controller (AMC). SDG&E also uses the term Distributed Energy Resource Management System (DERMS) to describe the implementation of Spirae's Wave™ at SDG&E. SDG&E intends to use the DERMS platform to monitor and manage Distributed Energy Resources at Borrego Springs, and other locations in its service territory. The project team initially intended to evaluate UCSD and OSIsoft innovative controls development for incorporation into the microgrid controller, but policy and business challenges prevented this.
- Task 3: Microgrid System Planning and Design
  - This task included planning and design of the Borrego Springs Microgrid to island the entire community during the day, reduce to critical loads at night and use energy storage to minimize generator operations. The project team evaluated the development of tools, techniques and equipment to provide visibility of the microgrid to the California Independent System Operator (California ISO). However, the California ISO chose not to get this information in real-time for their operations. Hence, the project team decided to not integrate the AMC with California ISO operations. Additionally, the project team made a strategic decision to not integrate electric vehicle (EV) smart charging and fleet management into the AMC operations. With limited EV resources at Borrego Springs, the objective to manage grid issues such as transformer stress and peak load through coordinated charging would not have been accomplished. SDG&E engaged with Maxwell Technologies to include their ultracapacitor in the preliminary design stage. The ultracapacitor is an emerging technology that is capable of storing and discharging energy very quickly and effectively. This engagement with Maxwell Technologies was outside the scope of the Energy Commission project but will benefit the Borrego Springs Microgrid. SDG&E continues to engage with Maxwell Technologies to implement the ultracapacitor in the near future.

- Task 4: Test Preparation
    - This task included experimental setup for a laboratory-scale, proof-of-concept, hardware-in-the-loop (HIL) evaluation that was undertaken at NREL's Energy Systems Integration Facility (ESIF). It included the use of Real-Time Digital Simulation (RTDS); the microgrid controller; distributed generator controllers; a battery energy storage system (BESS); a photovoltaic (PV) inverter; and the hardware/software interfaces among the RTDSs, controllers, and power hardware.
- Task 5: Test Execution
    - This task included the creation a detailed test execution plan and tests to evaluate the ability of the microgrid controller to meet the functional requirements for:
        - C1: Disconnection
        - C2: Resynchronization and reconnection
        - C3: Steady-state operation
        - C4: Protection
        - C5: Dispatch
        - C6: Enhanced resilience
- Task 6: Analysis and Reporting
    - This task included the analysis of test results and provide the necessary reports to fulfill the obligations of this research grant.
- Task 7: Evaluation of Project Benefits
    - This task included the reporting of the benefits questionnaire at three intervals during the project timeline:
        - Kick-off meeting benefits questionnaire
        - Mid-term benefits questionnaire
        - Final meeting benefits questionnaire
- Task 8: Technology/Knowledge Transfer Activities
    - This task included the development of knowledge gained, experimental results, and lessons learned into various artifacts that were made available to the public and key decision makers during project implementation.

Each primary task consisted of sub-tasks, which are documented as key developments in Chapter 3.

Project Team

Figure 1 shows the organizational chart illustrating team members that participated in the Borrego Springs Microgrid project.

Figure 1: Borrego Springs Microgrid Project Team

Source: Microgrid Energy Solutions

The roles and responsibilities of the project team members were:

San Diego Gas & Electric Company – Project Prime and Host utility

SDG&E was responsible for project management, deployment of the advanced controller, making system data available for model development and delivering a microgrid controller that meets the project requirements. Additionally, SDG&E was responsible for making system upgrades, deploying new equipment and measurement systems for the microgrid. SDG&E integrated the microgrid controller into its Distribution System Operations software environment. SDG&E served as the project management office responsible for executing contracts to allow team member participation in the project.

Technical Advisory Committee

USDOE, California ISO, and Lawrence Berkeley National Laboratory were part of the technical advisory committee established for the project.

Microgrid Community of Borrego Springs (Borrego Chamber of Commerce, Anza-Borrego Desert Natural History Association)

The Borrego Springs Chamber of Commerce reached out to the local community of Borrego Springs and worked with SDG&E to define the critical loads for the microgrid as well as determining cool zones during microgrid testing. Multiple large customer loads, such as resorts were identified in the community of Borrego Springs. They also supported on-going project activities related to community participation.

Spirae – Advanced Microgrid Controller developer

Spirae is under contract with SDG&E to develop a Distributed Energy Resource Management System (DERMS), which includes an advanced microgrid control application. Spirae provided the microgrid controller to NREL to verify performance with the project requirements. Spirae will also evaluate the UCSD and OSIsoft innovative phasor measurement unit (PMU)-based controls for incorporation in their product. Spirae conducted hardware in the loop testing to verify their controller's performance.

NRG, SMA, SunPower, Verus – 26 MW Solar Facility Team

NRG is the third-party entity that owns and operates the 26 MW solar facility connected to the 69 kV transmission system at Borrego Springs. SMA provided the inverters for the PV plant and SunPower provided the PV modules for the solar facility. Verus performed design work to connect the AMC to the NRG controller.

CAT/Hawthorne – Distributed Generation Provider

Two 1.8 MW CAT/Hawthorne generators situated at the microgrid yard in Borrego Springs were used for demonstration.

SAFT/ABB/Parker/ Maxwell Technologies – Advanced Energy Storage

Advanced Energy Storage (AES) units (identified as AES 1 and AES 2) in the report were used as battery energy storage systems for demonstration. The inverter and controls were provided by ABB and Parker Hannifin. Maxwell Technologies will be providing the ultracapacitor for installation at Borrego Springs (not part of this Energy Commission project but being pursued by SDG&E on another project).

National Renewable Energy Laboratory, OSISoft, and University of California San Diego – Real-Time Digital System (RTDS) and dynamic simulation tool development and testing

NREL, OSISoft, and UCSD were responsible for simulation testing via RTDS, to determine compliance of Spirae's microgrid controller with the technical requirements of the project.

eiPi10 - Testing and Integration

eiPi10 provided the technical support required during testing and integration of the AMC and other devices, both at the SDG&E lab and in the field.

Microgrid Energy Solutions – Analysis and Report Writing

Microgrid Energy Solutions (MES) provided analysis and report writing support to prepare the final report for submission to the Energy Commission.

Table 1 identifies the project schedule with various tasks that were completed during the project.

Table 1: Borrego Springs Microgrid Project Schedule

	2015				2016				2017				2018			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Award Date		1-May														
Kick off Mtg		7-May														
Advanced Microgrid Controller (AMC) Requirements			July										Feb			
Borrego Infrastructure Upgrades (SCADA switches, protection, transmission, MG yard)			July										Mar			
Equipment Procurment		May		Dec												
Test Preparation						15-Jun				1-Apr						
Asset Integration/Upgrades						May							Mar			
Permits: Noise Variance Complete									Feb							
Communication Link Installed/Complete									Feb							
Testing																
SDGE Testing (ITF)					Jan								Feb			
Spirae Testing (Integrid Lab)			Aug									Oct				
NREL Testing (ESIF)													Mar			
AMC Deployed in Borrego																
Island #1 Testing										21-Apr						
Island #2 Testing												4-Oct	6-Mar			
Island #3 Testing													7-Mar		Summer/Fall 2018	
Hand-off to EDO (Island 1&2)															14-Aug	
CEC Final Report															8-Aug	

Source: San Diego Gas & Electric Company

CHAPTER 3:
Key Developments

Project Performance Site

The community of Borrego Springs is approximately 80 miles northeast of San Diego, California, in the northeastern area of SDG&E's service territory (Figure 2). This area is at the western edge of the Sonoran Desert, the Colorado Desert sub region, with summer temperatures sometimes exceeding 120° Fahrenheit. The Borrego substation is located about three miles from the community's center, near the Borrego Valley airport.

Figure 2: San Diego County

Source: Microgrid Energy Solutions

A Google Earth image of Borrego Springs is shown in Figure 3. The airport on the east side and a high concentration of solar PV is located on the southwest side of the community. Residences and a golf course are located in the lower center of the image.

Microgrid Circuit Analysis and Baselining

Borrego Substation and Circuits

The Borrego substation is served by a single 69 kV transmission line. At the substation, the voltage is stepped down to 12 kV to feed three radial 12 kV distribution circuits. The 12 kV electrical boundaries include a transmission interconnected large PV facility, a distribution substation and three 12 kV circuits, which serve the entire community. The point of common coupling is the transmission circuit breaker connecting the community to the remainder of SDG&E's system. Figure 4 and Figure 5 are photographs of the substation.

Figure 3: Borrego Springs Aerial View

Source: Google Earth

Figure 4: Borrego Substation - Looking South

Source: San Diego Gas & Electric Company

Figure 5: Borrego Substation – Looking North

Source: San Diego Gas & Electric Company

The community of Borrego Springs is served by three 12 kV distribution circuits: Circuit 1, Circuit 2 and Circuit 3 (the specific circuit numbers have been omitted for security concerns). The project team chose all three 12 kV distribution circuits that encompass the entire community of Borrego Springs for this microgrid project. These circuits are referred to as the "microgrid circuits" in this report. Figure 6, Figure 7, and Figure 8 present the single-line diagrams for the each of the circuits. Table 2provides a legend for the symbols used in the diagrams.

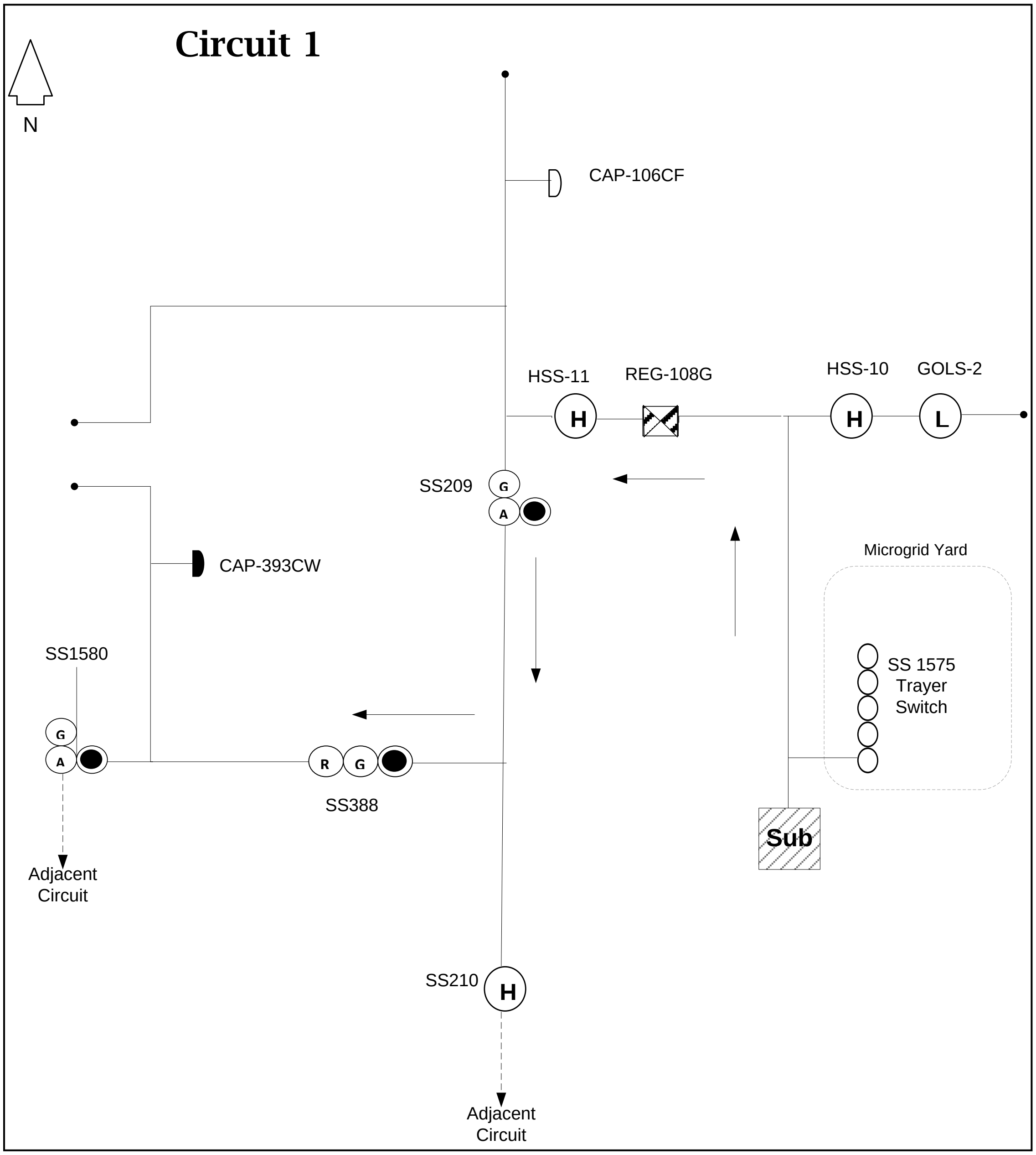
Existing Devices

The existing equipment and resources that were part of the Borrego Springs Microgrid include:

- Overhead switches controlled by Supervisory Control and Data Acquisition (SCADA) that provide connectivity from one microgrid circuit to another one of the microgrid circuits.
- Underground switches – This is a 5-way pad-mounted switch in the microgrid yard, adjacent to the Borrego substation. This switch provides the connection point for the microgrid assets that are installed in the microgrid yard. This switch, which is a Visible Fault Interrupter (VFI) with Visible Disconnect, provides over-current protection, and allows quick service restoration, eliminating the added expense and downtime associated with stocking and replacing fuses. The VFI along with its “Three-Phase” control provides remote functionality for monitoring through the SCADA system. Figure

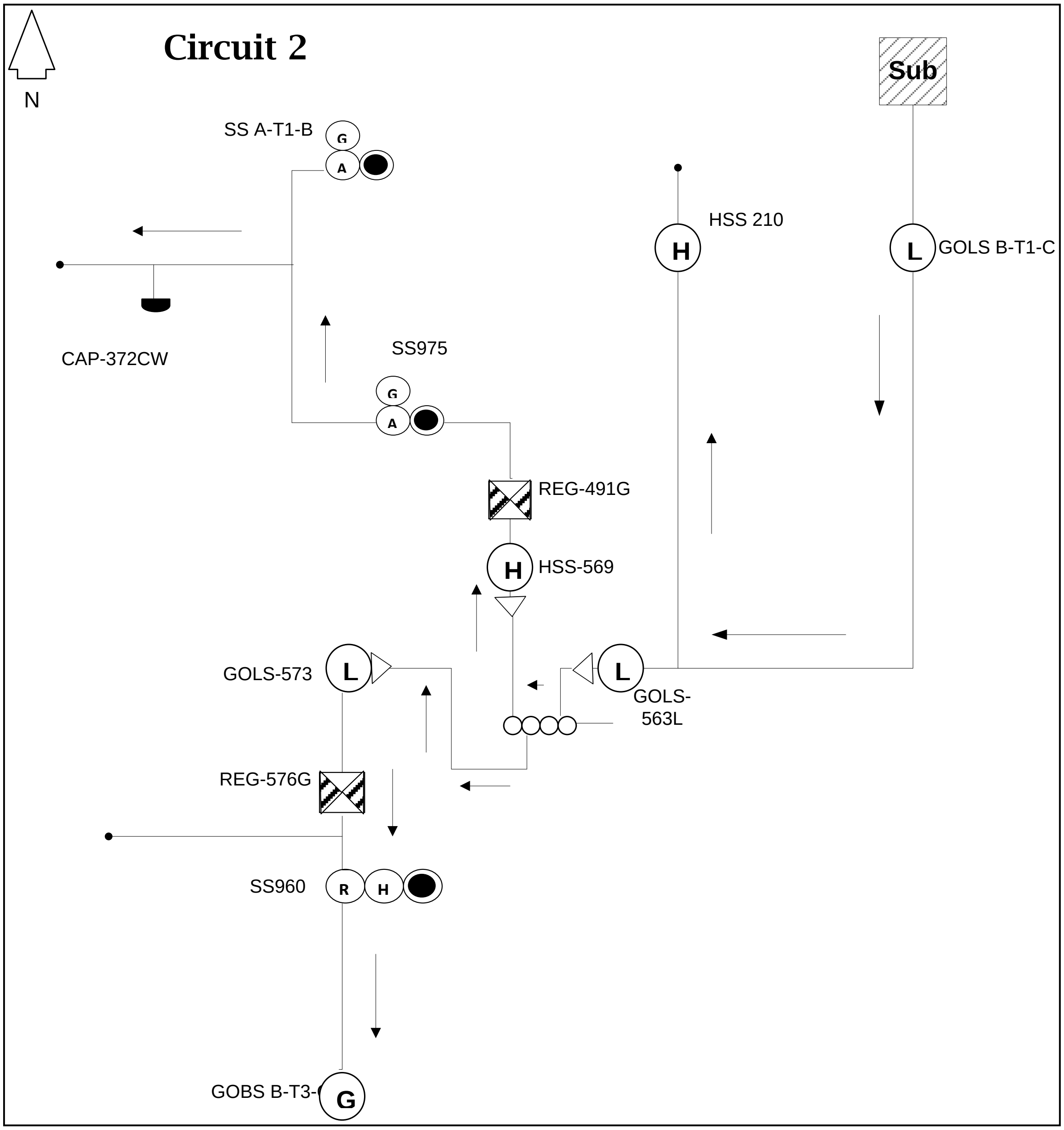
9 presents the 5-way underground switch. The switch has three relays that protect the circuit from over-current due to faults.

Figure 6: Circuit 1 of Borrego Substation



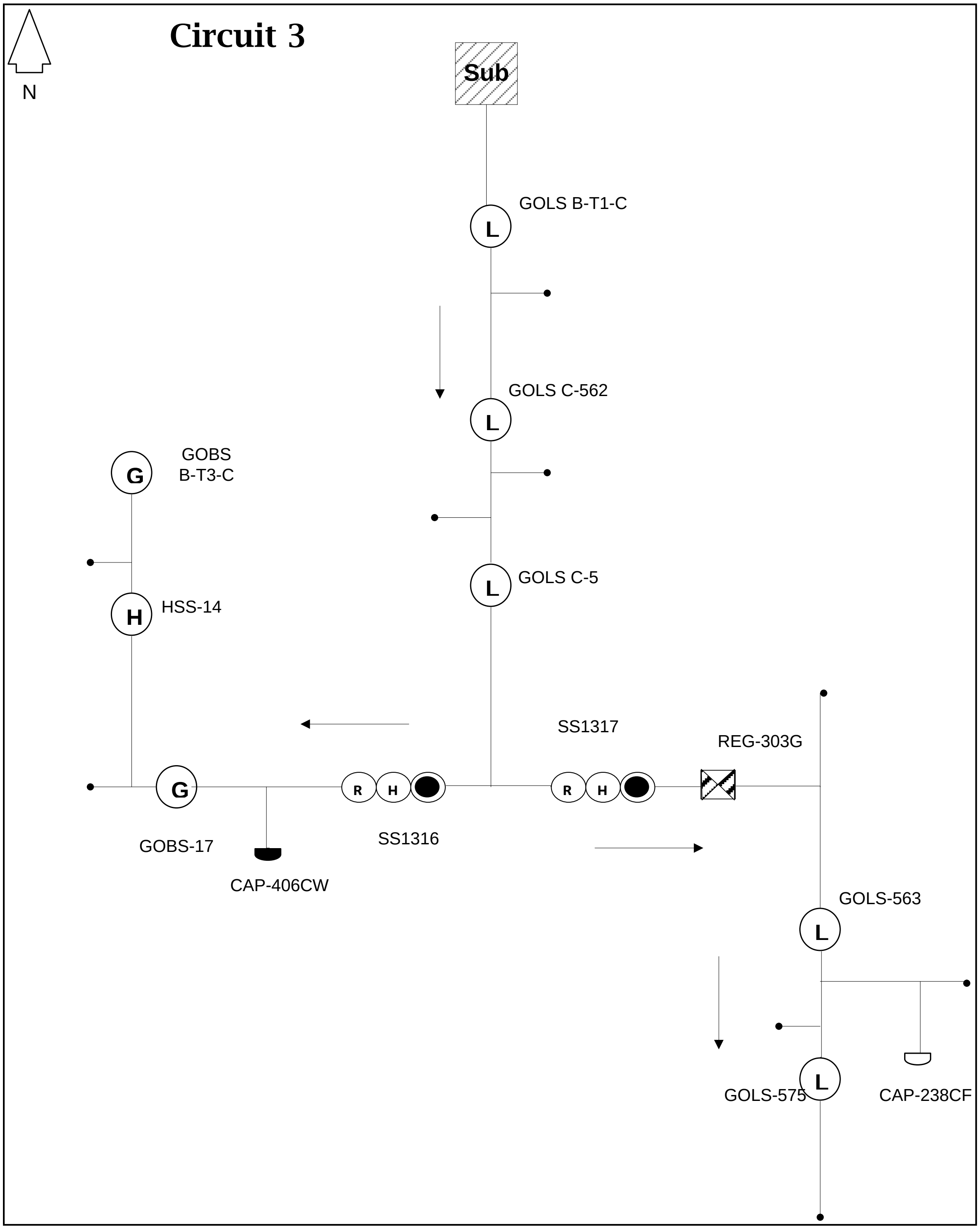
Source: San Diego Gas & Electric Company

Figure 7: Circuit 2 of Borrego Substation



Source: San Diego Gas & Electric Company

Figure 8: Circuit 3 of Borrego Substation



Source: San Diego Gas & Electric Company

Table 2: Legend for Symbols in Circuits 1, 2, and 3

Symbol	Description
H	Non-SCADA Switch
L	SCADA Switch
G	SCADA Switch
R H	SCADA Recloser
R G	Non-SCADA Recloser
G Δ	SCADA Switch
Sub	Substation
	Voltage Regulator (REG)
	SCADA Capacitor
	Non-SCADA Capacitor
	5-Way Pad Mounted Switch

Source: San Diego Gas & Electric Company

Figure 9: Five-Way Underground Switch

Source: San Diego Gas & Electric Company

- Capacitors
    - Substation Capacitor (Figure 10) - Capacitors are installed at the substation to compensate for the inductive load of the power transformers, conductors and circuit loads. The capacitors are controlled through a timer that is programmed to turn the capacitors on during times of high load and turn them off during times of lower load.

Figure 10: Substation Capacitor at Borrego Substation

Source: San Diego Gas & Electric Company

    - Line Capacitors - Capacitors are installed at various points on the circuits to improve system voltage and to improve the power factor of the loads. These capacitors are controlled using a scheme called “time bias with voltage override”. This scheme means that the capacitors will operate (turn on or off) based on a prearranged schedule unless the voltage is outside an acceptable range, in which case the capacitor operates in a manner that will keep the voltage as close to the desired level as possible.
- Voltage Regulators - SDG&E uses voltage regulators as electrical devices that compensate for variations in circuit voltage due to changing circuit load and automatically maintain a voltage level that is within a defined range. A regulator station consists of three single phase auto-transformers that are configured to operate as a three-phase device to control voltage in small increments. There are multiple voltage regulators installed on the microgrid circuits.
- Communication - Microwave systems, as well as leased lines from the local carrier, are used to provide communications from devices in the field back to SDG&E’s Mission Control Center. The Borrego substation microwave tower is shown in Figure 11.

Figure 11: Borrego Substation Microwave Communication

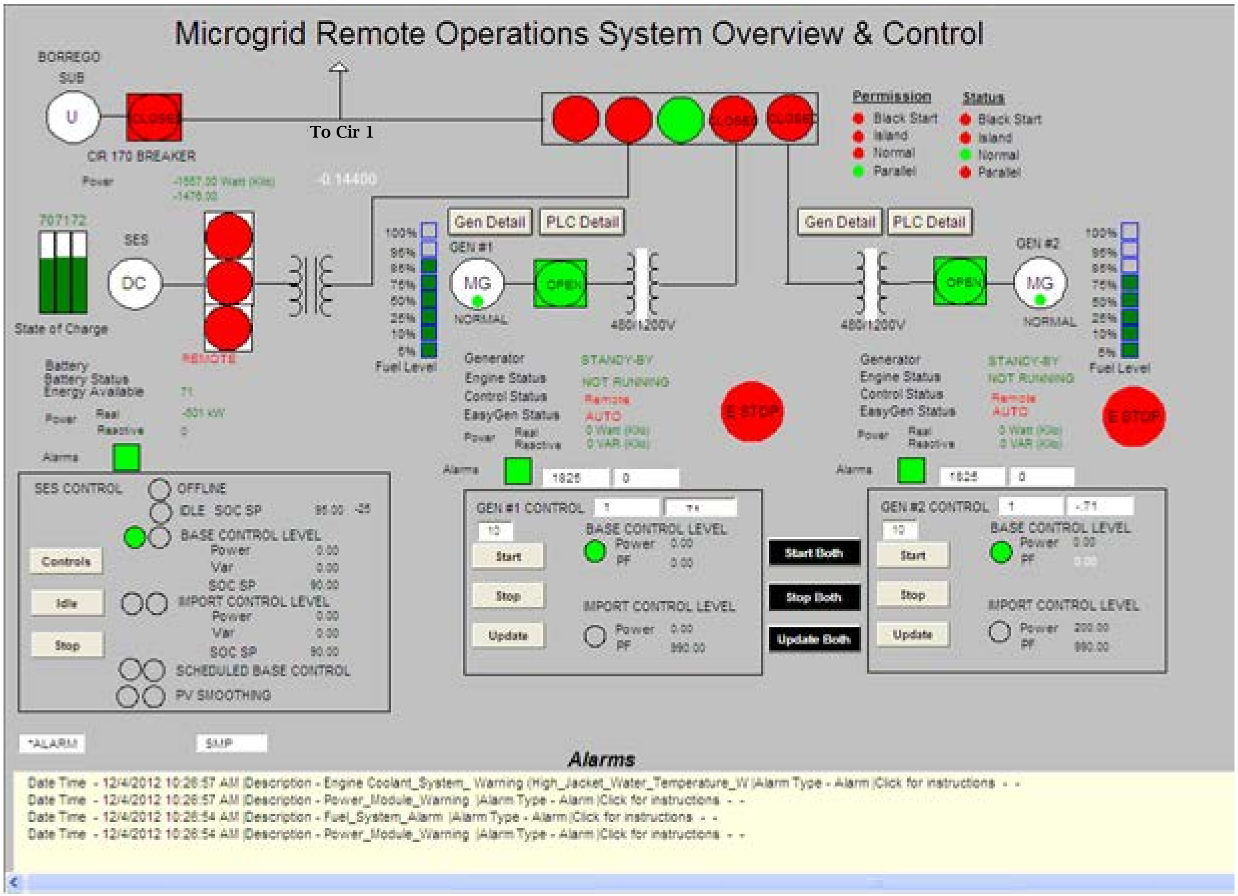
Source: San Diego Gas & Electric Company

- Distributed energy resource (DER) Assets – The key microgrid assets that existed prior to project implementation, and were deployed as part of the previous USDOE and Energy Commission Public Interest Energy Research (PIER) funding included:
  - Two 1.8 MW distributed generators marked as GEN 1 and GEN 2.
  - One advanced energy storage unit.
  - Three community energy storage units.

Microgrid Control Systems Baseline

The Borrego Springs Microgrid Demonstration project that was funded by USDOE and Energy Commission PIER program from 2009 to 2013 established a baseline for the microgrid control system that existed prior to this round of EPIC funding from the Energy Commission. The prior project funding was used to integrate microgrid resources that served one of the three circuits in Borrego Springs. The microgrid controller referred to as a "microgrid visualizer" from the previous effort was created using PI Process Book to act as the user interface. The microgrid operator could access the visualizer from the control van located within the Borrego Springs Microgrid yard or remotely from SDG&E's offices in San Diego. The visualizer user interface is presented in Figure 12 with key monitoring and control components for the critical SCADA switches, circuit load, each of the distributing generator (DG) units, advanced energy storage (AES) system, and system alarms. The DG units are the same units that were used in the prior demonstration project and in this project. The AES unit was a 500 kW/1,500 kWh Lithium Ion battery system that was deployed in the microgrid substation, also referred to as the substation energy storage (SES).

Figure 12: Microgrid Visualizer – Manual Mode Screen



Source: San Diego Gas & Electric Company

Figure 13 presents an overview of the controls that existed for the Borrego Springs Microgrid as the work product of the previous USDOE and Energy Commission PIER-funded programs, and which formed the baseline microgrid controls for work undertaken on this project.

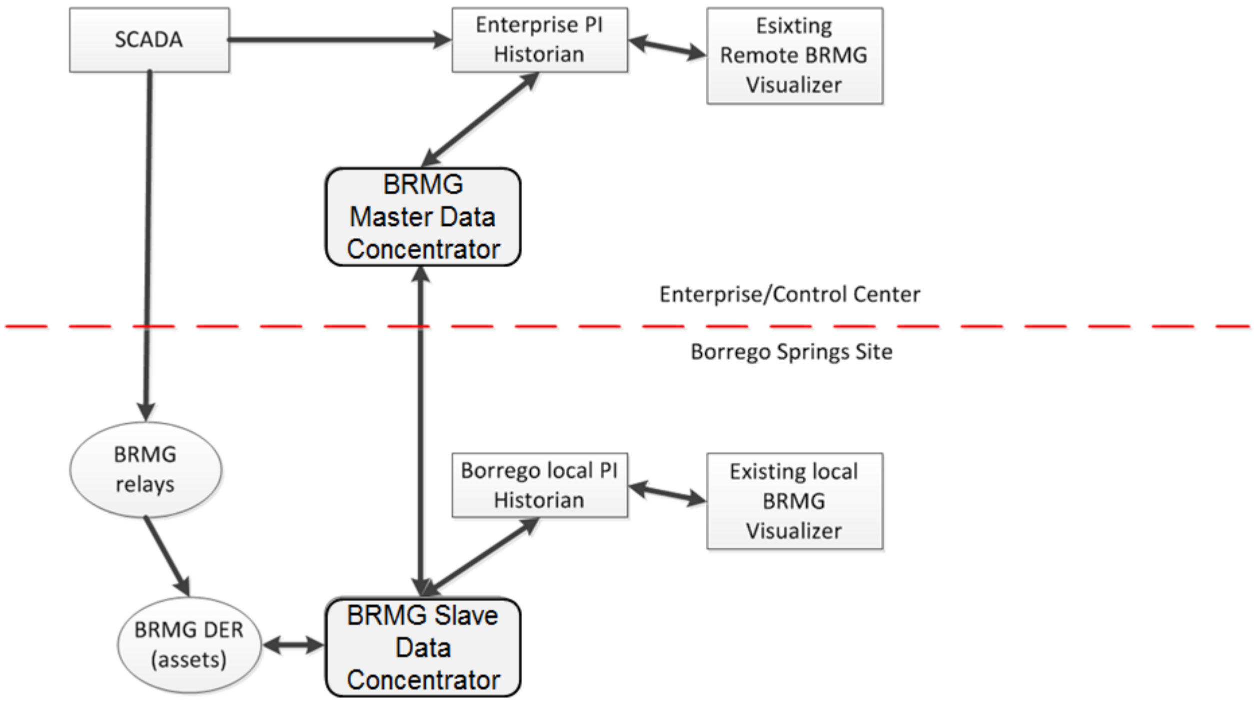
The microgrid visualizer provided the microgrid operator the option of operating the equipment in a manual mode or in a scheduled mode. The system was configured to continuously collect system data and store it in a PI database. Data could be easily extracted for analysis and reporting using a PI add-in for Excel.

The microgrid control system was used in the following demonstrations in 2012 – 2013:

- June 2012 - Planned outage where the microgrid provided power to 2,128 customers for about 5.5 hours.
- March 2013 - Conducted 7 planned islanding events over 3 days.
- April 2013 windstorm - microgrid provided power to 1,225 customers for about 6 hours.
- August 2013 Flash flood – The Community Energy Storage Systems that were deployed on the distribution circuit islanded six customers for about 5.5 hours.

- September 2013 Intense thunderstorms - microgrid provided power for up to 1,056 customers for more than 20 hours.

Figure 13: Microgrid Baseline Controls



Source: San Diego Gas & Electric Company

It is important to remember the backdrop that the prior Energy Commission funding provided to the Borrego Springs Microgrid. The prior project laid the foundation for SDG&E and the community of Borrego Springs to advance the microgrid to another level using the Advanced Microgrid Controller technology that was provided through this EPIC round of funding from the Energy Commission.

Baseline Load – Parametric Analysis

A performance baseline was established by identifying and collecting key microgrid circuit metrics. For this purpose, it was important to characterize the microgrid circuits in terms of parameters such as peak demand (MW) on the circuit and reliability indices that were recorded on the circuits. Parametric analysis provides supporting data for predicting the peak demand on the circuit. This data was used to schedule the dispatch of multiple DERs in the microgrid circuit to achieve the project objectives. This baseline approach provided the basis for comparison with the data collected during the demonstrations.

Peak Demand (megawatt) – Microgrid Circuits

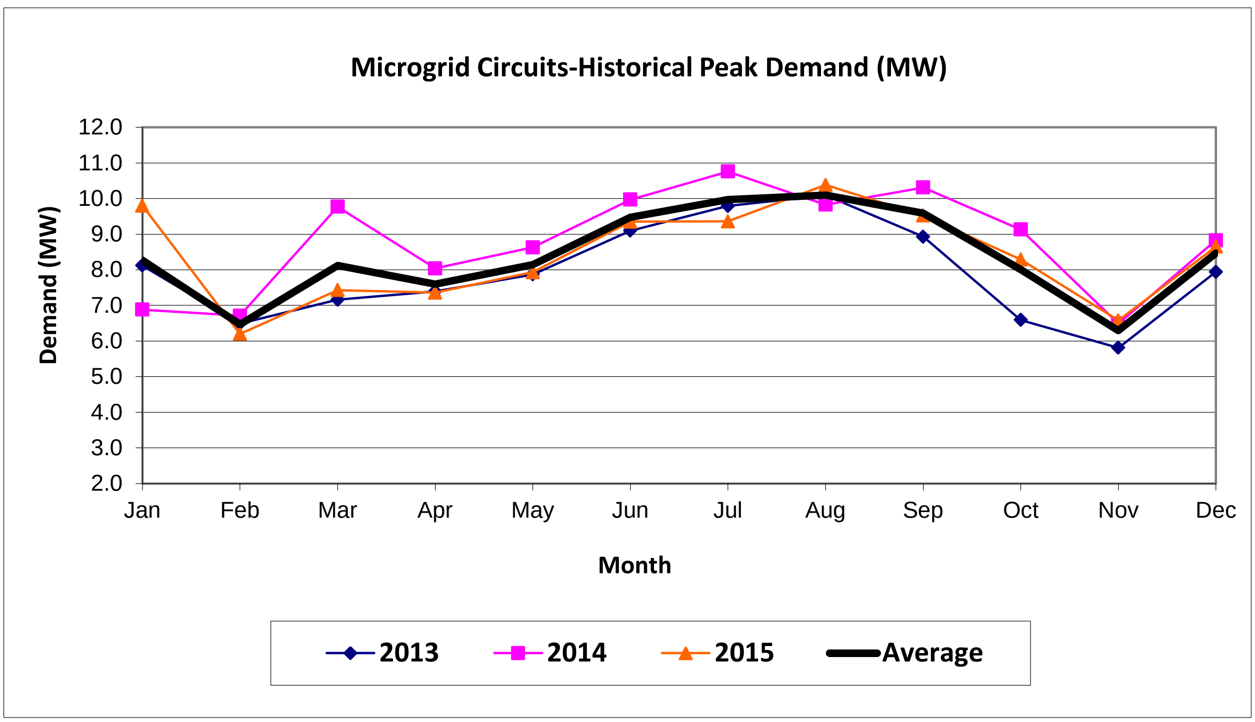
Historical data on the microgrid circuits was analyzed to develop daily load profiles for each month in 2013, 2014, and 2015. Table 3 and Figure 14 present a summary of the monthly peak demand for the microgrid circuits. The data shows a trend with higher peak demand in the summer with an average peak of 10.10 MW. The highest peak of 10.76 MW occurred in July 2009.

Table 3: Microgrid Circuits - Historical Monthly Peak Demand (MW)

Month	2013	2014	2015	Average
Jan	8.12	6.88	9.80	8.27
Feb	6.49	6.71	6.20	6.47
Mar	7.16	9.77	7.43	8.12
Apr	7.39	8.04	7.36	7.60
May	7.87	8.63	7.93	8.14
Jun	9.10	9.97	9.35	9.47
Jul	9.79	10.76	9.36	9.97
Aug	10.09	9.83	10.38	10.10
Sep	8.93	10.31	9.52	9.59
Oct	6.59	9.13	8.29	8.00
Nov	5.81	6.49	6.58	6.29
Dec	7.94	8.83	8.65	8.47
Max	**10.09**	**10.76**	**10.38**	**10.10**

Source: San Diego Gas & Electric Company

Figure 14: Microgrid Circuits - Historical Monthly Peak Demand (MW)

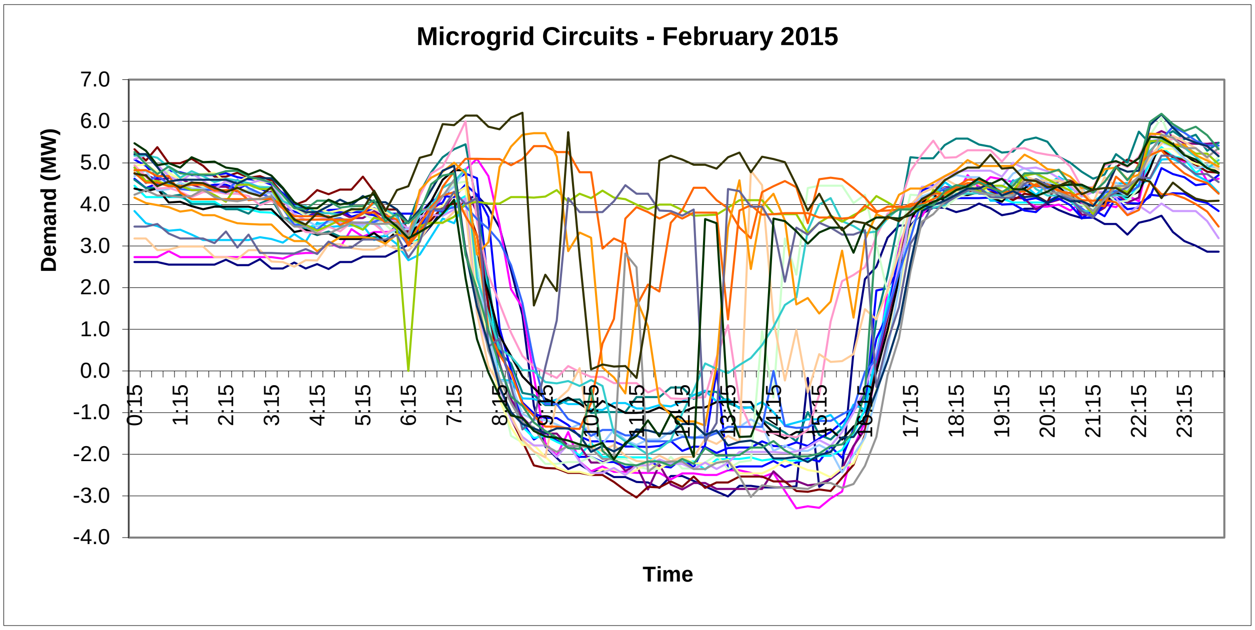


Source: San Diego Gas & Electric Company

Load Profiles from Parametric Analysis

The team analyzed hourly data to better understand the load characteristics on the microgrid circuits. Figure 15 and Figure 16 present daily load profiles for representative winter and summer months during 2015, with each line representing a day of the month. This data shows that the circuit has a unique load profile in that the day-time load is low and the circuit peak load occurs at night. The high night time load is due to the use of water pumps operated by the local water district and irrigation pumps operated by agricultural customers. The use of customer-owned PV shows that the daytime load demand is low on the circuit. This phenomenon is only increasing on the SDG&E circuits where there is increasing renewable energy penetration.

Figure 15: Microgrid Circuits Daily Load Profiles for the Month of February 2015

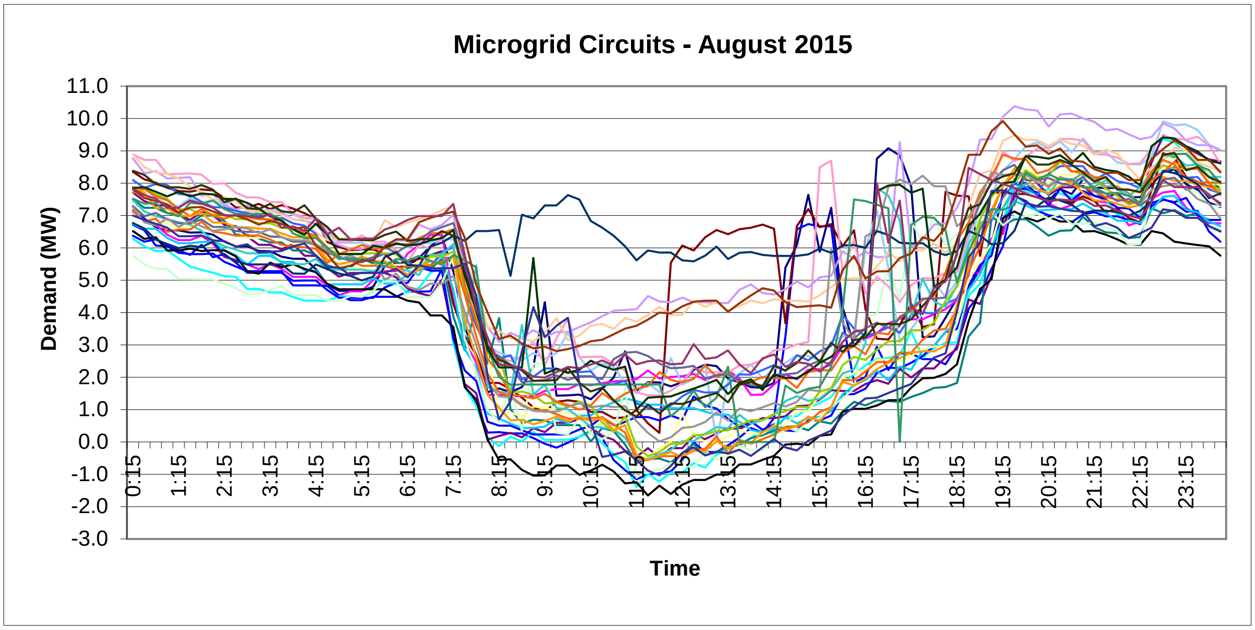


Source: San Diego Gas & Electric Company

For each month, the load profiles for the following critical day categories have been extracted from the raw data sets to represent the range of loads that the microgrid will need to address:

- Peak-MW Day:
  - o The day of the month in which the monthly peak occurs.
- Maximum-MWh Day:
  - o The day of the month that has the highest energy delivery for a 24-hour period.
- Average-MWh Day:
  - o The day of the month that has the statistical average energy delivery for a 24-hour period.

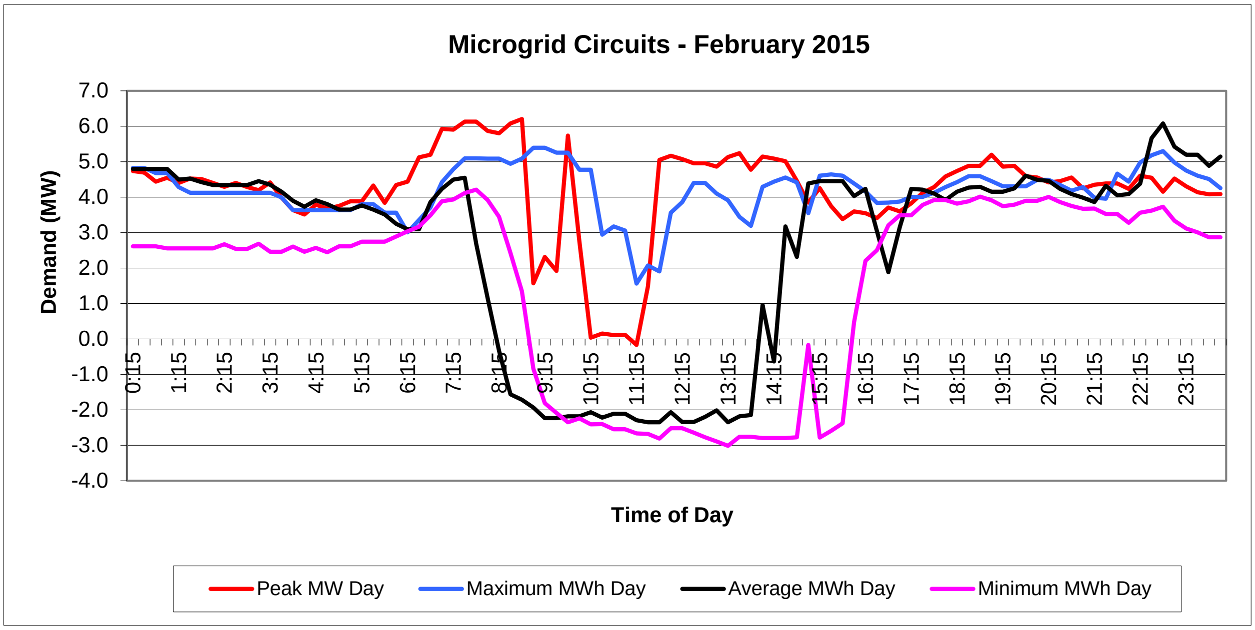
Figure 16: Microgrid Circuits Daily Load Profiles for the Month of August 2015



- Minimum-MWh Day:
  - o The day of the month that has the lowest energy delivery for a 24-hour period.

Figure 17 and Figure 18 present these day types for February and August of 2015.

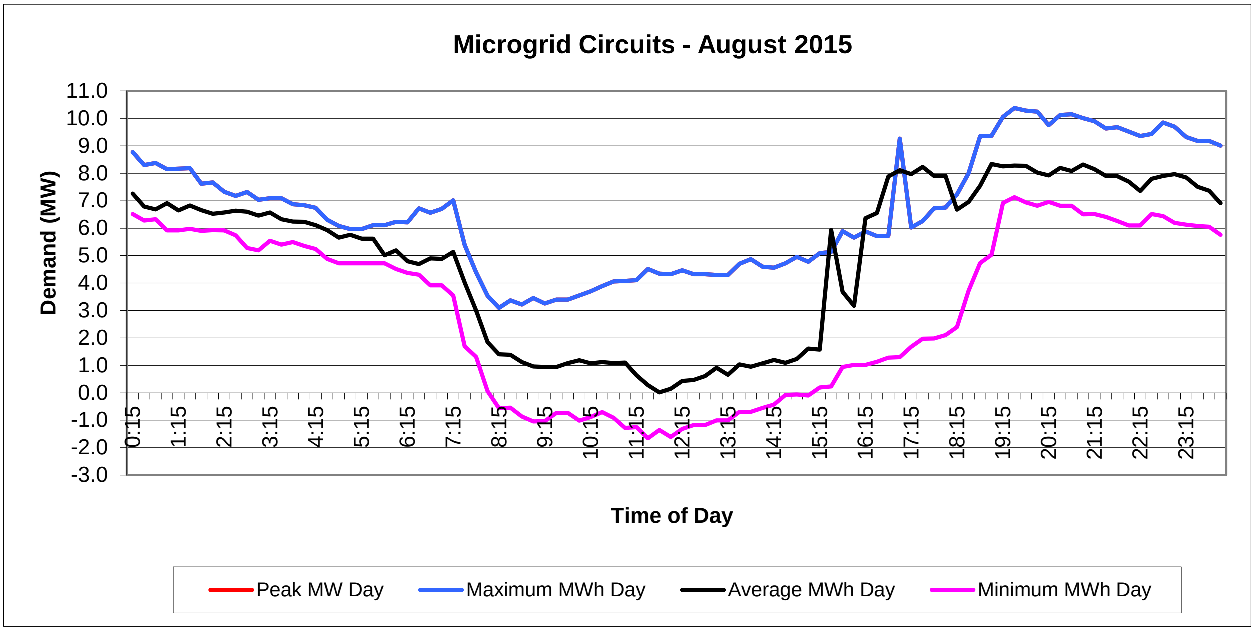
Figure 17: Microgrid Circuit Daily Load Profiles of Winter Critical Day Types - February 2015



Source: San Diego Gas & Electric Company

The winter load profiles show that on average the load is higher in the early morning hours when residential customers are expected to be waking up and starting their day. Since there is no natural gas service in this area, it is expected that the primary domestic hot water load is served by electric hot water heaters. During the day the customer PV systems operate, which in turn, bring the load down on the circuit. During winter months, the intermittency and variability of the PV systems means that the circuit demand increases as cloud cover increases. This demonstrates the need for the SDG&E grid to be accommodating and ready to provide reliable energy as the customer PV systems reduce their production due to weather changes.

Figure 18: Microgrid Circuits Daily Load Profiles for the Month of August 2015



Source: San Diego Gas & Electric Company

The summer load profiles show that on average the load is highest during the night and morning hours and is the lowest at mid-day. The reason for this pattern of electric consumption is the presence of industrial customers who start their irrigation pumps at night time when the time-of-use rate has lower energy and demand charges. The day time load is consistently low as the customer PV systems are operational.

Performance Metrics

Power system performance is measured using several reliability indices that measure outage duration, frequency of outages, availability of system and response time to restore the system. The following reliability indices were analyzed on the microgrid circuits.

- System Average Interruption Duration Index (SAIDI)
- System Average Interruption Frequency Index (SAIFI)
- Momentary Average Interruption Frequency Index (MAIFI)

The metrics reported in the following tables excludes planned outages and includes both momentary and sustained unplanned outage events. Table 4summarizes the Borrego substation reliability performance metrics (for sustained outages) measured between 2015 and 2017 for all three circuits at the Borrego substation.

Table 4: Borrego Springs Annual Reliability Performance Metrics (Sustained Outages)

Year	Number of Sustained Outages	Number of Sustained Customers Impacted	Borrego SAIDI	Borrego SAIFI
2015	10	3395	76.68	1.2108
2016	26	16168	390.61	5.7517
2017	18	4608	101.02	1.6434

Source: San Diego Gas & Electric Company

Table 5 summarizes the Borrego substation reliability performance metrics (for momentary outages) measured between 2015 and 2017 for all three circuits at the Borrego substation.

Table 5: Borrego Springs Annual Reliability Performance Metrics (Momentary Outages)

Year	Number of Momentary Outages	Number of Momentary Customers Impacted	Borrego MAIFI
2015	7	5520	1.9686
2016	7	2521	0.8968
2017	7	2458	0.8766

Source: San Diego Gas & Electric Company

Table 6 summarizes the annual SDG&E system-wide reliability performance metrics (for sustained outages) measured between 2015 and 2017.

Table 6: System-Wide Annual Reliability Performance Metrics (Sustained Outages)

Year	Number of Sustained Outages	Number of Sustained Customers Impacted	System SAIDI	System SAIFI
2015	1909	882163	63.26	0.6184
2016	2212	972484	86.01	0.6773
2017	2096	846963	117.49	0.5849

Source: San Diego Gas & Electric Company

Table 7 summarizes the annual SDG&E system-wide reliability performance metrics (for momentary outages) measured between 2015 and 2017.

Table 7: System-Wide Annual Reliability Performance Metrics (Momentary Outages)

Year	Number of Momentary Outages	Number of Momentary Customers Impacted	System MAIFI
2015	286	494487	0.3466
2016	327	636414	0.4432
2017	298	498345	0.3441

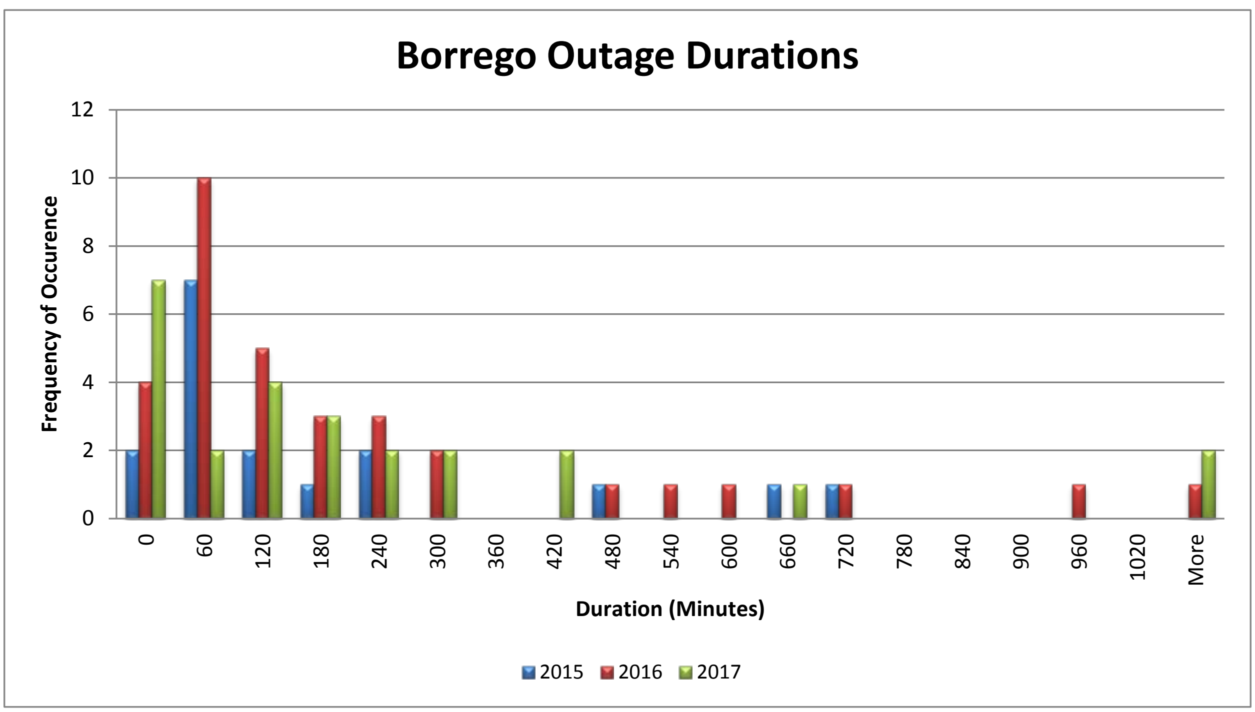
Source: San Diego Gas & Electric Company

The values presented represent all outages recorded during the identified time periods. Reporting of reliability metrics to other agencies by SDG&E may differ due to California Public Utilities Commission reporting rules that provide for exemptions of some events based on specified criteria.

Figure 19 presents a histogram of outage durations between 2015 and 2017. The data shows that the average outage duration during for each of the years was:

- 2015: 127 minutes
- 2016: 165 minutes
- 2017: 210 minutes

Figure 19: Histogram of Outage Durations



Source: San Diego Gas & Electric Company

The histogram shows that most of the outages (48 percent) are fewer than 120 minutes. This data demonstrates that integrating DERs presents an opportunity for the microgrid to improve reliability of the substation at Borrego Springs.

Microgrid Design and Operational Requirements

The objective of this task was to conduct the system engineering necessary to support a successful installation of the Borrego Springs Microgrid. This evaluation focused on system resources, microgrid operational requirements, and the system controls for the conventional grid and the microgrid.

Overall Architecture

The Borrego Springs Microgrid is a utility microgrid and provides an operational method for integrating a diverse set of DERs. It operates in three modes – microgrid non-operational, microgrid operational in parallel, and microgrid operational in island. The microgrid is capable of 3 different island configurations; this includes a single distribution feeder, the 12 kV distribution bus; and lastly the 69 kV transmission bus. Each island also has a different point of common coupling (PCC) that it references to transition to and from an island state. Most of the microgrid assets are connected to the 12 kV system with exception to the 26 MW third party owned solar facility, which is connected to the 69 kV system. Lastly, the microgrid uses numerous customer-owned DER (such as solar PV), also referred to as net energy metering (NEM) resources which are located at the customers premises, behind the meter.

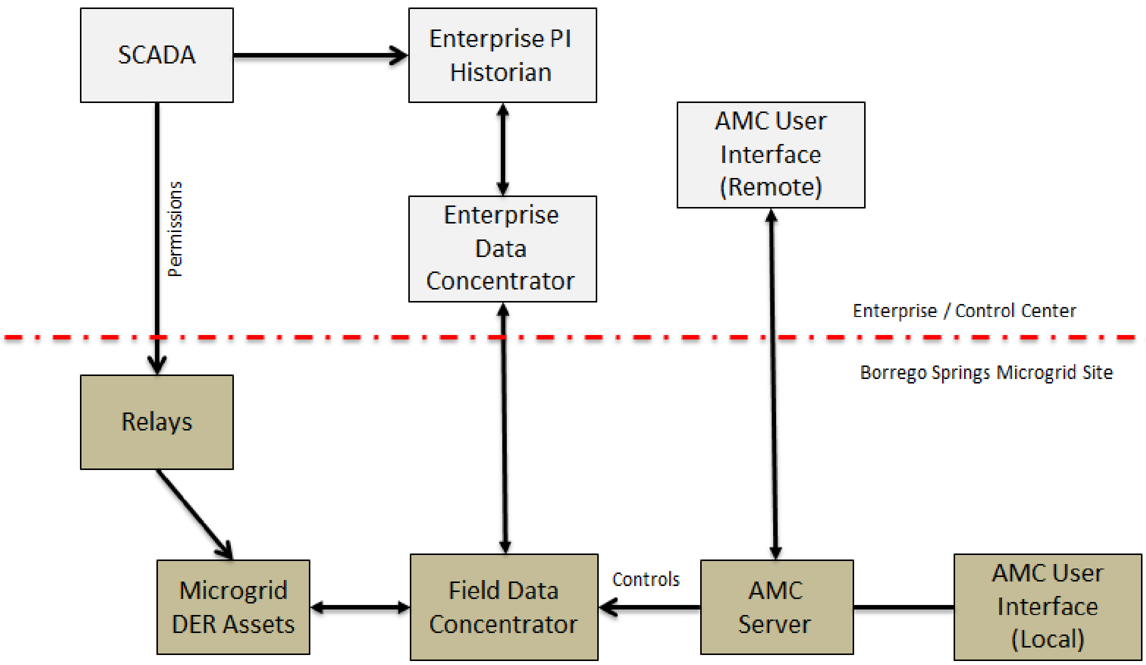
The microgrid is designed to be operated under the following operating scenarios:

- Scenario 1 – Planned outage: In this scenario the microgrid provides continuity of service to microgrid customers when an outage is needed for the transmission line feeding the substation for maintenance or upgrade.
- Scenario 2 – Unplanned outage (with blackstart capability): This scenario occurs when a fault in the main grid creates an outage at the substation. The microgrid is run with blackstart operation of microgrid resources (such as the distributed generation resources) and sequencing the microgrid loads and resources in a balanced way and restore as many microgrid customers as possible.

When testing or in an island mode, the microgrid is controlled by the advanced microgrid controller application that is part of the larger DERMS platform provided by Spirae. The AMC adjusts the output levels of its resources to meet system needs by dispatching operating set points to the local controllers of the microgrid resources. The local controllers at the device level respond to these set points and also respond immediately to changes in load and to transients through governor control, automatic voltage regulation, and inverter controls (if islanded). The AMC also monitors the health and operating status of microgrid resources. The circuit configuration is displayed in the Distribution Management System (DMS) and SCADA. The AMC uses local configuration and status information to provide supervisory level control over the microgrid and provide Electric Distribution Operations (EDO) operators the status of the microgrid, allowing alternative or proactive actions to be taken when deemed necessary or advantageous.

Figure 20 represents a high-level overview of the Borrego Springs Microgrid architecture. This architecture leverages existing utility systems, data warehouses and is expected to support a scalable solution that is capable of integrating multiple microgrids within the utility in the future.

Figure 20: Borrego Springs Microgrid Architecture Overview



Source: San Diego Gas & Electric Company

Operational Requirements

This section discusses how the operational requirements were determined and what those fundamental requirements are for the microgrid, its interactions with the main grid, and the various types of microgrid resources.

Development of Use Cases

Use cases were developed to identify the functional requirements for the Borrego Springs Microgrid. The use case workshops were extensive and included subject matter experts from numerous SDG&E departments and project team members. This work captured various scenarios for operation and control of the distributed energy resources within the microgrid. The use case outputs were then used to identify the fundamental operational requirements for the microgrid processes and resources.

Table 8 identifies the use cases that were developed during design of the Advanced Microgrid Controller.

Table 8: Advanced Microgrid Controller Use Cases

Usability	
Feature	**Description**
Alarms	The alarms feature allows the user to view, acknowledge and clear asset and control group alarms. The alarms can be configured to a chosen alarm threshold, so users can be aware when an asset goes outside of its desired range.
User Interface	The AMC interface provides a one-line view and allows the user to drill down to individual DER, providing access to all available telemetry, status points, and alarms. Additionally, the user can control DER by manually inputting setpoints.
Microgrid Controls	
Feature	**Description**
Blackstart, Island & Resync	The AMC can recognize the available amount of load that can be supported, in real time, so that power can be restored in increments by dispatching DER to pick up load on the grid. The AMC also has the ability to seamlessly transition from parallel operations to island operations, or vice versa, by inputting voltage and frequency setpoints, and sending commands to the assets in the field, to ensure power quality.
Time to Live (TTL)	The AMC calculates the TTL of a resource in use based on fuel level, state of charge, and demand (future reservation), and present it in the form of an alarm when a threshold is near violation.
Optimization	The AMC performs spinning reserve management and asset selection according to a user-selected local optimization objective. Throughout all operations, the application provides situational awareness of each microgrid group.
AES Application	
Feature	**Description**
Group Control Modes	The AES application provides near real-time feedback-based control of groups of energy storage assets. The different modes are dispatched through the AMC reservation system and can be used by operators to support local distribution operations as well as system-wide objectives.
State of Charge (SOC) Management	This allows the user to view the asset or group of assets state of charge, and to also modify the setpoints to charge or discharge the individual asset or group of assets.
Constant Output	This feature considers asset availability and SOC constraints, to allow the user to set a group of storage assets to a constant active and/or reactive power set point (charge or discharge).
Import/Export Limiting	The AMC can control available resources to limit power flow across the microgrid PCC during planned islanding and during times of high power usage. This feature also allows the user to input import or export setpoints for both active and reactive power during grid-connected operations to meet operational objectives.

Source: San Diego Gas & Electric Company

Modes of Operation

The microgrid is designed to operate in three distinct and fundamental modes.

- Microgrid non-operational
    - In this mode of operation, electric service in Borrego Springs is provided by the conventional grid (69 kV line feeding the three 12 kV circuits of Borrego). The microgrid resources are not operating in this mode.
- Microgrid operational – parallel
    - In this mode of operation, microgrid resources support the electric service provided by the conventional grid. The microgrid resources (DG and AES) operate in parallel with the grid. The AMC manages resources based on defined operational objectives such as import/export control. In this mode, the level of power flow into or out of the microgrid is scheduled and then controlled and maintained by the AMC at the scheduled level. Peak loads as viewed by the main grid can be managed to achieve peak load reduction objectives.
- Microgrid operational – island
    - In island operation, the microgrid is isolated from the conventional grid supply and the resources are managed to ensure a balance between generation and load while maintaining voltage, frequency and power factor within limits. In this mode, the AMC plays a similar role in achieving the same objectives as those discussed above. But, in this mode, the main grid is not available to support the reliability of the microgrid. Specifically, frequency will now depend on the degree of balance between the microgrid resources and the microgrid load. Voltage must also be controlled, locally. Microgrid resources (such as DG) are designed to self- control, that is react to changes in frequency and voltage, locally and rapidly, when disturbances or transients occur. Once stabilized by the decentralized controls of the individual resources, the AMC takes over to ensure the objectives are optimized at the new operating point.

Control Method

A distributed level of control that has been successfully applied to managing operations of the main grid was used as a starting point for evaluating the best control method for the microgrid, recognizing the uniqueness of a microgrid system. The project team considered both a centralized control method and a distributed control method.

- Centralized control: The assumption for the centralized control approach was to incorporate the microgrid controller within or as a module of the Distribution Management System (DMS). All control actions for the microgrid would be centralized and made by the AMC. While a centralized control method might possibly simplify microgrid operations and its integration with other distribution systems and processes, it was quickly deemed to be unpractical for a number of reasons:

- Latest microgrid research has concluded that centralized control is not feasible due to the rapid response needed to address expected transients in real-time. Centralized control is the control method of choice for non-critical applications that can be applied over many seconds to minutes.
- Centralized control is vulnerable to single failures in communication or even loss of AMC functionality.
- Demands on communications would be very high – high speed, low latency, and extremely high reliability to support the near real-time response to transients required by microgrid resources.

- Distributed control: A combination of centralized control and decentralized control. The assumptions for distributed control were to use local controllers and systems in a distributed fashion to provide short term response and coordinate longer term response using a centralized microgrid controller. In this model, the AMC is responsible for dispatching microgrid resources and high-level data collection and analysis. This model is similar to the approach used for the main grid with some exceptions:
  - When the microgrid is in parallel operation, the natural response of the main grid (both inertial and governor/voltage regulator responses) will maintain system frequency and therefore microgrid frequency within limits. The main grid will therefore respond to most microgrid transients without any specific action from the microgrid control systems.
  - When the microgrid is in island mode, the inertial response provided by the main grid is not available. As a result, the microgrid is more sensitive to disturbances and transients. Decentralized local controls at the microgrid resources are useful in responding to changes in frequency and voltage. This action is analogous to the action provided by governor and voltage regulator actions at the power plants connected to the main grid. The function of these controls is to maintain reliability, stability and PQ within limits, not necessarily to optimize around efficiency, economics, or environmental metrics.
  - The AMC provides centralized control in both modes of microgrid operation (parallel and island). It operates over a longer time horizon and dispatches microgrid resources by adjusting their operating set points to achieve operating objectives.

  In this distributed control model, each of the microgrid resources have their own local controls for system operation and protection. These equipment-specific control systems provide for individual control to turn the equipment on and off, set the mode of operation, accept changes to operating set points, and trigger operational events.

To coordinate the operation of all the microgrid resources, the AMC was integrated into the microgrid. The AMC is designed to analyze and control actions within the microgrid such as islanding, dispatching DER, and power flow management to meet all longer term operational constraints within the microgrid. The AMC will operate against a defined set of objectives within a set of defined constraints. As part of this microgrid design, the creation of islands is initiated through relay automation rather than the AMC.

Distributed Generation Operations

Two Caterpillar XQ-2000 Power Modules with CAT 3516TA Distributed Generators were used as the Distributed Generation (DG) component of the microgrid resources in Borrego Springs. Each generator set has a nominal generation capacity of 1,865 kW. These units can be controlled by the operators locally at the substation as well as through a remote interface via secure communication paths. The design includes the AMC sending commands and set points to the DG units. The DG units parallel with the grid through the generator breaker. The DG units provide two modes of operation when one or both units are paralleled with the grid:

- Baseload (constant output) - If the main breaker at the point of common coupling is closed and the AMC has selected “Base Load Mode” for either generator, the generator in Base-Load will operate to produce real (kW) and reactive (kVAr) power at the generator terminals that satisfy its current power (kW) and Power Factor set points.
- Import control (peak shaving) - If the microgrid circuit main breaker is closed and the AMC has selected “Import Control Mode” for one or both DG units, the generators will attempt to follow load to maintain real power flow to the microgrid through the microgrid circuit main breaker at or below the specified Import Control set point. If more than one generator is online in “Import Control Mode” the respective controllers will share load equally between the two generators to maintain real power flow to the microgrid through the microgrid circuit main breaker at the Import set point. Relative loading will vary to maintain the Import Control Power Factor set point.

The DG units provide a single mode of operation (Island Operating Mode) when the microgrid is in Island operation from the main grid.

- Island operating mode -When the microgrid circuit main breaker is open, each operated DG controller will load its engine generator to assume all available microgrid circuit power demand and kVAr load, sharing load equally between all operating generators. The generator controller will manage generator terminal voltage to affect VAR flow and must manage circuit demand within the constraints of the generators.

SCADA Integration and Protection System: SDG&E’s SCADA system was used to provide coordinated operation of existing switches and breakers within and at the boundary of the microgrid circuit. To maintain continuity with existing operations, the generator breaker protection is integrated into the existing SCADA system via fiber-optic communications between the generator breaker protection relays and the protection relay on the main breaker at the PCC. The following SCADA commands are used to manage the switching actions to transition the microgrid between its various operating states of Normal (Grid power only), Parallel (DER + Transmission), Island (DER power only), and De-energized (No power).

- Parallel command - Enables a sync-check across the generator breaker, allowing it to close when the generator output has matched frequency, voltage, and phase angle with the microgrid PCC and connected substation.

- Normal command (break parallel) - This command forces the DG units to disconnect ("break-parallel") from the substation leaving the microgrid circuit supplied by only the transmission network.
- Island command - Enables the generators to pick up the entire load of the microgrid circuit. The generators operate to drive power flow to zero across the substation breaker. When this is accomplished, the microgrid PCC is opened and the microgrid is separated from the substation and operating as an Island.
- Black-start command - This command (in the event of complete loss of power to the substation) enables a substation dead-bus check by the protection relay on the microgrid circuit breaker and opens the microgrid main breaker. Further, it facilitates the closing of the generators into the dead bus, energizing the microgrid circuit in an island operating state.

The DG controller's operational mode selection, set points, and operational status are accessible from the AMC via secure communications. On the network communication path, a dedicated microgrid gateway has been provided in the microgrid yard as the interface point for the generator controllers. Network communications between the generator controllers and the gateway use MODBUS-IP protocol. Network communications between the microgrid gateway and SDG&E back-office systems occurs via a proprietary protocol. The AMC communicates with the field data concentrator using DNP3.

AES Operations

The AES component of the DER for the Borrego Springs Microgrid project comprised of three Lithium Ion battery systems; AES 1 (0.5 MW), AES 2 (1 MW), and AES 3 (0.25 MW). The AES are capable of serving multiple purposes, each represented by a control mode. All functionality is managed by the AES to be within equipment rating capabilities and self-protection requirements. The AES unit is capable of operating in the following modes.

- Constant power charge and discharge modes
  - The AES user interface to the PCS controller provides for scheduling the AES for simultaneous constant kW and kVAr level output (any combination) as specified by the user and within the AES capabilities. Alternatively, constant kW level or kVA level and power factor may be specified.
  - The AES user interface to the PCS controller allows for selecting the desired time duration of the mode of operation. Options are to include a specific time period (start/stop) and an indefinite duration period which would continue until cancelled or overridden
  - Within this mode the PCS provides for the operator to set a specified time to re-charge (or discharge) the AES so it is ready for the next day's constant power event. Once programmed, it is expected the AES is capable of repeating a cycle in this mode on a daily basis without operator attention.

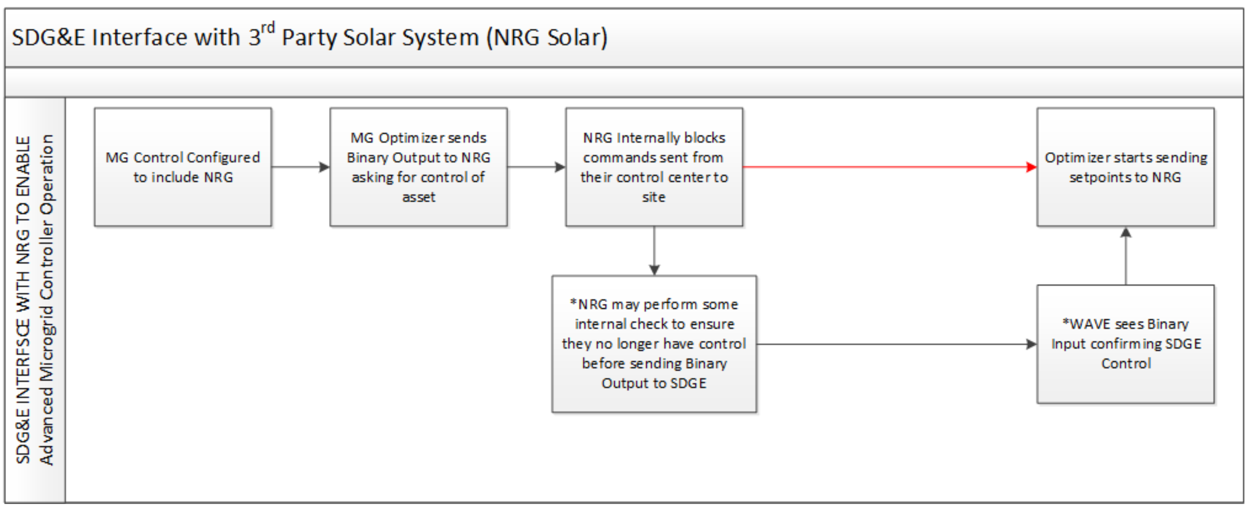
    - The scheduling interface accommodates seasonal and weekly schedules, and also allows for the differentiation of weekdays, weekends and holidays.
- Peak load management mode
    - The AES is capable of maintaining fixed load at the microgrid circuit main breaker. The AES monitors the output of a power meter that is installed at the microgrid circuit main breaker.
    - The AES user interface provides for selecting the mode and set point value (kW). The set point value is user selectable and prevents entries that exceed the limits of the AES capabilities.
    - The AES user interface allows for selecting the desired time duration of the mode of operation. Options are to include a specific time period (start/stop) and an indefinite duration period which continue until cancelled, overridden or operations are outside the limit of the AES capabilities.
    - The PCS algorithm uses the external signal information, along with the set point value to compute and directs the proper charge/discharge battery operation. The battery is expected to discharge at a power level sufficient to prevent the set point value from being exceeded on the selected grid component (within the AES capacity capabilities and within reasonable tolerances)
    - The PCS algorithm monitors the state of charge on the battery and can be set to operate at setpoint.
- PV smoothing mode
    - This mode allows the AES to add or subtract power to the grid based on the rate of change of power being injected from a solar array/PV.
- Standby mode
    - The AES system neither charges nor discharges, but only draws necessary auxiliary load. In the Standby Mode, the AES contactors are closed. Generally, this mode of operation is directed by the PCS or remote control as required to protect the health and safety of the AES and to meet the requirements of applicable standards for interconnecting distributed resources to the electric power system
- Shutdown mode
    - The AES system may open its contactors to prevent interaction with the grid (nominal auxiliary load contactors may continue to serve these loads). Generally, this mode of operation is directed by the PCS or remote control as required to protect the health and safety of the AES and to meet the requirements of applicable standards for interconnecting distributed resources to the electric power system.

At the time of this writing, these AES functions were not integrated with the current version of the AMC.

Third Party Solar PV Operations

The AMC developed for the microgrid can interface with the 3rd party solar system. This is the 26 MW solar facility operated by NRG. The project design included integration of this large renewable resource at Borrego Springs to leverage high penetration renewable energy, reduce dependency on fossil fuels, and improve operational reliability during islanded operations. The solar facility uses SMA inverters with which SDG&E did not have a direct interface. However, as part of this project, the settings in the SMA inverters were upgraded to allow for greater fluctuations in voltage and frequency. This was imperative to improve control during islanded operations by enabling the on or off, ramp up/ramp down of the solar facility output using the utility operated AMC. Figure 21 presents a high-level overview of the interaction between SDG&E's AMC and the third-party solar system from NRG.

Figure 21: Advanced Microgrid Controller Interface with Third-party Solar System



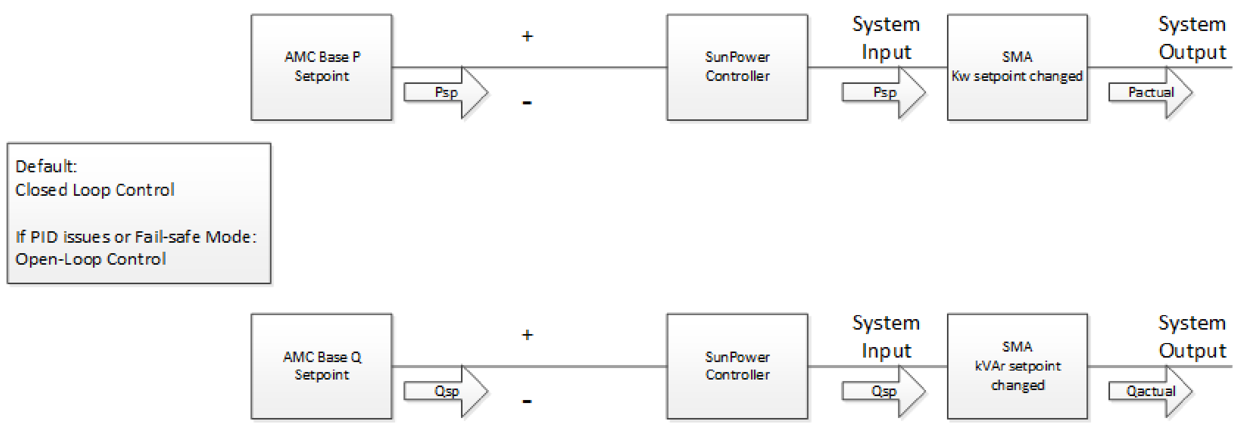
Source: San Diego Gas & Electric Company

Following are the modes of operation that were designed for interaction between the AMC and the third-party solar system.

- Base mode (Figure 22)– Constant Output Mode: In this mode the AMC sends a set point (P or Q) for the PV system operation.
- Peak Shave Mode (Figure 23) – In this mode the AMC sets a limiting power set point across the point of common coupling to curtail the output of the PV system.

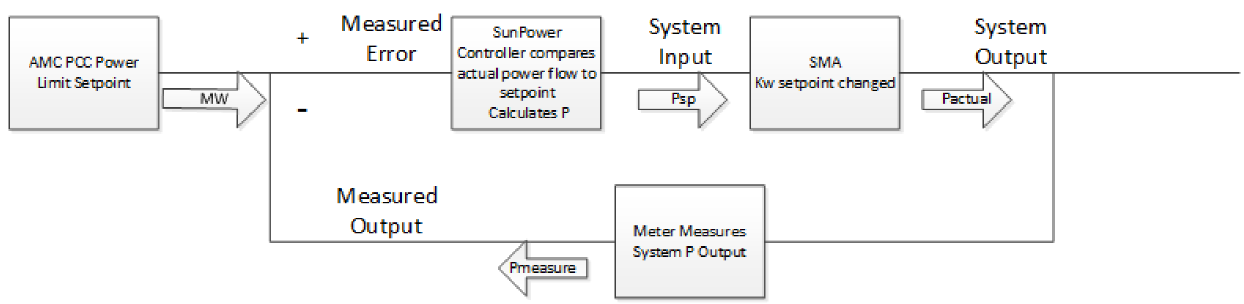
Figure 24 shows the data exchange and flow between the AMC Controller and the third-party PV system.

Figure 22: Third-party Solar System – Constant Output Mode Operation



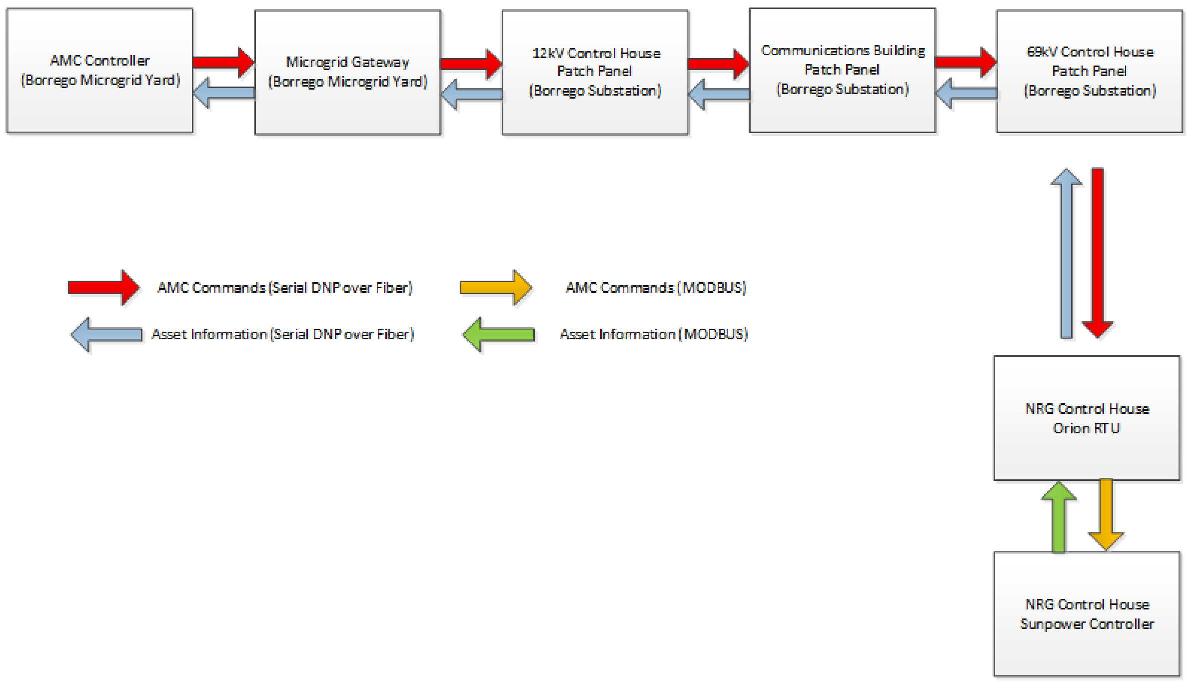
Source: San Diego Gas & Electric Company

Figure 23: Third-party Solar System – Peak Shave Mode Operation



Source: San Diego Gas & Electric Company

Figure 24: Data and Controls Path Between Advanced Microgrid Controller and Third-party Solar Facility



Source: San Diego Gas & Electric Company

Information Exchange

Table 9 on the following page summarizes the information exchanged between the AMC, the microgrid resources and backend utility systems.

Advanced Microgrid Controller Development

SDG&E is building a distribution energy resource management (DERMS) platform to integrate all DERs in its service territory. The AMC developed as part of this project integrates the microgrid assets with the DERMS operations. This was made possible with the implementation of our project team member's AMC functionality through its DERMS platform. This allows for greater operational benefits to be realized with the microgrid assets.

The AMC determines the preferred operating state of the microgrid based on the assessed state and operational constraints of the system. The AMC "optimizes" the behavior based on objective function(s) that evaluate the relative values of economic, environmental, and reliability factors. The AMC performs optimization considering the reliability objectives of maintaining voltage levels and supporting circuit load. It can dynamically weigh microgrid objectives and implement multiple objectives simultaneously (such as providing VAr optimization and Reduced Load Shaving at the same time). It will provide the Electric Distribution Operations (EDO) with the ability to monitor and control microgrid operations.

Table 9: Microgrid Information Exchange

Microgrid Process Interface	Information Exchanged
SCADA	Switching Device Status Distribution Circuit Analog Information Capacitor Device Status
DMS	Microgrid Circuit Network Topology Switching Requests Outage Restoration Time (ETR)
AES	Battery Status Information Analog Parameters (kW, kVAr) Mode of Operation State of Charge
DG	Generator Status Information Generating Analog Parameters (kW, kVAr) Generator Modes of Operation Fuel Level
3rd Party PV	Analog Parameters (kW, kVAr) Mode of Operation Event Request Historical Production Data
Data Warehouse	Storage of Operational Data Historical Data Storage and Lookup
Weather	Current Weather Conditions Forecast Weather Conditions

Source: San Diego Gas & Electric Company

The AMC is designed to perform the following optimizations:

- Perform EMS optimization: The AMC provides overall energy management services of the microgrid assets to ensure the stability and safe operation of the microgrid. The AMC performs required calculations necessary to maintain the power quality and use the results of optimization routines to develop control inputs for microgrid resources.
- Control voltage: The AMC monitors and controls voltage within the microgrid using DG (including generators) and AES to for voltage support.
- Control frequency: The AMC monitors and controls frequency within the microgrid, especially during island mode of operation. It will control frequency with the DG devices. Adjustments to frequency are meant to be done frequently to maintain a stable system. In microgrid operational parallel mode, the grid monitors and maintains frequency.
- Control VAr: The AMC monitors and controls VAr flow within the microgrid, especially during island mode of operation. In microgrid operational parallel mode, the AMC is capable of managing the VAr flow within the microgrid through the PCC. The AMC performs VAr optimization for power management of DER using AES in the microgrid. The AMC is capable of incorporating capacitor bank schedules in its optimization algorithms and calculate optimized VAr schedules for the microgrid.

- Optimize power reliability: The AMC power reliability algorithms determine the set of microgrid resources to maximize customer availability using both generation resources and advanced energy storage. The power reliability algorithms determine if power can be restored to portions of the microgrid and determine what microgrid resources can be used to improve reliability.
- Optimize DER: The AMC develops a plan to operate microgrid resources as needed to optimize the microgrid operating objectives. The DER optimization plan considers reliability, economic and environmental objectives as input from microgrid control objectives. The AMC's DER plan considers whether the microgrid is operating in an islanded or connected mode. The AMC considers the constraints of each DER resource (for example AES capacity and discharge/charge rate), the selected mode of operation.

Microgrid Infrastructure Upgrades

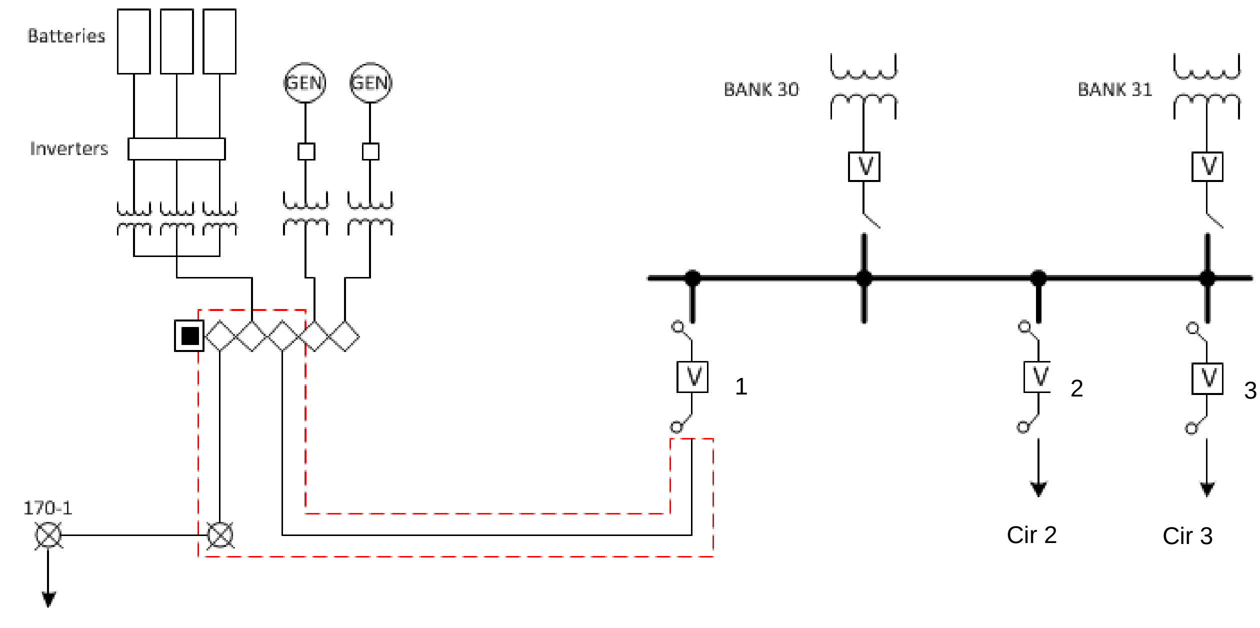
This task addressed the infrastructure upgrades, installation and integration of equipment and resources in the microgrid that were used for the project. Following activities were undertaken to upgrade the infrastructure necessary to support integrating resources within the microgrid:

Circuit Reconfiguration

The baseline analysis revealed many manual operations that were undertaken in Circuit 1 of Borrego Springs with the back feeding into the 12 kV bus from the existing microgrid resources were also done by manual switching. The project team undertook the following efforts to reconfigure one of the microgrid circuits for effective system operation:

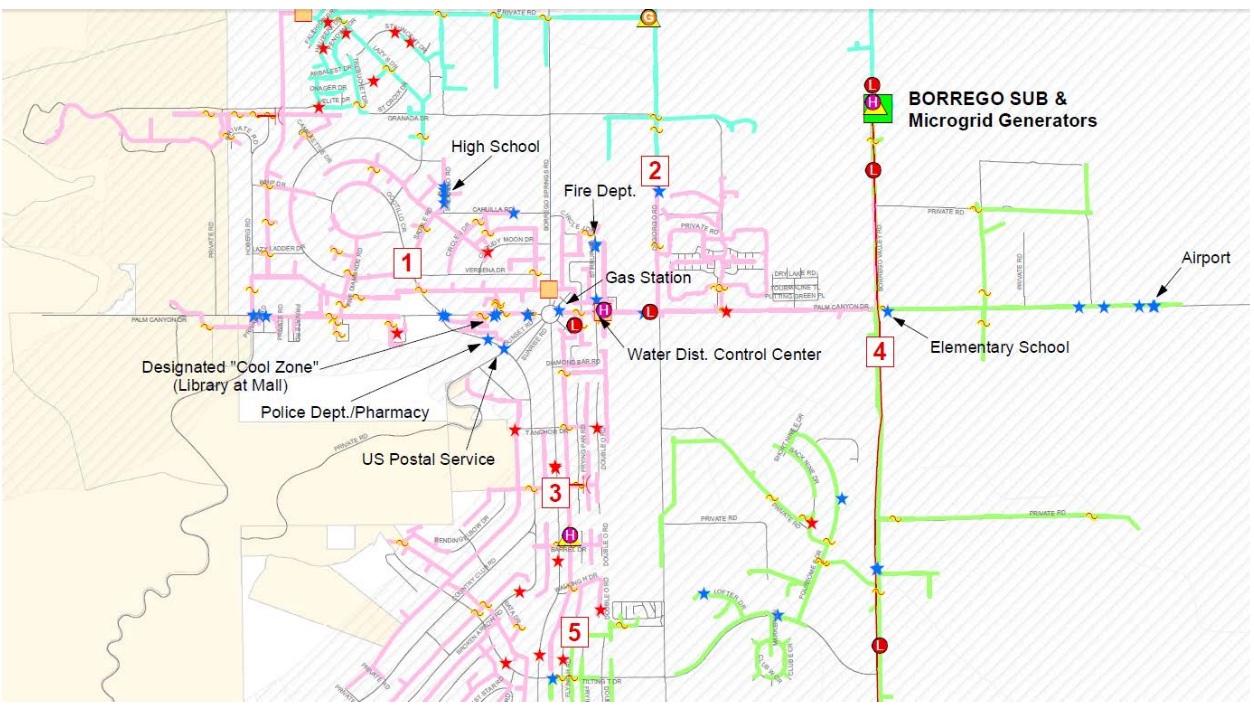
- Looping of Circuit 1 into microgrid yard (Figure 25) – This was undertaken via the 5-way pad-mounted switch to increase flexibility to feed any one of the three circuits in Borrego Springs, depending on operational needs.
- Installation of SCADA switches (Figure 26) – SCADA enabled switches that could be operated remotely through SCADA were placed strategically throughout Borrego Springs. This was completed to increase availability of real-time information on circuits, increase flexibility to pick up/restore/sectionalize loads more effectively, and reduce the duration of potential assessments and patrols to achieve economic efficiency and minimize customer impact during grid outages.
- Upgrades to SCADA capacitors and wireless fault indicators – Existing overhead capacitors and wireless fault indicators were upgraded to increase availability of information on circuits and reduce duration of potential assessments and patrols.

Figure 25: Reconfiguration of Circuit 1 - Loop into Microgrid Yard



Source: San Diego Gas & Electric Company

Figure 26: Reconfiguration of Circuit 1 - SCADA Switches



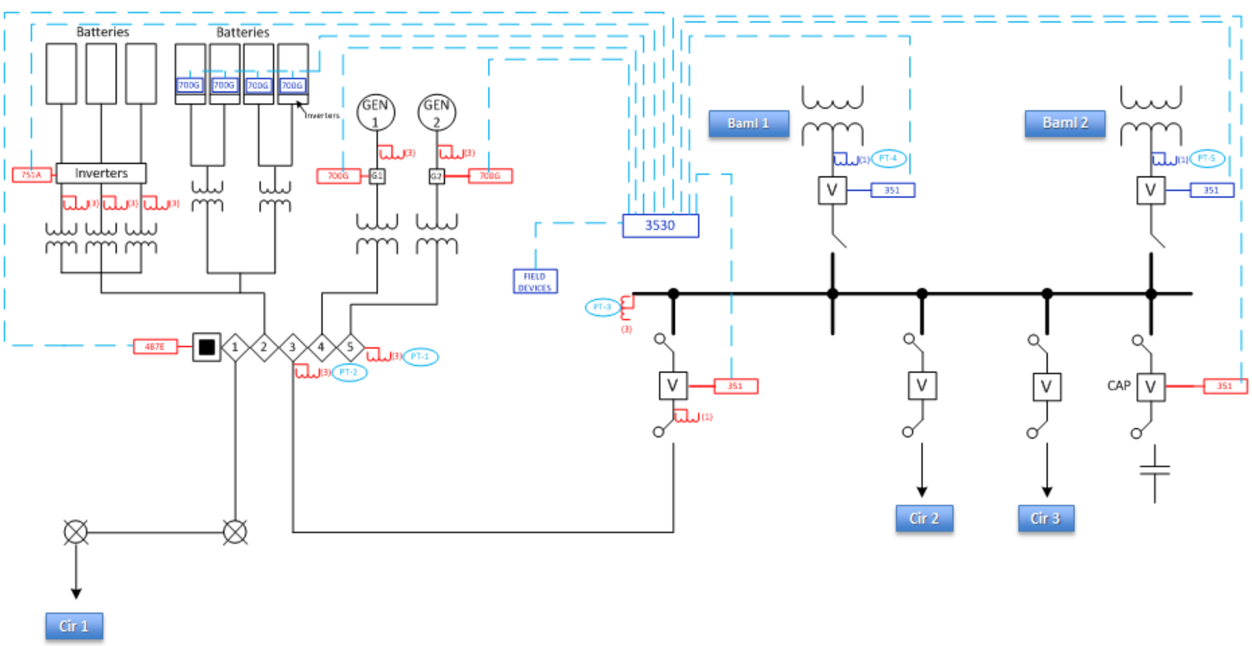
Source: San Diego Gas & Electric Company

Upgrade Protection and Permissions

The existing protection and permissions schemes were aimed at islanding only one circuit (Circuit 1) of the three circuits in Borrego Springs. These configurations and schemes required personnel onsite to manually operate the circuit breaker at the point of common coupling. Additionally, an outage was required to be undertaken to reconnect the tie-line with the substation. These limiting factors had to be upgraded to ensure all three microgrid circuits could seamlessly participate in the remote microgrid operations. The project team undertook the following efforts to upgrade the protection and permission schemes (Figure 27) including:

- Permissions to back feed generators to the dead 12 kV bus – Current permissions scheme were upgraded to allow for automated circuit breaker operation for energizing 12 kV bus.
- Synchronize to high-side of transformer – New protection relay panels and synchronizing potential transformers (PTs) were installed to enable seamless transition back from an island event, when the 69 kV transmission line is re-energized.
- Substation capacitor auto-disconnect – Additional controls were retrofit to existing substation capacitors as a preventive measure to mitigate operational issues while going into island operation. This will help automate transition to island and decrease manual operation of capacitors in the event of an outage.

Figure 27: Upgraded Protection and Permissions



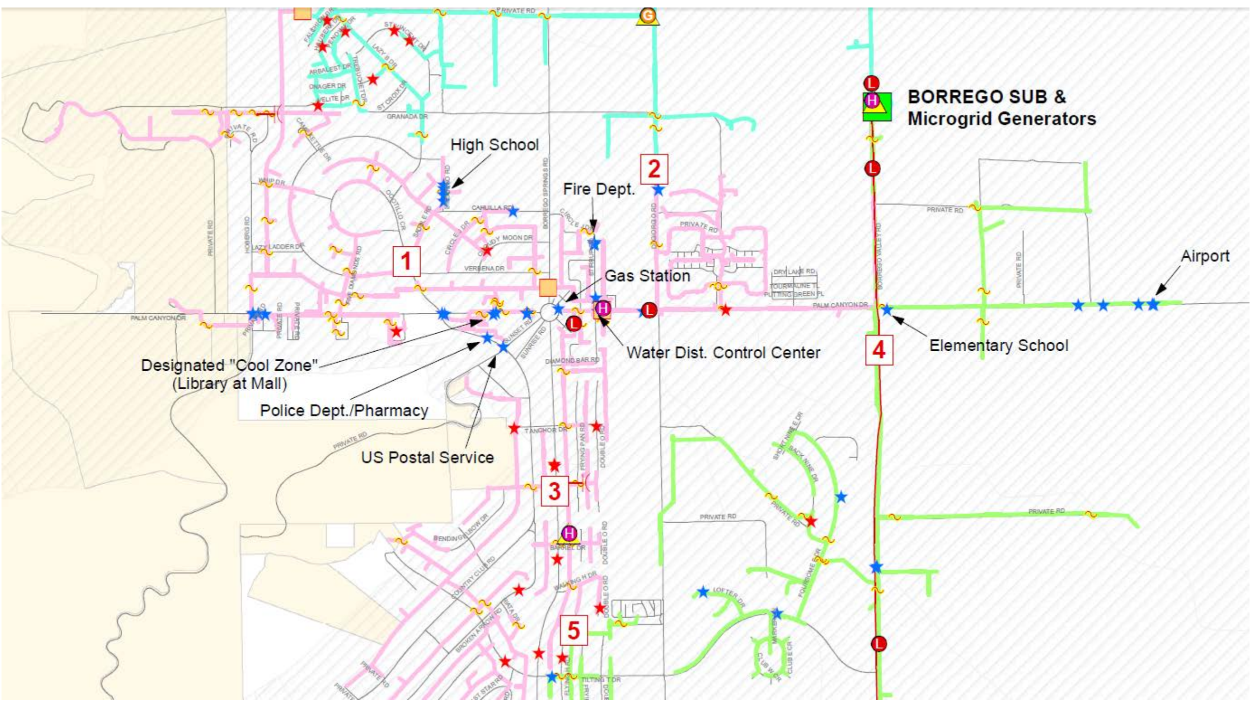
Source: San Diego Gas & Electric Company

Upgrade/Harden Circuits Harden Critical Stretch of Circuit 2

Borrego Springs lies in a desert climate and is known to be affected by extreme and adverse weather conditions due to high winds and flash floods. This has resulted in certain "weak points" in the existing electric infrastructure on the circuits. In addition, portions of the downtown area had been identified as a "cool zone" or critical site for residents, during excessive heat events and to maintain public safety. The project team undertook the following effort to upgrade/harden the circuits (Figure 28):

- Upgraded a section of the distribution line leading to the downtown area (cool zone) was from wooden to steel poles. This upgrade will allow for quicker re-energization to the downtown area during microgrid events.

Figure 28: Upgrade/Harden Circuits - Harden Critical Stretch of Circuit 2



Source: San Diego Gas & Electric Company

Integration with Third-party Solar Facility

The Borrego Springs Microgrid includes one large 26 MW solar facility that can provide additional generation sources to the grid. An upgrade and retrofit of the current microgrid was required to be able to integrate the solar facility. The project team undertook the following efforts to integrate the solar facility:

- Upgrade and retrofit current microgrid – This will allow for islanding all three circuits (potentially islanding all customers of Borrego Springs) during microgrid operations.
- Modification of system protection schemes – Existing protection schemes were modified that allowed for energization of the 69 kV bus and thereby the 26 MW solar facility, which is directly connected to the 69 kV bus.

- Installation of equipment for communications and interface – Additional equipment was installed and new communication interfaces with the solar facility were developed to allow for communication between the solar facility and SDG&E as the DERMS microgrid operator.
- Grid and generation operating procedures were modified to allow for safe, reliable, and efficient operation of this new generation resource within the microgrid.

Integration with Local Resorts

The project team identified three local resorts in the "cool zone" that needed upgrades to its interconnection point with the grid. In response, the project team undertook the following efforts to integrate the three local resorts' interconnection point with the microgrid:

- Transfer switches and connections were created for mobile generator deployment.
- Additional staging areas were created for SDG&E crews during adverse weather conditions.
- This upgrade allowed for a safe staging area for life support/medical baseline customers to stay at these resorts during emergencies and electric grid outages.

Upgrades to Site Communications and Demonstration Support

An onsite controller that was installed during the last phase of the Energy Commission funded project (in 2013) only had backup power for at most four hours. The project team undertook the following efforts to upgrade site communications for support of the microgrid operation:

- Upgrade of communications infrastructure – Backup uninterruptable power systems were deployed for onsite controller operations. A field data concentrator was installed that communicates with the enterprise data concentrator thereby enabling microgrid operational data to be sent to the enterprise data historian in the SDG&E control center.
- Support for generator operations and annual source testing was undertaken for generator emissions compliance and operations.
- A new flood control fence was installed to maintain site security while maintaining site integrity during flash floods

Integration with Electric Distribution Operations

A key aspect of this microgrid project was integration of local microgrid operations with SDG&E's Electric Distribution Operations (EDO). EDO is responsible for operations of SDG&E's electric distribution system through its control center in San Diego. It was imperative to handover operations of the microgrid to EDO, through the installation of an advanced microgrid controller for asset management and operations. The project team undertook the following efforts to integrate with EDO:

- The microgrid project team created a plan to transition operation responsibilities over to EDO after successful testing of individual assets and overall testing of the microgrid during actual test operations.
- The microgrid resources were identified as additional assets to be used by EDO to effectively operate the grid during normal and abnormal situations.
- The integration with EDO will result in quicker response times for microgrid assets to respond to emergencies and electric grid outages.
- SDG&E is building a DERMS platform to integrate all DERs in its service territory. The AMC developed as part of this project integrated the microgrid assets with the DERMS operations. This also allowed for greater operational benefits to be realized with the microgrid assets.

Community Participation

SDG&E's team worked closely with several key community organizations, local leaders and schools in Borrego Springs to complete some important community projects, summarized below.

Critical Load Report

At the start of the project, the team engaged with the Borrego Springs Chamber of Commerce and key stakeholders to help define the area's critical infrastructure such as "cool zones", gas stations, grocery stores and restaurants. Following is the list of primary and secondary critical loads that were identified by the community stakeholders.

Primary Critical Loads

Emergency Operations Centers

1. San Diego County Sheriff's Department (Local CHP Office) shown in Figure 29.

Figure 29: San Diego County Sheriff's Department

Source: San Diego Gas & Electric Company

2. Borrego Springs Fire District (Figure 30).

Figure 30: Borrego Springs Fire District

3. Verizon Wireless FCC Tower (Located at the Fire Department)

Communications - Schools – Services – Shelters - +55 Adult Communities

4. AT&T – Communications
5. Borrego Liquefied Natural Gas (SDG&E)
6. Borrego Medical Clinic - Borrego Community Health Foundation
7. Borrego Pharmacy - Borrego Community Health Foundation
8. Borrego Springs Branch Library – Cool Zone
9. Borrego Springs Children's Center - Borrego Community Health Foundation
10. Borrego Springs Elementary School (Red Cross Overflow – Evac/Kitchen)
11. Borrego Springs High/Middle School (Red Cross Emergency Evacuation Shelter)
12. Borrego Springs Senior Center - Borrego Community Health Foundation
13. Borrego Valley Airport
14. Borrego Water District Office & Maintenance Shop
15. Borrego Water District - Treatment Plant
16. Borrego Water District – Country Club Tank
17. Borrego Water District – Booster Station 1
18. Borrego Water District – New Lift Station
19. Borrego Water District – Well #4
20. Bottle Shoppe & Gas Station
21. Cable - USA Communications - Emergency Info – Channel 3

22. Center Market
23. Desert Green Solar Farm - Invenergy
24. Desert Pantry Supermarket
25. Mountain View Cottages – 24/7 Assisted Living Facility (Adult 55+ Community)
26. NRG Solar Facility – connected to the microgrid
27. ProFlame / Petrolane - Propane Gas Service
28. Roadrunner Community (Trailer Park – Adult 55+ Community)
29. San Diego County Roads Field Station (Fuel – Sheriff, CHP & Fire)
30. Village Food & Fuel
31. Woolcott Dental - Borrego Community Health Foundation (Gordon Wimer, DDS)
32. X L Co Fuel

Secondary Critical Loads

33. Borrego Springs Chamber of Commerce & Visitor Center
34. True Value Hardware

Borrego Desert Energy Project

SDG&E worked closely with the Anza-Borrego Desert Natural History Association (ABDNHA)[2] to create a community energy education program. The goal was to educate, inspire, empower and motivate the community to create a "Clean Energy Future" by protecting the environment through conservation and sustainable practices. ABDNHA created a comprehensive campaign that included elements such as:

1. ABDNHA Garden, Outdoor Educational Displays – UV resistant professional interpretive displays located along a footpath and plaza within the ABDNHA Botanical Garden. A highlight included in the display, is a hand-crank example of how energy is made. A large monitor is located right next to the plaza displaying informational messages to the visitors.
2. BDEP / Monitor / Displays / Info – Digital monitors display BDEP info in ABDNHA's Library, with an additional monitor at the Borrego Springs Chamber of Commerce office foyer. ABDNHA develops the messages and graphics for these Digiboards, and they will continue to update until 2019. Messages include information concerning energy and the environment with a section about the Borrego Springs Microgrid.
3. Sustainability Tour – A self-guiding tour via automobile, bicycle, or online tour of selected locations in Borrego Springs that are examples of renewable energy and

[2] http://www.abdnha.org/energycenter/SustainableBorrego/index.html.

efficient use of resources. Available online and by a map is featured in the BDEP brochure.

4. Social Media – BDEP's information is also be highlight at a website and a Facebook page managed by ABDNHA. It is targeted towards children, parents, and teachers. The website features topics such as: Project Background, Understanding Energy, Sustainable Borrego, Energy & Nature, Energy for Kids (Kids Club) and Energy Tips.
5. STEM Educational Energy Programs & Events for Children – A hands-on energy program in the local Borrego Springs school system, and a web-based program, "Energy: Just for Kids" with activities and experiments that kids can do with their parents and teachers. Includes leadership training and energy career opportunities.
6. Collateral Materials – Letterhead, Brochure, tour map, educational materials, articles and more.
7. Press Releases – Were sent to local and regional print, television and cable entities, as well as the ABDNHA newsletter. The Borrego Sun carried a story about the ABDNHA center kick-off reception.
8. Ribbon Cutting / Grand Opening – Wed, Feb 28, 2018 – Attended by more than 75 community leaders, business owners, students and residents.

Community Events Outreach:

As part of the outreach effort and customer feedback survey, the SDG&E project team organized and/or participated in multiple events to engage the Borrego Springs community. These included:

- Borrego Energy Day – ABDNHA's local community forum with presentations by energy/topic experts. Featured information, speakers, lectures, tours, and other special activities.
- Borrego Days – An annual community event that spans 3 days with food, entertainment, booths, and events. Attendance is estimated at more than 45,000 guests per year.
  - SDG&E has sponsored this event for more than 10 years and has a double-booth to talk to the community about the local microgrid project and other services.
- Local Farmer's Market – Recruited survey participants and distributing information about the Borrego Springs Microgrid.
- Borrego Springs Chamber of Commerce – SDG&E provided a large monitor for their conference room to support their community meetings. This is in addition to the large monitor in the foyer the Chamber received from the Borrego Desert Energy Project.
- Borrego Springs Microgrid FAQ – Borrego Sun Newspaper – SDG&E ran a large article that featured important Frequently Asked Questions (FAQ's) and facts about the Borrego Springs Microgrid and outages. Ran in the Oct 19, 2017 edition.

- SDG&E NewsCenter – SDG&E has shared information about the Borrego Springs Microgrid through articles published on its NewsCenter (sdgenews.com), which is accessible to the public and the media. These articles are shared through SDG&E's social media channels, which include Twitter, Facebook, Instagram, Pinterest, and LinkedIn.

Planned Outage Communications

The project team reached out to the Borrego Springs customers informing them of the Energy Commission project testing with details that included dates, duration, and contact information for inquiries and emergencies. Letters were sent to impacted customers ahead of any project testing.

Borrego Springs Microgrid Awareness Survey

A simple awareness survey was created for the Borrego Springs Microgrid. 82 Borrego Springs part-time or full-time residents were recruited at two events (Tables 10-12):

- October 28, 2017 – Borrego Days event (49 customers responded to the survey)
- March 23, 2018 – Local Farmer's Market (33 customers responded to the survey)

Table 10: Survey Results – Total Respondents – All 82 Survey Participants

Answer / Question	1 Have you ever heard about SDG&E's Borrego Springs Microgrid?	2 What is your opinion of the Borrego Springs Microgrid?	3 Would you like to learn more about the Borrego Springs Microgrid and what it does for the local community?
Yes	48		57
No	34		25
1 (Highly beneficial to the community)		33	
2 (Somewhat beneficial to the community)		13	
3 (Not beneficial to the community)		3	
4 (Have no opinion about the microgrid)		6	
5 (Don't know anything about the microgrid)		27	

Source: San Diego Gas & Electric Company

Table 11: Total Respondents – 48 of 82 Survey Participants "who were aware of the microgrid"

Answer	**Question**	**1** Have you ever heard about SDG&E's Borrego Springs Microgrid?	**2** What is your opinion of the Borrego Springs Microgrid?	**3** Would you like to learn more about the Borrego Springs Microgrid and what it does for the local community?
Yes		48		34
No				14
1 (Highly beneficial to the community)			26	
2 (Somewhat beneficial to the community)			12	
3 (Not beneficial to the community)			3	
4 (Have no opinion about the microgrid)			4	
5 (Don't know anything about the microgrid)			3	

Source: San Diego Gas & Electric Company

Table 12: Total Respondents – 34 out of 82 Survey Participants "who were NOT aware of the microgrid"

Answer	**Question**	**1** Have you ever heard about SDG&E's Borrego Springs Microgrid?	**2** What is your opinion of the Borrego Springs Microgrid?	**3** Would you like to learn more about the Borrego Springs Microgrid and what it does for the local community?
Yes				23
No		34		11
1 (Highly beneficial to the community)			7	
2 (Somewhat beneficial to the community)			1	
3 (Not beneficial to the community)			0	
4 (Have no opinion about the microgrid)			2	
5 (Don't know anything about the microgrid)			24	

Source: San Diego Gas & Electric Company

Borrego Springs Microgrid - Customer Feedback Survey:

In addition to the Borrego Springs Microgrid Awareness Survey, SDG&E also conducted a more in-depth customer feedback survey. This gauged the customer experience with the usage of the Borrego Springs Microgrid, planned outages, communication methods and usage of cool zones. The survey was emailed on July 25, 2018, to all part-time and full-time residents. The results were not available at the time of the submission of this report but will be forwarded at a later date.

Laboratory Testing

This task included experimental setup for a laboratory-scale, proof-of-concept, hardware-in-the-loop (HIL) evaluation that was undertaken at NREL's Energy Systems Integration Facility (ESIF). This section presents the results of the evaluation of an advanced controller and advanced control functions for the Borrego Springs Microgrid through controller-hardware-in-the-loop (CHIL) and/or power hardware-in-the-loop (PHIL) simulations. It also describes the hardware-in-the-loop (HIL) test configuration, the functionalities tested, the test procedure, the test results, and the lessons learned. The HIL evaluation setup allowed realistic testing of the ability of these advanced controls to manage the microgrid operation under conditions that would be difficult or expensive to create in the actual system.

The evaluations were conducted in two phases, described below, and different scenarios were simulated for each phase:

- Phase 1: Evaluation of an advanced microgrid controller for Borrego Springs; for this phase of testing, the Spirae Wave microgrid controller, similar to that deployed at Borrego Springs, was used.
- Phase 2: Evaluation of advanced R&D microgrid control functions; for this phase of testing, an implementation of the OSISoft/UCSD R&D microgrid functions called advanced control technology (ACT) was used.

Evaluation of an Advanced Microgrid Controller

The purpose of HIL testing is to validate the AMC's ability to meet the following functional requirements described below:

- C1: Disconnection
- C2: Resynchronization and reconnection
- C3: Steady-state frequency range, voltage range, and power quality
- C4: Protection
- C5: Dispatch
- C6: Enhanced resilience

Functional Requirements for Microgrid Controller Evaluation

C1: Disconnection was evaluated by determining whether the microgrid disconnects from the utility when a voltage or frequency threshold is reached, and within the time specified, based on the thresholds provided in IEEE 1547.1-2005, Section 5.2 (voltage) and Section 5.3 (frequency) that are configured in the individual asset controller. Table 13 lists the voltage thresholds, and Table 14 lists the frequency thresholds.

Table 13: Voltage Thresholds Disconnection

Default Settings[a]		
Voltage Range (% of Base Voltage[b])	**Clearing Time (s)**	**Clearing Time: Adjustable Up to and Including (s)**
V < 45	0.16	0.16
45 ≤ V < 60	1	11
60 ≤ V < 88	2	21
110 < V < 120	1	13
V ≥ 120	0.16	0.16

[a] **Under mutual agreement between the electric power system and demand response operators, other static or dynamic voltage and clearing-time trip settings shall be permitted.**

[b] **Base voltages are the nominal system voltages stated in American National Standards Institute (2011, Table 1).**

Source: IEEE 2014, Table 1

Table 14: Frequency Thresholds for Disconnection

	Default Settings		Ranges of Adjustability	
Function	**Frequency (Hz)**	**Clearing Time (s)**	**Frequency (Hz)**	**Clearing Time: Adjustable Up to and Including (s)**
UF1	< 57	0.16	56–60	10
UF2	< 59.5	2	56–60	300
OF1	> 60.5	2	60–64	300
OF2	> 62	0.16	60–64	10

Source: IEEE 2014, Table 2

Testing was undertaken to determine whether the microgrid controller detects an unintentional island and ceases to energize the area electric power system by disconnecting the microgrid from the utility within 2 seconds of the formation of an island, as specified in IEEE 1547, Section 4.4.1. Unintentional islanding disconnection testing was conducted based on test procedures from IEEE 1547.1, Section 5.7, in which the intent is to perform testing when the unit under test exchanges power with the area electric power system at a level that is less than 2 percent of its nominal power rating.

C2: Resynchronization and reconnection was evaluated by determining whether reconnection occurs only when the area electric power system voltage is within Range B (0.95 per unit < V < 1.05 per unit) of American National Standards Institute Standard C84.1-2011; and the frequency is in the range from 59.3 Hz–60.5 Hz (as defined by IEEE 1547-2003) at the individual asset controller. The reconnection was delayed for up to 5 minutes after the area electric power system steady-state voltage and frequency are restored to the ranges identified above. The delay time was tested by measuring the time between the presence of nominal conditions and the completion of reconnection.

The team further evaluated whether reconnection occurs only when the voltage, frequency, and voltage phase-angle differences are within the limits shown in Table 15, as defined by IEEE 1547-2003. The limits for a microgrid with a rating from 1.5 MVA–10 MVA was used.

Table 15: Difference Limits for Reconnection

Aggregate Rating of Demand Response Units (kVA)	Frequency Difference (Δf, Hz)	Voltage Difference (ΔV, %)	Phase Angle Difference (ΔΦ, °)
0–500	0.3	10	20
> 500–1,500	0.2	5	15
> 1,500–10,000	0.1	3	10

Source: IEEE 2014, Table 5

C3: Steady-state operation in islanded mode was evaluated by using measurements from sources and loads to determine whether the microgrid controller is able to maintain the voltage within Range B (0.95 per unit < V < 1.05 per unit) of American National Standards Institute C84.1-2011, and the frequency is within the range from 59.3 Hz–60.5 Hz.

C4: Protection was evaluated by simulating external and/or internal faults and determining whether the microgrid controller provides adequate control to serve and manage critical loads in both grid-connected and islanded modes of operation without triggering protective relays.

C5: Dispatch was evaluated by determining the microgrid controller's ability to dispatch resources to achieve survivability of critical loads when islanded, economic operation, and environmental performance compared to the outcomes for the community without the microgrid controller.

C6: Enhanced resilience was evaluated by validating that the microgrid controller is capable of managing the microgrid system effectively during contingencies with rapidly changing, weather-related, or other naturally occurring disruptive events.

Metrics for Advanced Microgrid Controller Evaluation

The metrics by which dispatch and resiliency were evaluated are described below.

Survivability of Critical Loads

The survivability metric will reflect whether sufficient resources (for example, generation and/or energy storage) are operating and available to support the microgrid's seamless transition to island mode, and it will be calculated as follows:

$$S_n = \frac{P_{loads,crit,n}}{P_{avail,n}}$$

where $P_{loads,crit,n}$ is the total active power of all loads that are identified as critical by the community and San Diego Gas & Electric during time step n, and $P_{avail,n}$ is the total power available from all dispatchable generation[3] during time step n. For energy storage systems, the calculation of $P_{avail,n}$ will consider the available state-of-charge of the batteries. The survivability metric should be less than 1 at all time steps.

Economic Operation

The cost of operating the microgrid for the duration of the scenario simulated, C, will be calculated as follows:

$$C = \sum_{N} P_{grid,n} \cdot \tau \cdot c_{grid,n} + \sum_{k} \left\{ \sum_{N} P_{DER,k,n} \cdot \tau \cdot c_{DER,k,n} \right\} + c_D \cdot \max\left(P_{grid,n} \cdot \tau\right)$$

where P_{grid} is the power supplied by the grid, c_{grid} is the cost of grid power, $P_{DER,k}$ is the power supplied by the k^{th} DER resource within the microgrid, $c_{DER,k}$ is the cost of supplying power from the k^{th} DER resource within the microgrid, c_D is the demand charge associated with grid power and τ is time step. The cost to operate the DER, $c_{DER,k}$ was assumed to be zero for PV and battery energy storage systems; and it was calculated based on representative efficiency data and fuel costs for the distributed generation resources.

Environmental Performance

The estimated carbon dioxide (CO_2) emissions associated with operating the microgrid for the duration of the scenario simulated, ϑ, will be calculated as follows:

$$\vartheta = \sum_{N} P_{grid,n} \cdot \tau \cdot \xi_e + \sum_{k} \left\{ \sum_{N} P_{DER,k,n} \cdot \tau \cdot \xi_g \right\}$$

where ξ_e is the electricity emissions factor for the grid, and ξ_g is the distributed generation resources emissions factor. Note that ξ_g is zero for photovoltaic (PV) systems and battery energy storage systems (BESSs). The electricity and gas emissions factors provided in Attachment 12 of PON-14-301 (California Energy Commission 2014) shown in Table 16, will be used for the grid.

Table 16: Emission Factors in Carbon Dioxide Equivalent

	Emissions Factor (CO_2e[a])	Emissions Factor (CO_2e[a])
Electricity	0.588 lbs/kWh saved	0.000283 metric tons/kWh
Gas	11.7 lbs/therm saved	0.0053 metric tons/therm

[a] **Carbon dioxide equivalent**

Source: California Energy Commission 2014

[3] For accelerated tests, only steady-state values that are achieved after assets have been dispatched for each time step are used.

Simulation Scenarios for Advanced Microgrid Controller Evaluation

To validate functional requirements C1–C6, the AMC was tested for the target community under four major scenarios as shown in Table 17:

- Scenario A: Operating the microgrid while connected to the utility
- Scenario B: Separating the microgrid from the utility
- Scenario C: Operating the microgrid while separated from the utility
- Scenario D: Connecting the microgrid to the utility

Table 17: Mapping Scenarios to Functional Requirements

Scenario Description	C1	C2	C3	C4	C5	C6
	Disconnection	**Resynchronization and Reconnection**	**Steady-State**	**Protection**	**Dispatch**	**Enhanced Resilience**
A. Operating While Connected to the Utility					X	
B. Separating from the Utility	X			X		
C. Operating While Separated from the Utility			X	X	X	X
D. Connecting to the Utility		X				

Hardware-In-Loop Test Setup for Advanced Microgrid Controller Evaluation

Three configurations of the experimental setup were developed:

1. ESIF local CHIL setup: The controller hardware at the ESIF is coupled to a model of Borrego Springs, which is run on the local real-time digital simulator (RTDS) at the ESIF.
2. ESIF local CHIL/PHIL setup: The scaled power hardware and controller hardware at the ESIF is coupled to a model of Borrego Springs, which is run on the local RTDS at the ESIF.
3. ESIF/ITF remote setup: The scaled power hardware and controller hardware at the ESIF is coupled with a model of Borrego Springs, which is run on a combination of the RTDS

at the ESIF and the RTDS at the Integrated Test Facility (ITF) facility at SDG&E, made possible by a remote connection between the two RTDS systems.

An RSCAD software model of the Borrego Springs Microgrid power system was provided to NREL for HIL simulations. This model includes the distribution lines, DERs, loads, and system protection devices that make up the microgrid. This model was configured to be executed in real time on four prior generation RTDS racks that consist of rack-mounted processor cards connected to a backplane. NREL had only two prior generation RTDS racks available at the start of the project and had to modify the model provided by SDG&E, including some simplifications to the circuit, to be able to execute the simulations. NREL acquired a Novacor RTDS rack with four activated cores during the project. With this upgrade, NREL was able to simulate a functionally equivalent model to the original RSCAD model of Borrego Springs using the Novacor rack and one prior generation RTDS rack. Many changes, especially to inputs and outputs, were required to compile the model on NREL's two racks, but the electric circuit is equivalent to the original model.

NREL's HIL evaluation platform can execute the model of the microgrid power system with time steps on the order of a hundred microseconds, monitor system behavior in real time, and store the data for post-processing. Data were collected during the HIL-based testing phase using software metering points inside the software microgrid system model. Physical oscilloscopes were used as the hardware for any diagnostic needs. Data were accumulated from the real-time simulation as a time series, collected for the duration of the test, stored in a structured file (for example, comma-separated values file), and organized according to test case name and a test run number for easy retrieval and analysis later.

A functional block diagram of the ESIF local CHIL setup is shown in Figure 31, and a similar diagram is shown of the ESIF local CHIL/PHIL setup in Figure 32 and the ESIF/ITF remote setup in Figure 33. The ESIF local CHIL setup shows a CHIL experiment with only the microgrid controller and the distributed generator controllers implemented in hardware. The other two setups show a CHIL/PHIL experiment with NRG's PV plant, one of the substation energy storage systems, and the distributed generation resource controllers implemented in hardware, along with the microgrid controller hardware. The physical test setup was located in the ESIF's Energy Storage Laboratory.

The ESIF local CHIL setup consists of RTDS racks and advanced microgrid controller very similar to that installed at Borrego Springs, distributed generator controllers, a data manager, and the hardware/software interfaces among the RTDSs and the controllers. The RTDSs also output signals to and receive inputs from the microgrid controller and distributed generator controllers in real time, providing for a closed-loop simulation of the microgrid controller and the microgrid power system. The Borrego Springs power distribution system has three distribution feeders – circuits 1, 2, and 3. The microgrid controller interacted transparently with both the hardware and virtual components of the PHIL model.

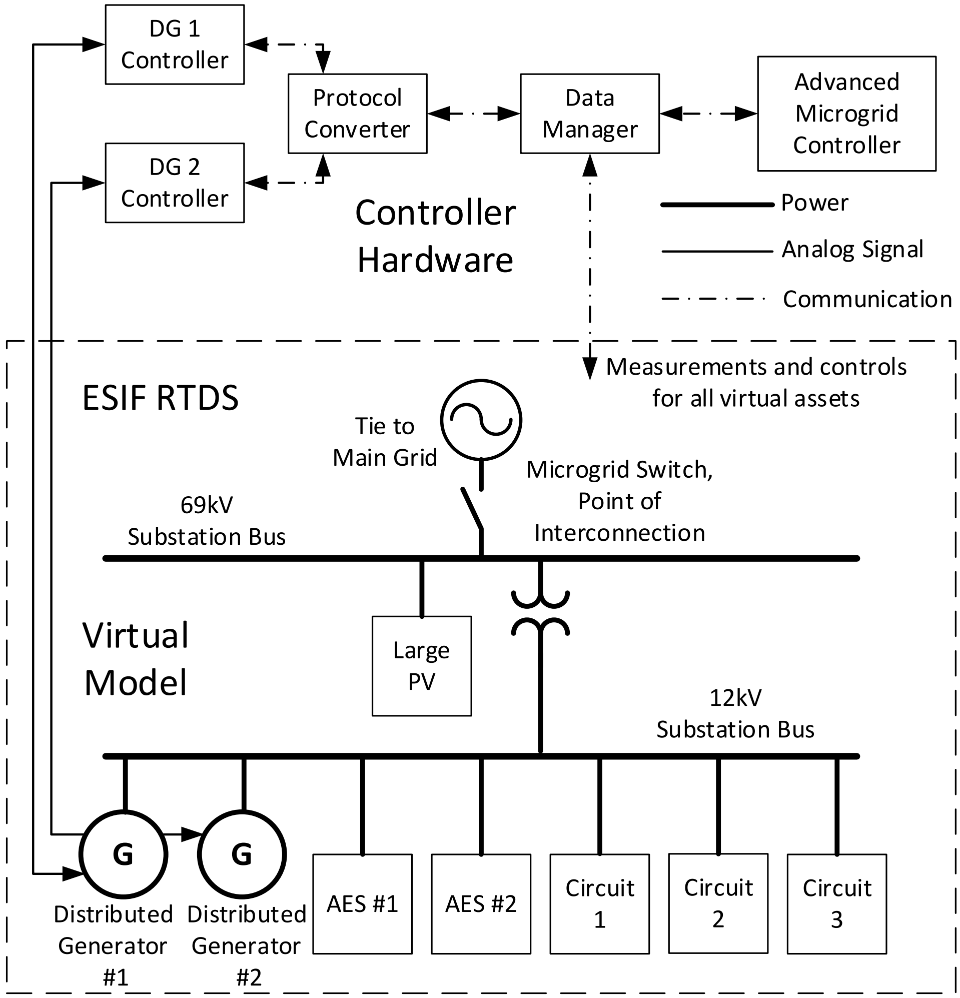
The ESIF local CHIL/PHIL setup consists of RTDS racks, the microgrid controller, a data manager, the distributed generation resource controllers, a battery inverter, a PV inverter, and the hardware/software interfaces among the RTDSs, controllers, and power hardware. The

RTDSs also output signals to and receive inputs from the microgrid controller, distributed generator controllers, battery inverter, and PV inverter in real time, providing for a closed-loop simulation of the microgrid controller and the microgrid power system. Closed-loop simulations were performed across a range of scenarios to evaluate the functional performance of the microgrid controller. NRG's PV plant and the non-grid-forming substation energy storage system (SESS) were represented by voltage and current-scaled power hardware. Whereas, the rest of the system was represented by virtual components implemented in an RTDS. The simulated distributed generation resources were interfaced with and controlled by hardware generator controllers. The Spirae microgrid controller interacted transparently with both the hardware and virtual components of the PHIL model. In Figure 32, the "V and I Scaling" block is used to interface the power hardware into the model. For the SESS inverter, the current measurements were scaled appropriately and injected into the controlled current source model. For the PV inverter, the current measurements and voltage feedback was used to calculate the real injected and reactive power injected or absorbed by the PV inverter into the grid simulator. These real and reactive power measurements were used to recreate a current sine wave, and this was injected into the model. This method of current injection was chosen to avoid any instability induced in the model due to direct injection of current signal into the model.

The ESIF/ITF remote setup is similar to the ESIF local CHIL/PHIL setup, except that the scaled power hardware and controller hardware at the ESIF is coupled with a model of Borrego Springs that is run on a combination of the RTDS at the ESIF and the RTDS at the SDG&E ITF, made possible by a remote connection between the two RTDS systems (Figure 33). The Gigabit Transceiver Network Interface (or GTNET) cards of the RTDS were used to enable the remote connectivity between the RTDS at ESIF and the RTDS at ITF. The remote connection uses transmission control protocol (or TCP)-based communication between the GTNET cards at the two locations through a secure virtual private network (or VPN) tunnel. Because of communication latencies between the ESIF and ITF, the remote setup will introduce modeling inaccuracies and will not be able to represent fast dynamics across the entire microgrid. This is expected to have a significant impact when testing is performed that is associated with transitions between grid-connected and islanded modes.

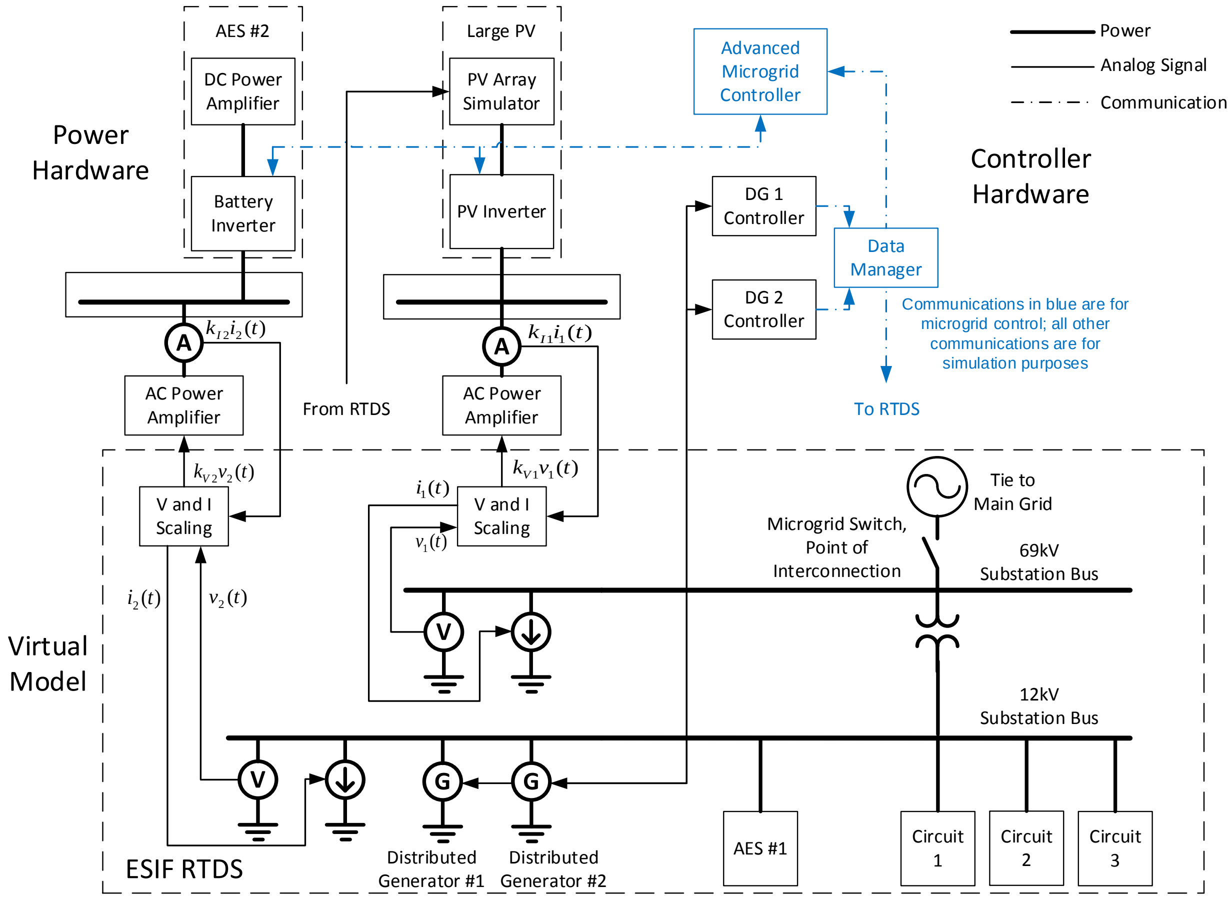
Table 18 specifies the hardware components that were used to implement each of the functional blocks of the HIL configuration along with their hardware ratings. The SMA PV inverter is the same model and has the same firmware and settings as those used at NRG's PV plant. The PV inverter is compliant with the IEEE Standard 1547, but the settings allow a wider voltage and frequency tolerance. The Schneider battery inverter is representative of the battery inverters used at Borrego Springs, but it is not the same model.

Figure 31: Borrego Springs ESIF local CHIL setup



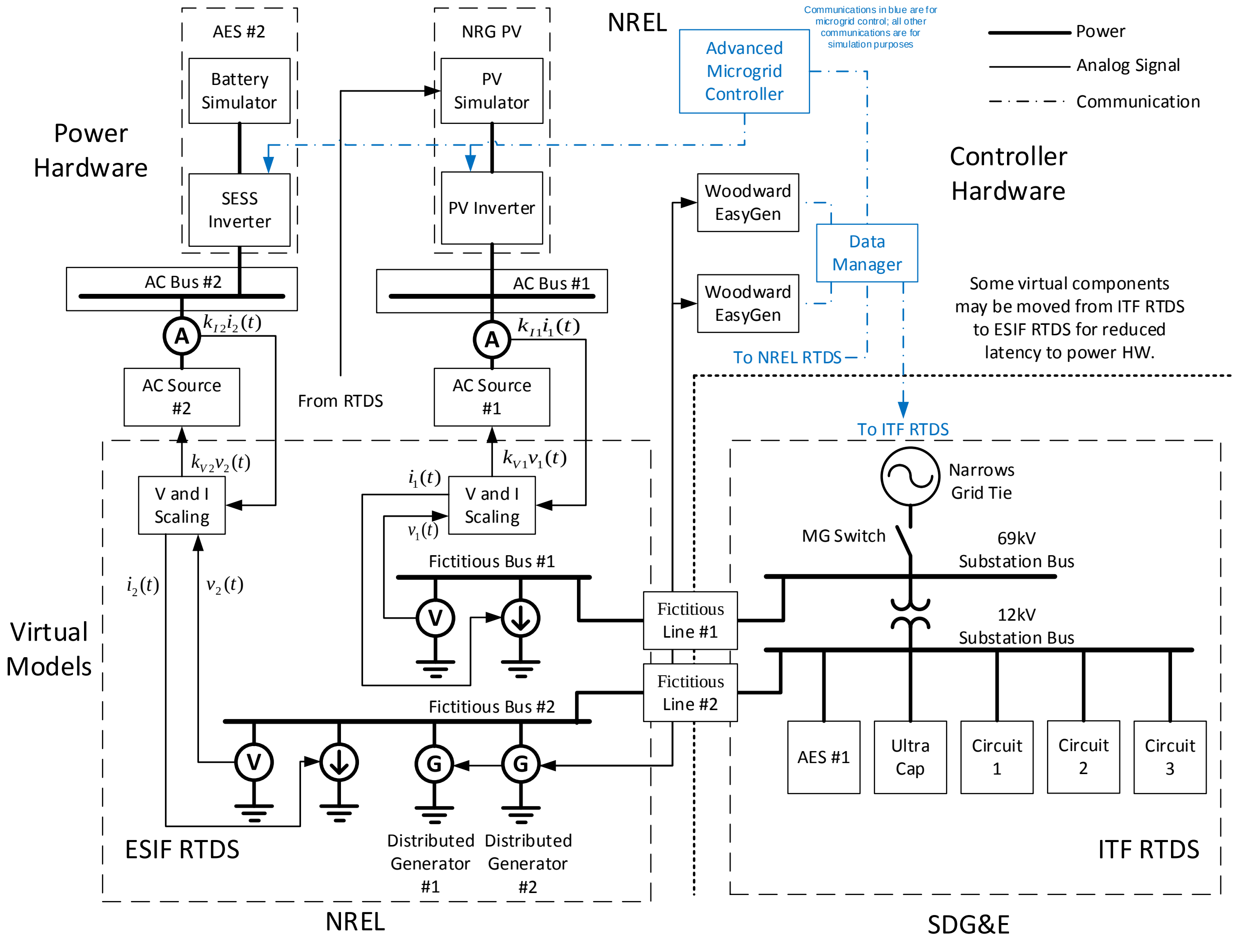
Source: San Diego Gas & Electric Company

Figure 32: Borrego Springs ESIF local CHIL/PHIL setup



Source: San Diego Gas & Electric Company

Figure 33: Borrego Springs ESIF/ITF Remote Setup



Source: San Diego Gas & Electric Company

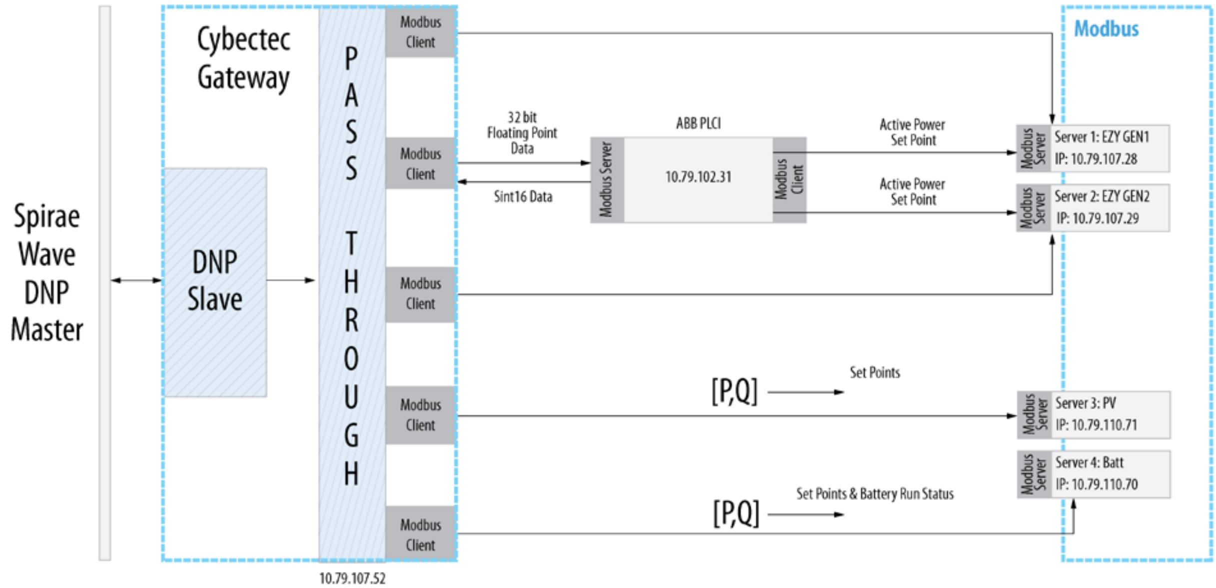
Table 18: Hardware-in-the-Loop Hardware Component Selections

Functional Component	Manufacturer	Part #	Ratings
Controllable AC Sources/Sinks	Ametek	RS540 (x 2)	540 kVA each, bidirectional, 0–600 VAC
Controllable DC Source/Sink	Anderson	AC2660P	660 kW bidirectional, 0–1,000 V DC
BESS Inverter	Schneider	Conext Core XC 540	540 kVA bidirectional, 300 V AC, 440–885 V DC
BESS Transformer	Square D	540 kVA	300 V Wye/480 Delta, 7.4% Impedance
PCC[a] Bus	NREL	REDB (x 2)	0–600 V AC, 0–1,600 A
Controllable DC Source	Magna Power	MT 1500 kW (250 kW x 6)	1,500 kW, 0–1,000 V DC
PV Inverter	SMA	Sunny Central 500CP-US	550 kVA, 270 V AC, 430–820 V DC
PV Inverter Transformer	Eaton	550 kVA	270 Wye/480 Delta, 5.74% Impedance
Simulation Computer	RTDS	Rack system (x 2)	4 Novacor processors and 6 PB5 processors
Distributed Generator Controller	Woodward	Easygen 3000 series	Control distributed generators during grid connected and islanded operation
Data Manager	Eaton Cybectec	SMP Gateway automation platform	Compatible with DNP3, MODBUS, and PMU[b] protocol

Source: San Diego Gas & Electric Company

The AMC platform was used to execute all of the control software necessary to manage the controllable assets within the microgrid. The AMC was coupled with the RTDS that simulated the microgrid's electricity distribution system through a data manager, the Cybectec Gateway, as shown in Figure 34. The RTDS solved the model of the feeder in real time and generated measurement signals as if it were the actual facility electricity distribution system. These measurement signals were received by the AMC, which acted on them and produced control commands for the facility's controllable devices, thus closing the control loop in real time as if it were connected to the real facility. The Cybectec Gateway provided unique Internet Protocol addresses for each controlled asset to the AMC platform, and it translated or concentrated data from Distributed Network Protocol (or DNP3) (used by Spirae's multiple energy resource managers [or ERMs]) to MODBUS or DNP3 (used by DER controllers and the RTDS) as necessary. The data manager acts as a server to the Spirae Wave's DNP3 clients and as a client for the RTDS servers. A software pass through in the data manager pushes data between the energy resource managers in the AMC and the RTDS. Information such as the circuit breaker status, voltage RMS, frequency, real power, and reactive power are sent from RTDS to Wave. Control commands such as open/close breaker, real and reactive power set points were sent to RTDS from Wave through the pass-through software. The data manager also translates control commands for the DERs (PV, battery, and distributed generation resources) modeled in CHIL and PHIL (Figure 34).

Figure 34: Connection of AMC to the RTDS through a data manager



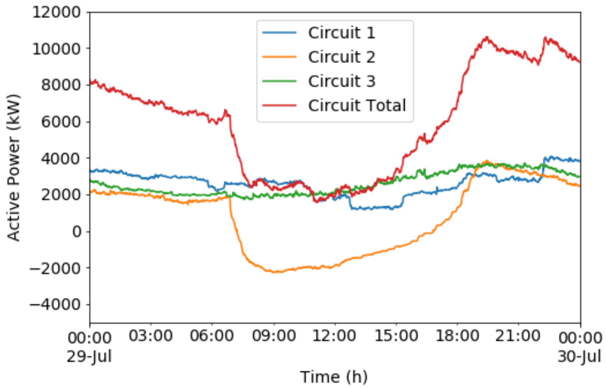
Source: San Diego Gas & Electric Company

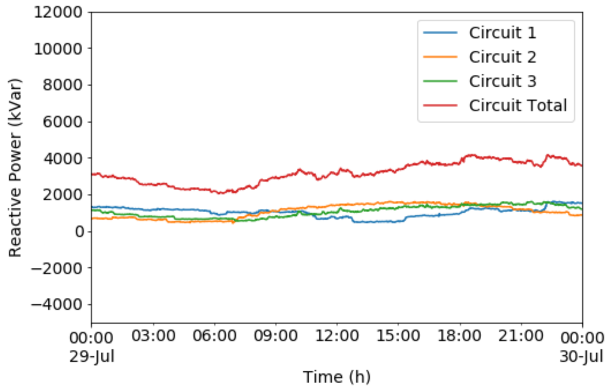
Input Data for Advanced Microgrid Controller Evaluation

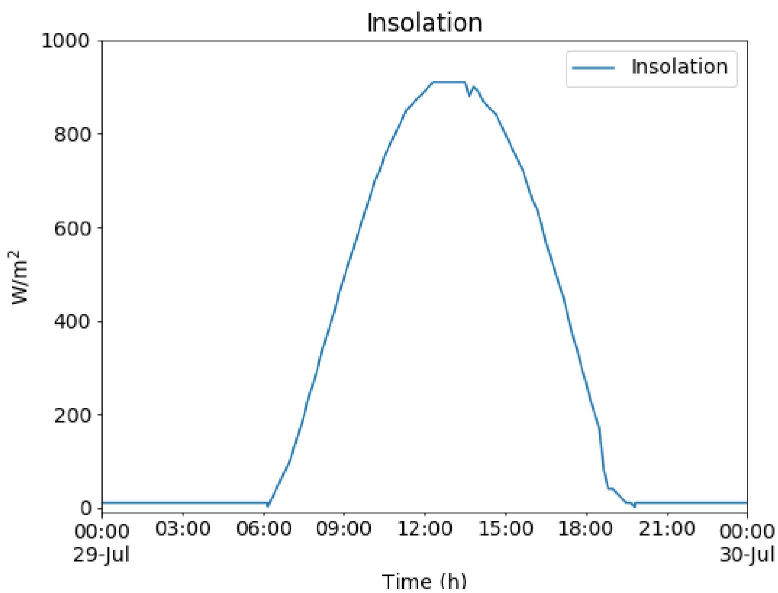
Net load profiles were based on data supplied by SDG&E for all three feeders within the Borrego Springs community for 2014. These net load data include about 3 MW of rooftop solar capacity and a 6.5 MW concentrated solar PV plant located on circuit 2 and this results in negative power flow on circuit 2 during the day. Because only feeder-level data was available, the same load profile is applied to all loads on a specific feeder but scaled according to the static loads that were supplied as part of the SDG&E RSCAD model. NREL selected three days to use for simulations:

1. Heavy load profile with a peak load of 10.5 MW/4.1 MVAr on July 29, 2014, shown in Figure 35.
2. Light load profile with a peak load of 5 MW/1.4 MVAr on January 24, 2014, shown in Figure 36.
3. Significant loss of PV generation due to drop in solar insolation, from 700 W/m2 to 90 W/m2 in 10 minutes (used to evaluate enhanced resiliency) on June 30, 2014, shown in Figure 37.

Figure 35: Load and Solar Insolation Profiles for Heavy Load on July 29, 2014

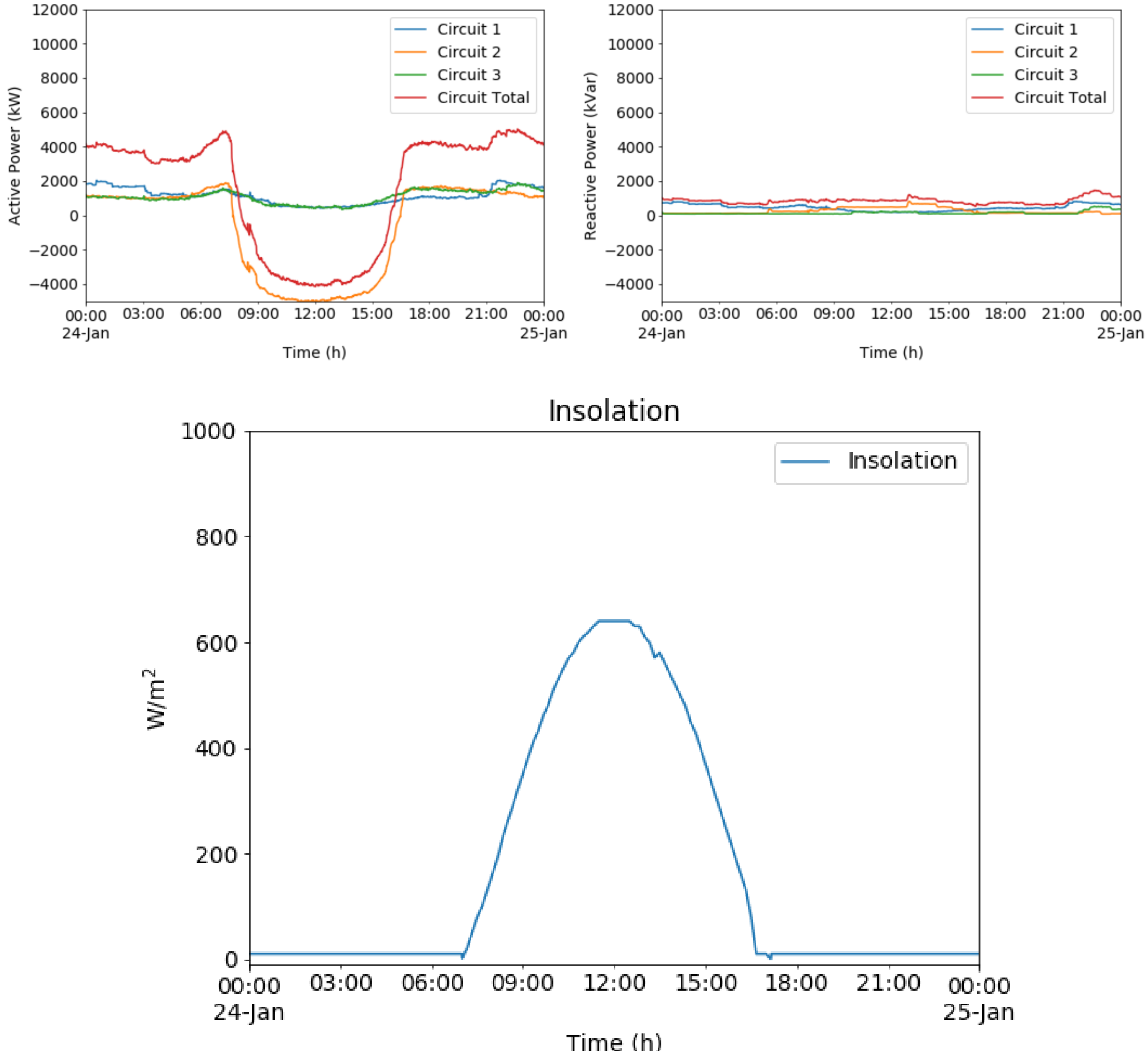






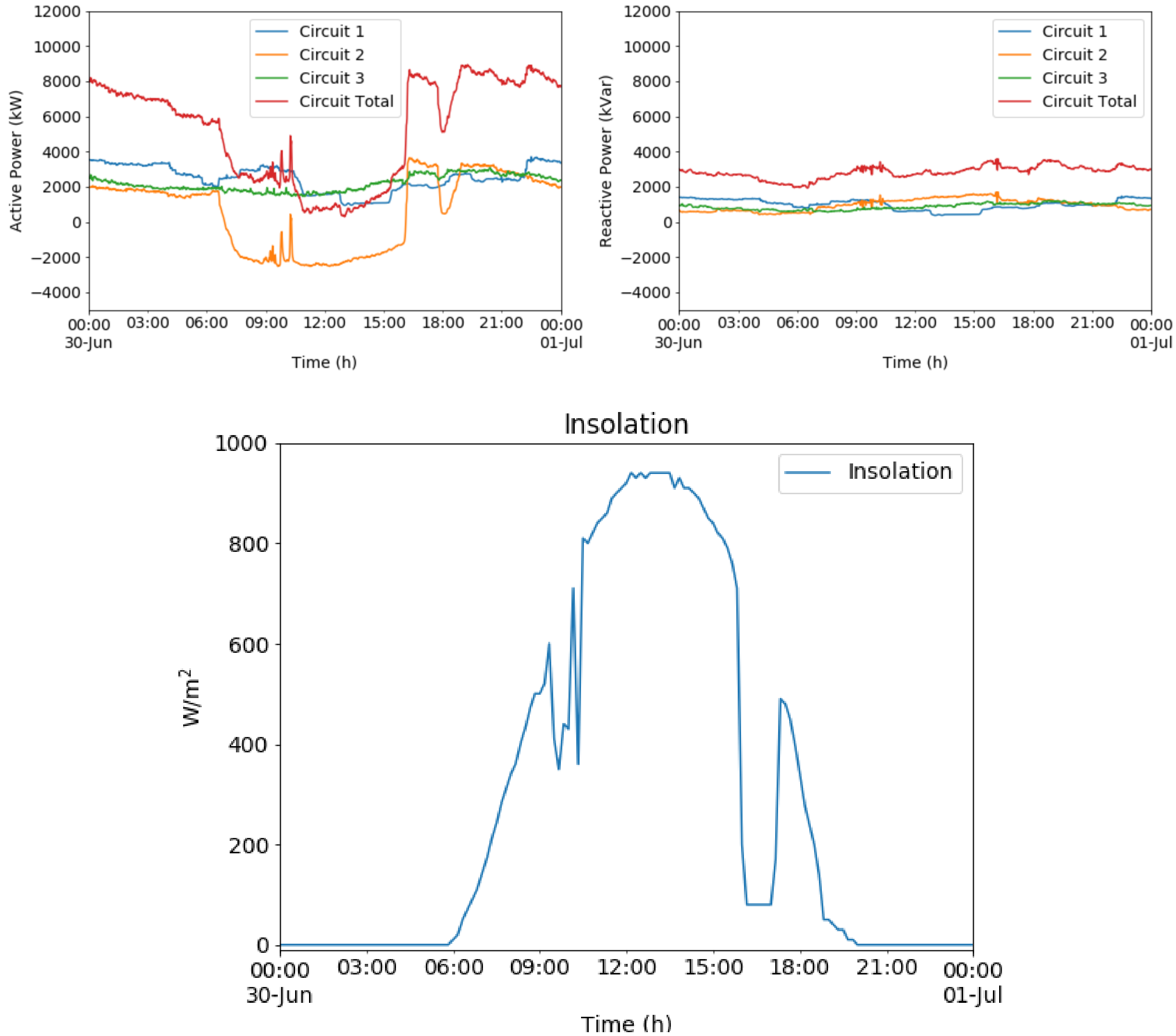
Source: San Diego Gas & Electric Company

Figure 36: Load and Solar Insolation Profiles for Light Load on January 24, 2014



Source: San Diego Gas & Electric Company

Figure 37: Load and Solar Insolation Profiles for Evaluating Enhanced Resiliency on June 30, 2014



Source: San Diego Gas & Electric Company

All load data were provided at 1-minute time steps. For 24-hour dispatch tests, NREL down-sampled the 1-minute data by calculating the average power to arrive at 10-minute data sets.

Insolation data is from the Anza Borrego Desert Research Center database, which provides data on a 10-minute basis. This insolation data was fed to a PV panel model inside the RTDS to model the panels at the NRG PV plant in the Borrego Springs Microgrid.

Collecting Data for Microgrid Controller Evaluation

Table 19 summarizes the data the project team collected to evaluate the microgrid controller's functional requirements. All data were collected from the RTDS using standard measurement blocks provided by RTDS as part of their RSCAD software. The types of data that were collected include voltage, current, power, energy, frequency, and phase angle. The voltage/current waveforms were captured at 1,000 Hz. Other data were captured at a rate of 100 Hz, which refers to the rate at which NREL read the values from the RTDSs. Root mean square (RMS) values were collected using single-phase and three-phase RMS meters that calculate the RMS value over a half cycle. Frequency data were collected from single-phase frequency meters that use a phase-locked loop (PLL) method with the nominal frequency set to 60 Hz. The meters are updated at every time step, but data were collected at a rate of 100 Hz. Phase-angle data were collected from three-phase phase-angle difference meters. Real and reactive power measurements were collected from three-phase power meters. Battery state-of-charge data were collected from a custom model within the RTDS that estimates the state-of-charge based on a charge-counting approach.

Table 19: Measured Quantities

Description of Measured Quantity	Rate	Scenarios			
		A	B	C	D
P&Q[a] on microgrid side of microgrid switch	100 Hz	X	X		X
P&Q for all critical loads	100 Hz	X		X	
P&Q for all DERs [c]	100 Hz	X		X	
State-of-charge of batteries	100 Hz	X		X	
RMS voltage at utility PCC [b]	100 Hz		X		X
Frequency at utility PCC [b]	100 Hz		X		X
Voltage phase angle at utility PCC [b]	100 Hz		X		X
RMS voltage on microgrid side of microgrid switch	100 Hz		X	X	X
Frequency on microgrid side of microgrid switch	100 Hz		X	X	X
Voltage phase angle on microgrid side of microgrid switch	100 Hz		X		X
RMS current on microgrid side of microgrid switch	100 Hz		X		X
Voltage waveform at utility PCC [b]	1,000 Hz		X		X
Voltage waveform on microgrid side of microgrid switch	1,000 Hz		X		X
Current waveform on microgrid side of microgrid switch	1,000 Hz		X		X

Source: San Diego Gas & Electric Company

Achieving Safe, Stable, and Accurate Simulations

The CHIL/PHIL test bed is very complex and challenging to operate due to the integration of multiple pieces of power hardware (two inverters with 500 kVA each combining to reach 1 MVA power hardware capability) and controller hardware (generator controllers, microgrid controller). The two power hardware inverters are connected at different locations in the microgrid, but there is interaction between them due to the high penetration of PV incorporated in the HIL. The dynamics involved in this test bed is complex due to fundamental power-electronic-based power system behavior (such as interactive dynamics between parallel inverters) and also due to PHIL-related dynamics (for example changing grid impedance and voltage at the PCC based on whether the microgrid is grid-connected or islanded). Essentially, the grid impedance observed at these two power hardware devices is variable and thus the stability of the setup is variable and not guaranteed at all operating points. For example, when one power hardware device successfully operates in a closed-loop PHIL simulation, connecting another power hardware device instantaneously changes the impedance of the real-time system model. This may cause significant transients (overshoot or oscillation) or even affect the stability of the whole test bed. Because the impedance of the inverter hardware depends on its output apparent power, the stability margin of operation (PQ operating range) should be defined to ensure safe operation and prevent hardware damage caused by instability. This will be done in future work.

An open loop transfer function was formulated to evaluate the stability using the Nyquist criterion (Ainsworth et al. 2016). However, this does not guarantee a reliable stability analysis for two reasons: 1) the nonlinear characteristic of the power amplifier and the inverter (both are switched mode converters) cannot be completely characterized by a linear approximation and this results in inaccurate transfer function models and thus inaccurate analysis and evaluation, and 2) the integrated PHIL test setup with two inverters is a multi-input, multi-output control system and using a single-input single-output open loop transfer function for stability evaluation may no longer be valid and theoretically sound. Thus, the stability evaluation using the conventional open loop transfer function can only be used as an estimation of system stability behavior and a more thorough stability analysis must be addressed in future work.

Test procedures were developed in addition to improved overvoltage protection and over frequency and under frequency protection for the grid simulators to safely operate the grid simulator and run the experiments. This helped reduce the outage time of grid simulators and resulted in more grid simulator operational time. The test procedures define the sequence of actions to start and shut down the test bed in a safe manner to avoid unwanted transients and instabilities. They are published in IEEE (Wang et al. 2018).

Evaluation of Advanced Research and Development Microgrid Control Functions

Simulation Scenarios for Evaluation of Advanced Research and Development Microgrid Control Functions

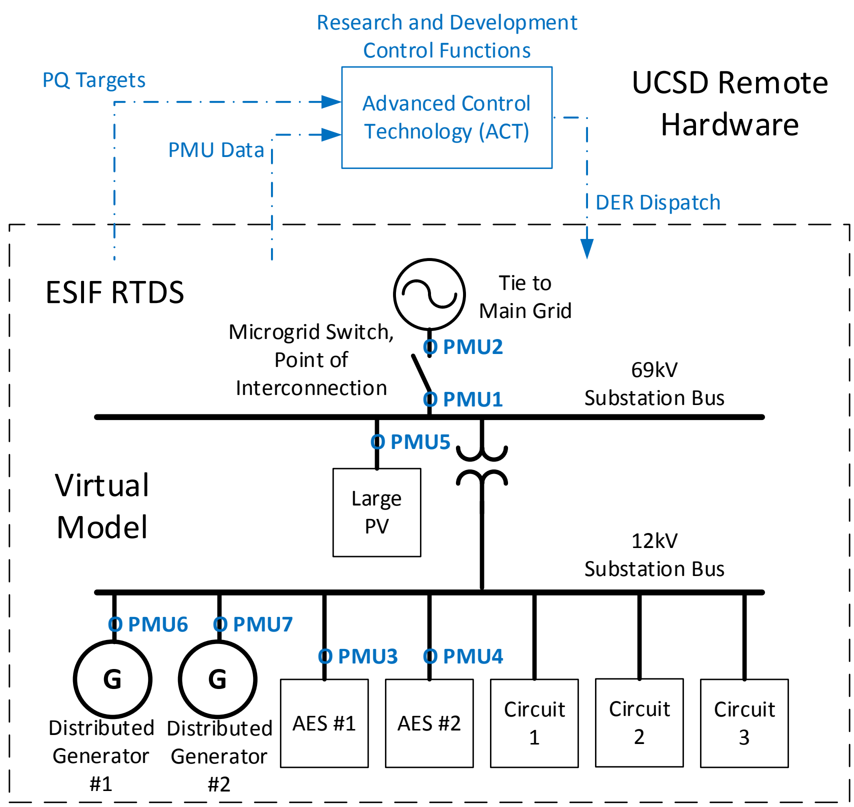
The simulation scenarios for evaluation of the OSISoft/UCSD hardware implementation of advanced R&D microgrid control functions, called ACT, are focused on the real and reactive power tracking and disturbance mitigation at the PCC. Islanding, resynchronization, and islanding under abnormal condition cases were not simulated for evaluating ACT.

Hardware-in-the-Loop Test Setup for Evaluation of Advanced Research and Development Microgrid Control Functions

ACT enables fast precision feedback control of power grid voltage and frequency using phasor measurement unit (PMU) data (also known as a synchrophasor). This approach reduces the variations in voltage and frequency that can negatively affect power quality especially in systems with highly variable renewable energy sources, low inertia, or weak grids. By commanding power dispatch of DERs, the ACT can manage the ramp rate or hold power flow steady/fixed at a desired point, despite high variations in load and generation. The ACT includes data management to handle large volumes of PMU data, configuration tools to generate a model (which can also be imported if the file is already available), and decoupled (voltage, phase) control of "state of the grid" using PMU angle information.

For testing the ACT controller, the test setup shown in Figure 38 was used. The ACT was coupled through a remote connection to an RSCAD model of Borrego Springs, which was run on the local RTDS at the ESIF. The RSCAD model was the same as that used for the evaluation of the Wave microgrid controller. Seven simulated PMUs were added to the RSCAD model to provide data to the ACT at a rate of 10 Hz. The ACT communicated set points to the PV inverter, battery inverter, and distributed generators in the RSCAD model through MODBUS at a rate of 10 Hz.

Figure 38: Borrego Springs Test Setup for Evaluation of Advanced R&D Control Functions



Source: San Diego Gas & Electric Company

Collecting Data for Evaluation of Advanced Research and Development Microgrid Control Functions

In addition to collecting data, the MODBUS control commands sent from the ACT were also stored. Appendix A presents the results of advanced microgrid controller evaluation. Appendix B presents the results of advanced microgrid R&D control functions evaluation.

Operational Testing and Demonstrations

Subsequent to the laboratory testing conducted at NREL, the project team conducted testing and demonstrations of the microgrid operation in two phases; 1) microgrid asset testing with a load bank, and 2) island testing. These tests were sequential to learn from the load bank testing prior to island testing on all the three microgrid circuits with real customers.

Operational Testing with Load Bank

This task addressed the individual testing of assets with the load bank at the microgrid yard. The objective of these tests was to quantify the contributions of individual assets to the microgrid operation. A component of the task was to compare the results from individual asset operation to the baseline to determine relative improvements in load reduction at the microgrid PCC, integration of renewable resources, and to evaluate the improvement in circuit reliability consistent with the objectives of the project. In addition, data collected from the tests was used to validate the operational efficiency of the assets under varying load conditions and to compare actual efficiency to the manufacturer's published performance curves.

The project team undertook preliminary load bank testing with individual resources on the following dates:

- April 11, 12, 13, 14 2017
- April 17, 18, 19, 20, 21 2017
- June 21, 22, 23 2017
- September 21, 22, 25, 26, 2017
- February 27, 28 2018

The two distributed generation resources (GEN 1, GEN2) and one energy storage unit (AES2) were used for these demonstrations along with the load bank. The tests included single distributed generator operation for individual timeslots on the dates mentioned above.

Island Testing

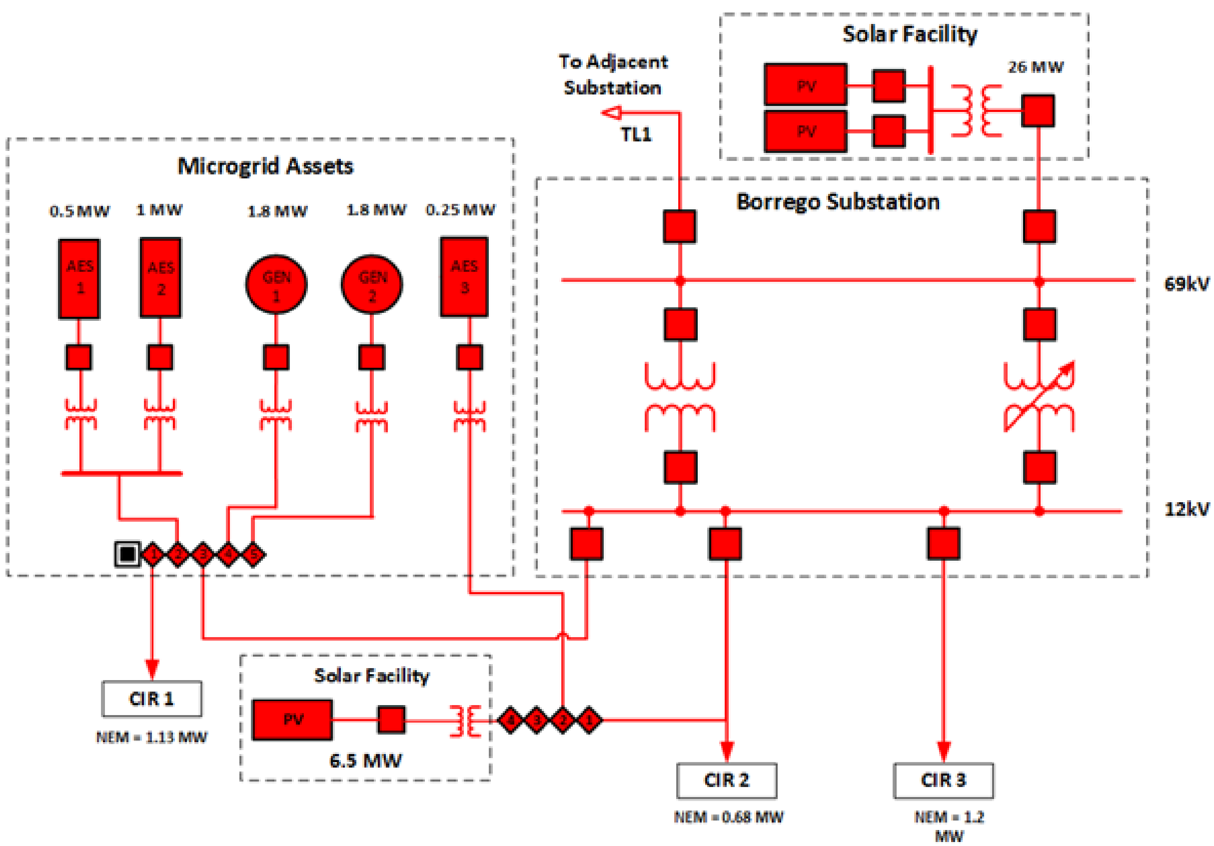
The objective of this task was to build on the individual asset testing undertaken with load banks to integrate various microgrid resources and operate them to achieve optimization of the resources on the microgrid circuits. Island testing was undertaken by using the AMC functionality of the DERMS platform, and integration with Electric Distribution Operations to monitor and control the tests remotely from the SDG&E control center. SDG&E project team members were present onsite for support and local operations as required.

When appropriate, SDG&E reached out to the Borrego Springs customers through advance notification and indicated time slots through which testing was going to be undertaken. The team also made alternative plans for handling contingencies and switching the circuit operation to grid mode, if the need arose. Key activities for undertaking these island tests included:

- Developing operational plans to support the operation plans
- Operation of the microgrid resources in the prescribed modes of operation
- Operation of the microgrid resources using the Advanced Microgrid Controller
- Data collection
- Data Analysis

Figure 39 presents a schematic of the microgrid circuits at Borrego along with the various assets that are deployed for the Borrego Springs Microgrid project. Island testing was undertaken with multiple microgrid resources in operation depending on the test objective.

Figure 39: Microgrid Circuits at Borrego



Source: San Diego Gas & Electric Company

The following island tests were undertaken to demonstrate the objectives of the project:

- Island Test #1 – Island Circuit 1

  - This test included the islanding of Circuit 1 with individual resources to test the functionality and operation using the AMC. This test was undertaken in two phases; a) first phase included day time testing with microgrid resources and a load bank, and b) second phase included day time testing with microgrid resources and load bank on Circuit 1.
- Island Test #2 – Island Circuits 1, 2, & 3 with opening of 12 kV Breaker
  - This test included the islanding of Circuits 1, 2, & 3 with individual resources and customer load by opening the transformer 12 kV breaker for Circuit 1, 2, & 3, and testing the functionality and operation of the microgrid (with real customers) using the AMC. This test was also undertaken in two phases with testing during night time and testing during day time.
- Island Test #3 – Island Borrego Springs with Maximum Renewable Energy Deployed within the microgrid
  - This test included the islanding of all three circuits of Borrego Springs and using the 26 MW PV plant by opening the breaker on the 69 kV side and using the microgrid resources to provide energy to the customers[4]. This test was undertaken during day time to incorporate real life operational scenario of islanding the entire community of Borrego Springs with local renewable microgrid resources and controls through the AMC.

The three island tests with AMC integration were undertaken on the following dates:

- Island #1 Operations
  - April 11, 12, 13, 14 2017
- Island #2 Operations
  - October 4, 2017 (Night time testing)
  - March 6, 2018 (Day time testing)
  - May 15, 2018 (Day time operations)
- Island #3 Operation
  - March 7, 2018
  - Summer/Fall 2018 (Additional island testing will continue after Energy Commission project ends)

When appropriate, SDG&E gave Borrego Springs customers advanced notice of these test dates. The project team also made alternate arrangements to manage contingencies, if the demonstrations did not go as planned.

Chapter 4 describes the island test procedures and outcome from the demonstrations.

[4] Not all 26 MW are used by the microgrid, the load will dictate how much power is needed from the NRG plant.

CHAPTER 4: Island Testing and Demonstrations

The project team planned and carried out the island tests iteratively to support the overall project objectives in support of microgrid operations. Testing and demonstrations were conducted on three separate occasions between April 2017 and March 2018. The demonstration involved operation of the microgrid resources under various scenarios. These demonstrations were planned to test the fundamental operation of the resources in various modes of operation to achieve specific project objectives. This section presents the approach, observations and key findings that illustrate the ability of the microgrid to meet overall projective objective of islanding the entire community of Borrego Springs and an attempt to use renewable local resources to supply 100 percent of the community's load.

Island 1 Test

Objective

The primary objective of island 1 test was to island Circuit 1 with individual resources and a load bank to test the functionality and operation using the AMC. These tests were conducted during day time operations on multiple occasions.

Method

Figure 40 shows the microgrid resources that were used in the island 1 test. Only one of the two distributed power generators (GEN 1 and GEN 2) and one of the energy storage systems (AES 2) were used to carry the islanded Circuit 1. The circuit breakers that are greyed out indicate open circuit on the other two feeders. This island did not affect real customers as the island operation on Circuit 1 was tested with the load bank.

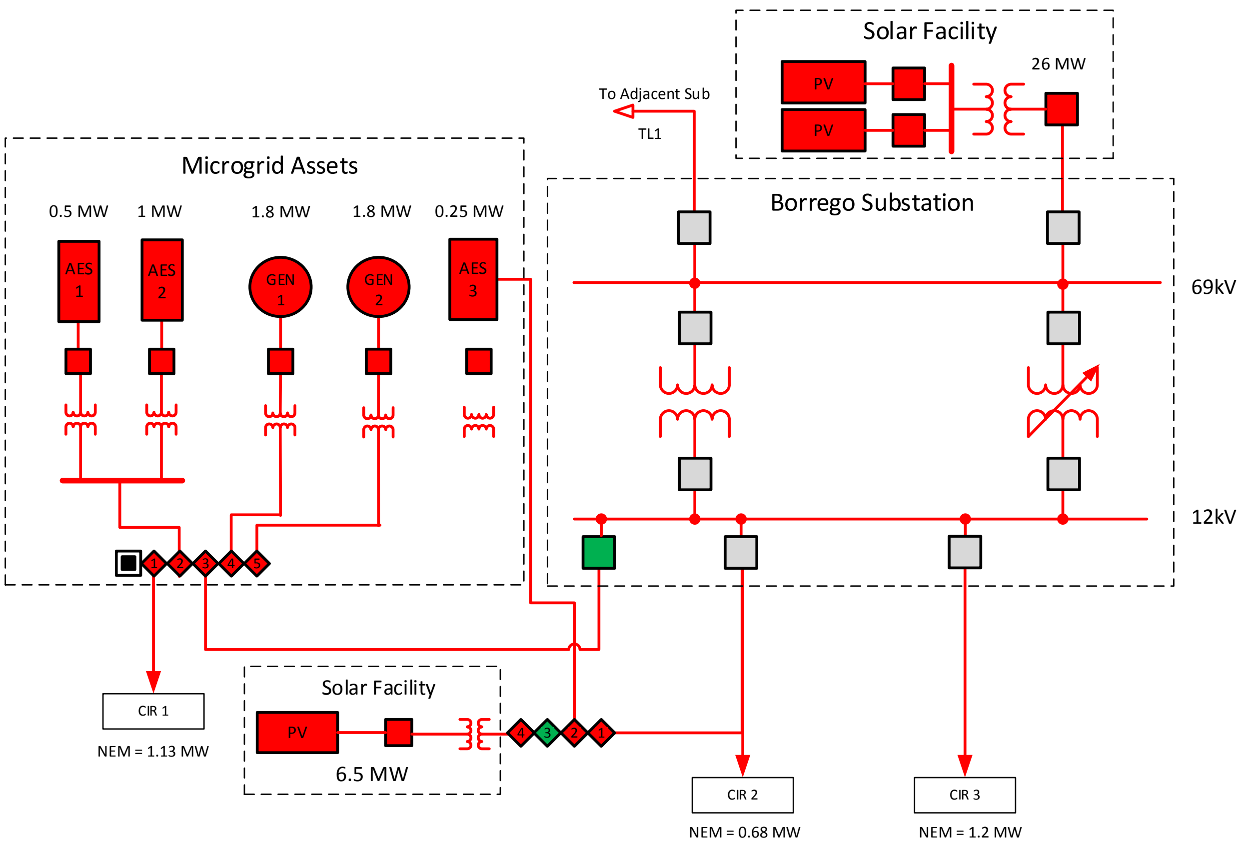
Table 20 describe in detail the operational procedures that were undertaken in support of island test #1.

Observations

Island 1 Test observations using microgrid resources (DG and AES) and load bank was demonstrated successfully by remotely controlling the microgrid resource using the AMC.
Source: San Diego Gas & Electric Company

Figure 41 presents a summary of the island demonstration on February 28, 2018. This island demonstration was run during day time between 8:30 am to 11 am. For this demonstration, DG1, DG2 and the load bank were synchronized to simulate a load of approximately 5,300 kW. All these operations were remotely controlled through the AMC. After the end if Island 1 test at 11 am, the customers on Circuit 1 were cutover and serviced through Circuit 2.

Figure 40: Island 1 Test Demonstration



Source: San Diego Gas & Electric Company

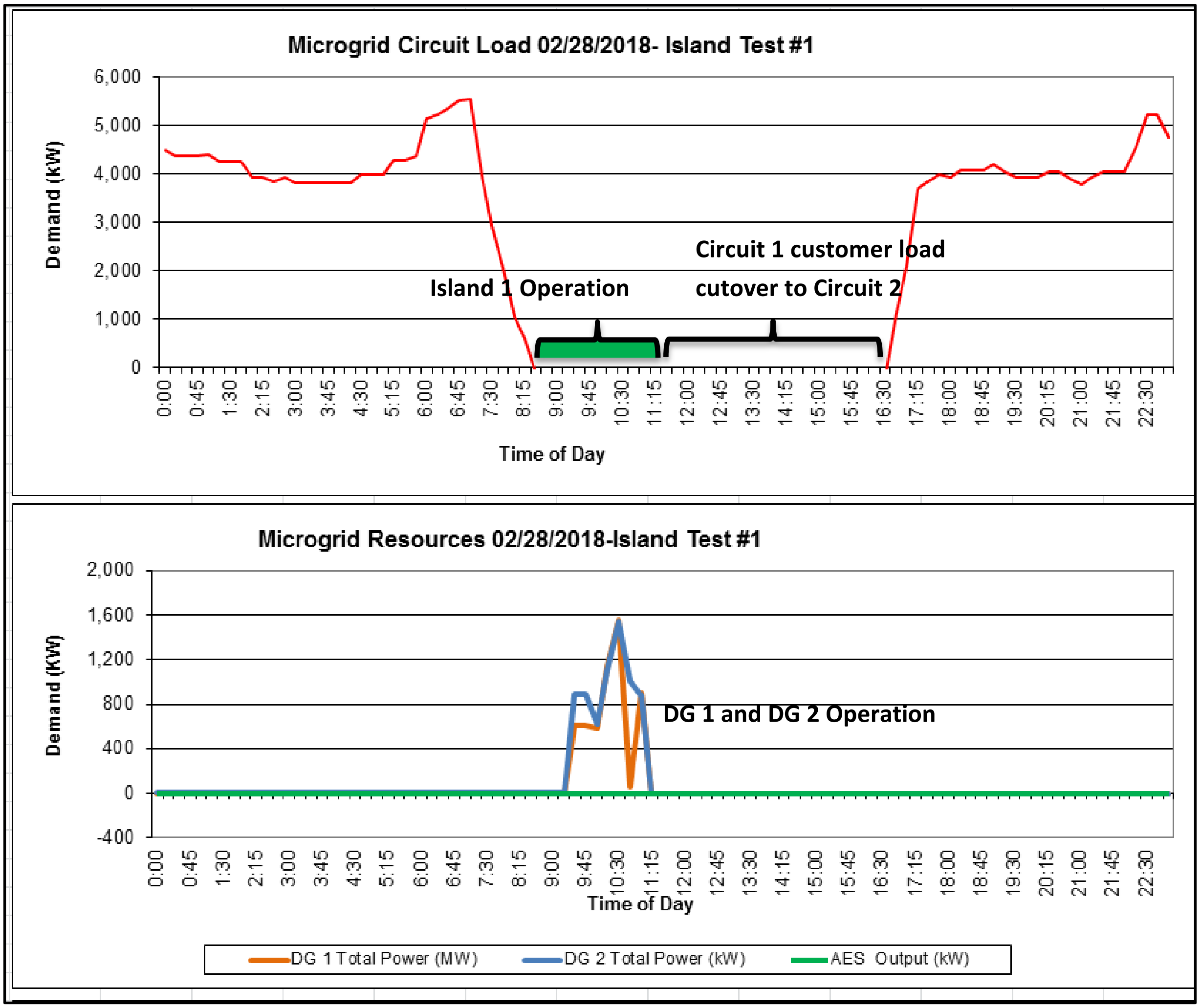
Table 20: Operational Procedures – Island Test 1

Test Step	Brief Description
Update distributed generation resources permission logic	Distributed generation resources logic tested by starting distributed generation resources with no, yes, and remove permissions. Subsequently opened five-way switch to test distributed generation resources go through cool down.
Update relay with permission logic	Relay updated for distributed generation resources to receive correct permission status
Update distributed generation resources mode status feedback	This brings feedback into AMC (part of the DERMS platform)
Update models at SDG&E lab	As a backup, the current field configuration was reflected back at SDG&E lab.
Parallel with Distributed Generation Resources and SES Batteries in Base Load Device Operating Mode	AMC was used to remotely control all DER devices individually in combination at varying set points. Negative testing was undertaken where permissions are not sent to the distributed generation resource to test that the commands are prevented, and the systems respond as expected. Testing was undertaken for a period of time to allow for possible events and system response.
Virtual Island on Circuit 1 Using Distributed Generation Resources	AMC was used to remotely to run the distributed generation resources in parallel with the grid and using import device operating mode to confirm that the microgrid can maintain zero flow at the Circuit 1 breaker for an extended period of time. .
Virtual Island on Circuit 1 SES	AMC was run remotely to run the DER devices in parallel with the grid and using import device operating mode to confirm that the microgrid can maintain zero flow at the Circuit 1 breaker for an extended period of time. SES batteries were used to vary the load on Circuit 1 in a manner that is consistent with the load change expected in a planned or unplanned outage on Circuit 1.
Virtual Island on Circuit 1 Using Generators and SES	AMC was used remotely to establish a virtual island with zero flow at the Circuit 1 breaker.
Switching Steps Update	Distribution operation procedures were updated with the following: - Normal → Parallel - Parallel → Circuit 1 Island - Circuit 1 Island → Parallel - Parallel → Normal
Initial Island Entry Check #1	Is AMC using its import mode to zero flow at the PCC breaker
Initial Island Entry Check #2	Once island permission was given generators move into interchange mode where final zero flow happens.

Test Step	Brief Description
Initial Island Entry Check #3	Relay check to ensure zero flow through the PCC breaker before opening to create the island.
Island Circuit 1 Using Single Generator and load bank testing from Parallel	AMC was used to remotely control the DER devices, test that commands from AMC to the Generator were correctly processed and that coordination with switch planning and Island Circuit 1 distribution operations procedure (DOP) were effective. After confirming that the protection systems interact with the devices, the system continued running in Island mode for a significant duration to allow for operational and distribution events that could disrupt the island. All tests include following the DOP and using a standard switch plan as the basis for the test. Return to grid connected with no outage (re-sync to grid).
Island Circuit 1 Using Two Generators from Parallel	AMC was used to remotely control the DER devices, test that commands from AMC to the two Generators were correctly processed and that coordination with switch planning and Island Circuit 1 distribution operations procedure (DOP) were effective. After confirming that the protection systems interact with the devices, the system continued running in Island mode for a significant duration to allow for operational and distribution events that could disrupt the island. All tests include following the DOP and using a standard switch plan as the basis for the test. Return to grid connected with no outage (re-sync to grid).
Island Circuit 1 Using all DER Devices from Parallel	Similar steps were followed to use all DER devices and using AMC to maintain optimal power factor for the generators.
Black-start Island Circuit 1	Circuit 1 was black-started using: - SES - Generators - All available DER devices

Source: San Diego Gas & Electric Company

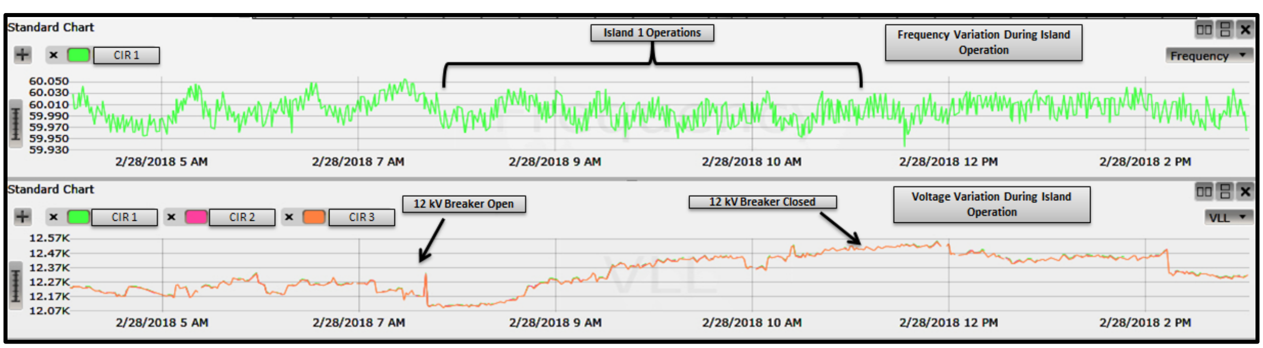
Figure 41: Island 1 Test on February 28, 2018



Source: San Diego Gas & Electric Company

The microgrid resources (DG1 and DG2) in this case were able to maintain the voltage and frequency within the acceptable limits. Figure 42

Figure 42: Frequency and Voltage Observation During Island 1 Test #1



Source: San Diego Gas & Electric Company

Island 2 Test

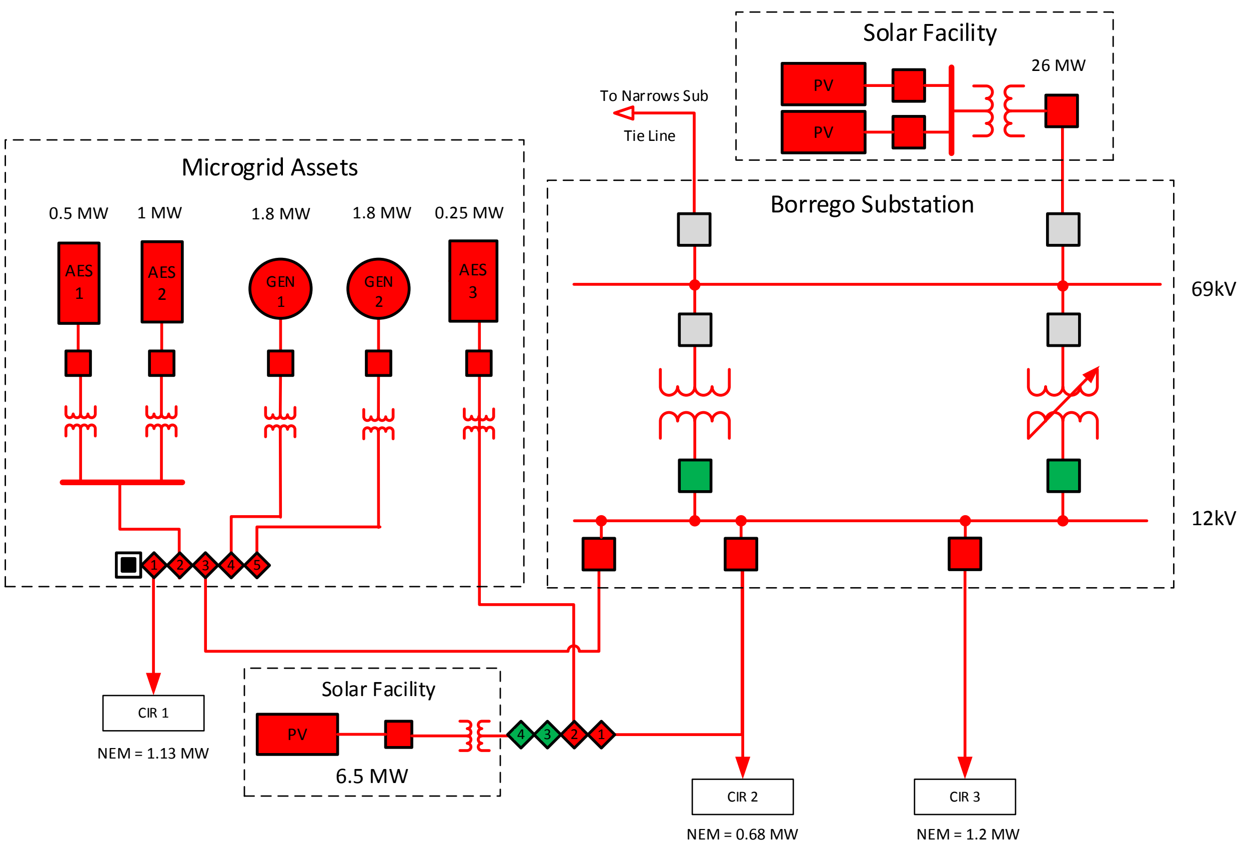
Objective

The primary objective of island 2 test was to island all three circuits with microgrid resources and real customer load to test the functionality and operation using the AMC. These tests were carried out during night time and day time operations on three separate occasions.

Method

Figure 43 shows the microgrid resources that were used in island 2 test. An island situation was created by opening the breaker on one of the 12 kV transformer banks. Subsequently, the control and automation at the substation opened the second 12 kV transformer bank, thereby islanding all three circuits. This is shown by the two greened out breakers between the 12 kV bus and the two transformers. The two distributed generation resources (GEN 1 and GEN 2) and one of the energy storage systems (AES 2) were used to carry all three islanded circuits. The circuit breakers that are greyed out indicate open or closed for testing the two feeders. This island test included real customer load being provided by the local microgrid resources.

Figure 43: Island 2 Test Demonstration



Source: San Diego Gas & Electric Company

Table 21 describes the operational procedures undertaken in support of island test #2:

Table 21: Operational Procedures - Island Test 2

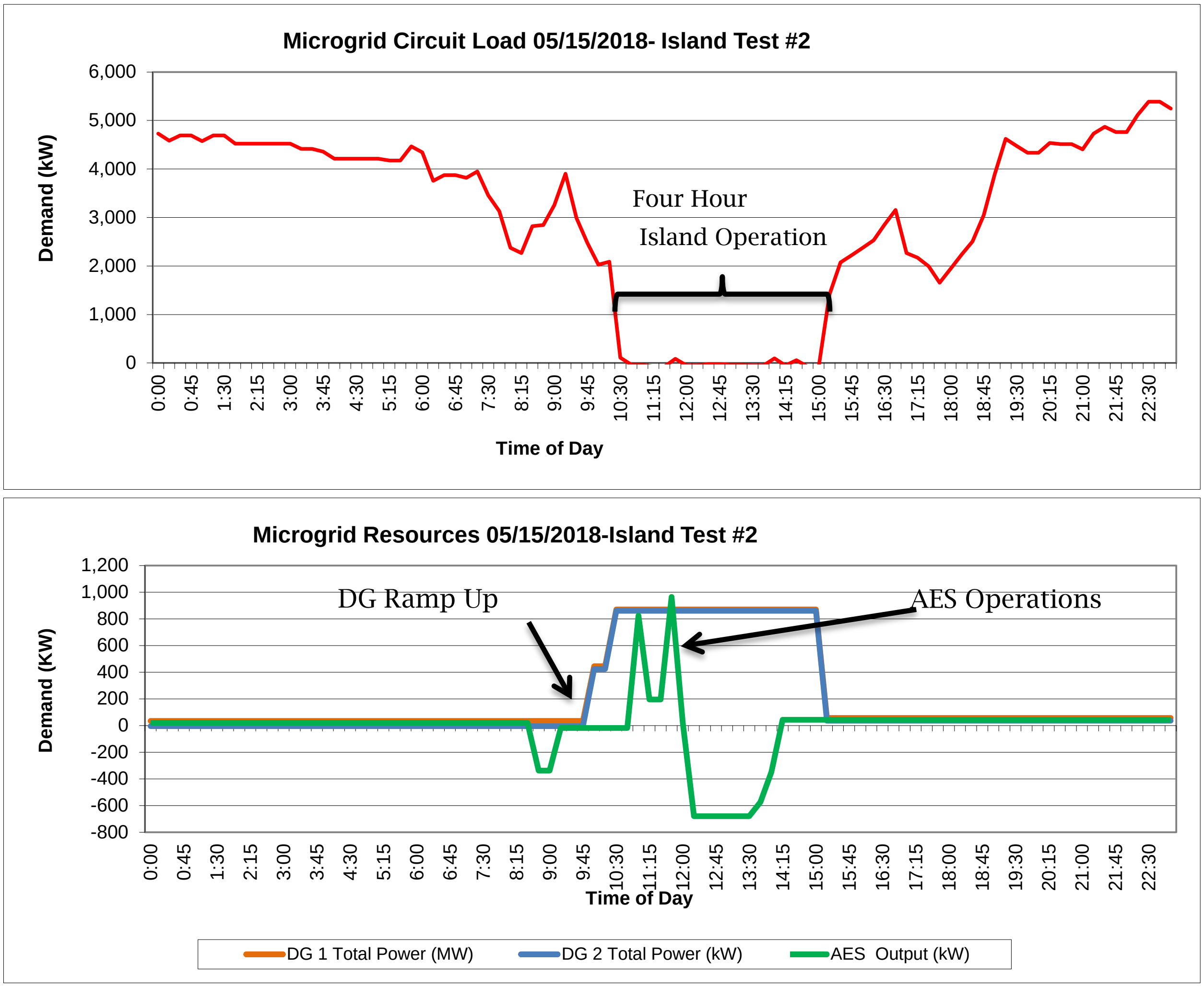
Test Step	Brief Description
Update distributed generation resources permission logic	Distributed generation resources logic tested by starting distributed generation resources with no, yes, and remove permissions. Subsequently opened five-way switch to test distributed generation resources go through cool down.
Update relay with permission logic	Relay updated for distributed generation resources to receive correct permission status
Update distributed generation resources mode status feedback	This brings feedback into AMC (part of the DERMS platform)
Switching Steps Update	Distribution Operation Procedures were updated with the following: - Microgrid non-operational to microgrid operational parallel - Microgrid operational parallel to Circuit 2 Island - Back to Operational parallel - Back to Non operational
Island #2 Entry Check	AMC updated to include Island 2 control group. Automated permissions completed for 12 kV bus. Update models at SDG&E Integrated Test Facility to validate the current field configuration. Is AMC using its import mode to zero flow at the PCC breaker. Once island permission was given generators move into interchange mode where final zero flow happens. Relay check to ensure zero flow through the PCC breaker before opening to create the island.
Virtual Island 12 kV Bus Using distributed generation resources (and AES)	This virtual island creation is similar to Island #1 test, except for the difference in signal source and management of permissive to support Island 12 kV Bus. Depending on the actual load, the AES device was added in base device operating mode to supplement the 3.6 MW available from the two distributed generation resources. When the AES device was involved in the Island, this test also evaluated the ability of the AMC to provide VAr support to maintain optimal generator power factor.
Island Circuit 1, 2 and 3 using the distributed generation resources and AES	This step builds on the virtual island step to island all the three circuits and have the microgrid resources carry the entire load on the circuits. The signal source and management of permission to support this island test come from the AMC. The AES device was added in the base device operating mode to supplement the 3.6 MW available from the two distributed generation resources. In the event that the actual load is greater than the capacity of the devices the import set point was varied to simulate dropping load. After confirming that the protection systems interact with the devices and AMC as expected, the system continued running in Island mode for a significant duration to allow for operational and distribution events that could disrupt the island. All tests include following the DOP and using a standard switch plan as the basis for the test. Return to grid connected with no outage (re-sync to grid).

Source: San Diego Gas & Electric Company

Observations

Island 2 Test observations using microgrid resources (DG and AES) was demonstrated successfully by remotely controlling the microgrid resource using the AMC. Figure 44 presents a summary of the island demonstration on May 15, 2018. This island demonstration was run during day time between 10:30 am to 3:15 pm. For this demonstration, DG1 and DG2 were synchronized with the microgrid circuits with a load of approximately 3,000 kW. The AES units were operated initially in charging mode for about one hour between 11:00am to 12:00pm. Later, the AES units operated in discharging mode for about two hours between 12:00pm to 2 pm, followed again by charging the AES units between 2 pm to 3 pm. All these operations were remotely controlled through the AMC.

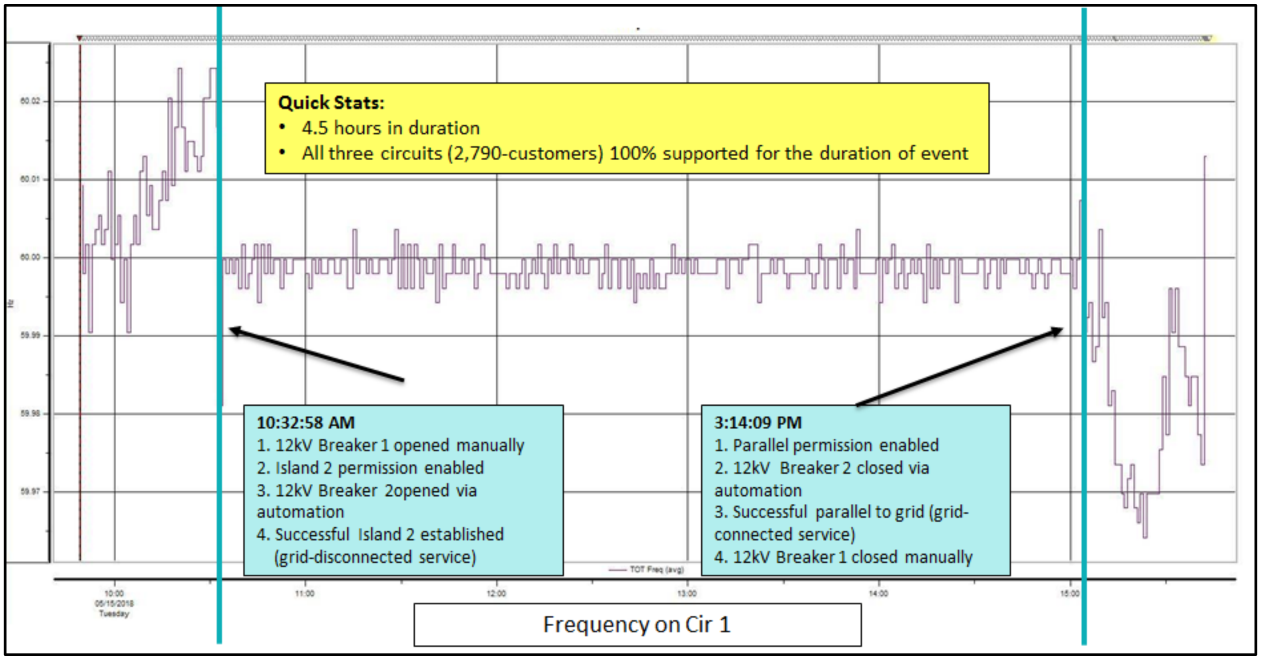
Figure 44: Island 2 Test on May 15, 2018



Source: San Diego Gas & Electric Company

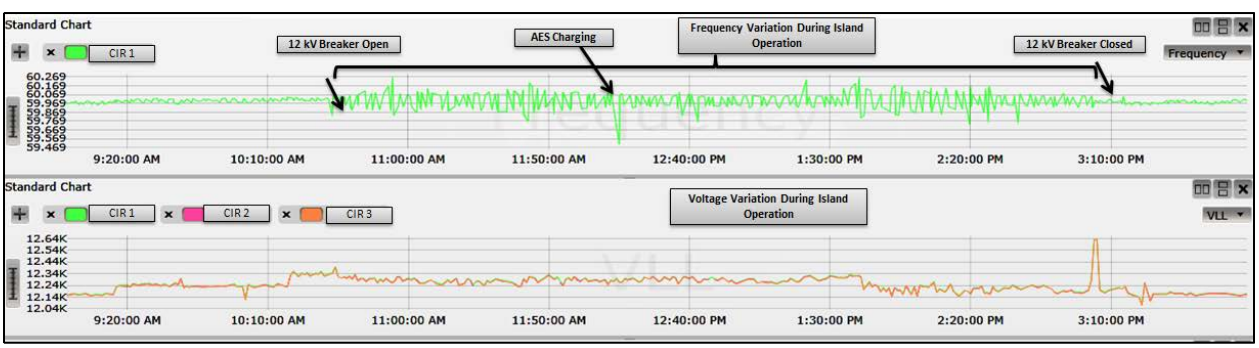
The island test #2 was undertaken on May 15, 2018 with a relatively high temperature of ~93 degrees Fahrenheit. The Borrego community load was forecasted at ~ 3.2 MW. During the island demonstration between 10:30 am to 3 pm, all three circuits (2,790 customers) were 100 percent supported for the duration of the event, with no outage observed on the customer side. The transition of the resources into island mode and back in grid-parallel mode was seamless, with the overall system seamlessly transition to the electric grid at ~3:14 pm. Figure 45 and Figure 46 outline the frequency observed at Circuit 1 breaker and the voltage observed at Circuit 1, Circuit 2 and Circuit 3 during island operation. The step change in frequency and voltage during island formation is noteworthy and can be a challenge to manage.

Figure 45: Frequency Observation at Circuit 1 Breaker During Island Test #2



Source: San Diego Gas & Electric Company

Figure 46: Frequency and Voltage Observation During Island Test #2



Source: San Diego Gas & Electric Company

Island 3 Test

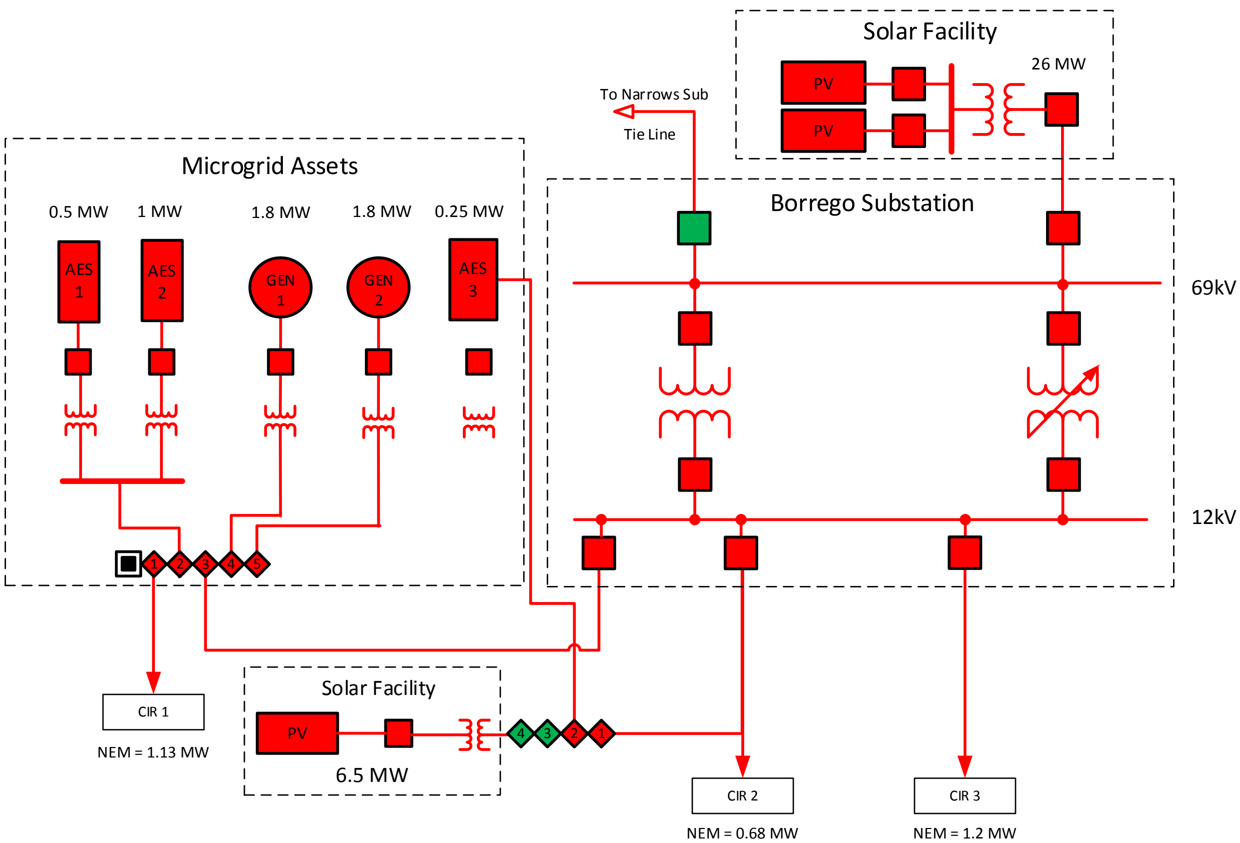
Objective

The primary objective of island 3 test was to island all three circuits with microgrid resources (including the large 3rd party solar facility on the 69 kV) and real customer load to test the functionality and operation using the AMC. These tests were carried out during day time once during the project performance period.

Method

Figure 47 shows the microgrid resources that were used in the island 3 test. An island situation was created by opening the breaker on the tie line to the 69 kV breaker; as shown by the greened out breaker in the diagram below. The two distributed generation resources (GEN 1 and GEN 2), the 26 MW PV facility, and the energy storage system (AES 2) were used to carry the three circuits during island testing. This test included actual customer load and customer-owned rooftop PV.

Figure 47: Island 3 Test Demonstration



Source: San Diego Gas & Electric Company

Table 22 describes the operational procedures undertaken in support of island 3 test.

Table 22: Operational Procedures - Island Test 3

Test Step	Brief Description
Update distributed generation resources permission logic	Distributed generation resources logic tested by starting the distributed generation resources with no, yes, and remove permissions. Subsequently, opened five-way switch to test the distributed generation resources go through cool down.
Update relay with permission logic	Relay updated for distributed generation resources to receive correct permission status
Update generator mode status feedback	This brings feedback into AMC (part of the DERMS platform)
Switching Steps Update	Distribution Operation Procedures were updated with the following: - Microgrid non-operational to microgrid operational parallel - Microgrid operational parallel to Circuit 3 Island - Back to Operational parallel - Back to Non-operational
Island 3 Entry Check	AMC updated to include Island 3 control group. Automated permissions completed for 69 kV bus. Update models at SDG&E Integrated Test Facility, to validate the current field configuration.
Virtual Island 69 kV Bus Using Generators (and AES)	This virtual island creation is similar to Island #1 test, except for the difference in signal source and management of permissive to support Island 12 kV Bus. Depending on the actual load, the AES device was added in base device operating mode to supplement the 3.6 MW available from the two distributed generation resources. When the AES device was involved in the Island, this test also evaluated the ability of the AMC to provide VAr support to maintain optimal distributed generation resources power factor.
Virtual Island 69 kV Bus Using Distributed generation resources, AES, and 3rd Party Solar Facility	This test is equivalent to island 1 test and includes integrating 3rd Party PV interfaces, controls and generation to achieve “virtual island” of 69 kV bus (zero flow from transmission).
Island Circuit 1, 2 and 3 using the 3rd Party Solar Facility, Distributed generation resources and AES	This step builds on the virtual island step to island all the three circuits and have the microgrid resources (including the 26 MW PV Facility on the 69 kV) carry the entire load on the circuits. The signal source and management of permission to support this island test come from the AMC. The AES device was added in the base device operating mode to supplement the 3.6 MW available from the two distributed generation resources. In the event that the actual load is greater than the capacity of the devices the import set point was varied to simulate dropping load. After confirming that the protection systems interact with the devices and AMC as expected, the system continued running in Island mode for a significant duration to allow for operational and distribution events that could disrupt the island. All tests include following the DOP and using a standard switch plan as the basis for the test. Return to grid connected with no outage (re-sync to grid).

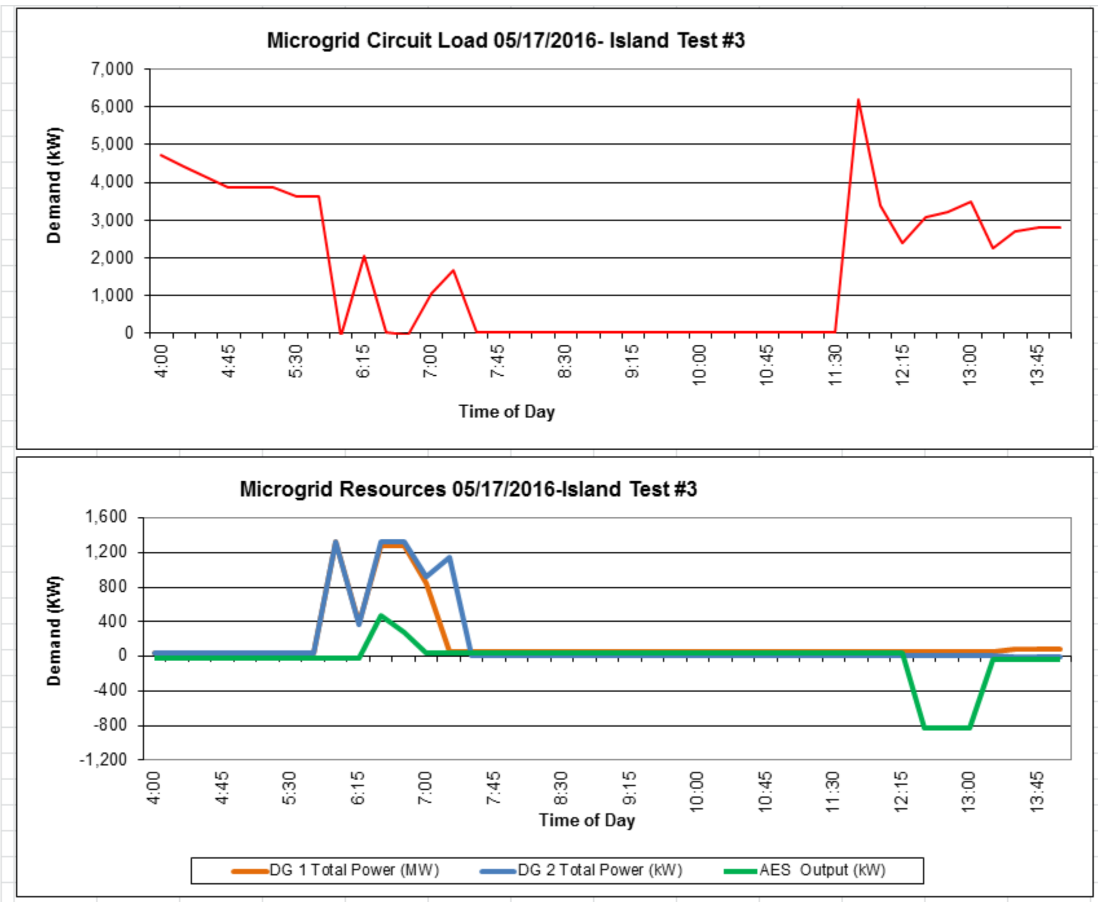
Source: San Diego Gas & Electric Company

Observations

Island 3 testing occurred on May 17, 2016 and March 7, 2018. For the test on May 17, 2016, Island 3 test was undertaken as a planned outage with several poles on the 69 kV transmission line scheduled for replacement. The objective of this test was to use the microgrid resources (distributed generation and large 3rd party solar) to island the entire community of Borrego Springs. Around 5:30 am the team began executing the switching plan by firing up the resources. Once the island permission was granted the 69 kV tie line was opened and the microgrid started operating in island mode at 6:16am. However, the third-party solar system dropped due to frequency and voltage excursion. The microgrid operated in island mode for the next hour until both the distributed generation units were taken offline.

The test was partially successful as the microgrid operated in island mode with distributed generation resources even after the third-party solar system dropped off. The microgrid uptime for this test was 61 minutes. After 61 minutes customers were notified of outage durations which lasted for about 4.5 hours. A logic test was conducted at 11 am to determine return to parallel operations, followed by return to parallel at 11:40 am with full service restored to customers. Figure 48 presents a summary of the island demonstration on May 17, 2016.

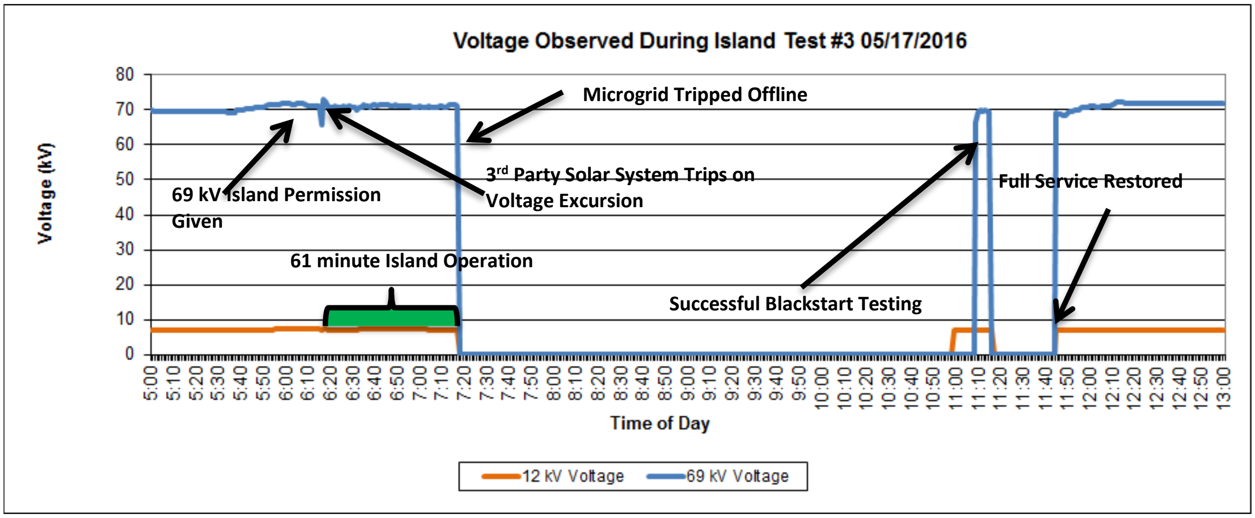
Figure 48: Island 3 Test on May 17, 2016



Source: San Diego Gas & Electric Company

Figure 49 shows the voltage observed on the 69 kV and 12 kV during Island 3 operations.

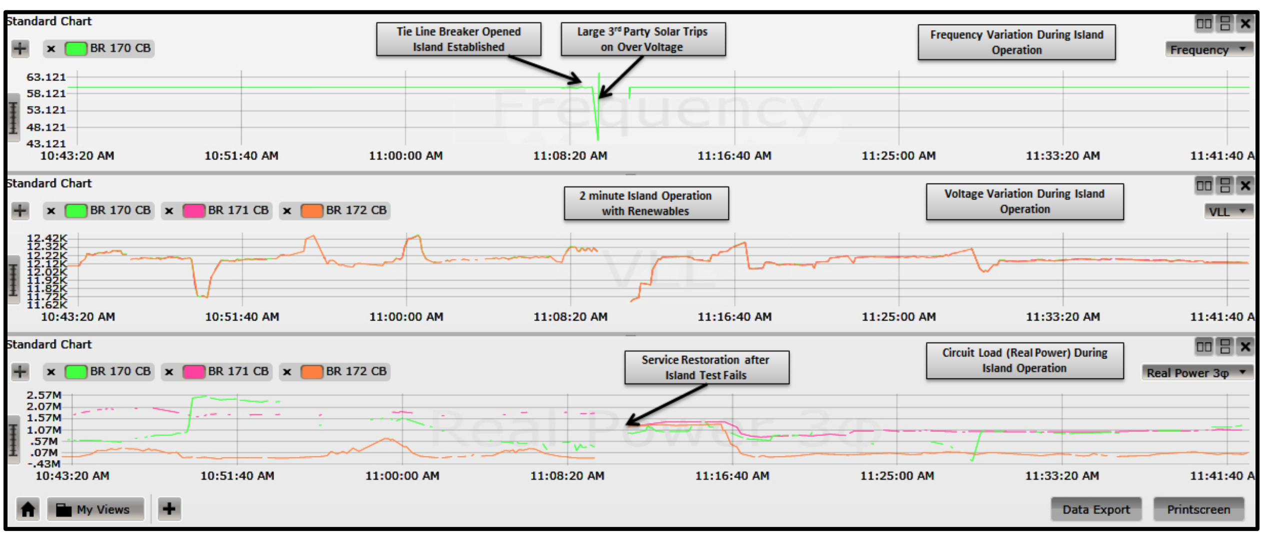
Figure 49: 69 kV and 12 kV Voltage During Island 3 Test on May 17, 2016



Source: San Diego Gas & Electric Company

Island 3 test on March 7, 2018 was undertaken with communication interface between the AMC and the large 3rd party solar facility. The test was deemed unsuccessful after the third-party solar system tripped on over voltage conditions. The microgrid ran in Island 3 scenario for two minutes between 11:08am to 11:10am. Service was restored subsequently to all customers. Figure 50 outlines the frequency, voltage and circuit load observed during island 3 testing.

Figure 50: Frequency, Voltage and Circuit Load Observation during Island Test #3 on March 7, 2018



Source: San Diego Gas & Electric Company

CHAPTER 5:
Lessons Learned and Recommendations

Lessons Learned

The PV-based microgrid project was a challenging effort due to the complexity of the integration of high PV penetration systems, both at the 12 kV distribution level, and the 69 kV sub-transmission level. An increasing number of PV systems are being deployed in the SDG&E service territory, which have the potential of impacting electric transmission and distribution operations, and, in turn, the customers. The project team with multiple stakeholders; both internally and externally identified these complexities through a rigorous process of requirements data gathering and use-case definitions.

SDG&E's Electric Distribution Operations (EDO) department manages the distribution network; but EDO did not have significant experience managing multiple DERs at the distribution level. To improve this situation, one of the core objectives of this project was the development of an AMC that would allow EDO to operate these DERs in an automated manner. The project team understood the challenge and developed an approach that allowed EDO, over time, to take ownership of the operation of the Borrego Springs Microgrid.

Voltage and frequency stability is one of the primary responsibilities to ensure safe and reliable operation of DERs within a microgrid. The project team undertook preliminary individual asset tests to understand how each asset responds to changes in load, thereby documenting their responses to change in voltage and frequency. Testing performed at the SDG&E Integrated Test Facility and NREL laboratory was invaluable in understanding the AMC functional requirements.

Protection and resynchronization capabilities that are required to meet the functional requirements were not implemented in the AMC test platform at the lab. Instead, the AMC is designed to coordinate with constituent components of the microgrid to achieve the required functionality. For example, the functional requirement for reconnection requires that the PCC circuit breaker be closed only when amplitude, frequency, and phase angle differences between the microgrid voltage and area electric power system voltage are small enough. In this case, the AMC relies on the synchronization logic implemented in the synchronization relay of the PCC circuit breaker, and the AMC is not actively involved with synchronization after a command is issued to the PCC circuit breaker to initiate synchronization.

It is possible to include active resynchronization capability in the AMC. This requires the controller to adjust the voltage and frequency set points of the asset acting as voltage and frequency master to reduce the magnitude, frequency, and phase angle errors. However, it is typical for microgrid controllers to rely on a constituent component to perform this function. Therefore, for future microgrid controller evaluations, it is recommended that this task should be performed considering the standard capabilities of constituent components. This approach was taken in the draft version of the IEEE P2030.8 standard (IEEE 2018), released in March 2018.

Frequency measurements must be accurate because frequency is an important indicator of microgrid stability, especially in a low-inertia environment, such as the Borrego Springs Microgrid, when it is operating with a high level of renewable generation. Therefore, SDG&E and NREL worked with researchers from the National Institute of Standards and Technology (NIST) to identify potential improvements in frequency measurement, both in RTDS software and in the hardware for grid simulator protection. Some anonymized data collected during testing will be provided to NIST for analysis. NREL and NIST will publish the results in a peer reviewed conference or journal to disseminate the findings.

Based on the amount of load that the microgrid had to service, the availability of two distributed generation resources provided increased stability when both were online at all times during microgrid operations. This was particularly important to EDO to ensure that no customer outage was observed if some of the tests did not perform as planned. Even though extensive testing of the distributed generation resources controller was performed in the laboratory, not all field operations were able to be simulated. The project team recommends that when practical, it is essential that all possible tests be conducted in the test facility to simulate every possible issue found in field operations.

The RSCAD model for Borrego Springs did not contain capacitor controller logic. This made the 24-hour simulations performed (at the lab) for evaluation of the AMC's dispatch functionality cumbersome. Capacitor control logic was added, but the team was unable to obtain data on the controls used in the field and implemented typical controller logic with typical settings. These controls, however, did not interact well with the voltage regulator controls in the RSCAD file, and it was necessary to fix the voltage regulator settings for the simulations to maintain voltage regulation. For this reason, the project team recommends any other microgrid research should include a RSCAD model for such simulations.

During testing of the ACT control functions, incompatibility with control settings for the capacitor banks and voltage regulator controller were observed. It is believed that the best approach to address this dilemma would be to add voltage regulator and capacitor controller hardware to the Hardware-in-the-Loop (HIL) simulation setup with the same settings programmed as those used in the field. Performance could also be improved by replicating the controls and control settings from the field in the simulation. Furthermore, regulation of reactive power flow across the PCC could be improved if the voltage regulator and capacitor controllers are coordinated with the microgrid controller.

AMC functionality is still evolving, but having a controller that can manage multiple DERs in a way that extend the life of operations is important for successful operations. A significant effort was placed on the development of an AMC for this project. The challenge for the AMC was that there was not an existing product in the market that could easily be acquired and modified to meet the needs of the project. SDG&E decided to work with Spirae to provide the AMC functionality as part of the overall DERMS platform for SDG&E. The AMC managed the microgrid tests and demonstrations by providing a method to easily operate the systems from a single screen, schedule equipment, monitor operations, and collect data. The AMC was successfully used to support the demonstrations, including islanding operations, but is not a standalone and fully-automated control system. SDG&E has plans to integrate the DERMS AMC functionality with SDG&E's Distribution Management System (DMS).

Energy storage deployments are increasing exponentially, as this technology has demonstrated the potential to effectively incorporate renewables into utility distribution operations. The integration of energy storage in the microgrid through the AMC is crucial for successful operations in a highly renewable and variably loaded microgrid. Challenges remain with the characterization and selection of battery chemistry, especially given the harsh weather challenges that a desert location imposes on the battery compartment. Cooling of the storage containers and the protection control systems for the battery systems is required to maintain appropriate operating temperatures in the storage system enclosures. It is important to note that the cooling of the storage enclosures may potentially decrease the efficiency of the units; as some battery capacity may be diverted from the microgrid towards powering the cooling component of the storage system enclosures during islanding.

The integration of DER devices along with the traditional devices of the power system such as voltage regulators and capacitors is important for remote control of feeder voltage regulation. Since the DMS, SCADA, and the protection systems were designed for a centralized control through those systems, it becomes an important design challenge to ensure that the control actions of the AMC do not conflict with the control actions of the DMS. Devices such as capacitors, voltage regulators, and DER devices such as inverter-based storage systems can potentially fight amongst one another to solve a volt/VAr issue. A comprehensive protection update along with updates to the communication infrastructure is required to ensure coordination and interoperability amongst various devices.

Operation of a utility microgrid along with the ability to sectionalize load in portions that are relatively small, compared to the voltage/frequency regulating devices, results in better voltage and frequency, and thereby better power quality on the circuits. Additionally, single point of common coupling for multiple resources within a microgrid drastically reduces the amount of automation required for seamless movement between parallel operation and island operation of the microgrid. The complexity of integration increases exponentially as assets are added to the microgrid.

CHAPTER 6: Public Benefits to California

The extrapolation of the lessons learned from the Borrego Springs Microgrid project are expected to benefit California electricity ratepayers. The deployment of DERs at the distribution level increases the requirement for a technologically proven concept to address issues such as bi-directional power flow, power quality issues, and reliability of service. Microgrids such as the Borrego Springs Microgrid can address these issues and provide wide ranging benefits to the ratepayers. Some of the benefits include:

- Greater grid reliability – Microgrids can increase grid reliability by reducing peak-demand on the circuit and providing the mechanism to incorporate DERs as a solution to increasing the reliability. This in turn, enhances the power quality at various points in the power system, which may otherwise require expensive upgrades.
- Increased safety – Microgrids enhance safety in locations where they are deployed by creating seamless islanding capability for critical emergency operations in the event of a grid outage, including natural disasters such as wildfires or other emergency situations.
- Impact on load profile and duck curve – Microgrids are capable of ramping DERs quickly to reduce intermittency from renewables and provide reduced and consistent load profile for the electric grid.
- Environmental support – Microgrids enable inclusion of high renewable energy generation resources (such as the 26 MW solar facility), thereby supporting the environmental targets and grid operations concurrently. It also provides alternative options to secure infrastructure that pass through environmentally sensitive areas such as state parks, bodies of water, or other sensitive areas.
- Societal benefits - Residents of Borrego Springs can seek refuge in the designated “cool zones” served by the microgrid during power interruptions that are planned or unplanned.

Using an AMC under real-time operating situations advances future deployment of microgrids by California utilities, third party developers, and electric consumers alike. All market segments will benefit from microgrid adoption including universities, large corporations, military bases, and utilities seeking non-wires alternatives to capital investment in distribution infrastructure. Microgrids such as the Borrego Springs Microgrid will serve as technology solution for the Distribution Resources Plan (DRP) that the California utilities are mandated to adopt. Points that are identified through the Integration Capacity Analysis and Locational Net Benefit Analysis potentially can be operated as a microgrid if DERs and a AMC are deployed. The entire state could benefit from wide scale adoption of microgrids that can operate and interoperate to provide greater local grid resiliency.

CHAPTER 7: Technology / Knowledge Transfer Activities

Microgrids are a relatively recent technology solution that are not known to many in industry, academia, and customers. And most have limited exposure to the workings of a microgrid. The SDG&E project team has engaged in multiple knowledge sharing sessions with various stakeholders since the early days of the Borrego Springs community microgrid. For this task, the project team implemented a plan to make the knowledge gained, experimental results, and lessons learned available to the public and key decision makers. Education, outreach and knowledge transfer activities included:

- Outreach to the residents and community of Borrego Springs.
- Development of project documents and distribution, including:
  - Project fact sheets and presentations
  - Press releases
  - Project videos and outreach materials
- Participation in conferences, webinars, and workshops that included knowledge transfer activities.
- Stakeholder holder engagement included the outreach to the following stakeholders:
  - Borrego Springs Community
    - Borrego Springs Chamber of Commerce
    - Anza-Borrego Desert Natural History Association
    - San Diego County Sheriff's Department (Local CHP Office)
    - Borrego Springs Fire District
    - La Casa Del Zorro Resort
    - Borrego Springs Resort
  - Government Entities
    - USDOE
    - California Public Utilities Commission
    - National Laboratories
    - National Renewable Energy Laboratory
    - Sandia National Laboratory
    - Pacific Northwest National Laboratory
    - California Independent System Operator
  - Academic Institutions

        - University of California San Diego
        - University of San Diego
        - California Polytechnic State University – San Luis Obispo
    - Industry Participation
        - DistribuTECH Conferences
        - IEEE Conferences
        - Smart Energy Power Alliance
        - Oncor Electric
        - Korea Electric Power Company
        - Southern California Edison
        - Pacific Gas & Electric
        - Sumitomo Electric
        - New Energy and Industrial Technology Development (NEDO), Japan

Appendix D presents the news stories, website postings, presentations, and videos that were developed to support the Borrego Springs Microgrid project.

LIST OF ACRONYMS

Term	Definition
ABDNHA	Anza-Borrego Desert Natural History Association
ACT	Advance Control Technology
AES	Advanced Energy Storage
AMC	Advanced Microgrid Controller
BDEP	Borrego Desert Energy Project
BESS	Battery Energy Storage System
CAISO	California Independent System Operator
CHIL	Controller Hardware-in-the Loop
CHP	California Highway Patrol
DER	Distributed Energy Resources
DERMS	Distributed Energy Resource Management System
DMS	Distribution Management System
DNP	Distribution Network Protocol
USDOE	United States Department of Energy
DOP	Distribution Operations Procedure
EDO	Electric Distribution Operations
EPIC	Electric Program Investment Charge
ERM	Energy Resource Manager
ESIF	Energy Systems Integration Facility
FAQ	Frequently Asked Questions
GTNET	Gigabit Transceiver Network Interface
HIL	Hardware-in-Loop
IEEE	Institute of Electrical and Electronics Engineers
kV	Kilovolt
kVA	Kilovolt Ampere
kVAr	Kilovolt Ampere Reactive

Term	Definition
kW	Kilowatt
MAIFI	Momentary Average Interruption Frequency Index
MW	Megawatt
NEDO	New Energy and Industrial Technology Development
NIST	National Institute of Standards and Technology
NREL	National Renewable Energy Laboratory
PCC	Point of Common Coupling
PHIL	Power Hardware-in-the-Loop
PIER	Public Interest Energy Research
PMU	Phasor Measurement Unit
PV	Photovoltaic
REG	Regulator
RMS	Root Mean Square
RTDS	Real-Time Digital Simulator
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SDG&E	San Diego Gas & Electric
SES	Substation Energy Storage
UCSD	University of California San Diego
VAr	Volt-Ampere-Reactive
VFI	Variable Fault Indicator
VPN	Virtual Private Network

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APPENDIX A: Results of Advanced Microgrid Controller Evaluation in the Laboratory

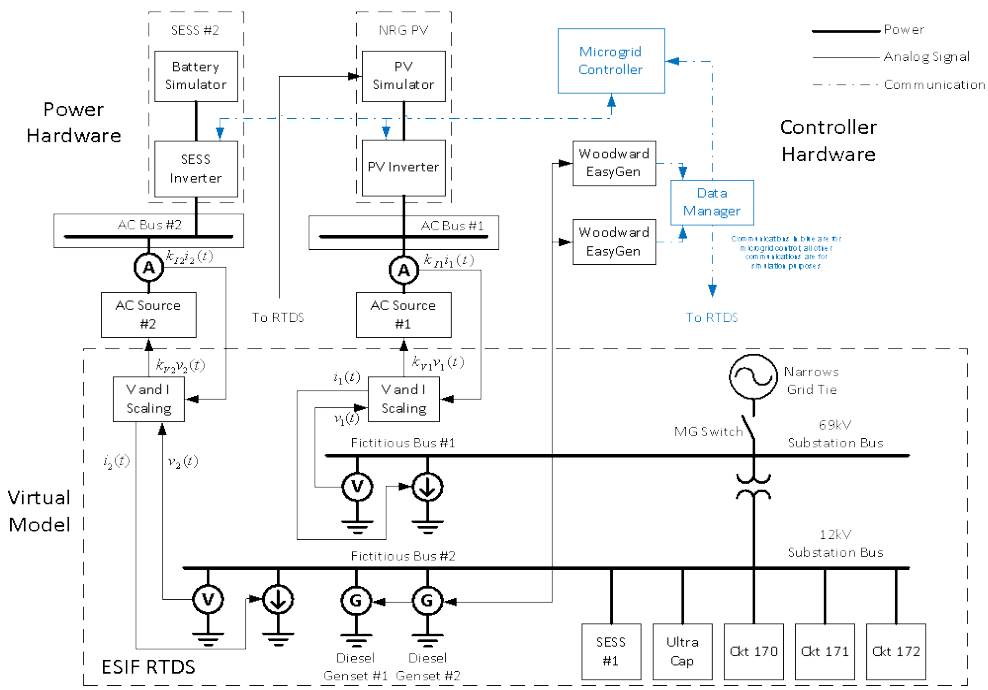
This section presents results from the microgrid controller evaluation for the different test cases outlined in the test plan. Not all the test cases described in the test plan were completed due to significant delays in delivery of the microgrid controller to NREL.

Scenario A: Operating the Microgrid While Connected to the Utility

The purpose of simulating the scenario of operating the microgrid while connected to the utility was to validate the ability of the Spirea Wave Advanced Microgrid Controller to dispatch the DERs while grid-connected and to achieve survivability of critical loads when islanded, economic operation, and environmental performance compared to the outcomes for the community without the microgrid controller, as specified by the functional requirement C5: Dispatch.

The test setup as shown in Figure A-1 was used, unless noted otherwise.

Figure A-1: Borrego Springs ESIF local CHIL/PHIL setup



Cir 1 Cir 2 Cir 3

Source: San Diego Gas & Electric Company

In this scenario, the microgrid switch was closed, and the community microgrid was connected to the external utility, which effectively controls both voltage and frequency in the microgrid. Net load data profiles for heavy and light load days were used, down sampled to 10-minute time steps.

For the baseline, the Wave controller was disabled; for other test cases, the Wave controller provided dispatch. The Wave code that NREL used was only able to dispatch one BESS, because only one BESS is dispatchable in the field. NREL set up our experiment so that the Schneider inverter hardware represented the dispatchable BESS and the simulated BESS was not used.

Accelerated (faster than real time) simulations were performed whereby 10 minutes of simulation time equaled 15 seconds of real time. NREL used 15 seconds to allow transients to settle after a load step. The results presented in this section are based on the values reached in the last 3 seconds of each 15-second period to exclude the transients after a change in load or insolation.

Results for Test Case A1: Normal Grid-Connected Operation with No Dispatch (Baseline)

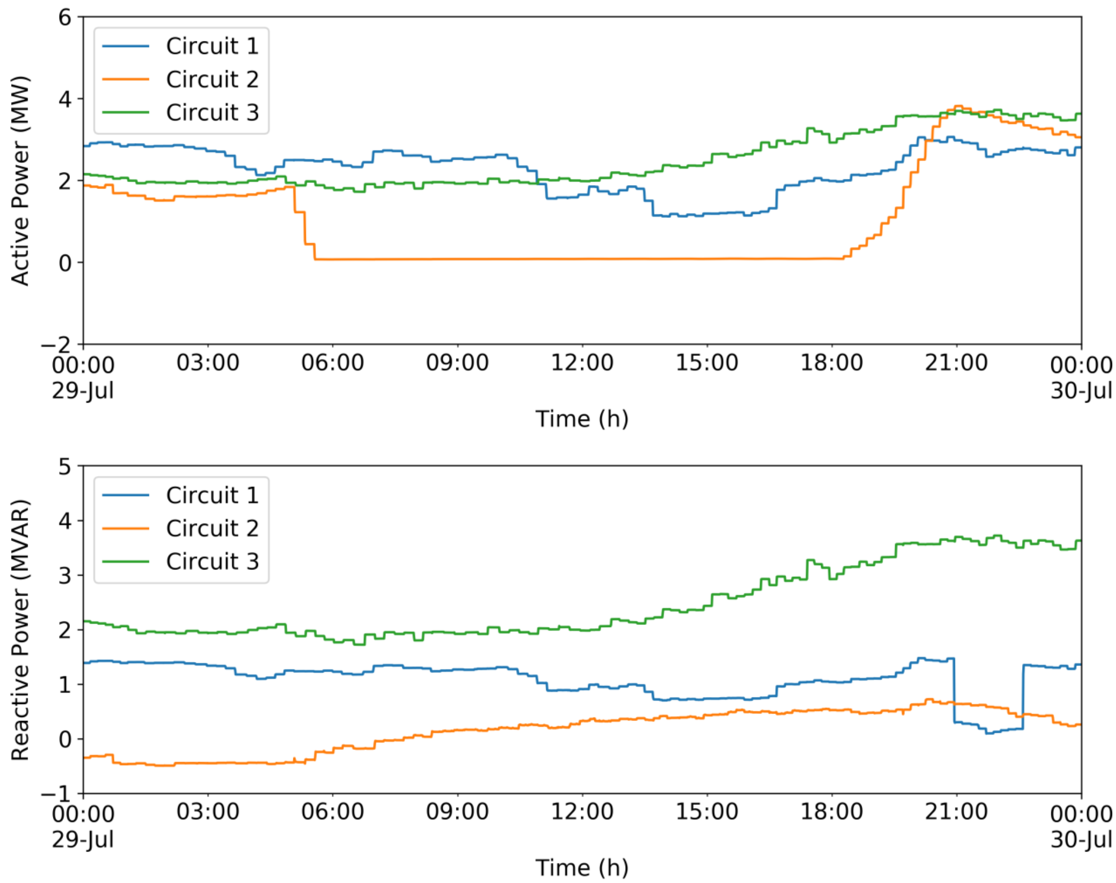
In this test, dispatch was not enabled in the Wave microgrid controller, all dispatchable generation sources were offline, and PV was the only asset running.

Results for Test A1.1: Heavily Loaded Normal Grid-Connected Operation with No Dispatch

The net load and insolation profiles for heavy load, were used for the simulation. The net power profiles for each distribution circuit are shown in Figure A-2. The active power profiles match the loads, except for circuit 2 between about 06:00 and 18:00. The active power should be negative, but it is zero. This is because the dynamic load models in RSCAD can only simulate positive power. NREL replaced the dynamic loads with a power injection model that can absorb and supply both positive and negative active and reactive power, but this was unstable and there was not sufficient time to resolve this. The reactive power profiles for circuits 2 and 3 are shifted compared to the net reactive load profiles because of reactive power added by the inter-rack transformers in the RSCAD model, and this impacts the results of the controller dispatch of reactive power. In addition, the reactive power profiles for circuits 1 and 3 are different because there are capacitor banks on the distribution circuits that have local control that turns the capacitor banks on or off based on the local voltage. The step changes in reactive power at about 12:00 and 14:00 on circuit 3 and at about 21:00 and 22:30 on circuit 1 are due to the switching of capacitor banks on those circuits (Figure A-3).

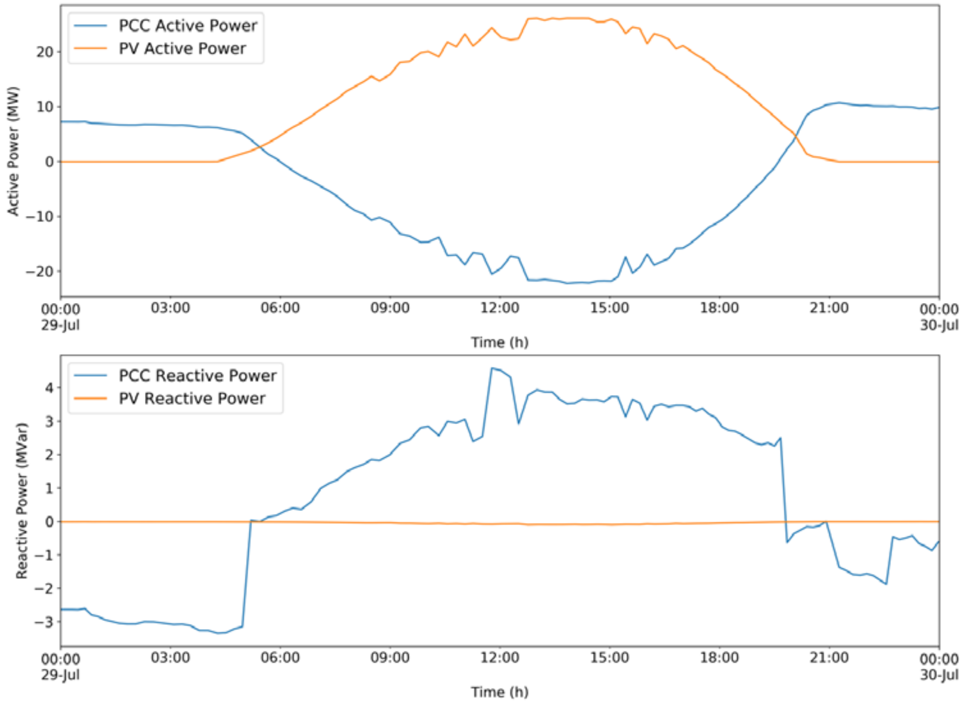
A line plot of generation, which is only PV for this test, along with the power flow through the PCC circuit breaker, is shown in Figure A-4 shows the PCC voltage and current. The PCC power flow is dominated by PV generation and it significantly impacts the voltage at the microgrid PCC, raising it to almost 1.045 p.u. in the early afternoon. The impact of the capacitor switching on circuits 1 and 3 can also be seen on the PCC reactive power flow and the PCC voltage. The increase in PCC reactive power at about 5:00 and the decrease at about 20:00 are because of the switching action of two capacitor banks on the 12 kV bus.

Figure A-2: Line Plot of Net Power Flow for Each Individual Circuit Within the Microgrid for Test A1.1



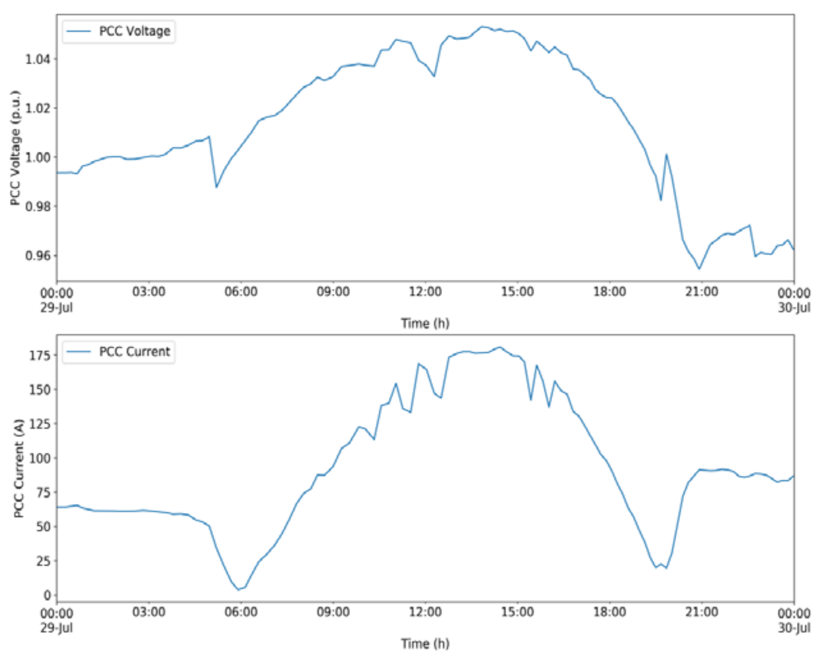
Source: San Diego Gas & Electric Company

Figure A-3: Line Plot of Generation and PCC Power Flow Within the Microgrid for Test A1.1



Source: San Diego Gas & Electric Company

Figure A-4: PCC Voltage and Current for Test A1.1

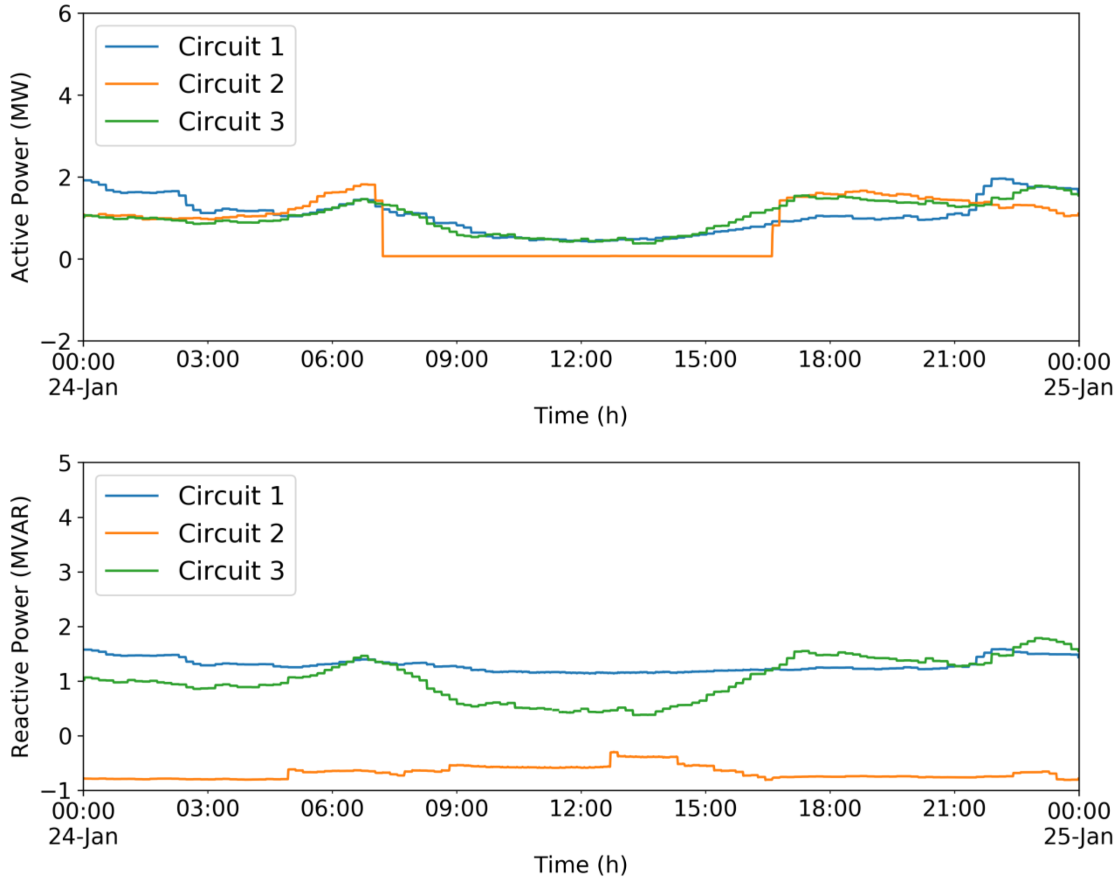


Source: San Diego Gas & Electric Company

Results for Test A1.2: Lightly Loaded Normal Grid-Connected Operation with No Dispatch

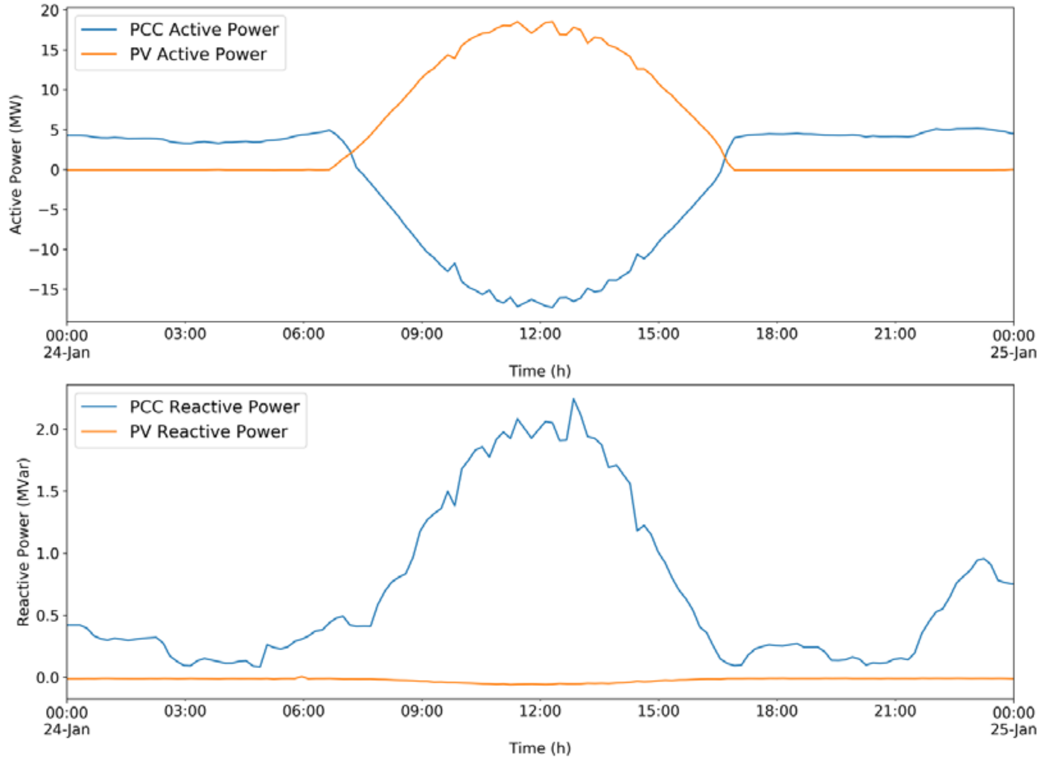
In this test, the load and insolation profiles for lightly loaded conditions was used. The net power profiles for each distribution circuit is shown in Figure A-5. The generation, which is only PV, and PCC active power and reactive power is shown in Figure A-6. The power generated from the PV is distributed to the loads and also to the grid through the PCC. The voltage at the PCC and the current through the PCC circuit breaker, shown in Figure A-7, increases as the power generated from the PV increases.

Figure A-5: Line Plot of Net Power Flow for Each Individual Circuit Within the Microgrid for Test A1.2



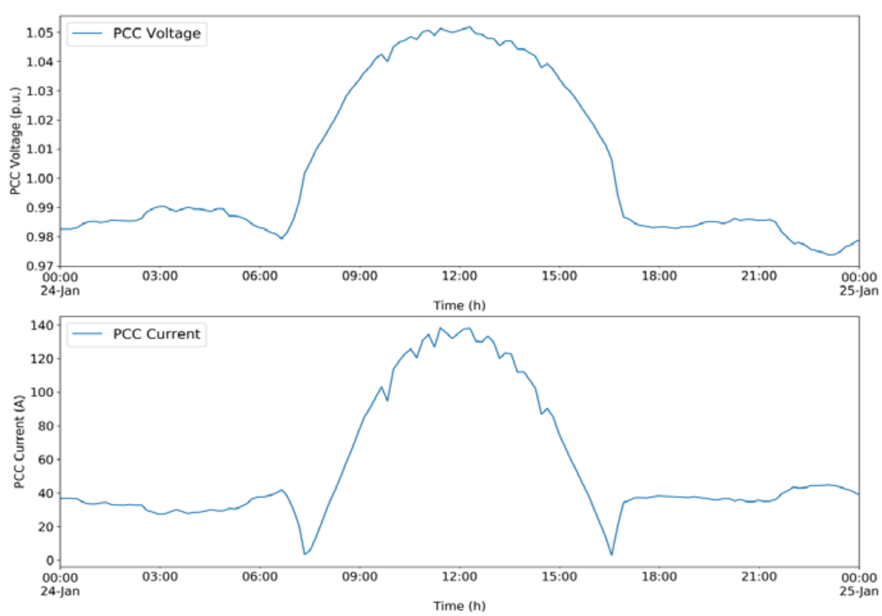
Source: San Diego Gas & Electric Company

Figure A-6: Line Plot of Generation and PCC Power Flow Within the Microgrid for Test A1.2



Source: San Diego Gas & Electric Company

Figure A-7: PCC Voltage and Current for Test A1.2



Source: San Diego Gas & Electric Company

The results presented in test case A1 indicate that in the heavily loaded condition and the lightly loaded condition, the PV generation can have significant impact on the microgrid voltage. These two cases present a baseline understanding of the operation of the microgrid without the DERs (except for the 26 MW PV inverter that was operational) and without the microgrid controller.

Results for Test Case A2: Normal Grid-Connected Operation with Dispatch

In this test case, the Wave microgrid controller was set to provide dispatch. The test plan calls for setting up the dispatch of assets to meet one of three objectives – survivability, economic operation, and environmental performance – as defined in Appendix A-1. Dispatch for survivability was achieved by using the Wave microgrid controller's "PQ set points using reliability heuristic" optimizer, which chooses assets based on cost parameters (startup, hourly, operating, stopping, and so on) to achieve the active and reactive set points for PCC power flow. Wave does not have the capability to calculate appropriate power set points to achieve survivability, and therefore NREL manually set the PCC active and reactive power set points to zero and this ensured survivability. In addition, Wave does not offer a solution that optimizes for the economic and environmental objectives and therefore those tests could not be simulated.

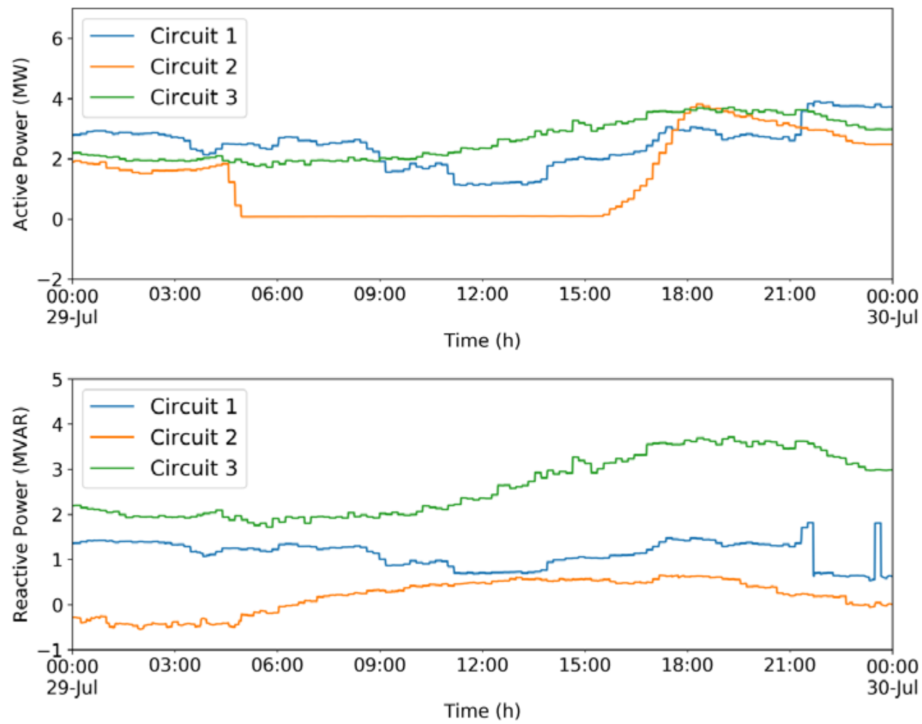
Results for Test A2.1: Heavily Loaded Normal Grid-Connected Operation with Dispatch

The load profiles and solar insolation profile are the same as those for Test A1.1. The net power profiles for each distribution circuit within the microgrid are shown in Figure A-8. A line plot of generation and the power flows through the PCC circuit breaker are shown in Figure A-9, and Figure A-10 shows the PCC voltage and current. During the day from 6 am to 6 pm, Wave dispatches the distributed generators and the PV to keep the active and reactive power flow across the PCC close to zero. The Wave dispatches distributed generators 1 and 2 at about 60 percent of their rated power and it dispatches the PV to serve the rest of the load. Even though the PV has the capacity to serve all the load, the distributed generators are dispatched for survivability, that is, to ensure the availability of grid-forming generators in the event of unplanned islanding.

When the PCC power flow is regulated to zero, the voltage at the microgrid PCC is close to unity, compared to a peak of more than 1.04 per unit (p.u.) for the baseline case. The capacitors on circuit 1 switch several times in the early morning hours and the Wave dispatches the PV to attempt to regulate the PCC reactive power flow to zero. The reactive power is regulated to an average value of about zero during the early morning hours, but the Wave is not able to regulate the reactive power to zero between capacitor switching events and therefore the PCC reactive power fluctuates significantly, and this causes fluctuations in the PCC voltage.

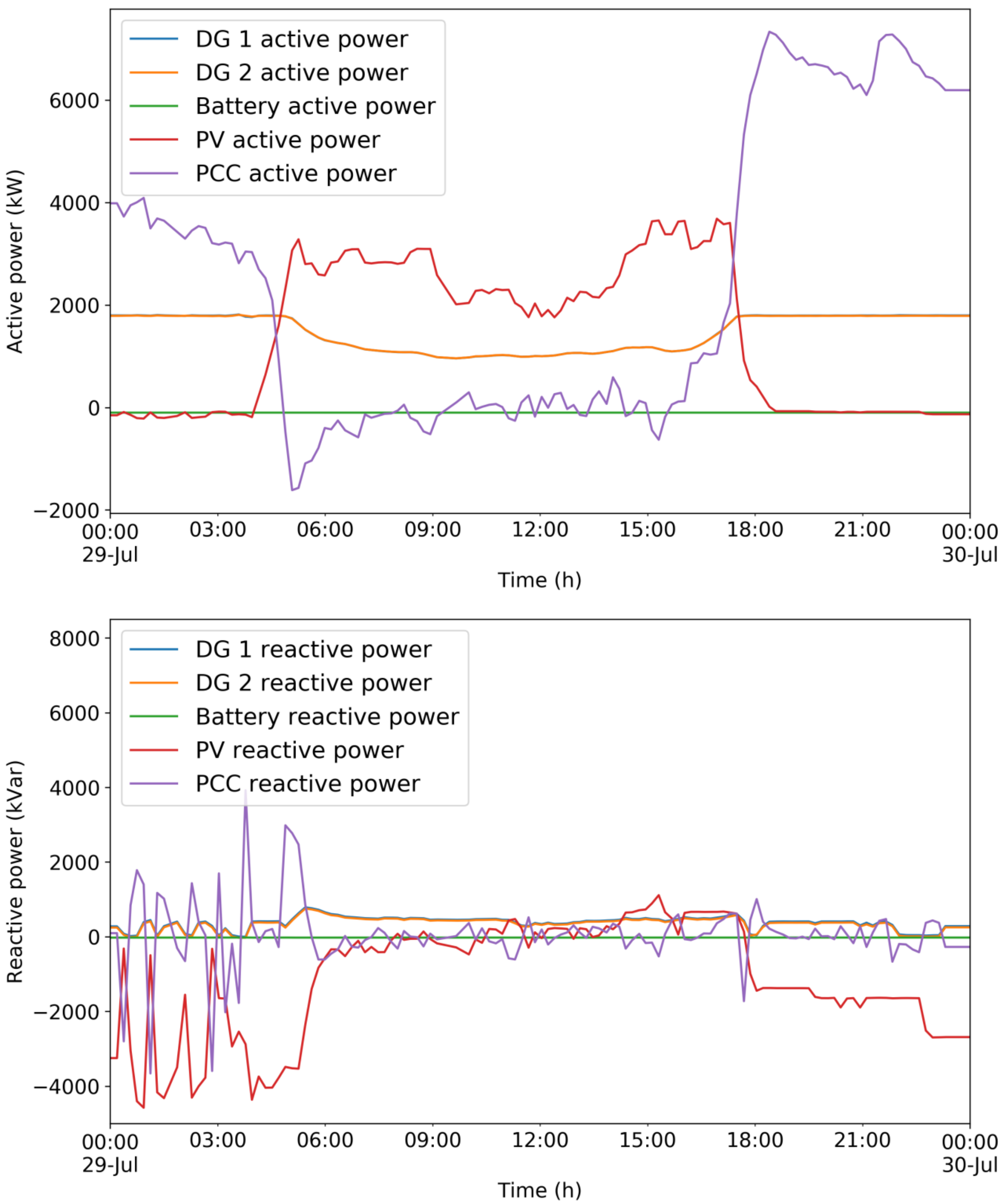
At the beginning of the experiment, there is no PV generation, the total load in the microgrid is close to 8 MW, and the Wave dispatches the two generators at their rated power to generate a total of 3.6 MW. The rest of the load (around 4 MW) is supplied by the grid through the PCC. Therefore, the active power flow through the PCC circuit breaker is nonzero during the early morning hours when there is no PV generation available. The SESS is brought online, but is only dispatched at its minimum charge rate of 100 kW or 10 percent of rated power during the entire day. Once enough PV is available, the Wave is able to regulate the PCC power to zero.

Figure A-8: Line Plot of Net Power Flow for Each Individual Circuit Within the Microgrid for Test A2.1



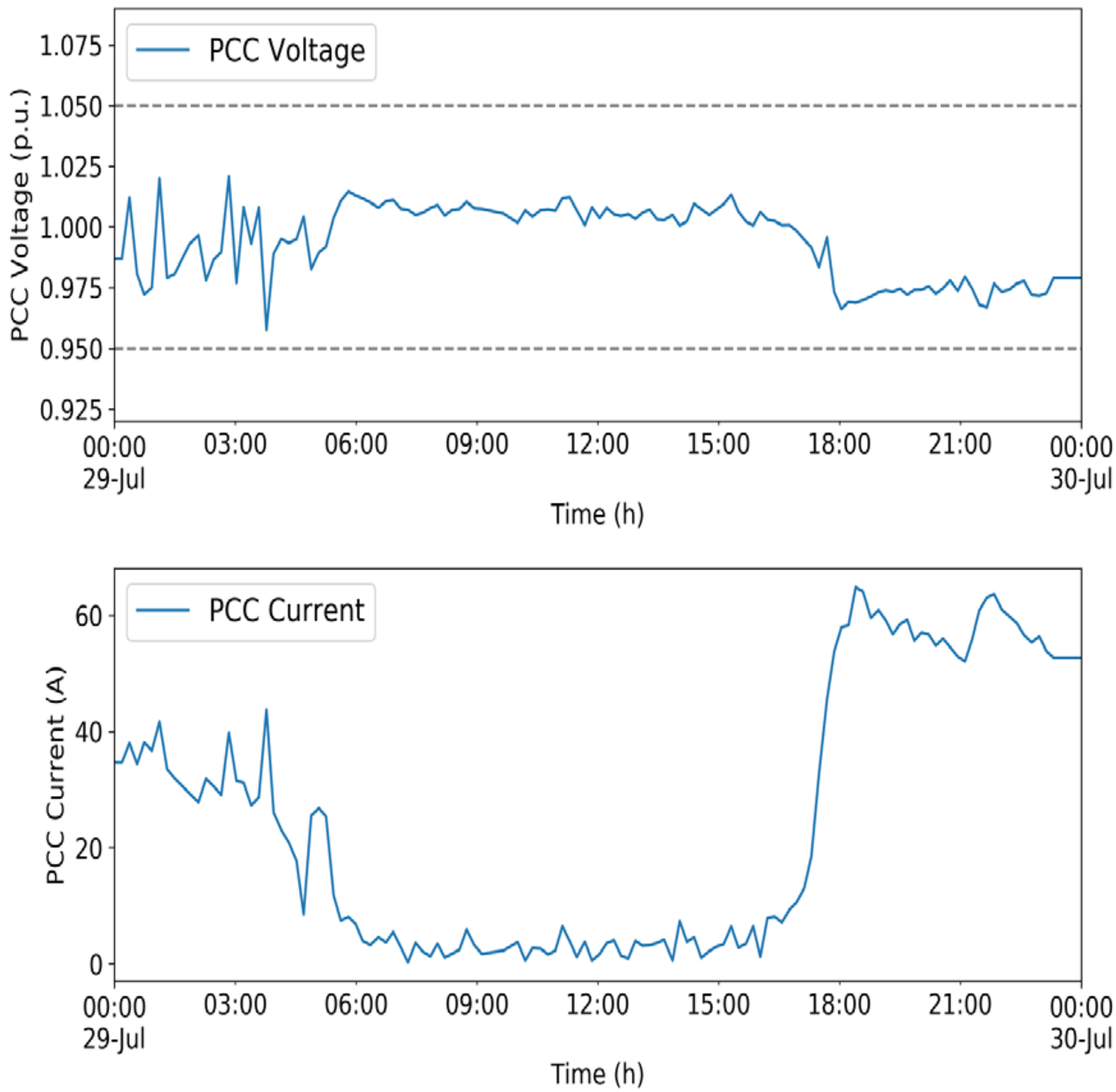
Source: San Diego Gas & Electric Company

Figure A-9: Line Plot of Generation and PCC Power Flow Within the Microgrid for Test Case A2.1



Source: San Diego Gas & Electric Company

Figure A-10: PCC Voltage and Current for Test A2.1

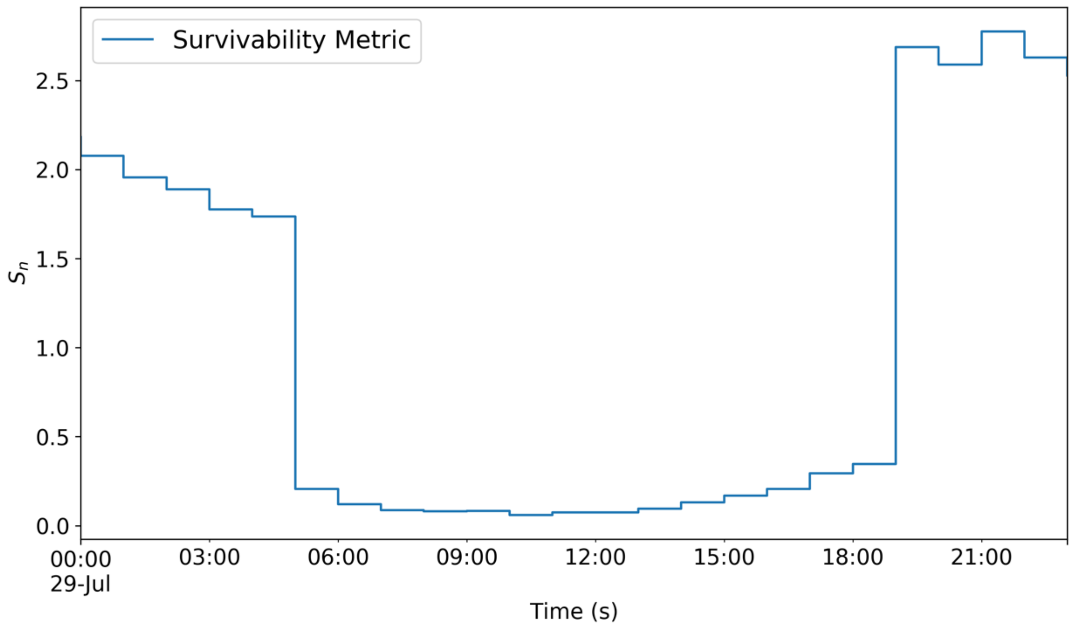


Source: San Diego Gas & Electric Company

The metrics related to survivability, economic operation, and environmental performance were calculated. The survivability metric reflects whether sufficient resources (generation and/or energy storage) are operating and are available to support the microgrid's seamless transition to islanded mode. For the baseline test A1.1, the available generation is zero because the PV inverter cannot operate in grid-forming mode and that results in an infinite value for S_n. Note that if the PV inverter was able to operate in grid-forming mode, S_n would be infinite during the night when no generation is possible.

For the dispatch test A2.1, the survivability metric result in Figure A-11 shows that the microgrid cannot support islanded operation during the night due to insufficient available generation, but it is able to support islanded operation during the day from 5 in the morning to around 7 in the evening when enough PV becomes available.

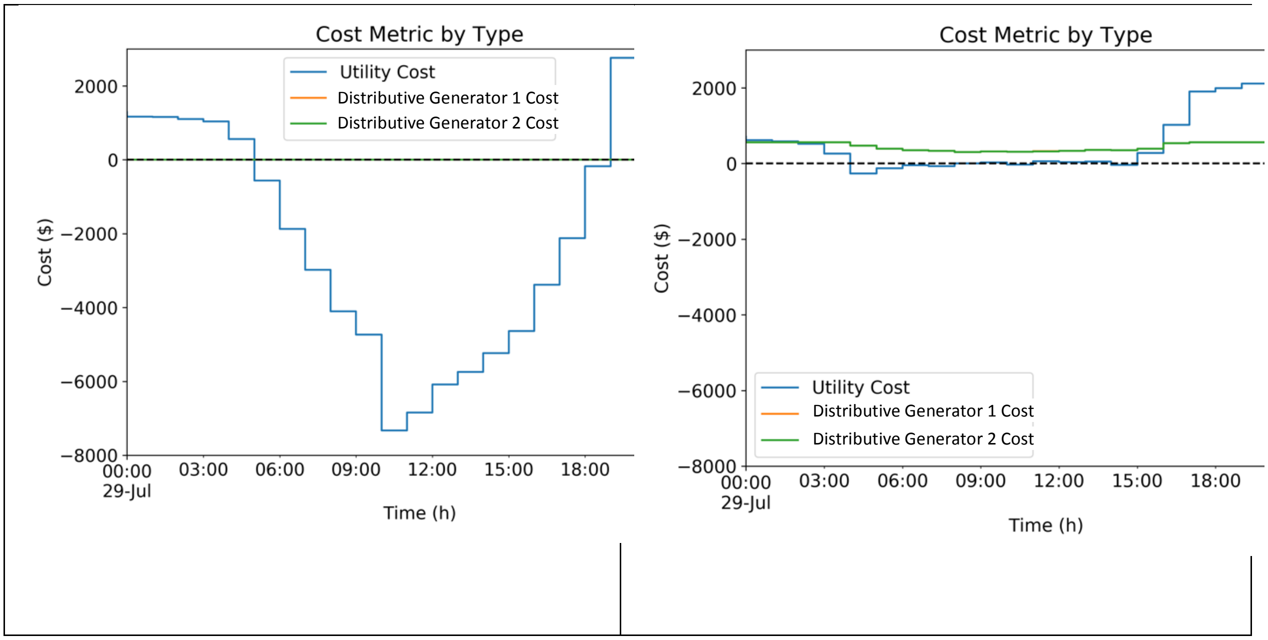
Figure A-11: Survivability Metric Results for Test A2.1



Source: San Diego Gas & Electric Company

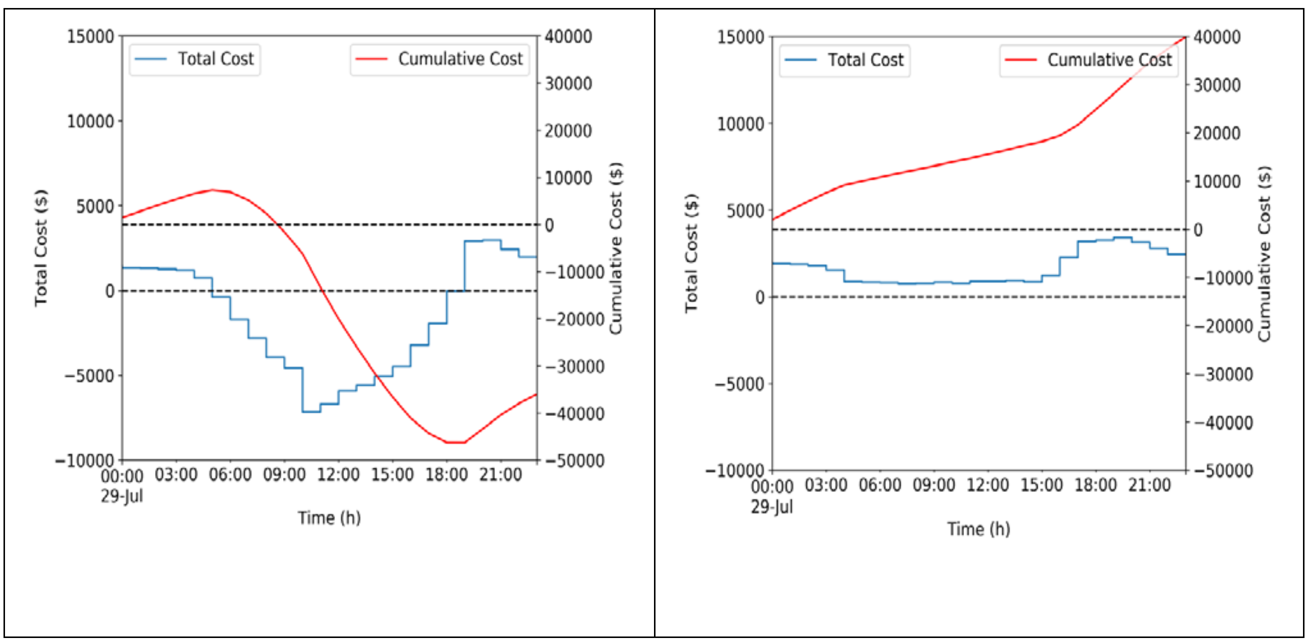
The cost metric was calculated using a representative time-of-use rate and the same rate is used for the power consumed and supplied by the microgrid. The comparison of cost by type between tests A1.1 and A2.1 is shown in Figure A-12. The cumulative cost incurred is shown in Figure A-13. The utility cost for Test A2.1, with dispatch, is lower when there is no sun (PV insolation data is “0”) because the Wave dispatches the distributed generators. When there is sun, the utility cost for Test A1.1, without dispatch, is negative, because the microgrid exports a significant amount of active power to the main grid. In Test A1.2, the PV is curtailed to regulate the PCC power to zero and therefore the payment for the PV generation is eliminated and the cumulative cost for the test case with no dispatch is less than for the test case with dispatch. However, because cost is not explicitly optimized, this result is not an indication of the Wave microgrid controller’s ability to operate a microgrid in the most cost-effective way.

Figure A-12: Cost Results by Type for Test A1.1 (baseline) on the left and Test A2.1 (with dispatch) on the right.



Source: San Diego Gas & Electric Company

Figure A-13: Total and Cumulative Cost Results for Test A1.1 (baseline) on the left and Test A2.1 (with dispatch) on the right

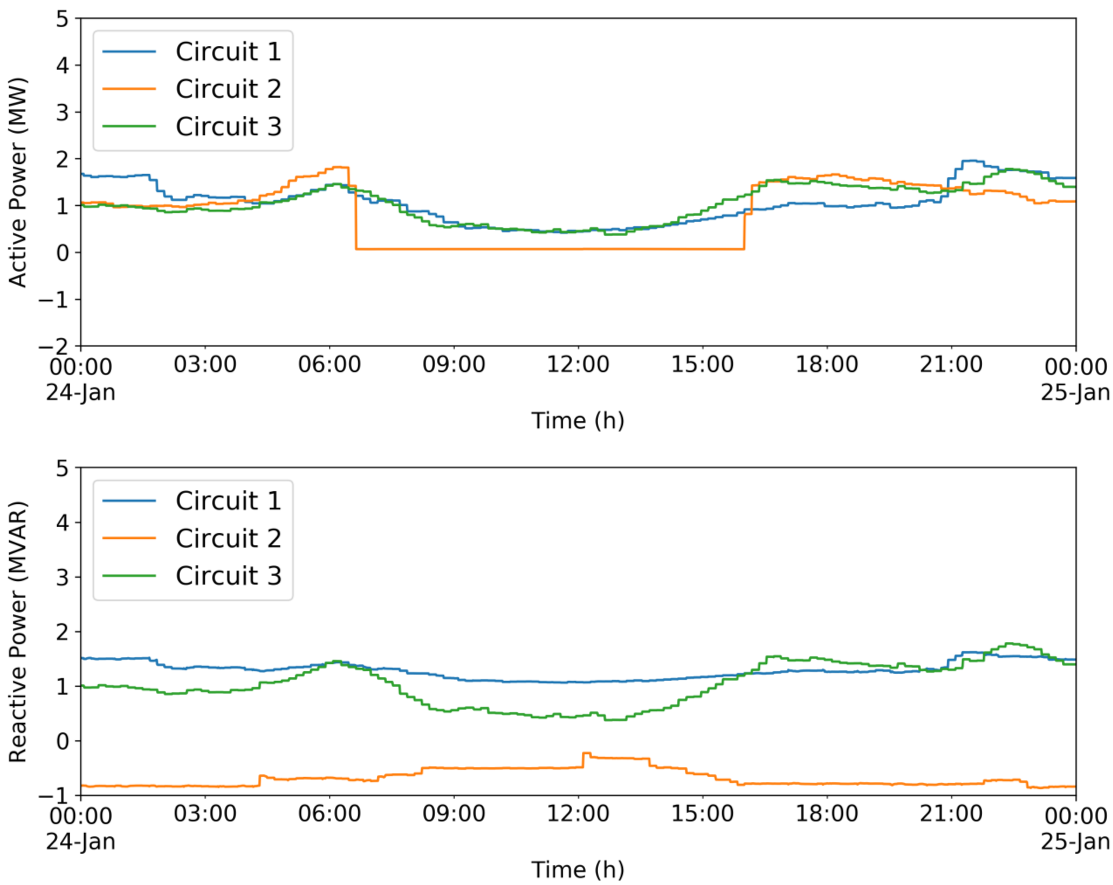


Source: San Diego Gas & Electric Company

Results for Test A2.2: Lightly Loaded Normal Grid-Connected Operation with Dispatch

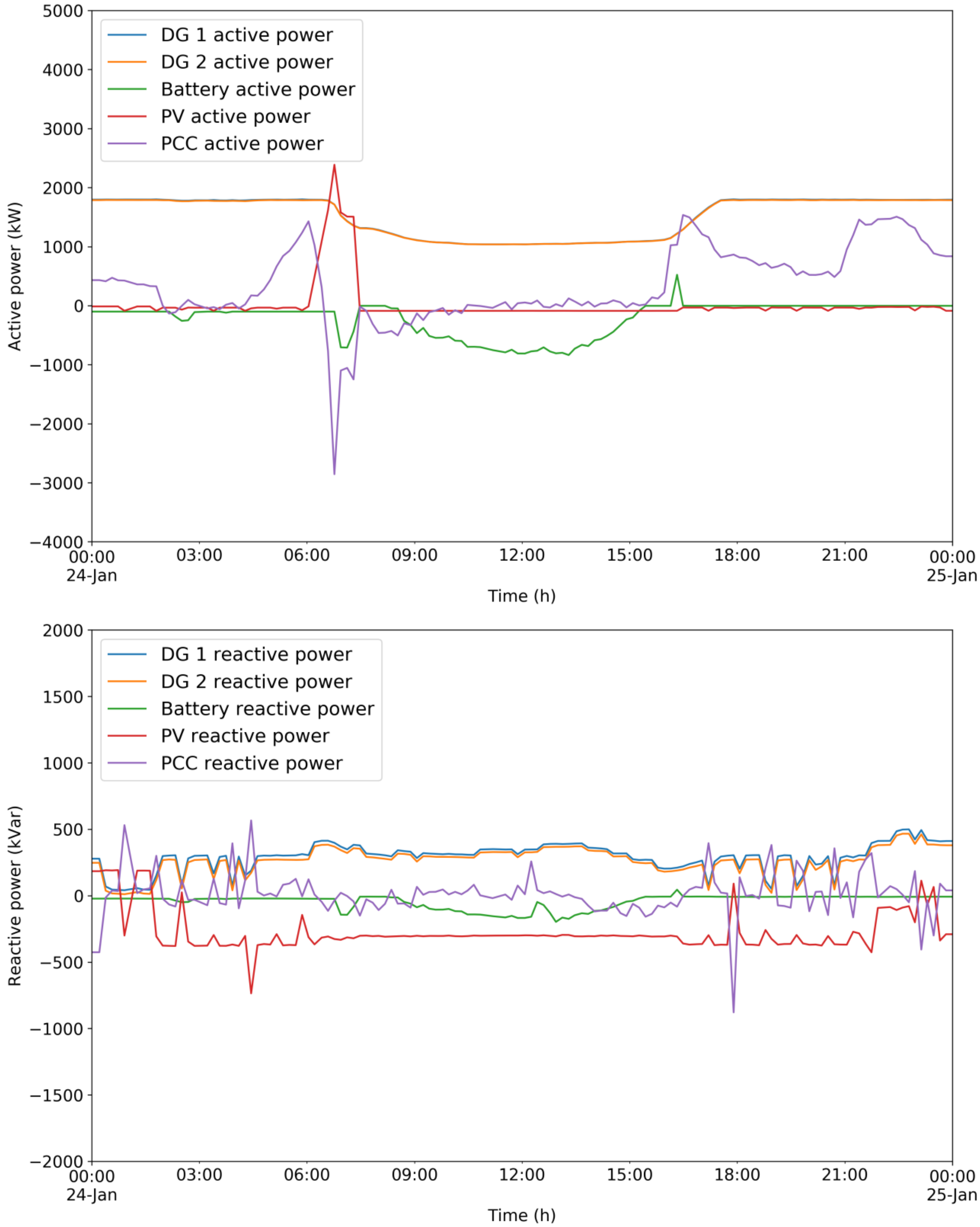
The load profiles and solar insolation profile are the same as those for Test A1.2. The net power profiles for each distribution circuit within the microgrid are shown in Figure A-14. A line plot of generation and the power flows through the PCC circuit breaker are shown in Figure A-15, and Figure A-16 shows the PCC voltage and current. The distributed generators are dispatched at their rated power at the start of the simulation and because the loads are lower, the generators can regulate the PCC power flow to within 1 MW of zero until about 04:00 when the load increases to above the generators' rated output power. When the sun comes up, the total net load drops and the Wave curtails the PV to regulate the PCC power to zero. The PV is curtailed to below its minimum operating output of 1.5MW and is therefore turned off. The generators are dispatched at about 60 percent of their rated power during the day and the battery is dispatched to absorb the difference between the distributed generator power and the net load.

Figure A-14: Line Plot of Net Power Flow for each Individual Circuit within the Microgrid for Test Case A2.2



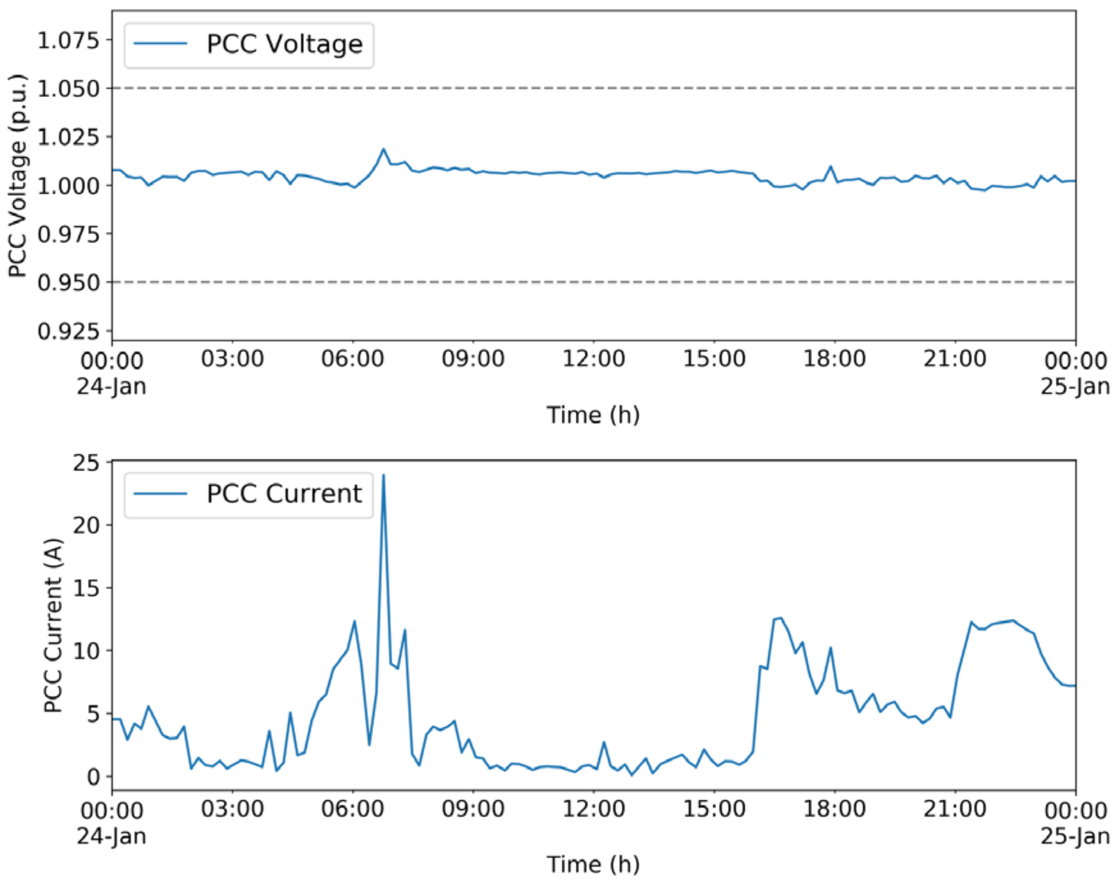
Source: San Diego Gas & Electric Company

Figure A-15: Line Plots of Generation and PCC Power Flow for Test A2.2



Source: San Diego Gas & Electric Company

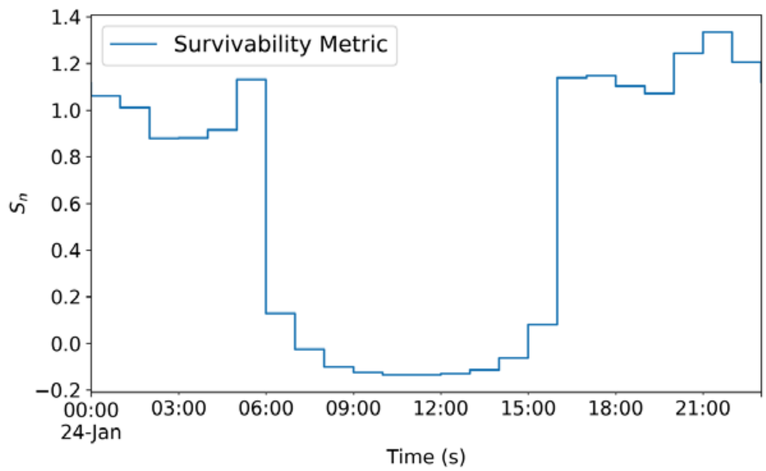
Figure A-16: PCC Voltage and Current for Test Case A2.2



Source: San Diego Gas & Electric Company

Metrics related to survivability, economic operation, and satisfactory environmental performance were also calculated for this test case. The survivability metric S_n for the baseline test A1.2 is infinite because the PV inverter cannot operate in grid-forming mode, so the available generation is zero. For the dispatch test A2.2, the survivability metric result in Figure A-17 shows that the microgrid cannot support islanded operation during the early morning and evening hours because S_n is greater than one when there is no sun. Therefore, some load will have to be curtailed to have sufficient resources to allow for a seamless transition to islanded mode. During the daylight hours, seamless operation to islanded mode is possible. Note that S_n is negative because the total net load is negative during the day.

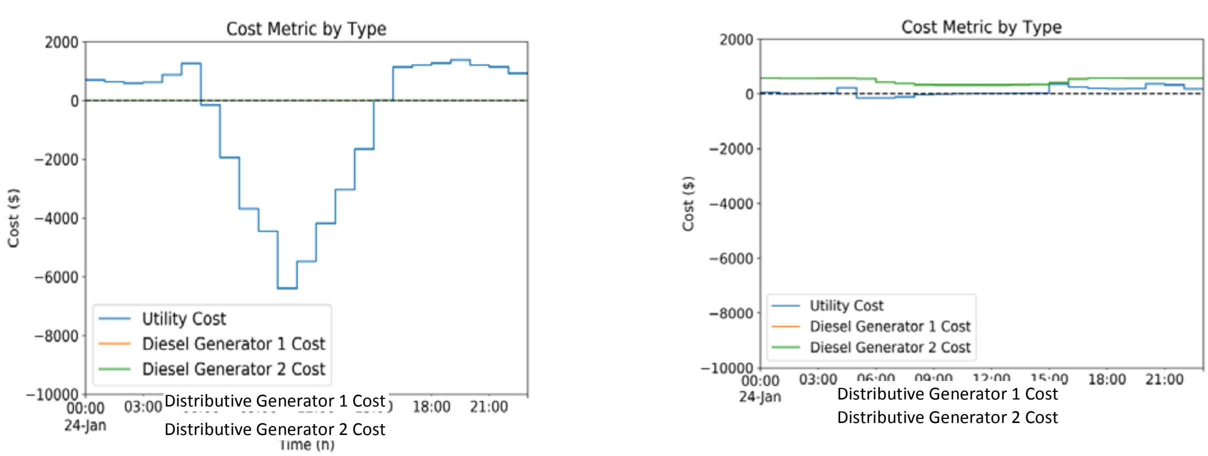
Figure A-17: Survivability Metric Results for Test A2.2



Source: San Diego Gas & Electric Company

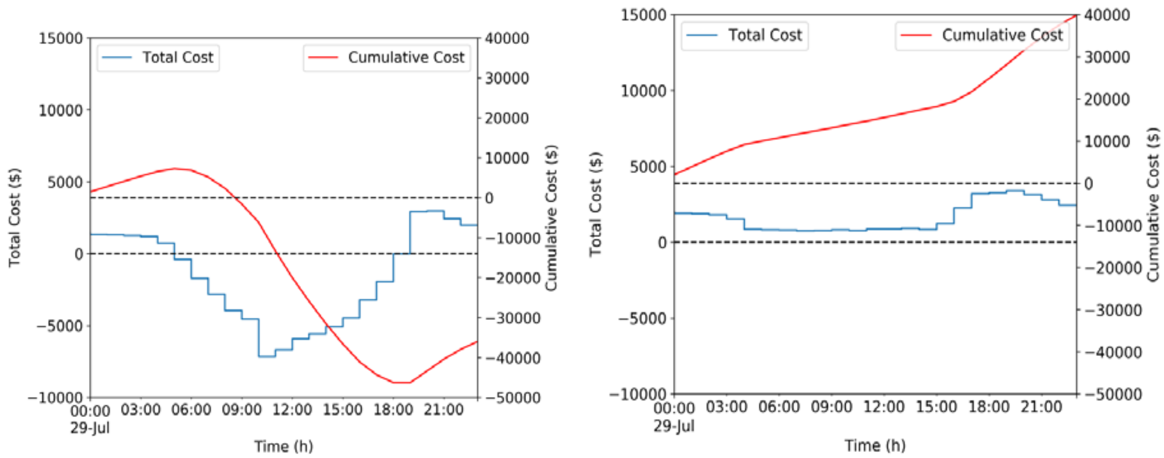
The cost results are shown in Figure A-18 and Figure A-19. Similar to the Test Case A1.1 and A2.1, the utility cost for Test Case A2.2, with dispatch, is lower when there is no sun (PV insolation data is "0") because the Wave is regulating the PCC power to zero. When there is sun, the cost for Test Case A1.2, without dispatch, is negative, because the microgrid exports a significant amount of active power to the main grid. The cumulative cost is higher with dispatch enabled in the Wave microgrid controller. This is due to the PV curtailment and the use of distributed generators in test case A2.2. However, because cost is not explicitly optimized, this result is not an indication of the Wave microgrid controller's ability to operate a microgrid in the most cost-effective way.

Figure A-18: Cost Results by Type for Test A1.2 (baseline, left) and Test A2.2 (with dispatch, right)



Source: San Diego Gas & Electric Company

Figure A-19: Total and cumulative cost results for Test A1.2 (baseline) on the left and Test A2.2 (with dispatch) on the right



Source: San Diego Gas & Electric Company

Scenario B: Separating the Microgrid from the Utility

The purpose of simulating the scenario of separating the microgrid from the utility was to validate the ability of the Wave microgrid controller to successfully separate the microgrid from the external utility, either as part of a planned operation or in response to an external fault or loss of utility power, and to ensure that it meets the specifications of the functional requirements C1: Disconnection and C4: Protection.

In this scenario, the PCC circuit breakers were initially closed, and the microgrid was connected to the area grid. The operating mode of the distributed generators is determined by the status of the PCC circuit breaker. When the PCC circuit breaker is closed, the distributed generators follow the real power and the power factor set point from the Wave. If the PCC circuit breaker opens, the distributed generators transition to droop control (SDG&E and Wave refer to this mode as "isochronous master") with a fixed slope of 2.45 percent and they become the voltage and frequency masters. It takes two simulation time steps (400 microseconds) for the simulated distributed generators to transition from power set point-following to voltage/frequency master mode.

In addition, the PCC circuit breaker logic in the simulated PCC circuit breaker was set up so that NREL could observe the response of the Wave for protection. The circuit breaker logic was delayed from taking action for half a cycle once it identifies an abnormal condition. The circuit breaker logic does not include any overcurrent protection. The protection logic opens the PCC circuit breaker and islands the microgrid from the main grid in response to the voltage measured across the circuit breaker.

Results for Test Case B1: Planned Separation

In this test case, the area grid remained within normal operating conditions, and the microgrid separation is part of a planned operation. Two different load and solar insolation conditions were simulated. The initial state-of-charge for the batteries was set to 70 percent for all tests.

The active and reactive power exchange across the PCC was set to zero. Once the Wave controller brought the power flow across the PCC to zero, a request was initiated to island the microgrid. This sends a signal to the RTDS model to open the PCC circuit breaker. Once the circuit breaker opens, the distributed generators need to switch from power set point-following to voltage/frequency master mode. The microgrid was run for more than two minutes to confirm stable operation.

Results for Test B1.1: Planned Separation When Load Exceeds Non-dispatchable Generation

The loads and solar insolation were set to values at 18:00 on July 29. At this time, the net load exceeds generation from the PV plant. Figure A-20 shows simulation results that can be used to evaluate the operation of the PCC circuit breaker controller logic, voltage stability, and stability of PHIL operation during the transient event. The top trace shows the disconnect signal issued by the microgrid controller and the status of the PCC circuit breaker, the trace second from the top shows the voltage on the microgrid side of the PCC breaker, the third trace shows the PCC current, and the bottom two traces show the PHIL current injection of the battery and the PV inverters. To ensure a smooth transition, the Wave reduces the power flow across the PCC to nearly zero prior to islanding by dispatching generation assets to supply the load. This can be seen from the low PCC current shown in Figure A-20. The simulation results of the microgrid voltage and measured battery and PV PHIL currents confirm that a smooth transition was observed during islanding.

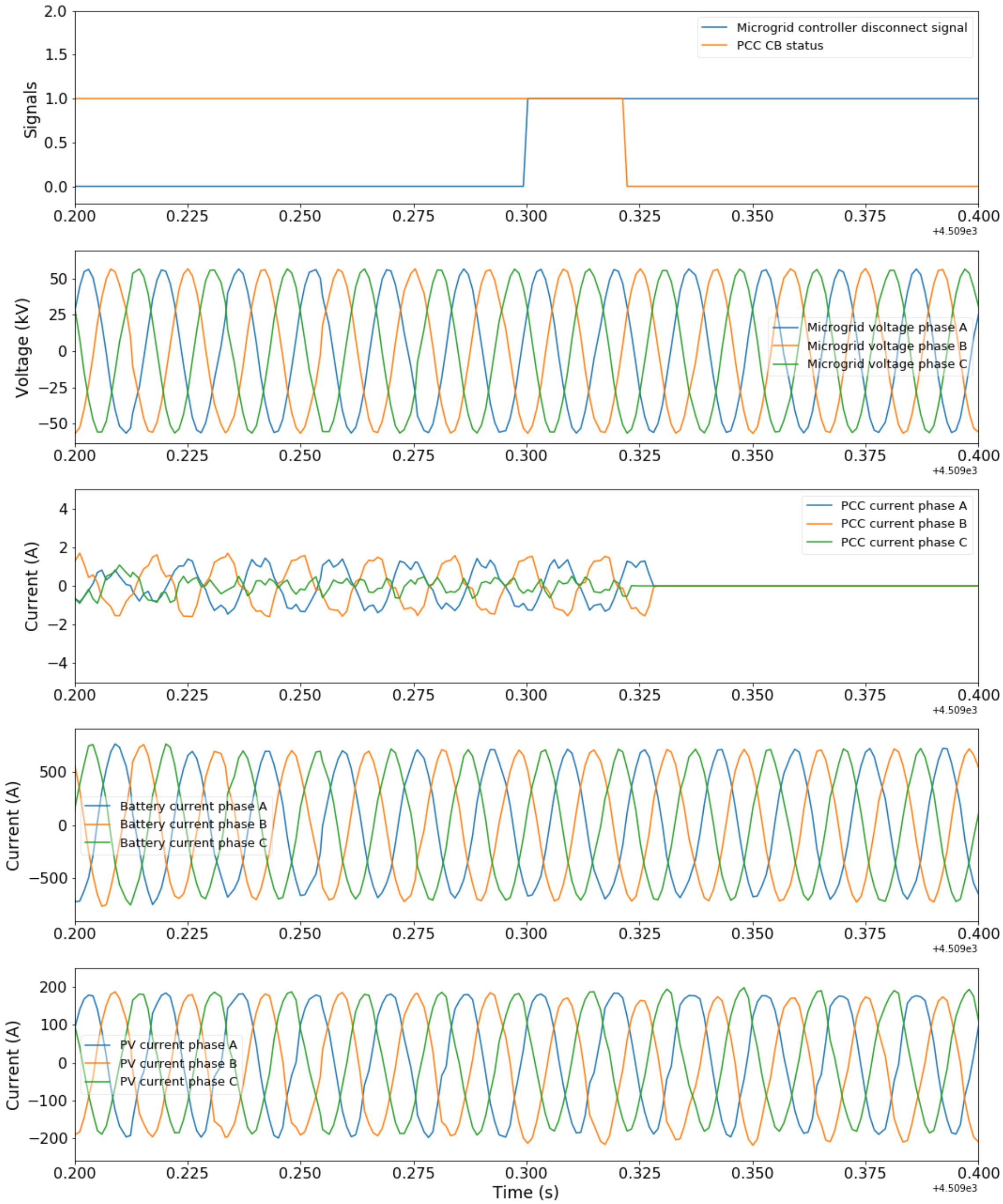
Voltage and frequency deviations are important measures of the performance of the microgrid during and after transitions. Voltages and frequencies were measured as described in section 1.1.6 and the results are shown in Figure A-21 over an extended period of time to allow evaluation of stable operation of the microgrid after the transient event. Dotted lines show the limits for steady-state operation to provide perspective on the observed deviations.

A voltage transient occurs at approximately 4,500 seconds, when islanding occurs. After transition to islanded mode, the voltage exhibits smooth dynamics and settles at around 0.99 p.u. During the test, the voltage is maintained within 0.99–1.01 p.u., which meets the steady-state standards from ANSI. The measured frequency at the microgrid PCC also exhibits smooth response during the test.

Results for Test B1.2: Planned Separation When Non-dispatchable Generation Exceeds Load

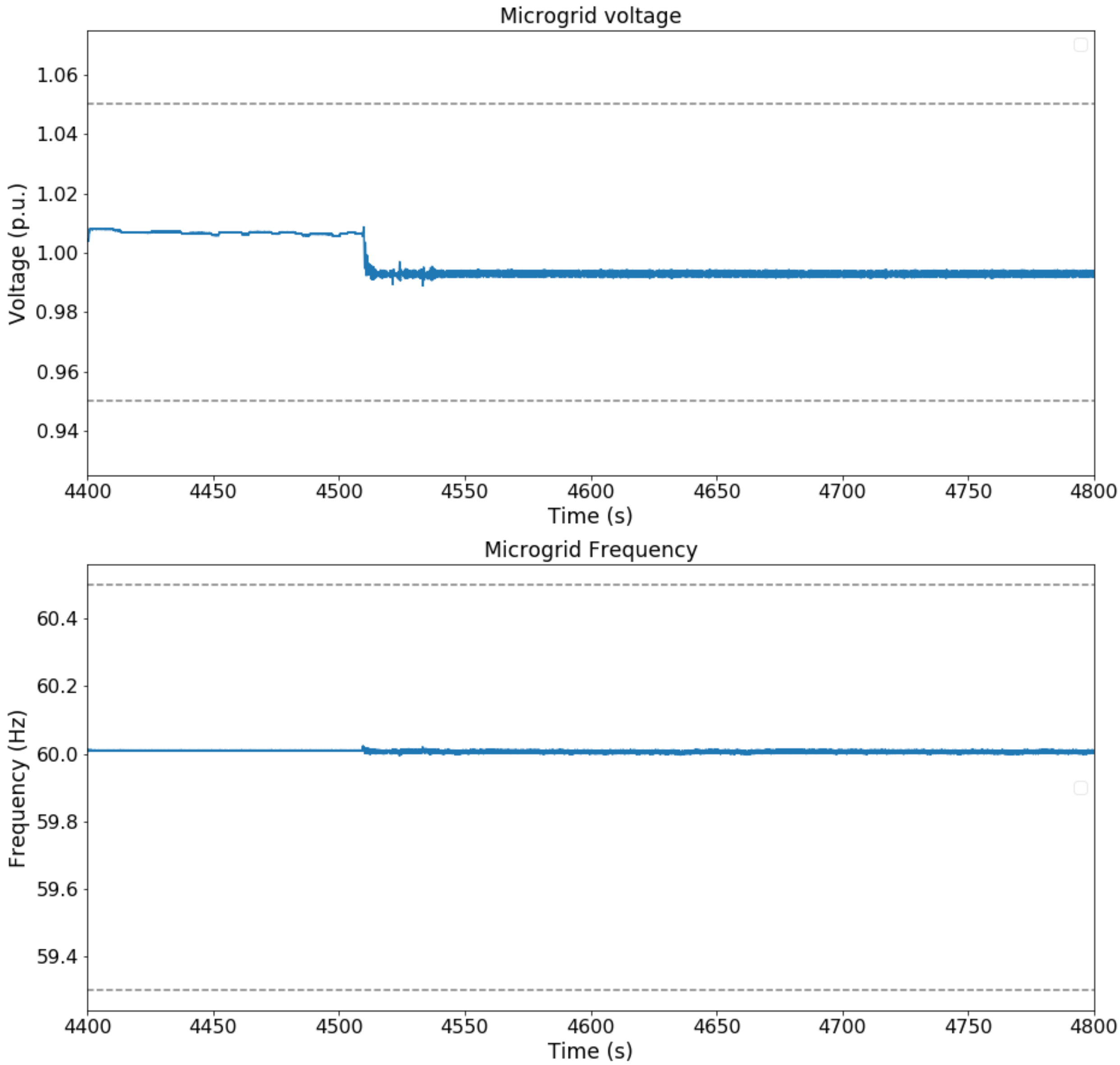
The loads and solar insolation were set to values at 16:45 on July 29. At this time, generation from the NRG PV plant exceeded net load. The simulation results are shown in Figure A-22. Similar to the previous test, the microgrid controller maintained a power flow close to zero at the PCC prior to islanding, as can be seen from the PCC current measurements. The simulation results of the microgrid voltage and measured battery and PV PHIL currents confirm that a smooth transition was observed during islanding.

Figure A-20: Planned Disconnection Results for Test B1.1



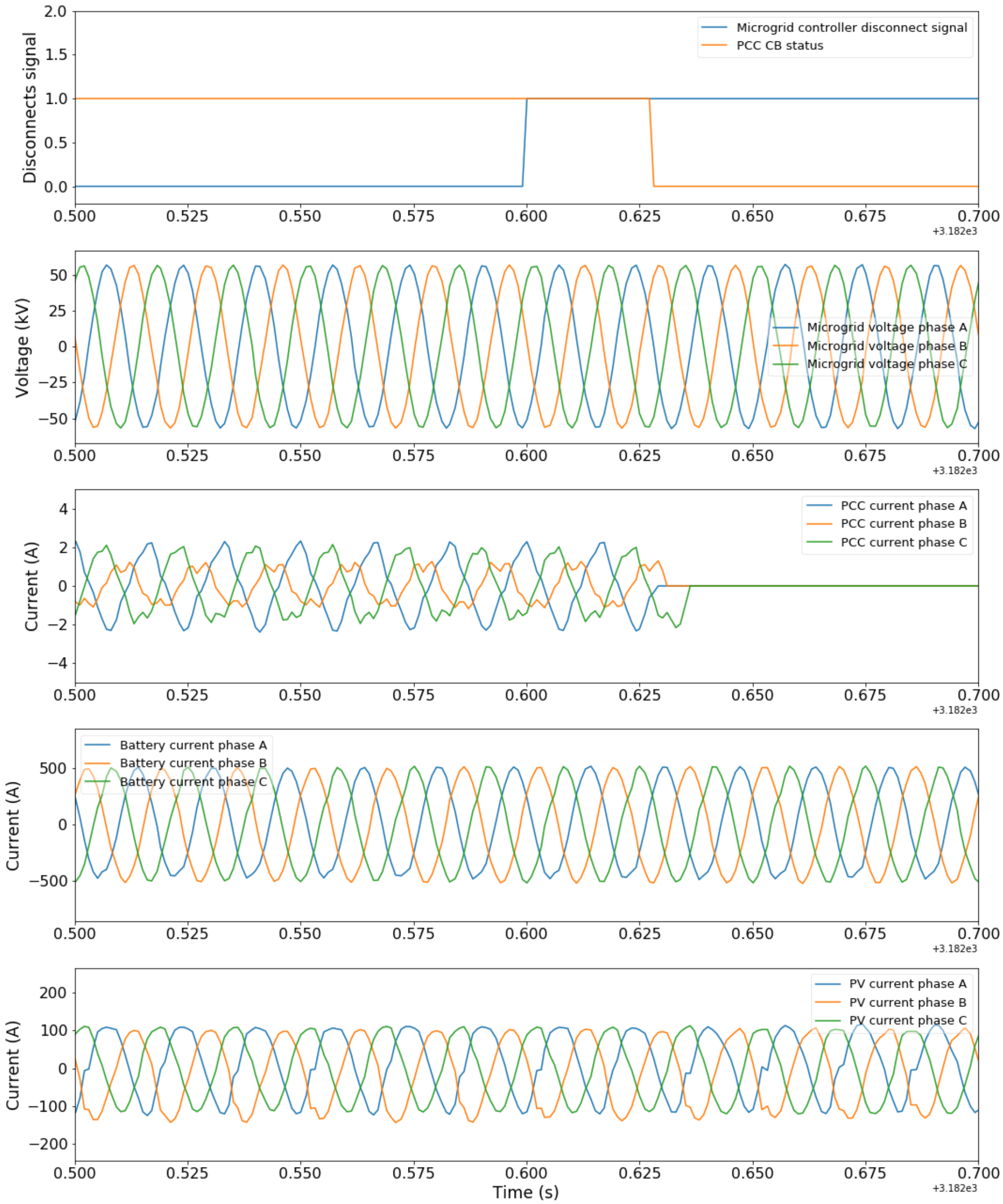
Source: San Diego Gas & Electric Company

Figure A-21: Voltage Amplitude and Frequency during Planned Disconnection (Test B1.1)



Source: San Diego Gas & Electric Company

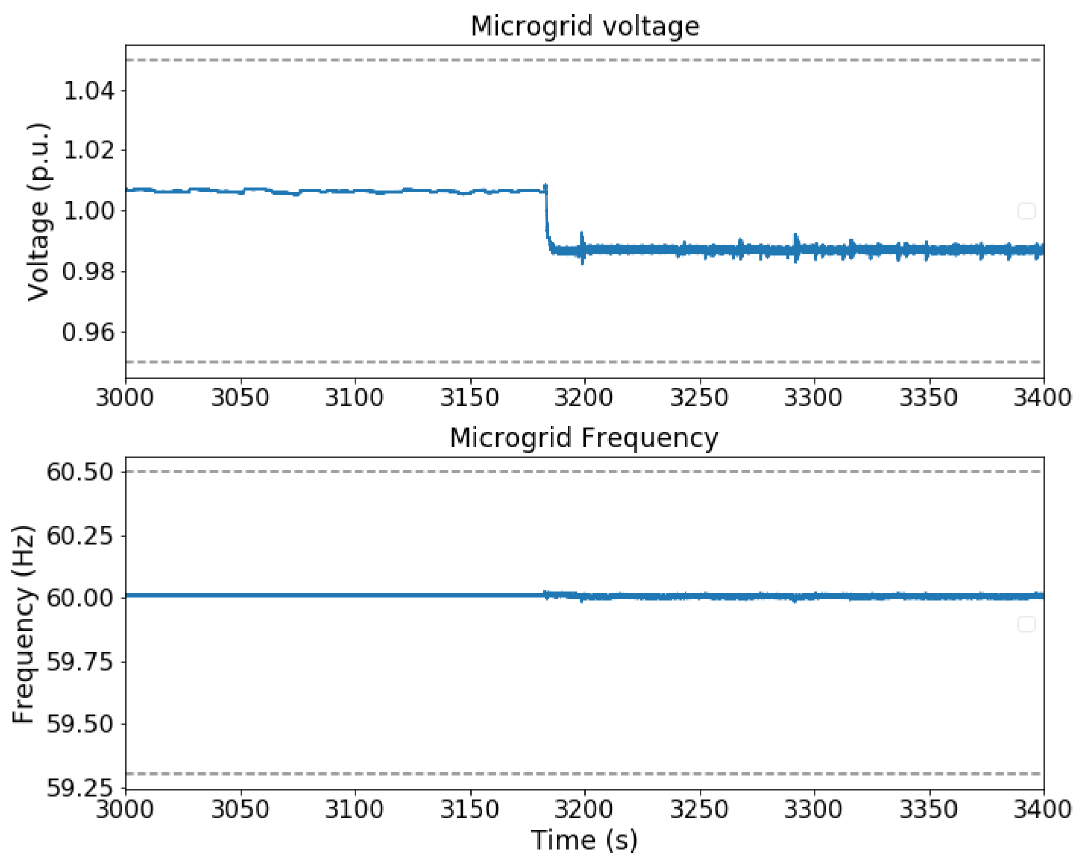
Figure A-22: Planned Disconnection Results for Test B1.2



Source: San Diego Gas & Electric Company

Voltage and frequency measurement for this test case is shown in Figure A-23. A voltage transient occurs at approximately 3,180 seconds, when islanding occurs. After the transition to islanded mode, the voltage exhibits some dynamics but settles to around 0.985 p.u. The spikes in the voltage are caused by switching of capacitor banks. During the test, the voltage is maintained within 0.98–1.01 p.u., which meets the steady-state standards from ANSI. The measured frequency at microgrid PCC exhibits a smooth response during the test, and only a very small overshoot is observed during the islanding moment. The frequency at the PCC meets the steady-state standards from ANSI as well.

Figure A-23: Voltage Magnitude and Frequency during Planned Disconnection (Test B1.2)



Source: San Diego Gas & Electric Company

Results for Test Case B2: Unplanned Separation Due to Abnormal Voltage/Frequency

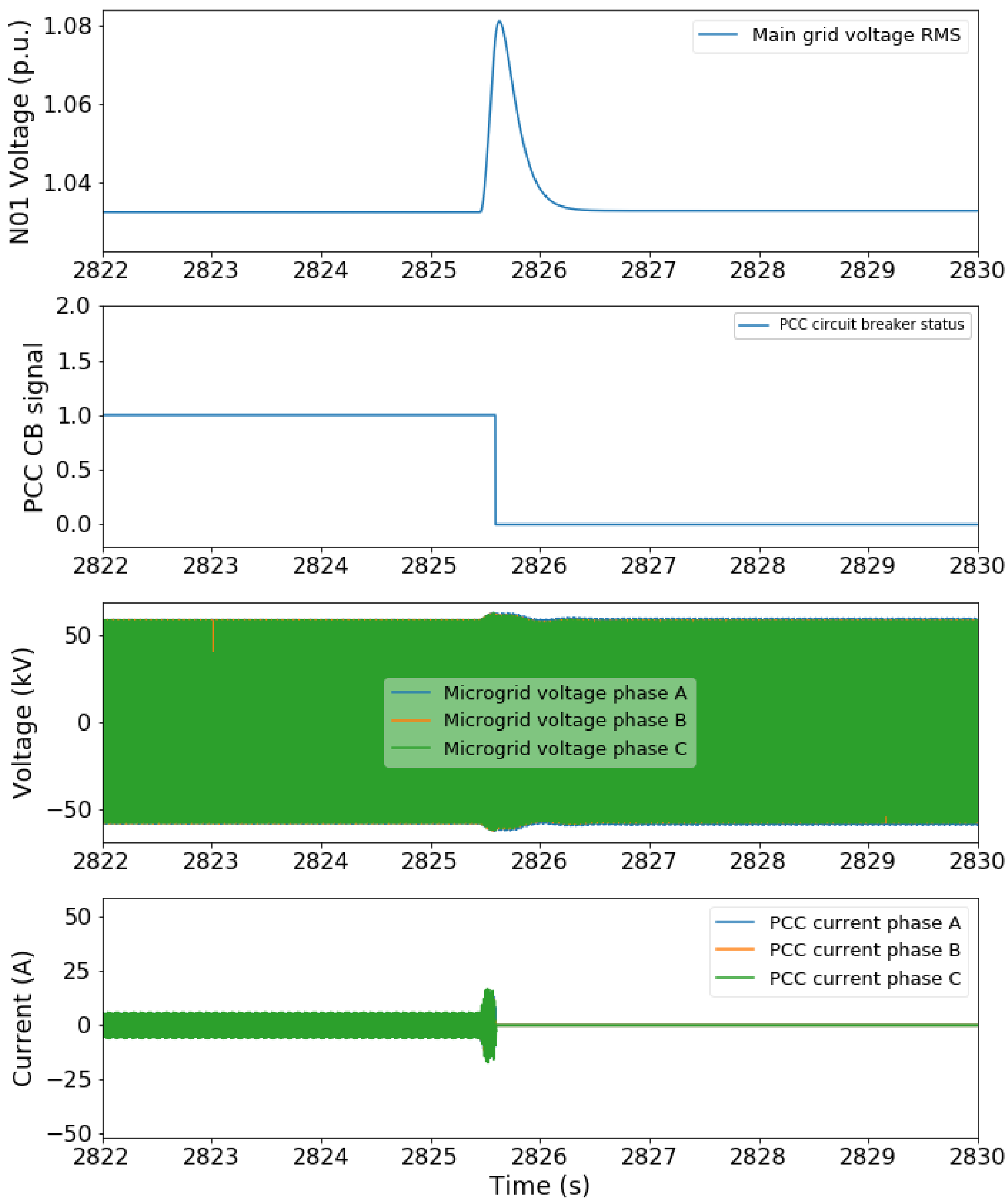
In this case, the microgrid was required to perform an emergency separation from the utility in response to abnormal voltage or frequency conditions observed on the area electric power system. The PV plant and BESS were implemented as virtual components in the RTDS.

The loads and solar insolation were set to the same values as for Test B1.1, when net load exceeded generation from the PV plant, and the active and reactive power exchange across the PCC was set to zero so that the load was supplied by the generators. NREL applied nominal frequency and slightly higher than nominal voltage – based on typical field conditions – for at least two times the trip time allowed per the tables in Section 1.1.1.1. Then NREL applied an abnormal voltage/frequency condition to the area electric power system, on phase A only. To validate the operation of the microgrid, the island was run for a minimum of 2 minutes after the transient event.

Results for Test B2.1.1: Unplanned Separation Due to an Overvoltage (115 percent)

The B2.1 cases tested overvoltage events and in test B2.1.1, an overvoltage of 115 percent was applied at the grid side. Simulation results are shown in Figure A-24.

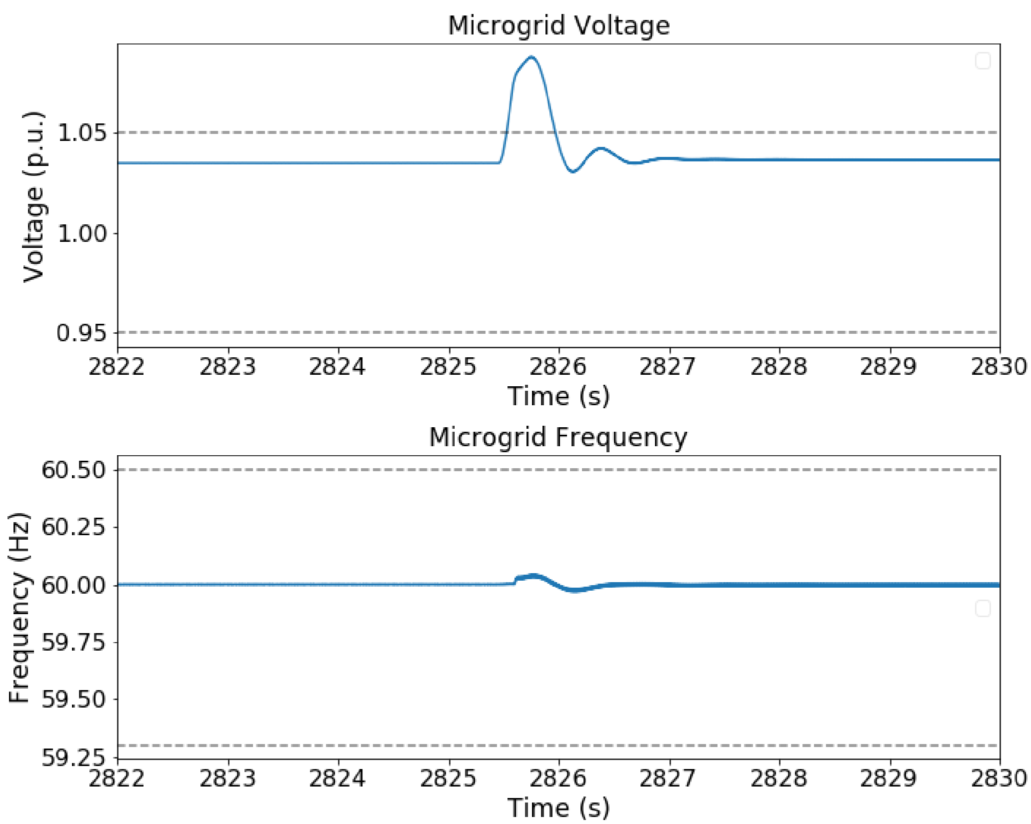
Figure A-24: Unplanned Disconnection Results for Test B2.1.1



Source: San Diego Gas & Electric Company

The top trace shows the grid side voltage of the PCC circuit breaker (N01). The RMS voltage in the plot shows voltage less the 115 percent because the overvoltage event was applied to only one phase. The Wave did not control any protection devices, which is typical for microgrid controllers; rather, it relied on other assets within the microgrid to provide protection functions. The second trace from the top shows that the PCC breaker logic opened the breaker once the voltage went beyond the normal operating voltage and islanded the microgrid from the utility grid. Once the circuit breaker is open, the distributed generators change to voltage/frequency master mode and regulate the microgrid voltage and frequency. The third trace shows the microgrid voltage waveforms and the bottom trace shows the PCC current that goes to zero after the PCC circuit breaker opens. Figure A-25 shows the microgrid RMS voltage and frequency. The voltage remains high after islanding because the voltage reference for the distributed generators is set to match the grid side voltage.

Figure A-25: Voltage Magnitude and Frequency during Unplanned Disconnection (Test B2.1.1)

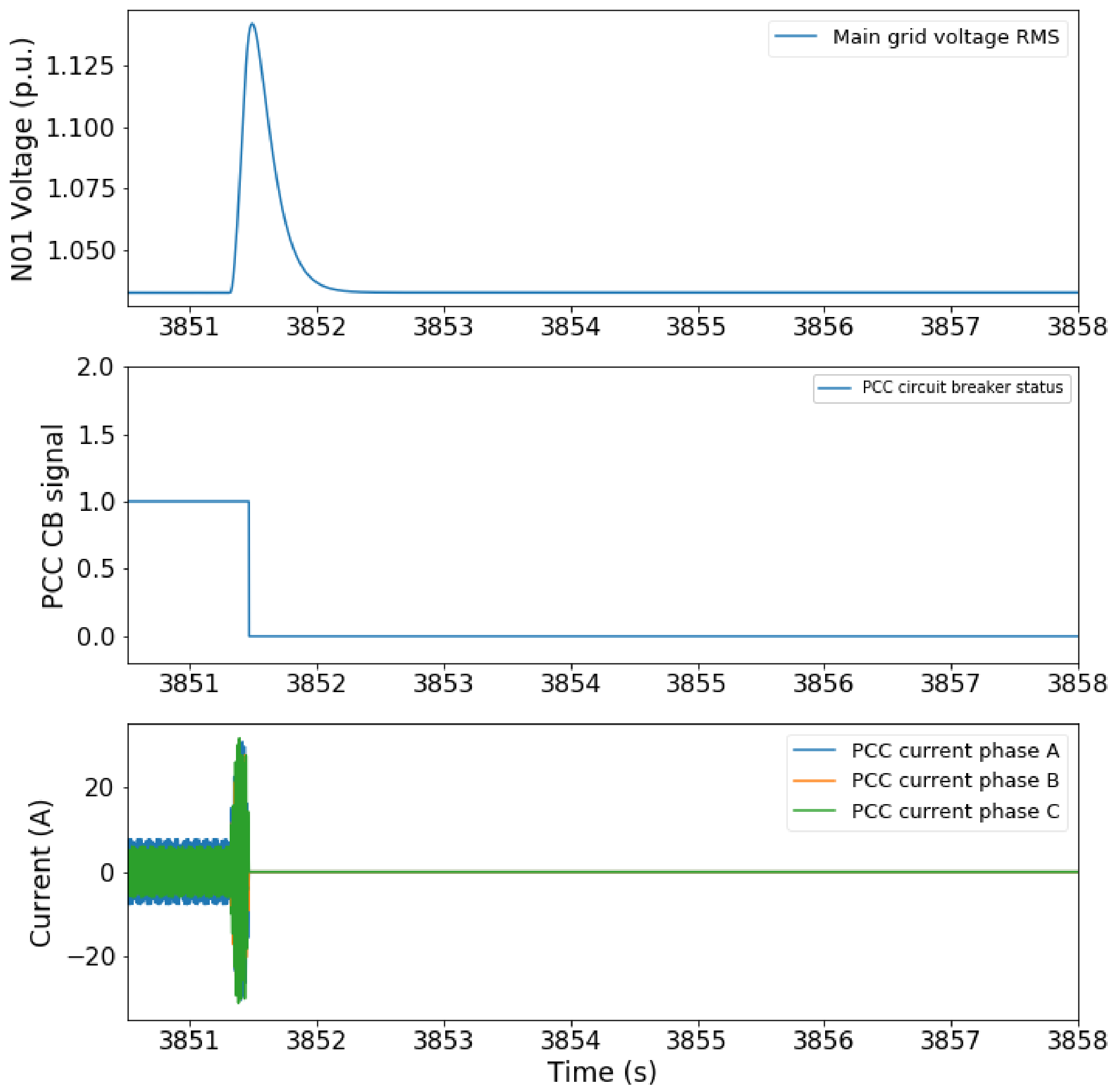


Source: San Diego Gas & Electric Company

Results for Test B2.1.2: Unplanned Separation Due to an Overvoltage (125 percent)

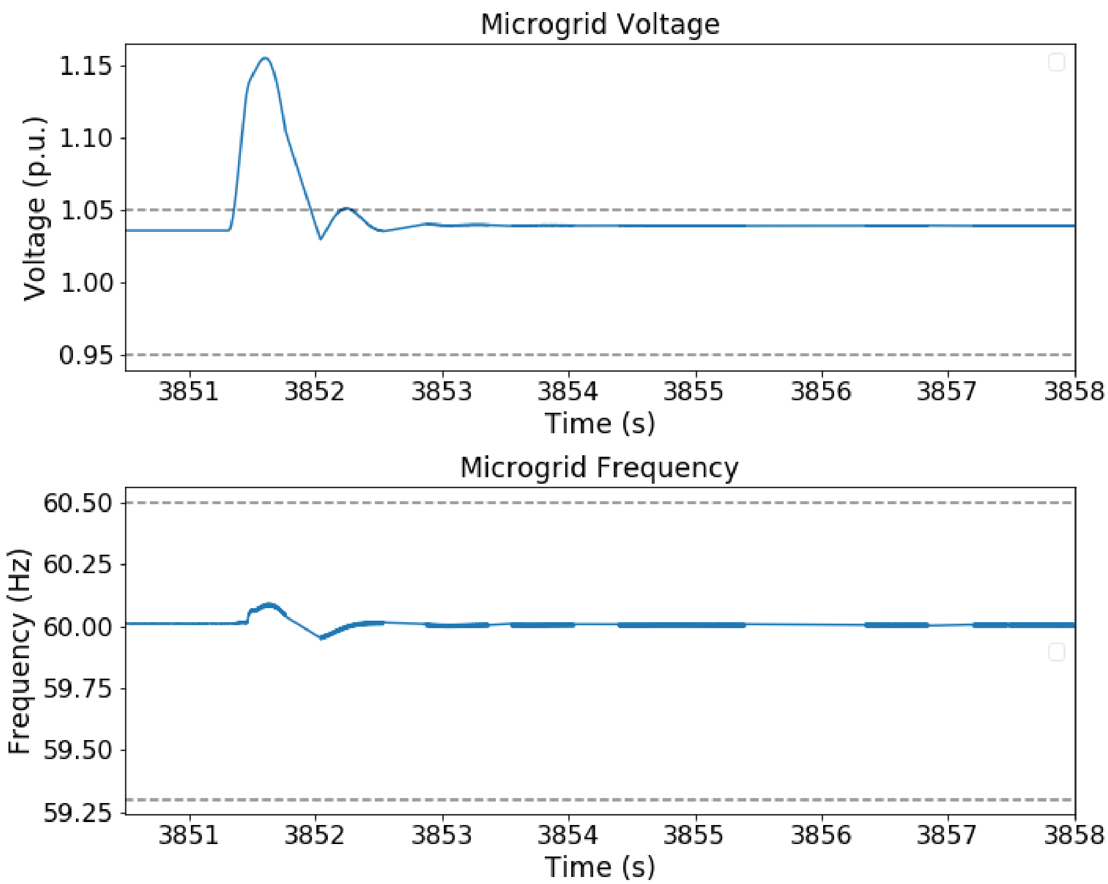
In test B2.1.2, an overvoltage of 125 percent was applied at the grid side, as shown in Figure A-26. The circuit breaker protection tripped once the voltage went beyond the normal operating voltage. This can be observed in Figure A-26 and Figure A-27.

Figure A-26: Unplanned Disconnection Results for Test B2.1.2



Source: San Diego Gas & Electric Company

Figure A-27: Voltage Magnitude and Frequency during Unplanned Disconnection (Test B2.1.2)

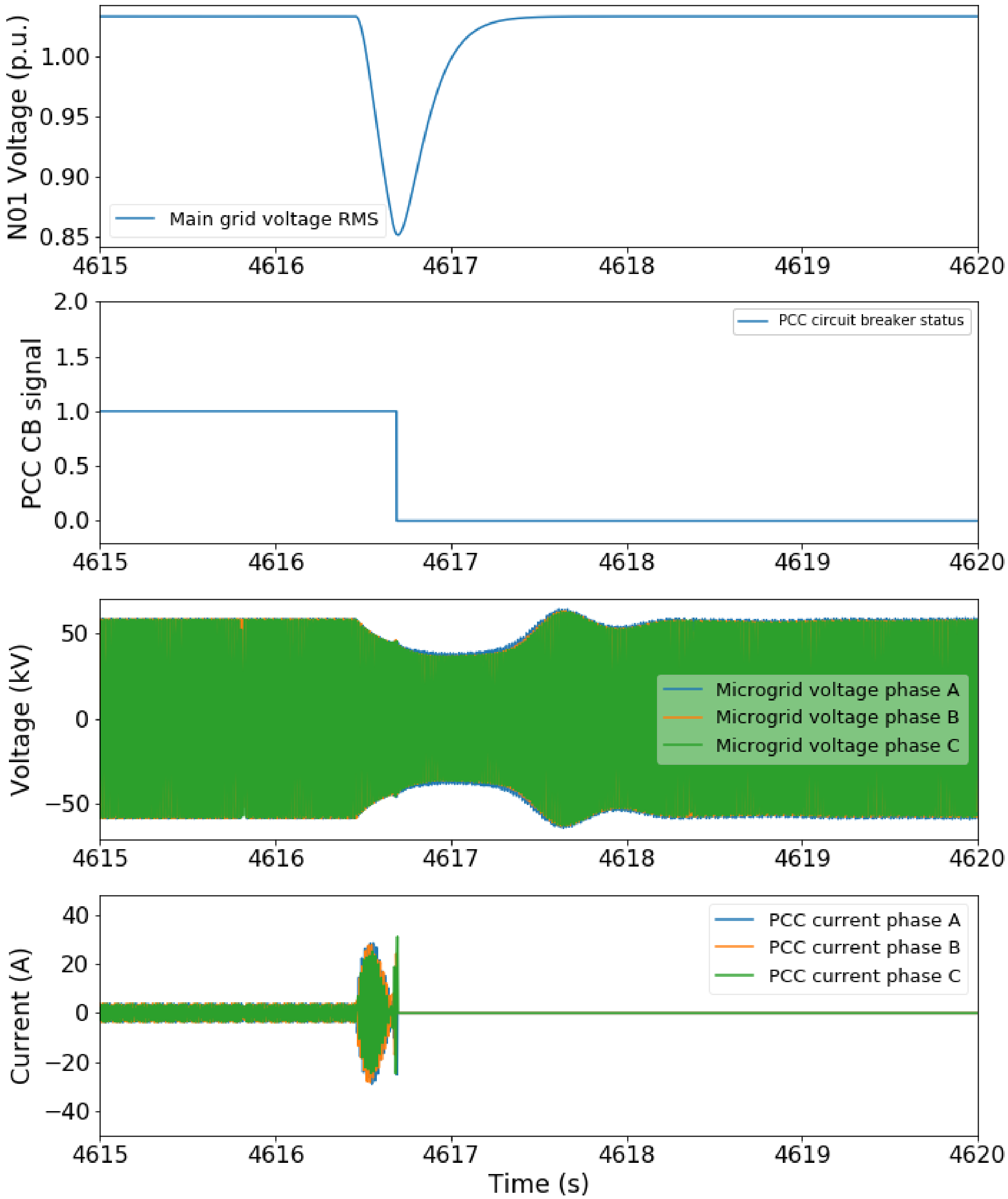


Source: San Diego Gas & Electric Company

Results for Test B2.2.1: Unplanned Separation Due to an Under voltage (75 percent)

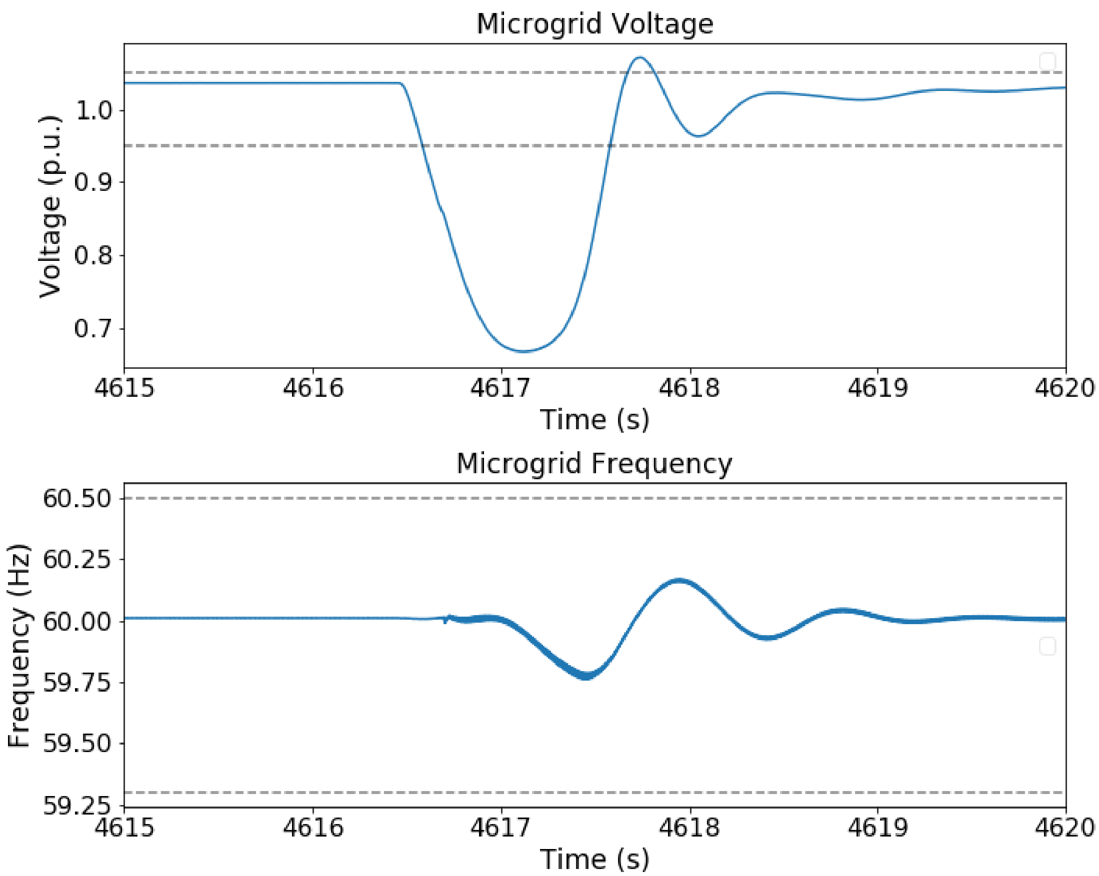
In test cases B2.2, under voltage events were tested. In test case B2.2.1, an under voltage of 75 percent was applied at the grid side, as shown in Figure A-28. The RMS voltage in the plot shows voltage close to 85 percent because the under-voltage event was applied to only one phase. The circuit breaker protection tripped once the voltage went beyond the normal operating voltage. This can be observed in Figure A-28 and Figure A-29. When the PCC circuit breaker opens, the microgrid voltage recovers from the event due to the operation of the distributed generators.

Figure A-28: Unplanned Disconnection Results for Test B2.2.1



Source: San Diego Gas & Electric Company

Figure A-29: Voltage Magnitude and Frequency during Unplanned Disconnection (Test B2.2.1)

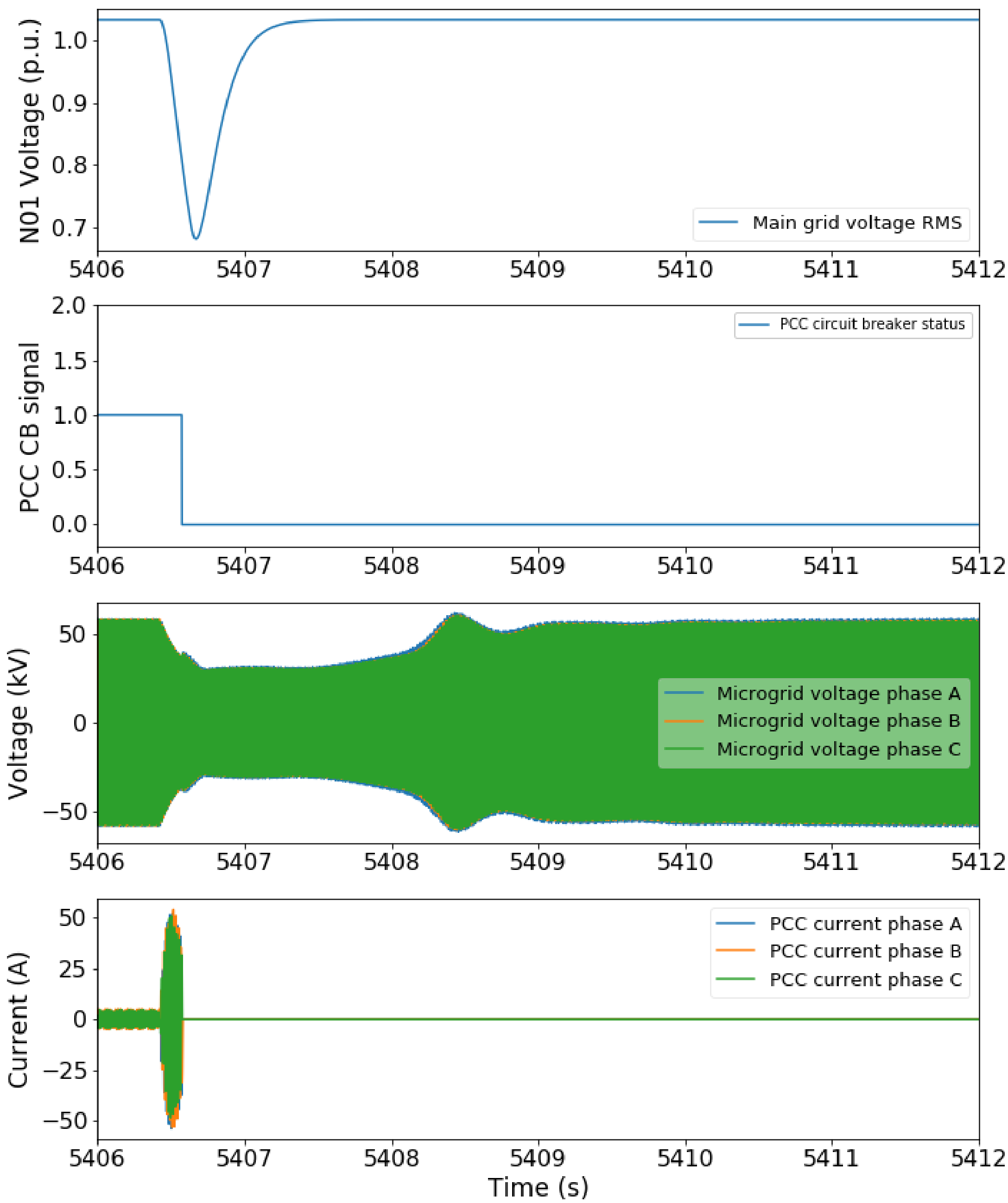


Source: San Diego Gas & Electric Company

Results for Test B2.2.2: Unplanned Separation Due to an Under voltage (50 percent)

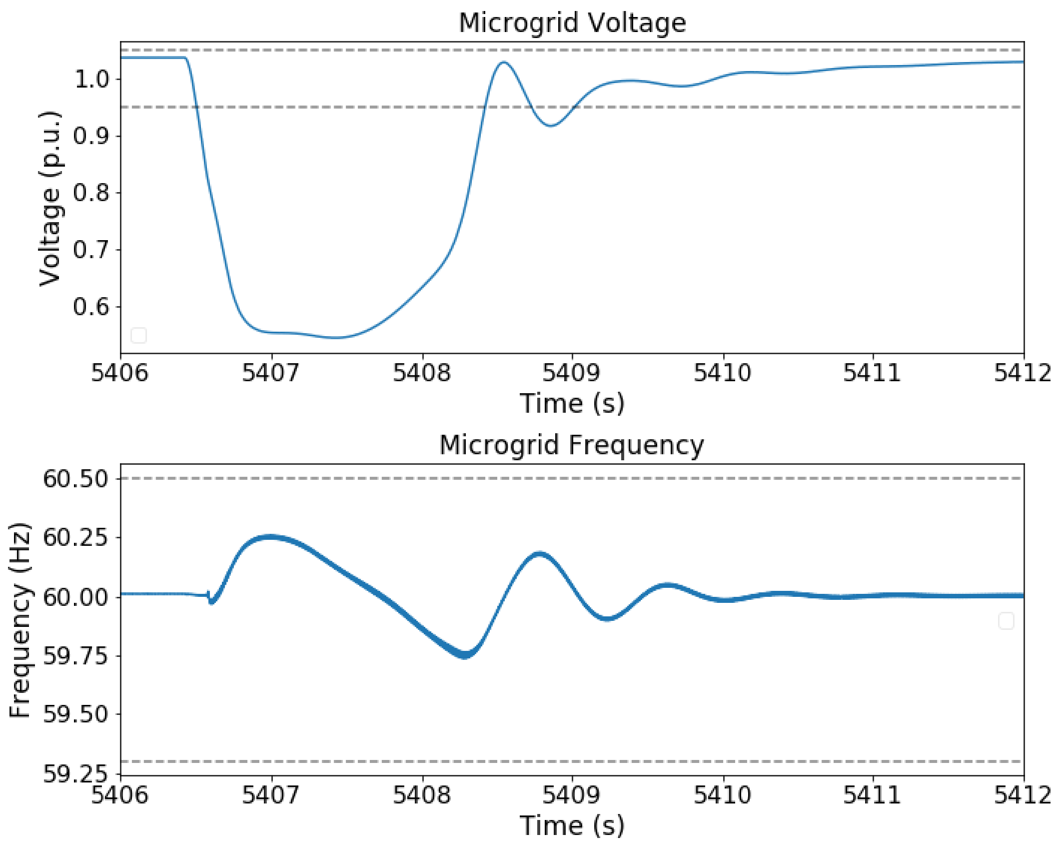
In test case B2.2.2, an under voltage of 50 percent was applied at the grid side as shown in Figure A-30. The circuit breaker protection tripped once the voltage went beyond the normal operating voltage. This can be observed in Figure A-30 and Figure A-31. When the PCC circuit breaker opens, the microgrid voltage recovers from the event due to the operation of the distributed generators.

Figure A-30: Unplanned Disconnection Results for Test B2.2.2



Source: San Diego Gas & Electric Company

Figure A-31: Voltage Magnitude and Frequency during Unplanned Disconnection (Test B2.2.2)

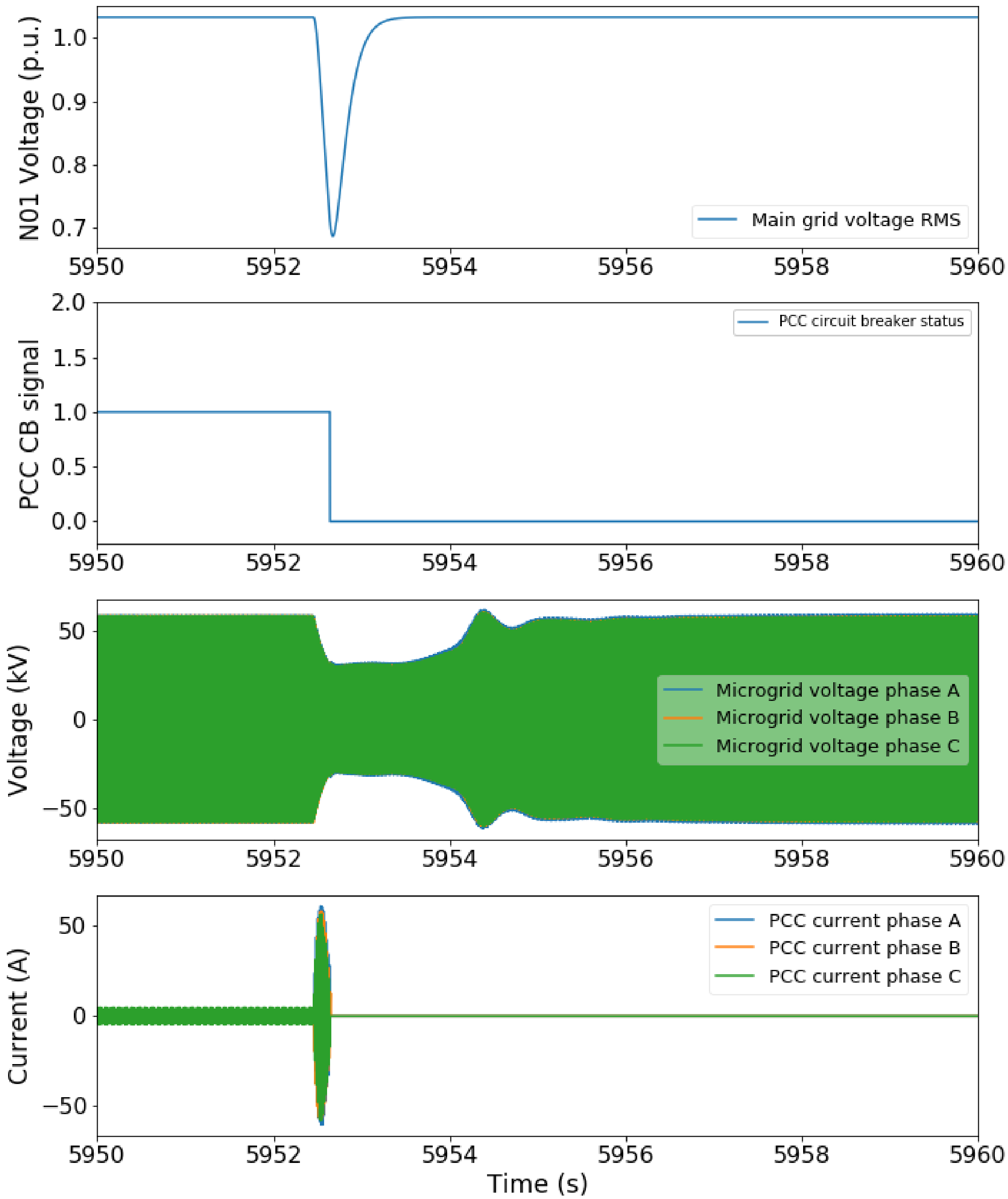


Source: San Diego Gas & Electric Company

Results for Test B2.2.3: Unplanned Separation Due to an Under voltage (43 percent)

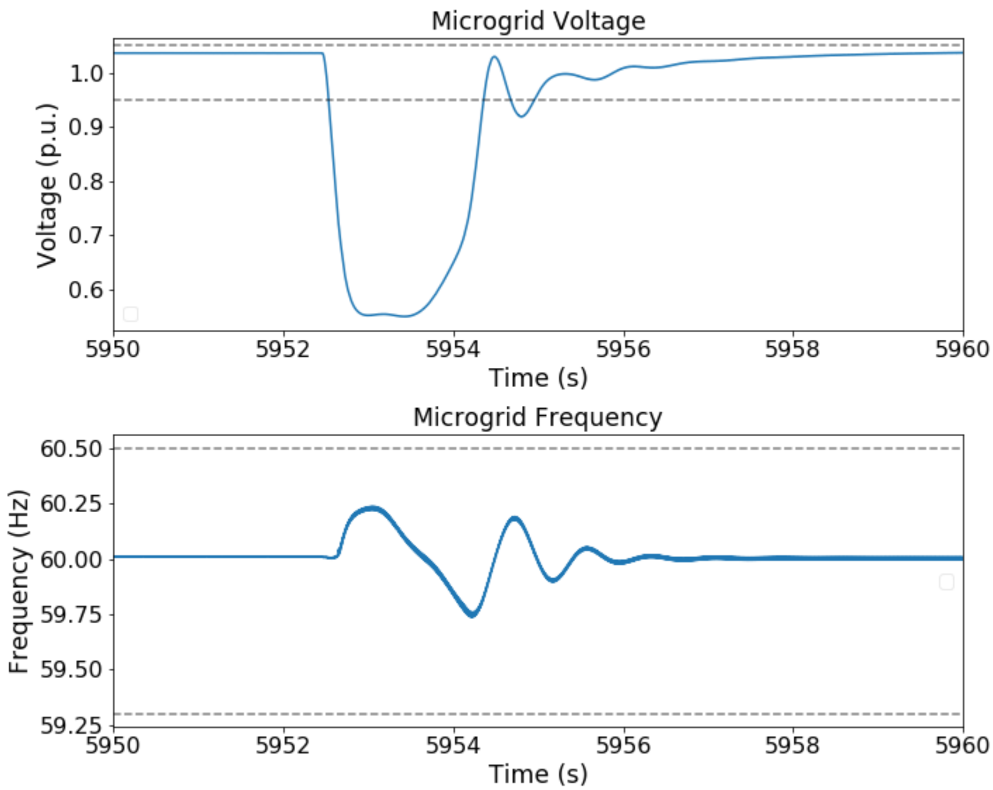
In test B2.2.3, an under voltage of 43 percent was applied at the grid side as shown in Figure A-32. The circuit breaker protection tripped once the voltage went below the normal operating voltage. This can be observed in Figure A-32 and Figure A-33. When the PCC circuit breaker opens, the microgrid voltage recovers from the event due to the operation of the distributed generators.

Figure A-32: Unplanned Disconnection Results for Test B2.2.3



Source: San Diego Gas & Electric Company

Figure A-33: Voltage Magnitude and Frequency during Unplanned Disconnection (Test B2.2.3)



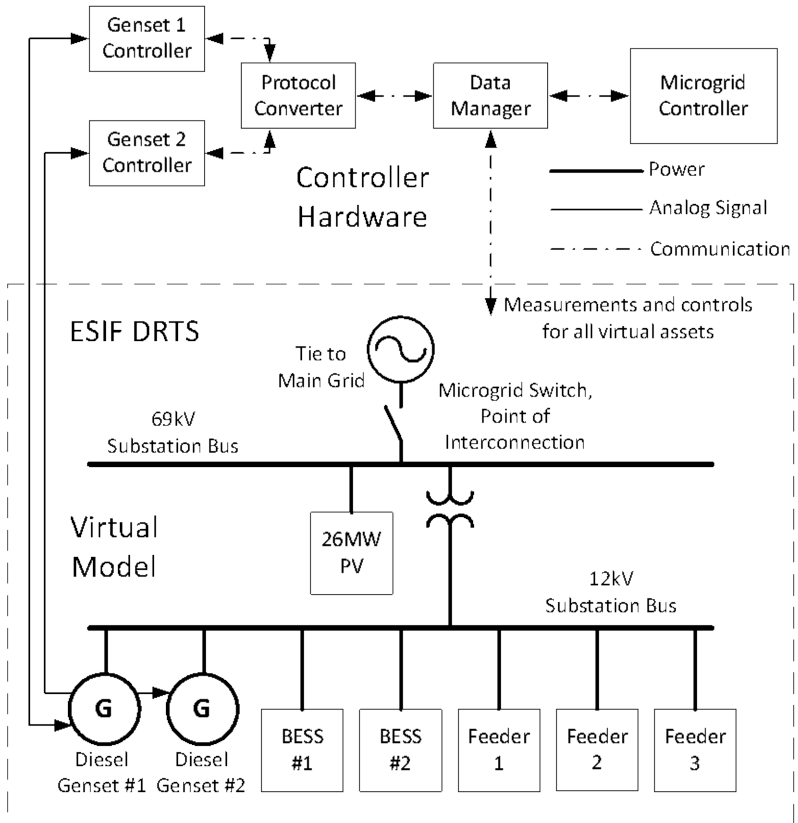
Source: San Diego Gas & Electric Company

Results for Test Case B3: Unplanned Separation Due to an External Fault

In this case, the controller should separate the microgrid from the utility in response to an external fault. Two different load and insolation conditions were simulated. The Wave controller was set to dispatch according to "PQ set points using reliability heuristic" optimizer, and the active and reactive power exchange across the PCC was set to zero. Then an external single-phase-to-ground fault was applied on Phase A, electrically close to the PCC, for one cycle. Similar to test cases B1 and B2, the model was run for a minimum of two minutes after islanding to observe stable operation of the microgrid.

According to the test plan, the ESIF local CHIL/PHIL setup was used (Figure A-34). However, this test case involves applying a fault on the grid side and the fault voltage might damage the grid simulators. For this reason, for the fault scenarios, the PHIL setup was not used for the PV and battery inverter. The inverters were therefore simulated in RSCAD, as shown in Figure A-1. Additionally, NREL observed that the generator controller hardware tripped the distributed generators after the fault was cleared. This was erroneous behavior on the part of the controller and it also did not report an error for opening the distributed generator circuit breaker.

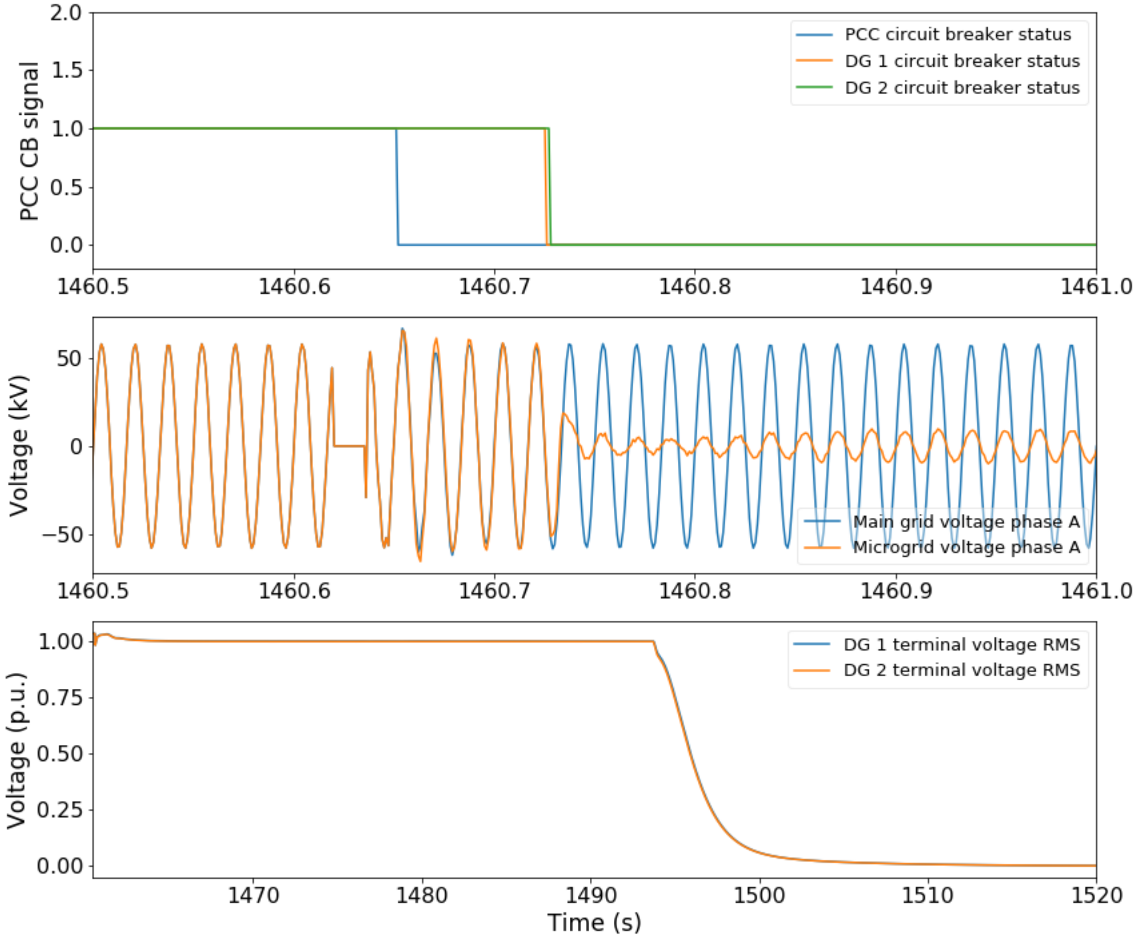
Figure A-34: Borrego Springs ESIF Local CHIL Setup



Source: San Diego Gas & Electric Company

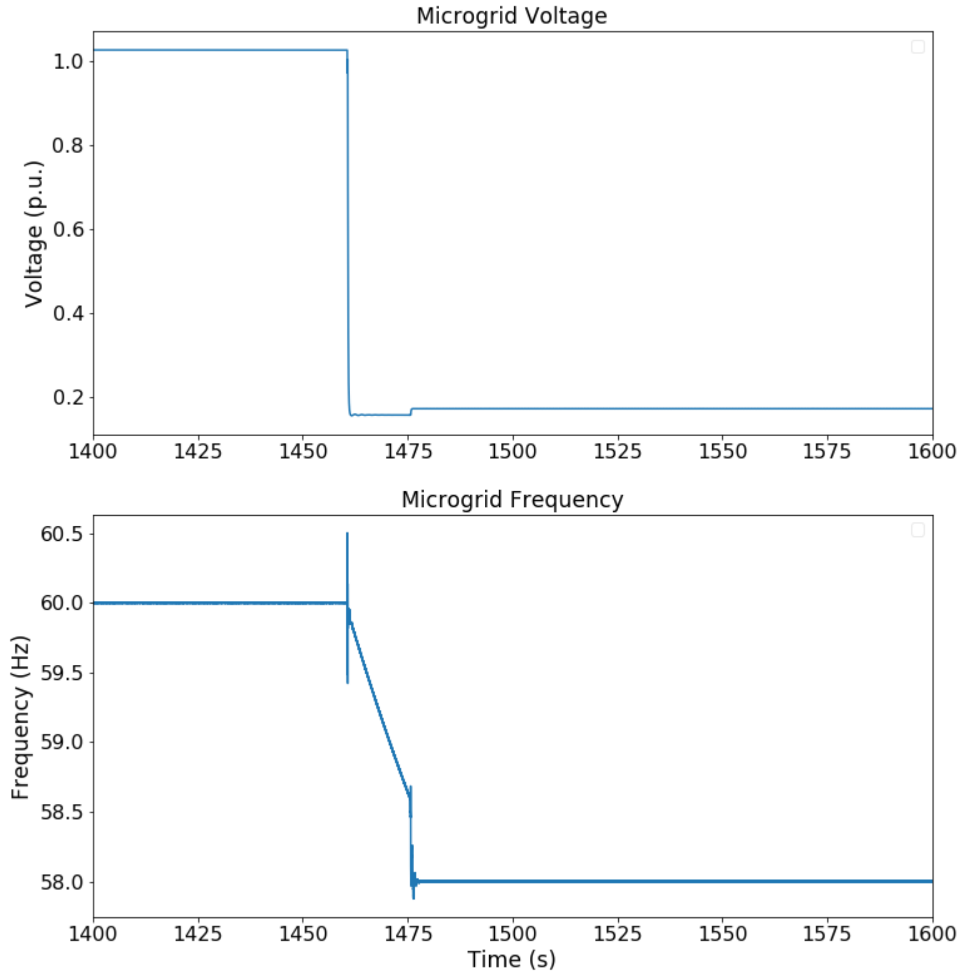
Figure A-35 and Figure A-36 show the results of Test B3.1 with the distributed generator controller hardware. The fault was applied on the grid side on phase A at 1460.63 seconds and it was cleared in half a cycle. The PCC circuit breaker opened and the microgrid was sustained for another few cycles, but the distributed generator controller opened the distributed generators' terminal circuit breakers at approximately 1460.75 seconds. Therefore, the B3 tests were executed with the simulated distributed generator controller in the RSCAD model.

Figure A-35: Unplanned Disconnection Results for Test B3.1 with Generator Controller Hardware



Source: San Diego Gas & Electric Company

Figure A-36: Microgrid Voltage and Frequency at PCC for Test B3.1 with Generator Controller Hardware

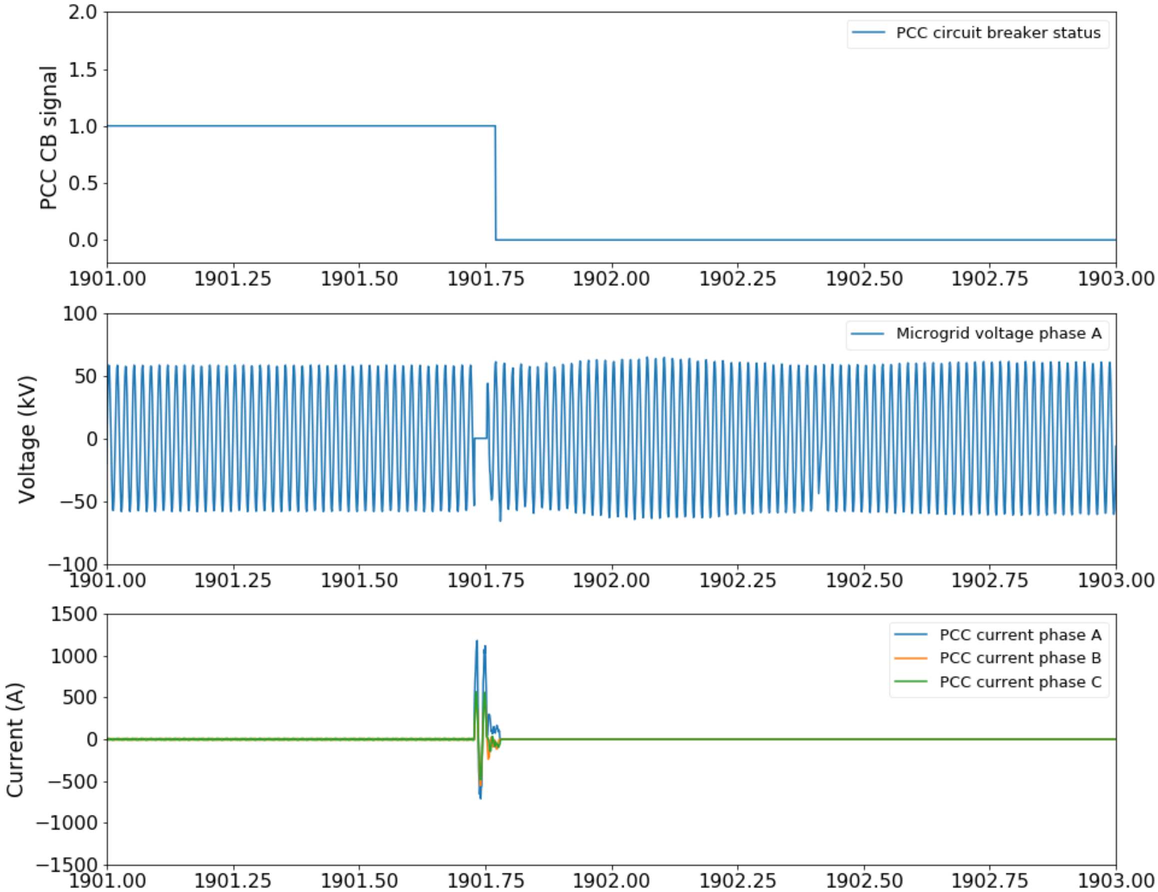


Source: San Diego Gas & Electric Company

Results for Test B3.1: Unplanned Separation Due to an External Fault with High Load and Low Non-dispatchable Generation

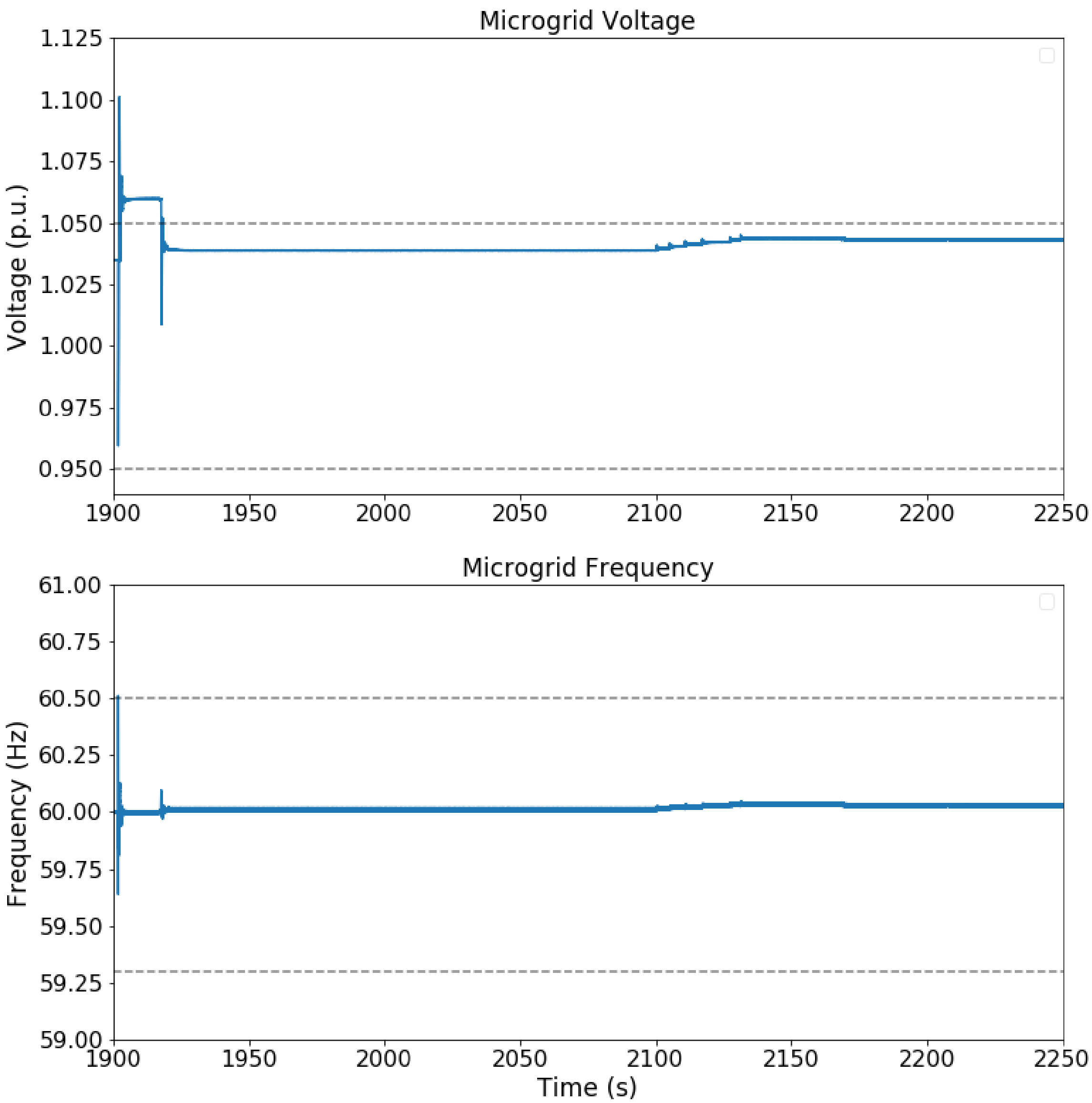
The loads and solar insolation were set to the same values as for Test B1.1 when the net load was high and generation from the NRG PV plant was low. Simulation results for Test Case B3.1 are shown in Figure A-37 and Figure A-38. The Wave did not control any protection devices, which is typical for microgrid controllers; rather, it relied on other assets within the microgrid to provide protection functions. Therefore, the PCC circuit breaker protection logic opened the PCC breaker after observing the fault. Once the PCC circuit breaker opened, the mode of operation of the distributed generators was changed to voltage/frequency master. The top trace shows the disconnect signal issued by the PCC circuit breaker controller because of the fault. The trace second from the top shows the voltage on the microgrid side of the PCC breaker. The bottom trace shows the current through the PCC breaker. The microgrid operated in islanded mode for several minutes.

Figure A-37: Unplanned Disconnection Results for Test B3.1



Source: San Diego Gas & Electric Company

Figure A-38: Microgrid Voltage and Frequency at PCC for Test B3.1

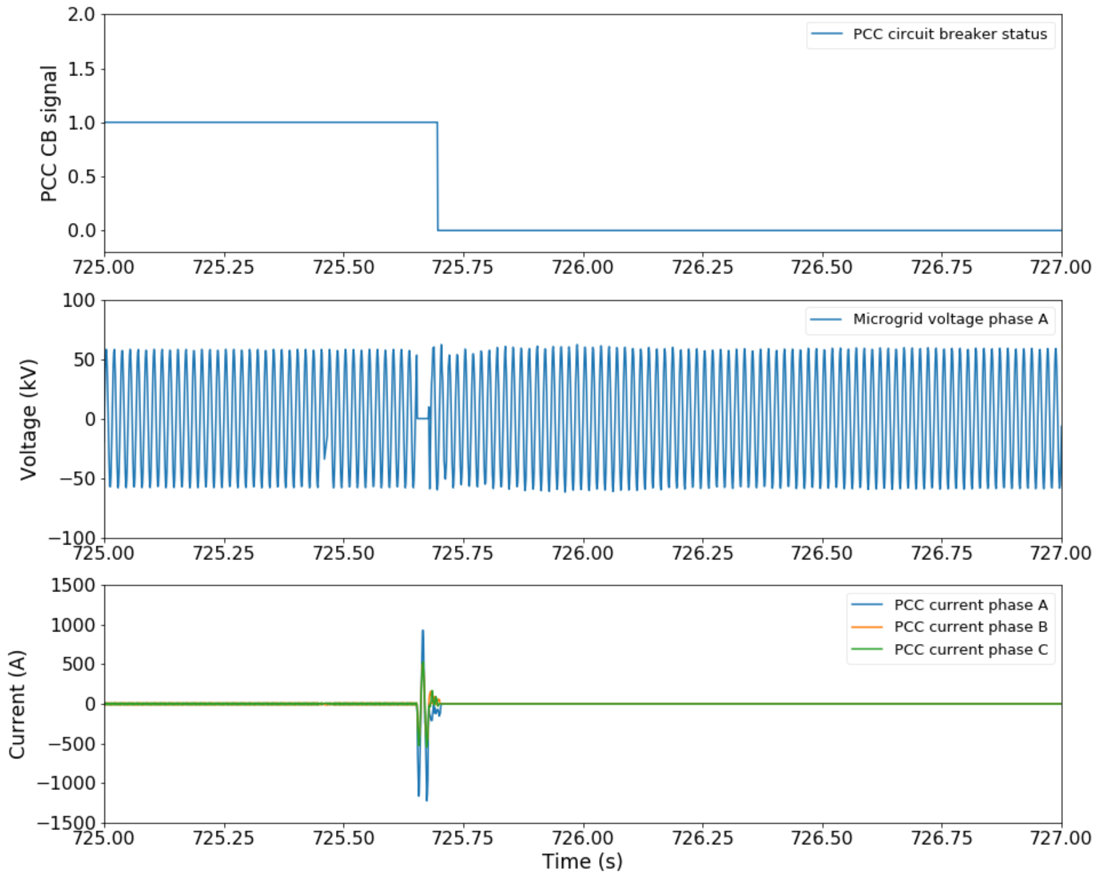


Source: San Diego Gas & Electric Company

Results for Test B3.2: Unplanned Separation Due to an External Fault with Low Load and High Non-dispatchable Generation

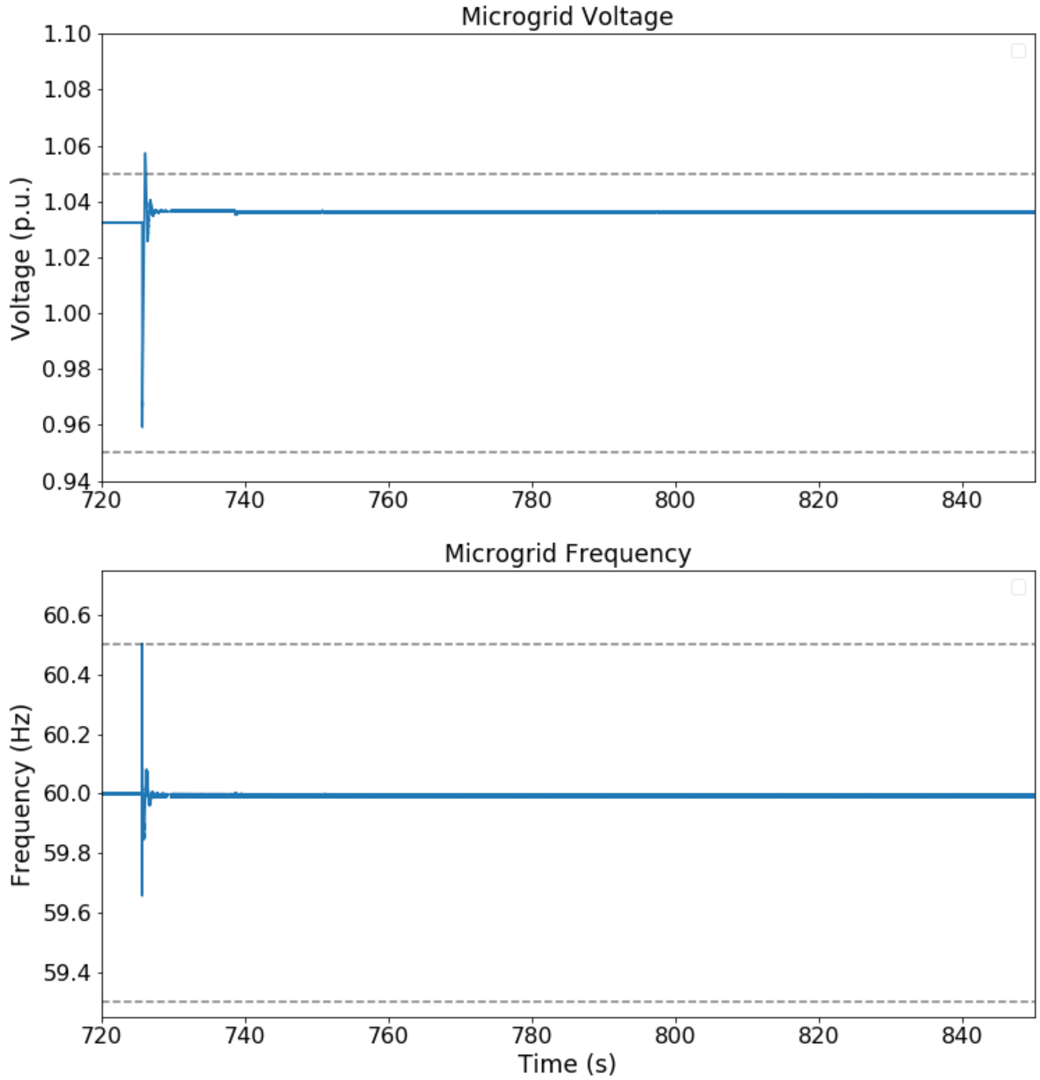
The loads and solar insolation were set to the same values as for Test B1.2 when the net load was low and generation from the PV plant was high. Simulation results for Test B3.2 are shown in Figure A-39 and Figure A-40. The top trace shows the disconnect signal issued by PCC protection. The trace second from the top shows the voltage on the microgrid side of the PCC breaker. Once the fault is cleared and the PCC breaker is open, the distributed generators become the voltage and frequency masters and maintain the voltage and frequency. The bottom trace shows the current through the PCC breaker. Similar to Test B3.1, the Wave microgrid controller did not control any protection devices, and the PCC breaker logic opened the breaker and islanded the microgrid from the utility grid. The microgrid operated in islanded mode for several minutes.

Figure A-39: Unplanned Disconnection Results for Test B3.2



Source: San Diego Gas & Electric Company

Figure A-40: Microgrid Voltage and Frequency at PCC for Test B3.2



Source: San Diego Gas & Electric Company

Results for Test Case B4: Unplanned Separation Due to the Loss of Utility Power

In this case, the microgrid controller should separate the microgrid from the area utility in response to an unplanned utility outage and the formation of an unintentional island. Due to time constraints, this test case was not simulated.

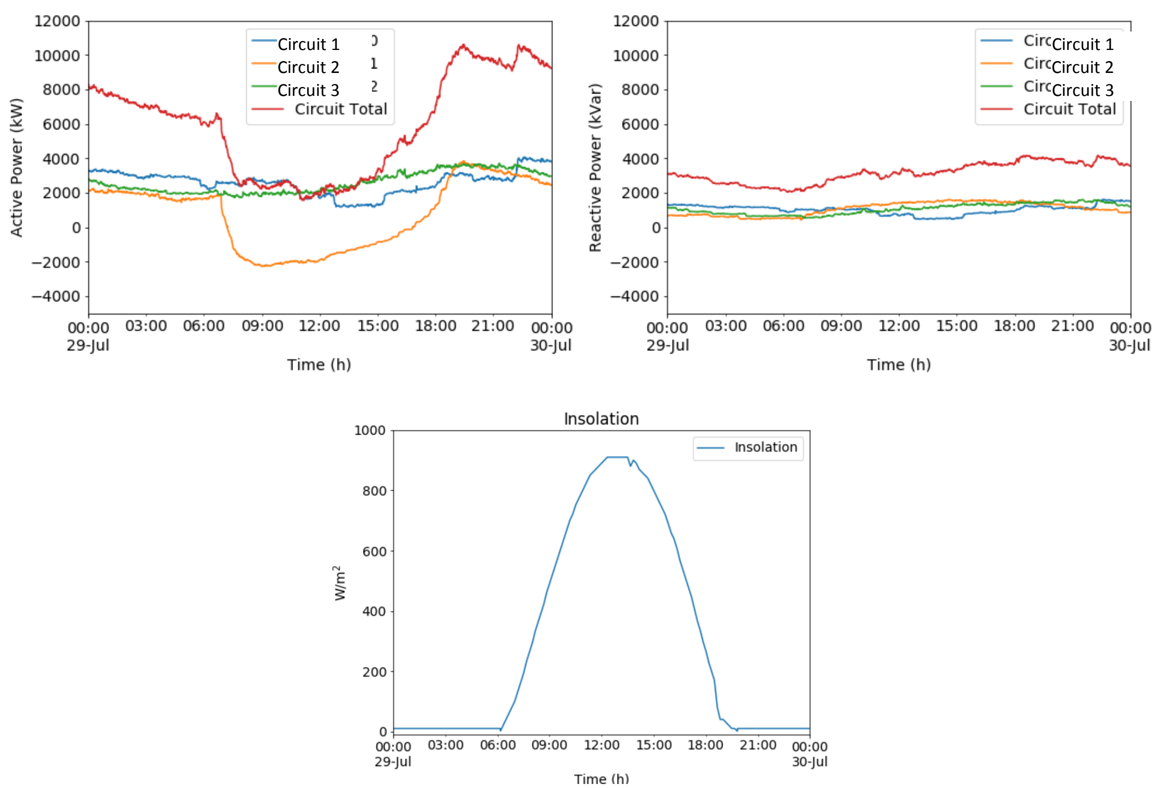
Scenario C: Operating the Microgrid While Separated from the Utility

The purpose of simulating the scenario of operating the microgrid while separated from the utility was to validate the ability of the Wave control platform to successfully operate the microgrid within normal operating conditions while separated from the external utility (microgrid switch is open). NREL evaluated whether the microgrid voltage amplitude and frequency were maintained within specified ranges under typical load and generation profiles (functional requirement C3). NREL also evaluated whether the controller responded appropriately to internal faults (functional requirement C4), appropriately dispatched generation and controllable loads to meet the dispatch objectives during islanded operation (functional requirement C5) and provided enhanced resilience (functional requirement C6).

Similar to Scenario A, NREL simulated the heavy and light load profiles shown in Figure A-41 and Figure A-42 and NREL set dispatch for survivability. Accelerated (faster than real time) simulations were performed whereby 10 minutes of simulation time equaled 15 seconds of real time. As noted for Scenario A, the Wave code that NREL used was only able to dispatch one SESS, because only one SESS is dispatchable in the field.

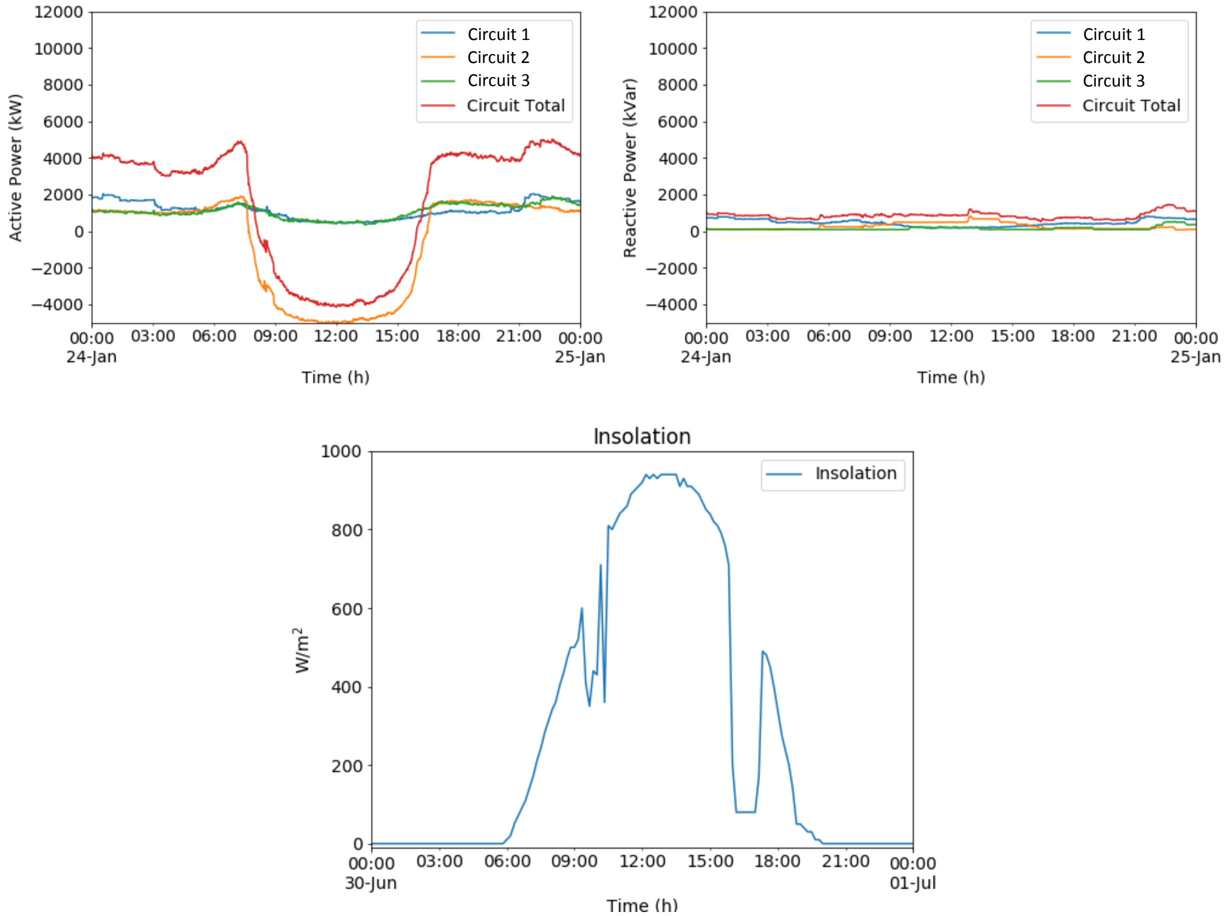
The microgrid was set up to run in islanded mode (separated from the area grid) following the procedure for planned islanding described in Test Case B1.

Figure A-41: Load and Solar Insolation Profiles for Heavy Load on July 29, 2014



Source: San Diego Gas & Electric Company

Figure A-42: Load and Solar Insolation Profiles for Light Load on January 24, 2014



Source: San Diego Gas & Electric Company

Results for Test Case C1: Normal Islanded Operation in Baseline Configuration

For this test case, the microgrid should be configured such that only the distributed generators are available for the Wave to dispatch. Due to time constraints, this test case was not simulated.

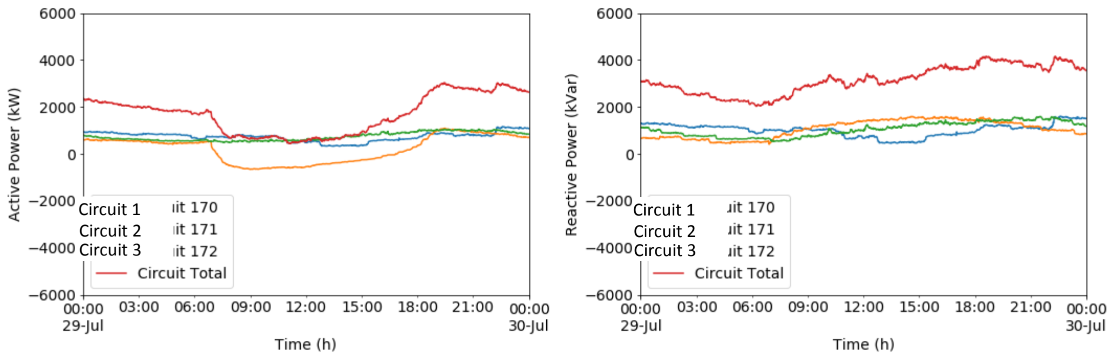
Results for Test Case C2: Normal Islanded Operation

In this test case, the microgrid was configured such that all assets were available for dispatch by the Wave. Due to time constraints, only one battery initial state-of-charge condition was simulated and repetition of the lightly loaded tests using the remote ESIF/ITF CHIL/PHIL test setup and simulation of contingency conditions could not be completed.

Results for Test C2.1: Normal Islanded Operation with Heavy Load

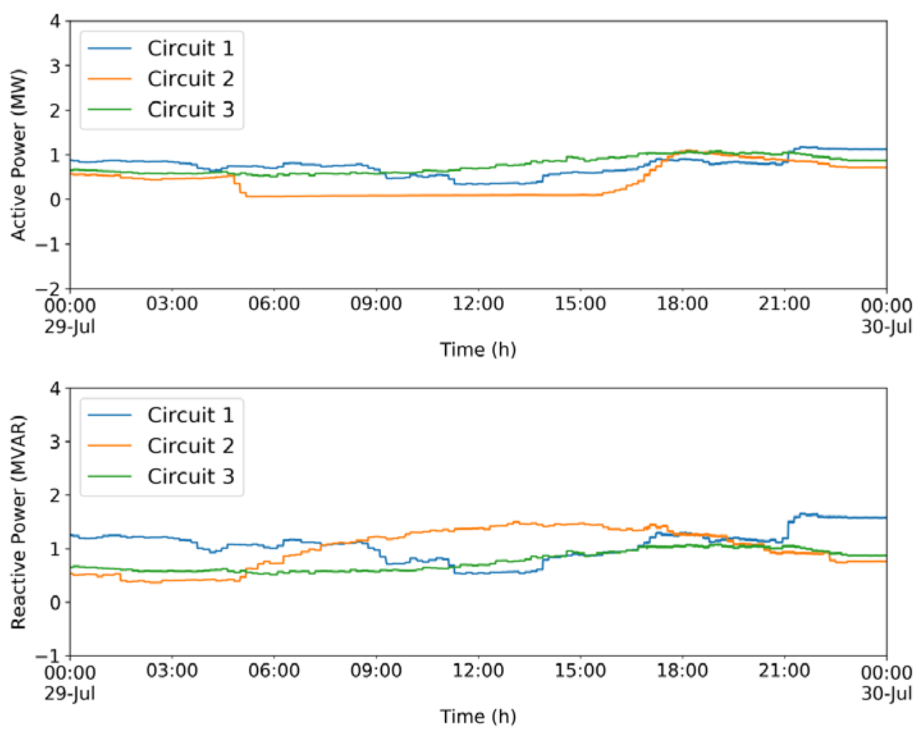
For this test, NREL used the insolation profile for the heavy load condition shown in Figure A-41 and the initial battery state of charge was set to 70 percent for the SESS. The results from test A2.1 showed that the microgrid generation assets cannot support islanded operation during the early morning hours and late night hours when there is no PV generation, and therefore the net active load power was scaled down by a factor of 3.5 from the heavy net load profiles shown in Figure 35 and this resulted in the net load profiles shown in Figure A-43. The net power profiles for each distribution circuit within the microgrid are shown in Figure A-44. A line plot of generation and power references for the PV and battery inverters are shown in Figure A-45. During the night, the distributed generators provide support for the load. During the day, the PV supports most of the load and charges the batteries. The power flow through the PCC circuit breaker is zero because the microgrid is operated in islanded mode.

Figure A-43: Plots of Net Load Power Profiles for Test C2.1



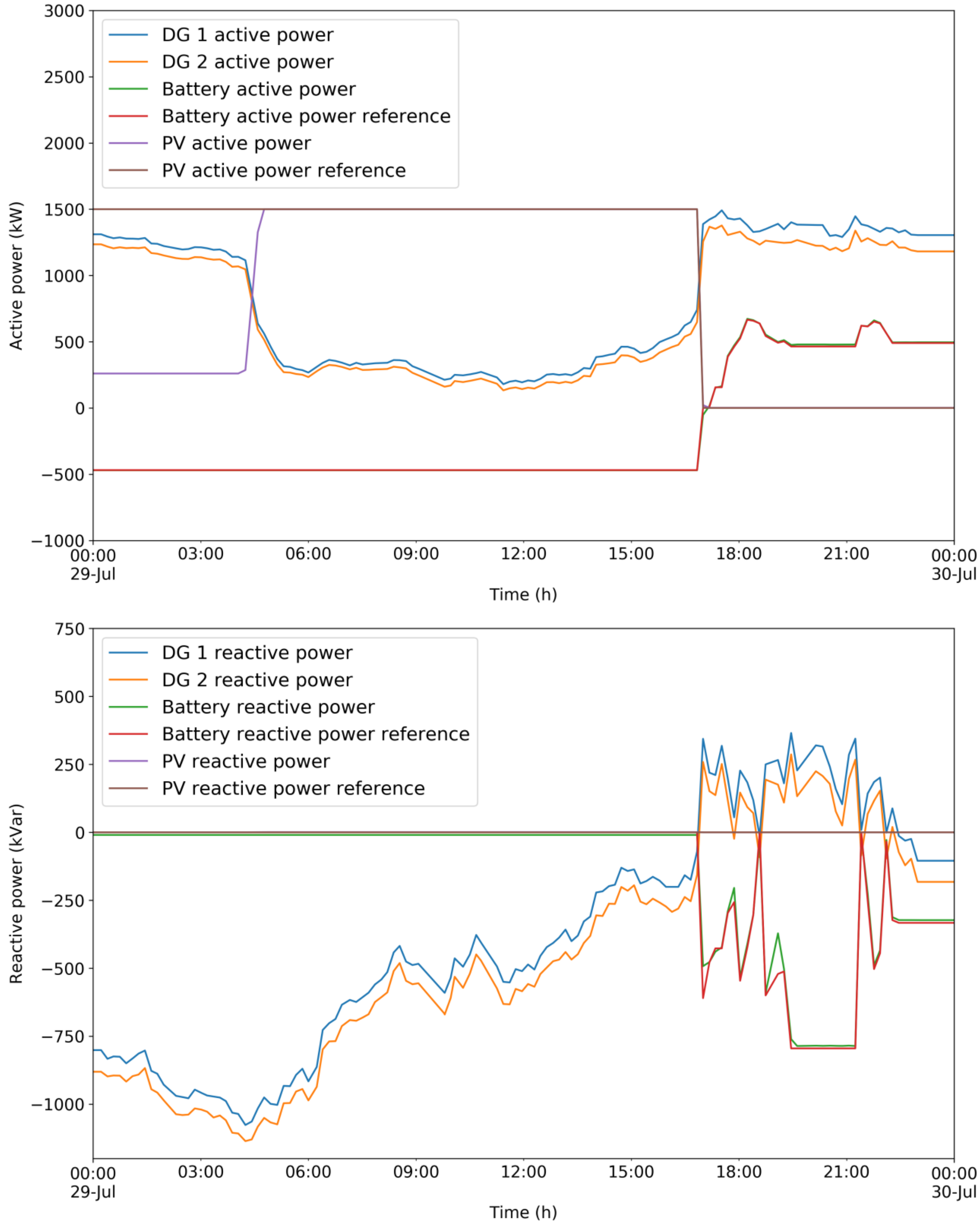
Source: San Diego Gas & Electric Company

Figure A-44: Line Plot of Net Power Flow for each Individual Circuit within the Microgrid for Test C2.1



Source: San Diego Gas & Electric Company

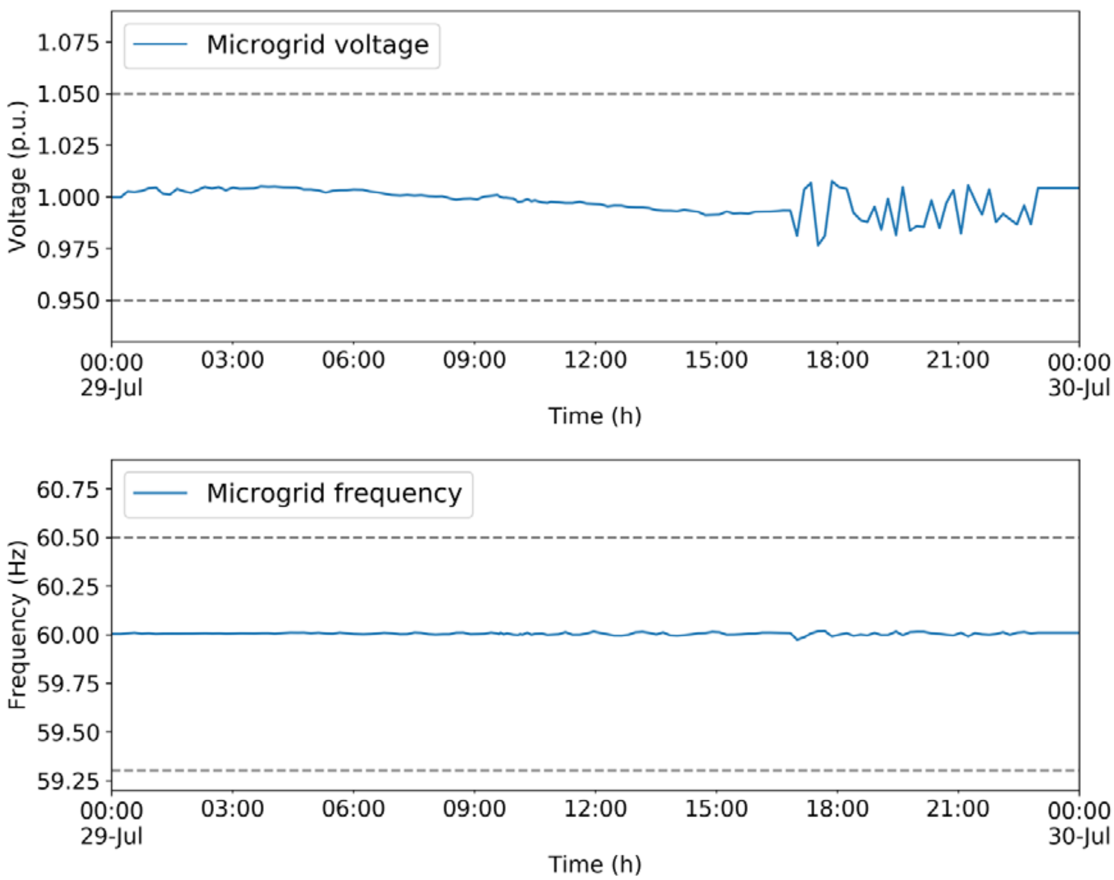
Figure A-45: Line plot of generation within the microgrid for Test C2.1



Source: San Diego Gas & Electric Company

The simulated microgrid voltage amplitude and frequency are shown in Figure A-46. Dotted lines show the limits for steady-state operation to provide perspective on the observed deviations. The voltage remains within the steady state limits, but there are significant voltage fluctuations after about 17:00, when the SESS is dispatched to discharge. The voltage fluctuations are due to significant variation in the reactive power reference that Wave issues to the battery, and the genset controllers cannot adjust their reactive power fast enough to mitigate the voltage fluctuations. These results meet the steady-state frequency requirements. However, the Wave microgrid controller does not provide closed-loop control of voltage amplitude and frequency. Instead, it relies on the distributed generators to regulate the voltage and frequency to the set points provided by the Wave microgrid controller. The voltage amplitude and frequency results are therefore a reflection of the distributed generator controllers' capabilities and not of the Wave microgrid controller's capabilities to directly maintain voltage and frequencies within the desired ranges.

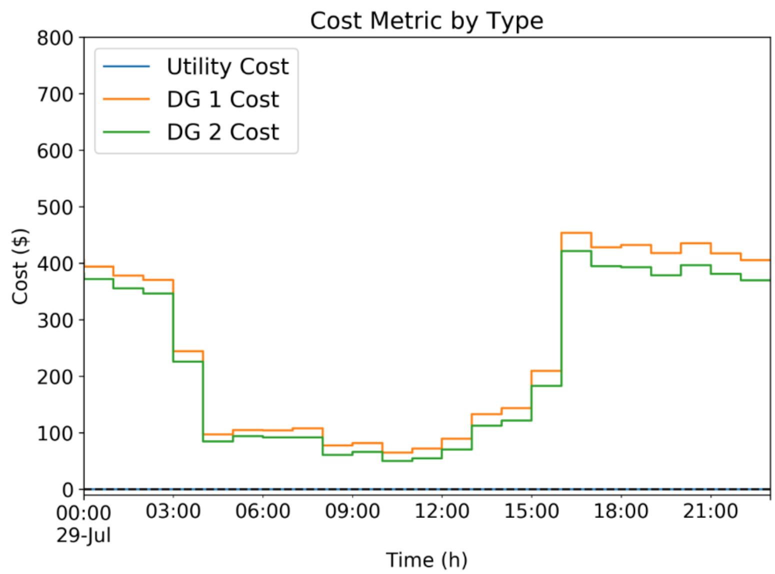
Figure A-46: Voltage Amplitude and Frequency Results for Test C2.1

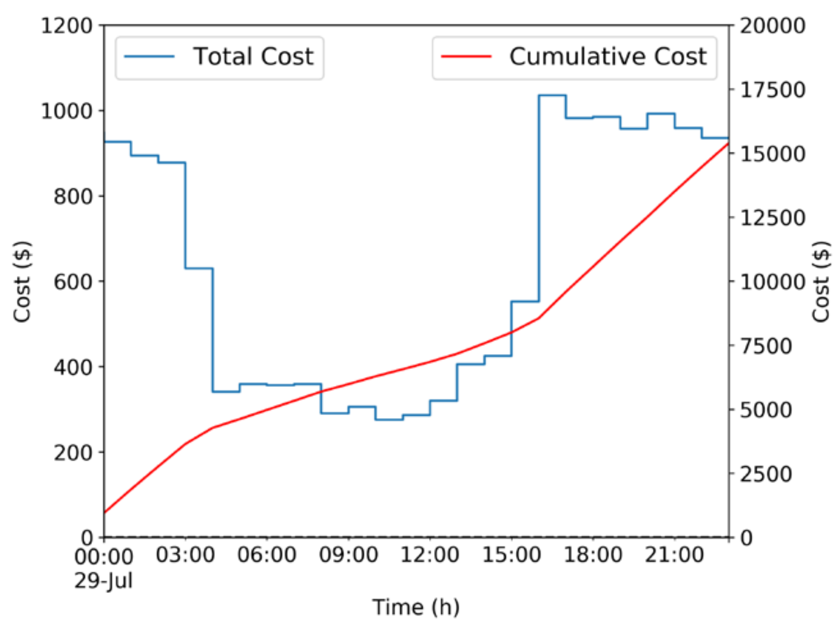


Source: San Diego Gas & Electric Company

NREL calculated metrics related to economic operation, shown in Figure A-47. The survivability metric reflects whether sufficient resources are operating and available to support the microgrid's seamless transition to island mode, so it does not apply here.

Figure A-47: Total and cumulative cost results for Test C2.1



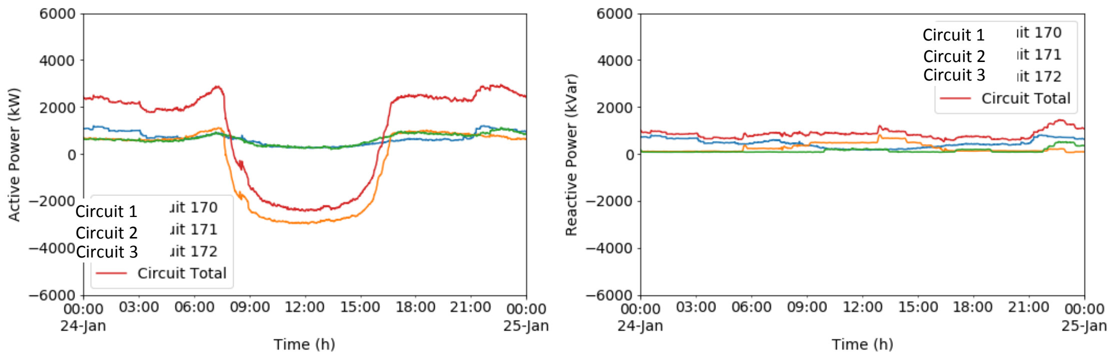


Source: San Diego Gas & Electric Company

Results for Test C2.2: Normal Islanded Operation with Light Load

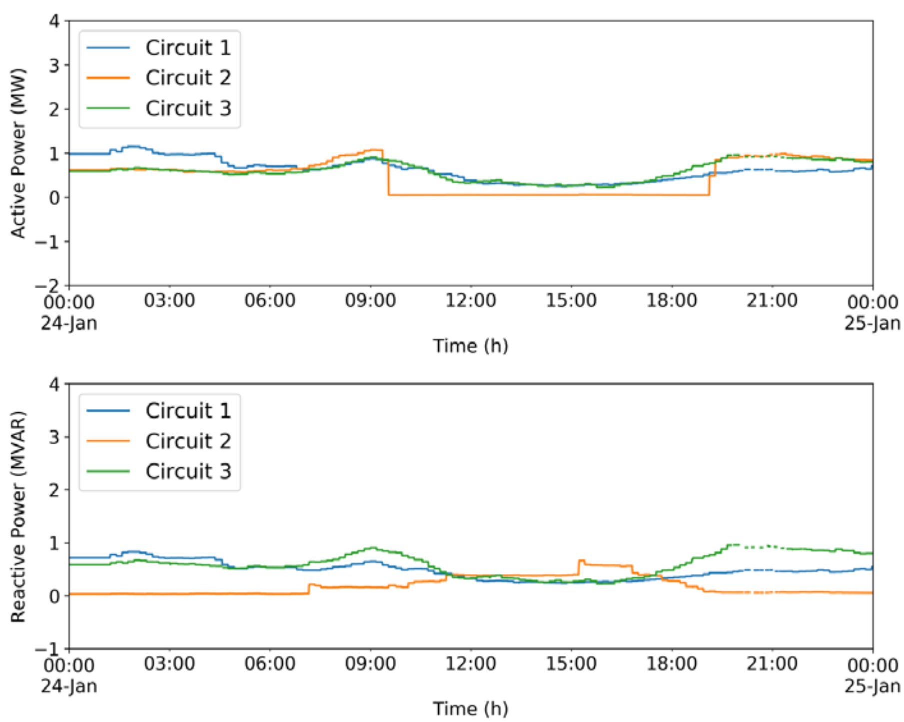
The net active load power was scaled down by a factor of 1.7 from the light net load profiles shown in Figure A-42 and this resulted in the net load profiles shown in Figure A-48. Insolation profiles are set to be the same as for test C1.2, and the initial battery state of charge is set to 70 percent for the SESS. The net power profiles for each distribution circuit within the microgrid are shown in Figure A-49. A line plot of generation is shown in Figure A-50. The power flow through the PCC circuit breaker is zero because the model is operated in islanded mode. The distributed generators are set to operate in voltage/frequency mode and they are able to supply all the load in the microgrid. The PV is not dispatched because it would not reach the minimum dispatch requirement for the PV inverters. The battery is dispatched to charge late in the day to compensate for capacitor switching that results in a very low power factor for the distributed generators.

Figure A-48: Plots of Net Load Power Profiles for Test C2.2



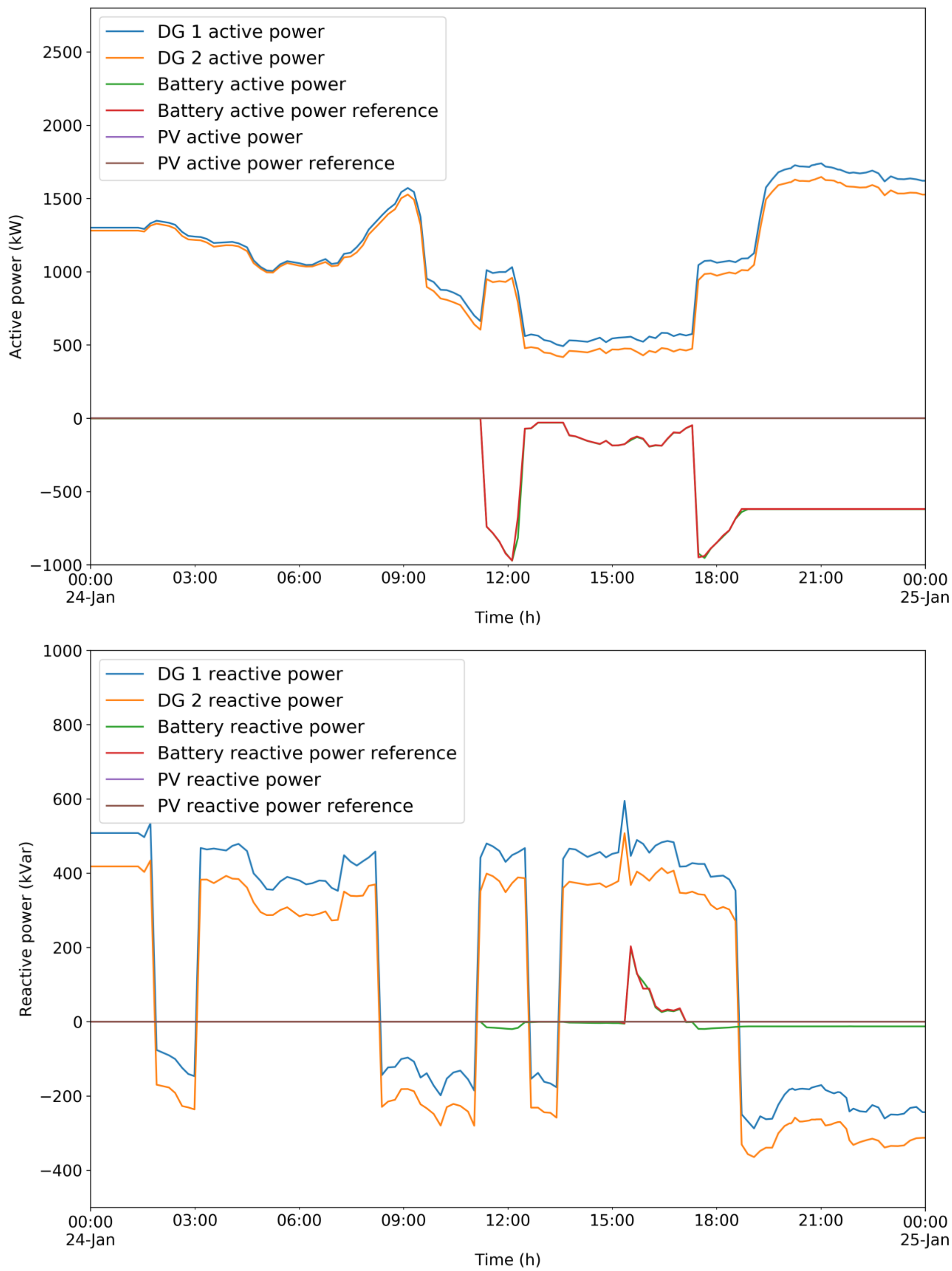
Source: San Diego Gas & Electric Company

Figure A-49: Line Plot of Net Power Flow for each Individual Circuit within the Microgrid for Test C2.2



Source: San Diego Gas & Electric Company

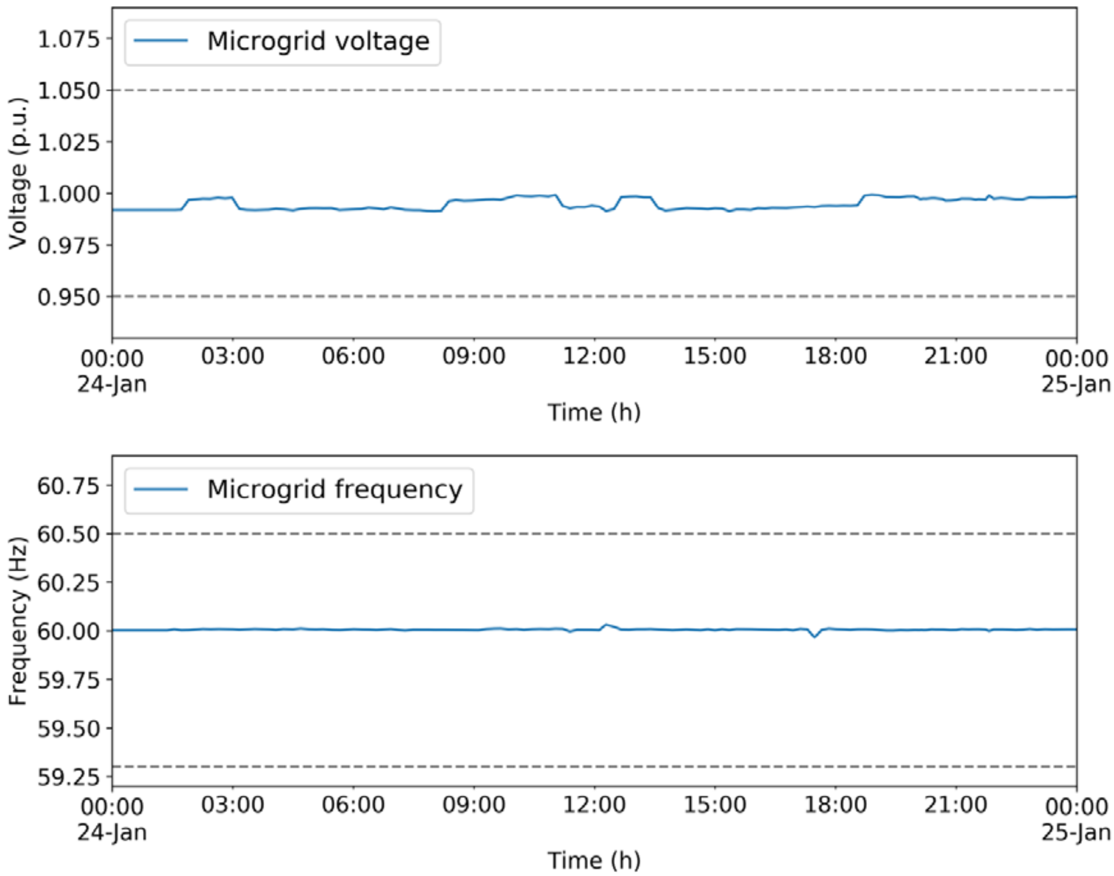
Figure A-50: Line Plot of Generation within the Microgrid for Test C2.2



Source: San Diego Gas & Electric Company

The simulated microgrid voltage amplitude and frequency are shown in Figure A-51. Both the voltage and frequency remain within the steady state limits. The step changes in voltage are due to capacitor switching on the distribution circuits. As discussed in Test C2.1, the voltage amplitude and frequency results are not a reflection of the Wave microgrid controller's capabilities to maintain voltage and frequencies.

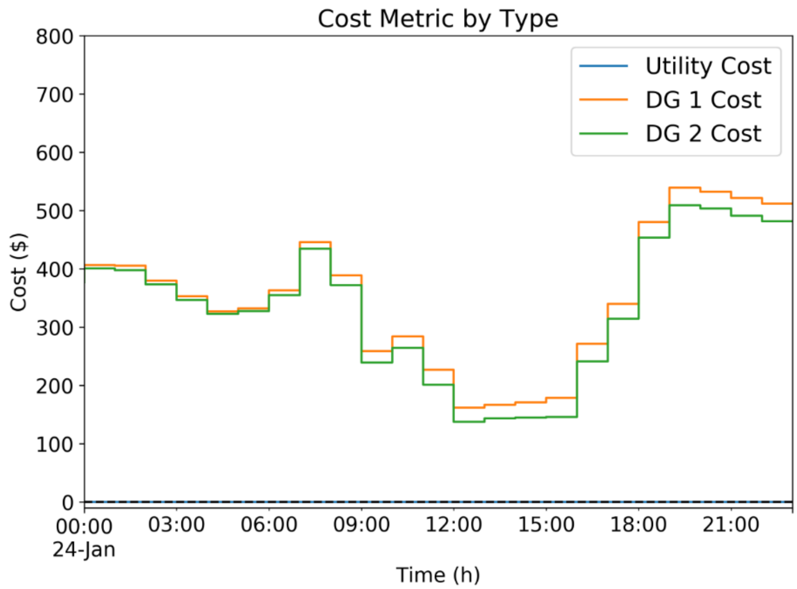
Figure A-51: Voltage Amplitude and Frequency Results for Test C2.2



Source: San Diego Gas & Electric Company

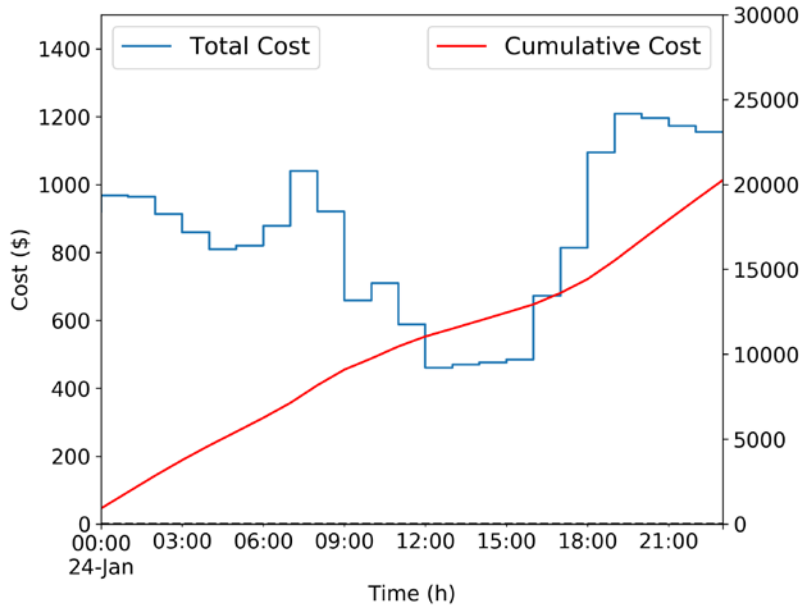
The calculated cost metrics are shown in Figure A-52 and Figure A-53.

Figure A-52: Cost by Asset Type Results for Test C2.2



Source: San Diego Gas & Electric Company

Figure A-53: Total and Cumulative Cost Results for Test C2.2



Source: San Diego Gas & Electric Company

Results for Test C2.3.1: Normal Islanded Operation with Light Load and Low Initial State of Charge (remote HIL setup)

For this test, the load and insolation profiles and initial battery state of charge should be set to be the same as for test C2.2, and this test should be run using the remote ESIF/ITF CHIL/PHIL setup. Due to time constraints, this test was not simulated.

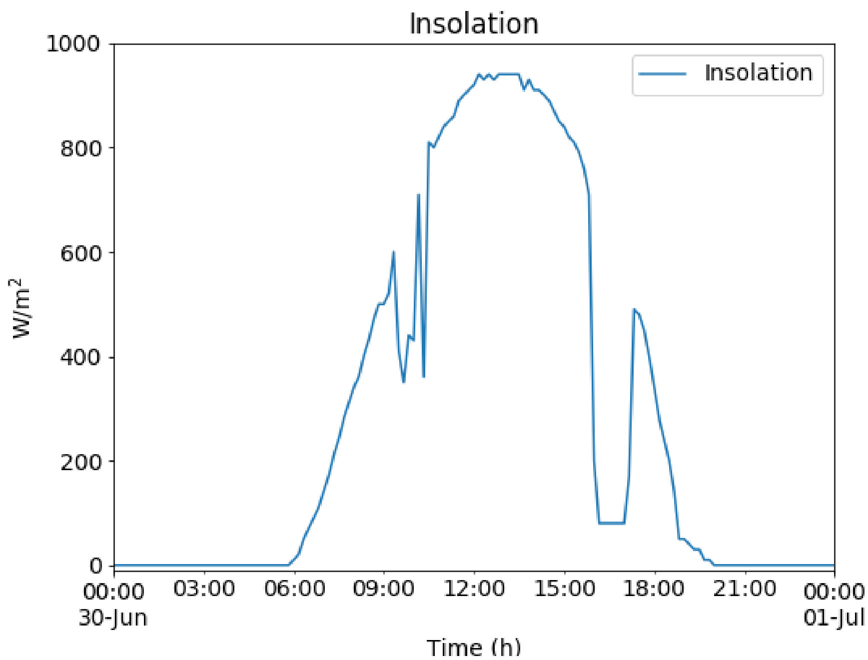
Results for Test C2.3.2: Normal Islanded Operation with Light Load and High Initial State of Charge (remote HIL setup)

For this test, the load and insolation profiles and initial battery state-of-charge should be set to be the same as for test C2.2, and this test should be run using the remote ESIF/ITF CHIL/PHIL setup. Due to time constraints, this test was not simulated.

Results for Test C2.4: Normal Islanded Operation with Contingency Conditions

For this test, the load and insolation profiles should be set to a profile with significant loss of PV generation due to cloud cover in the afternoon as shown in Figure A-54. Due to time constraints, this test was not simulated.

Figure A-54: Load and Solar Insolation Profiles for Evaluating Enhanced Resiliency on June 30, 2014



Source: San Diego Gas & Electric Company

Results for Test Case C3: Load Step during Islanded Operation

For this test case, a load step should be simulated during islanded operation. Due to time constraints, this test case was not simulated.

Results for Test Case C4: Internal Short during Islanded Operation

For this test case, an internal single-phase-to-ground fault should be applied. Due to time constraints, this test case was not simulated.

Results for Test Case C5: Black Start

For this test case, a black start of the microgrid should be simulated. Due to time constraints, this test case was not simulated.

Scenario D: Connecting the Microgrid to the Utility

The purpose of simulating the scenario of connecting the microgrid to the utility was to validate the ability of the Wave microgrid controller to reconnect the (islanded) microgrid to the utility following a restoration of utility service. It must resynchronize the microgrid to the external utility, maintain conditions in the range specified during reconnection (functional requirement C2), and restore the microgrid to normal grid-connected operation following reconnection.

The microgrid was set to operate in islanded mode following the procedure described for planned islanding in Test Case B1.

Results for Test Case D1: Reconnection

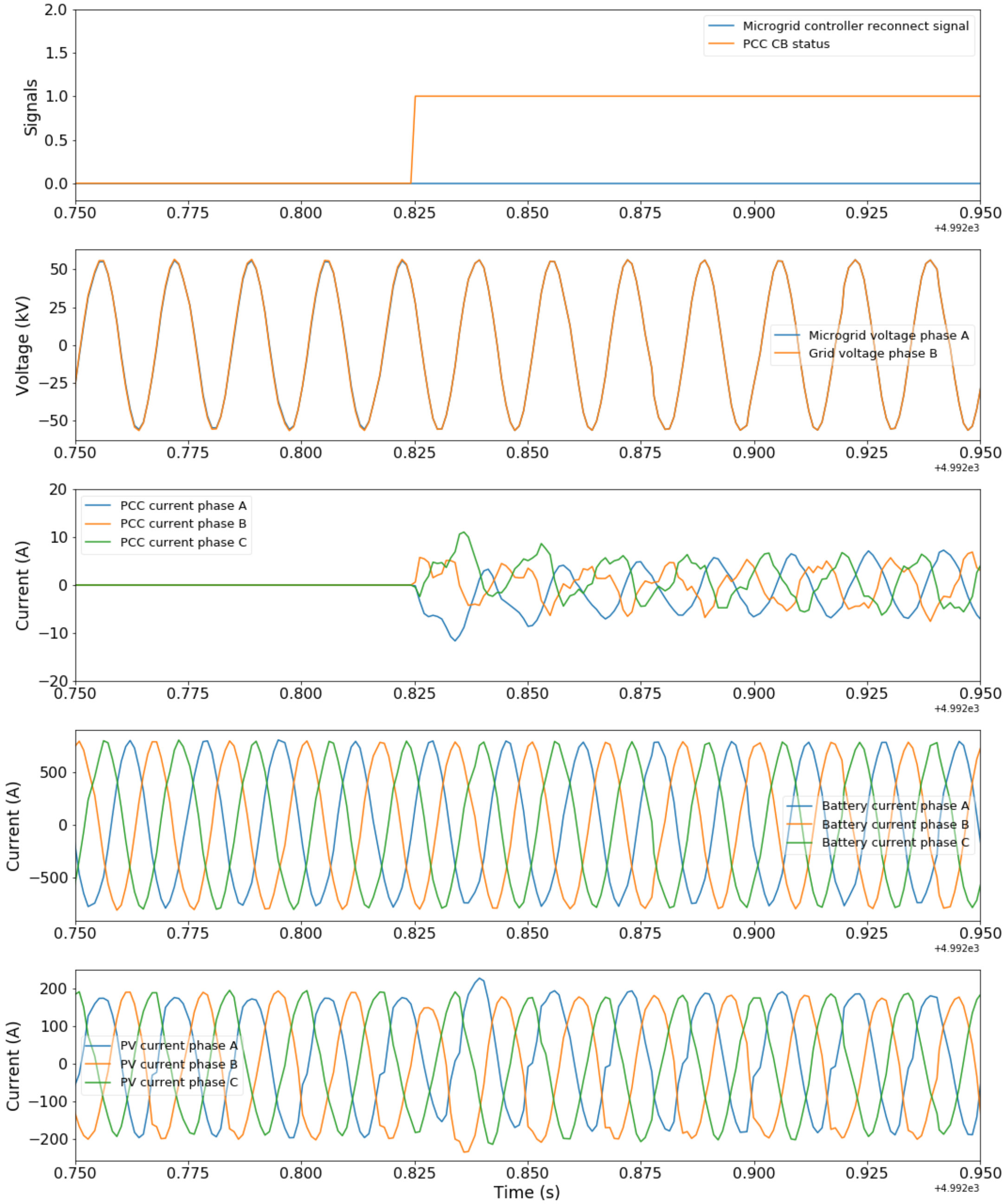
The Wave microgrid controller does not verify that the electric power system voltage and frequency are within normal ranges before initiating reconnection. This is left to the operator to confirm. Therefore, for our simulation, NREL implemented the synchronization logic in the simulated PCC circuit breaker model so that the Wave's command to start synchronization is sent to the PCC circuit breaker. NREL performed passive resynchronization – that is, the logic waits for the voltage amplitude, frequency, and phase angle differences to come within the specified ranges and then closes the PCC circuit breaker.

NREL requested that the Wave send the synchronize signal. NREL observed whether the system runs for 2 minutes to verify stable operation after resynchronizing back to the grid.

Results for Test D1.1: Reconnection with High Load

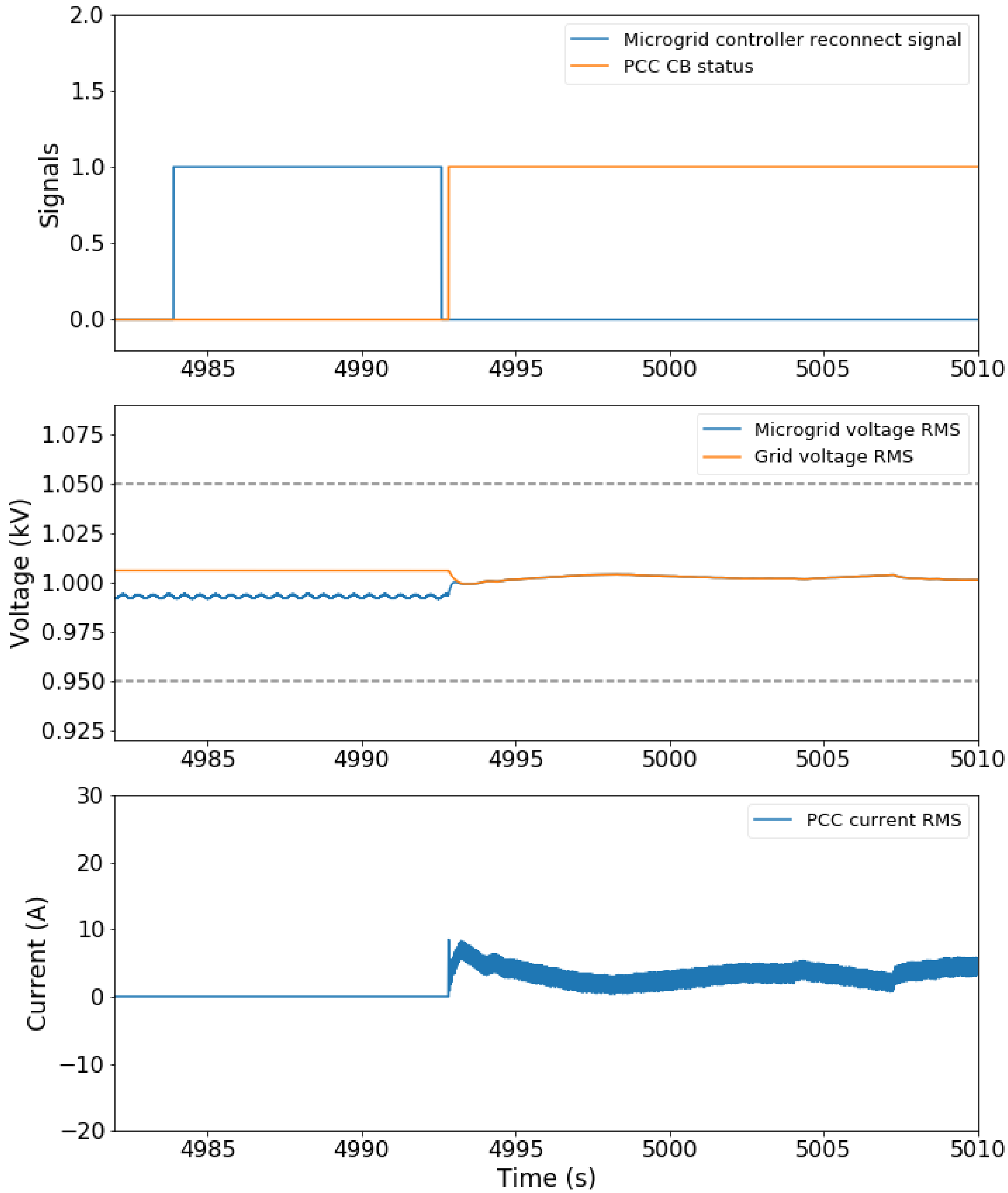
The loads and solar insolation were set to the same values as for Test B1.1 when the net load was high. Simulation results for Test D1.1 are shown in Figure A-55 for a few cycles before and after reconnection. The microgrid controller's resynchronization signal appears to be zero a few cycles before the resynchronization event. This is because the resynchronization signal is typically a pulse. The pulse can be observed in Figure A-56, which shows the simulation results for a longer period of 20 seconds. In Figure A-55, the trace at the top shows the microgrid controller disconnect signal and the PCC circuit breaker status. The microgrid controller disconnect signal is zero, indicating that the Wave microgrid controller had previously issued a signal to reconnect. The second trace shows both the area grid and microgrid voltages for Phase A, and the third trace shows the current through the PCC circuit breaker. The fourth and fifth traces show the measured output current of the hardware battery storage inverter and PV inverter. The microgrid was successfully reconnected to the area grid.

Figure A-55: Simulation Results for Test Case D1.1 (reconnection) during a Few Cycles



Source: San Diego Gas & Electric Company

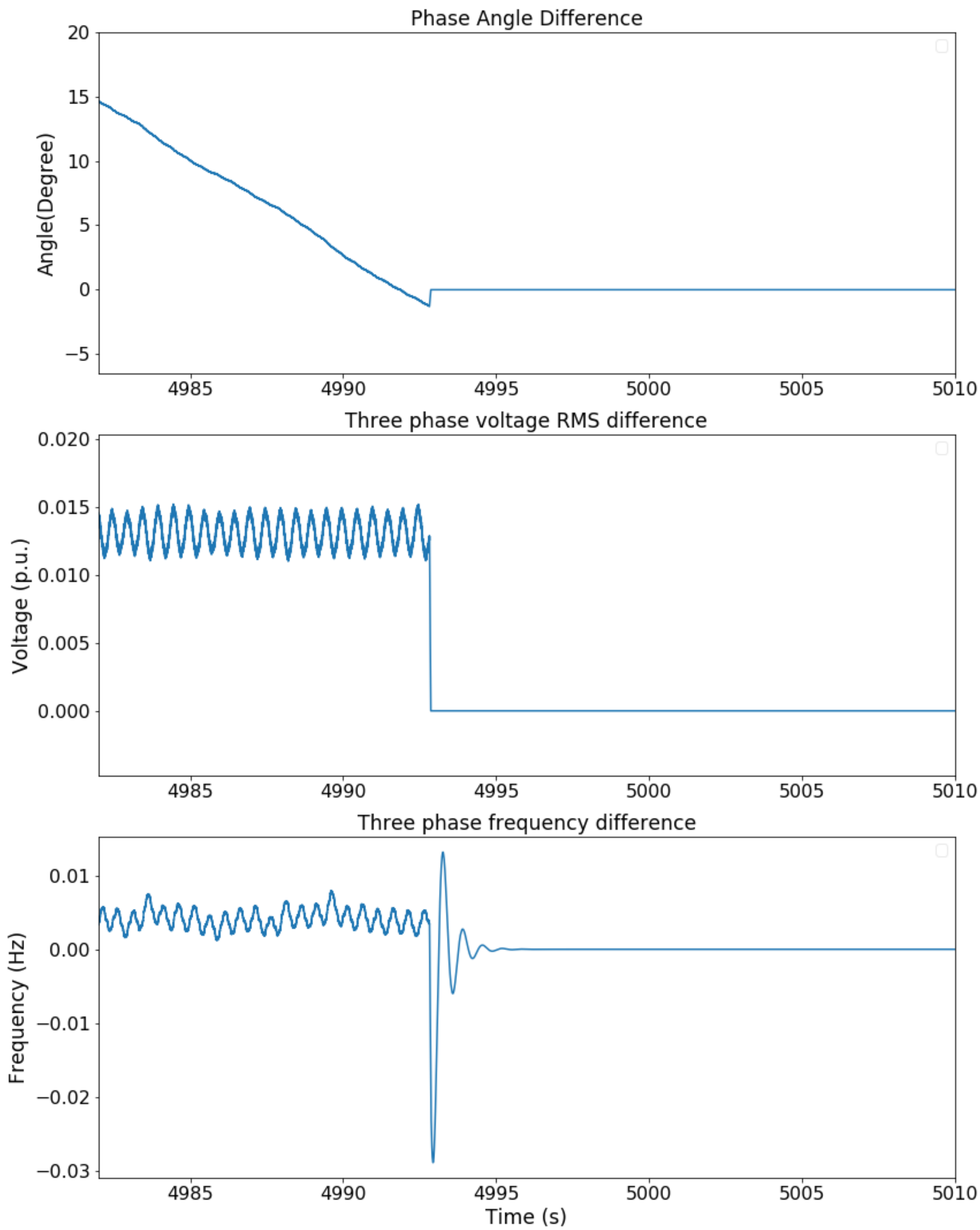
Figure A-56: Simulation Results for Test D1.1 (reconnection) during a Longer Time Period



Source: San Diego Gas & Electric Company

The voltage amplitude, phase angle, and frequency difference are shown in Figure A-57. These results show that the logic implemented in the simulated PCC circuit breaker meets the requirements for reconnection. The phase angle difference shown in Figure A-57 matches the voltage waveforms in Figure A-55.

Figure A-57: Voltage Phase Angle, RMS, and Frequency Difference between Grid and Microgrid Side

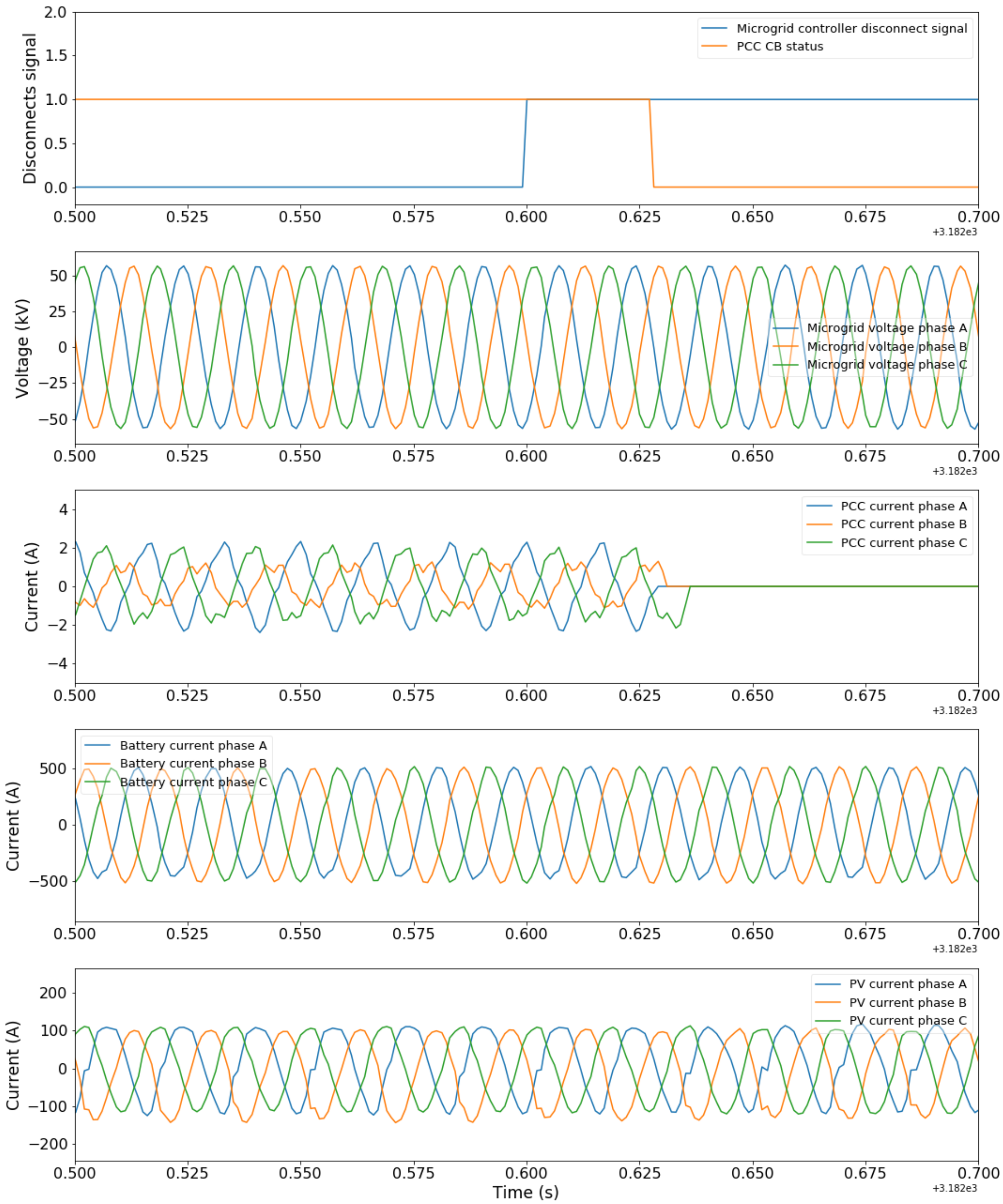


Source: San Diego Gas & Electric Company

Results for Test D1.2: Reconnection with Low Load

The loads and solar insolation were set to the same values as for Test B1.2 when the net load was low. Simulation results for Test D1.2 are shown in Figure A-58 for a few cycles before and after reconnection.

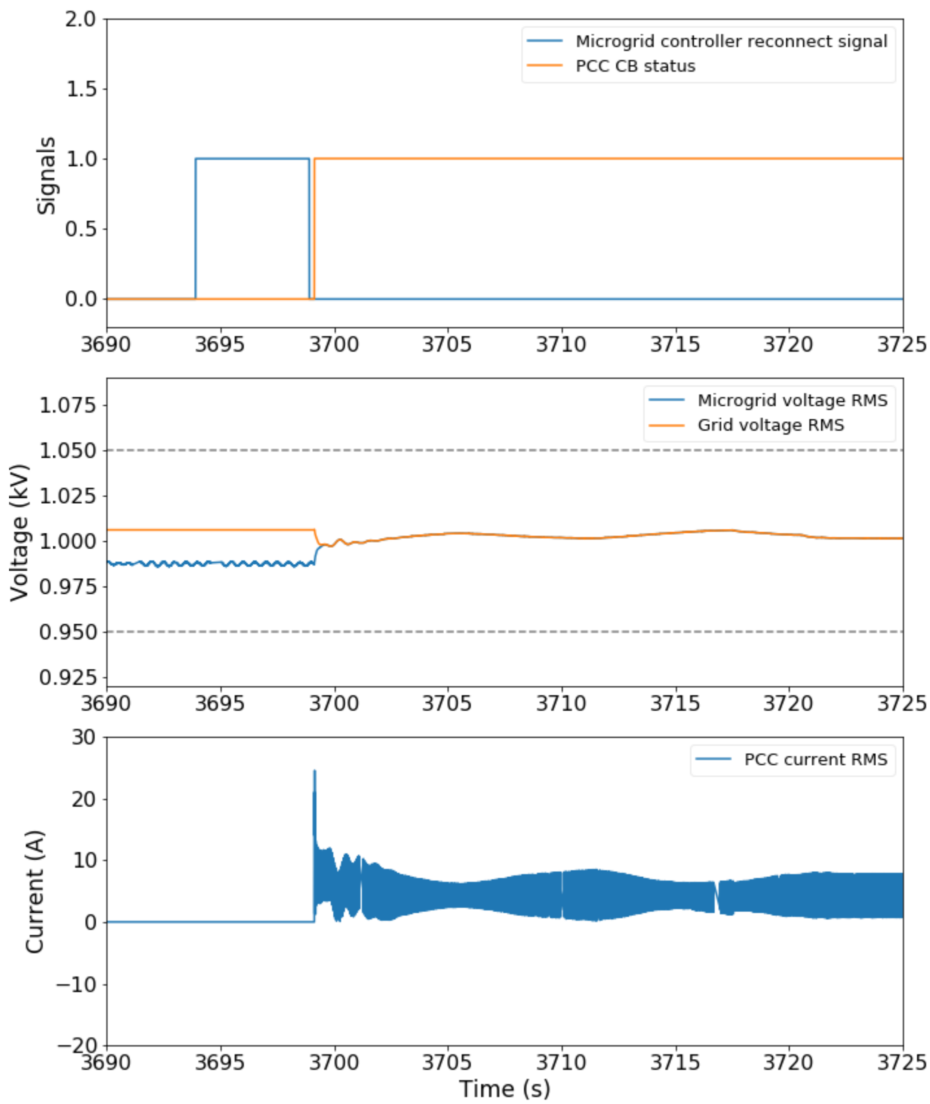
Figure A-58: Simulation Results for Test D1.2 (reconnection) during a Few Cycles



Source: San Diego Gas & Electric Company

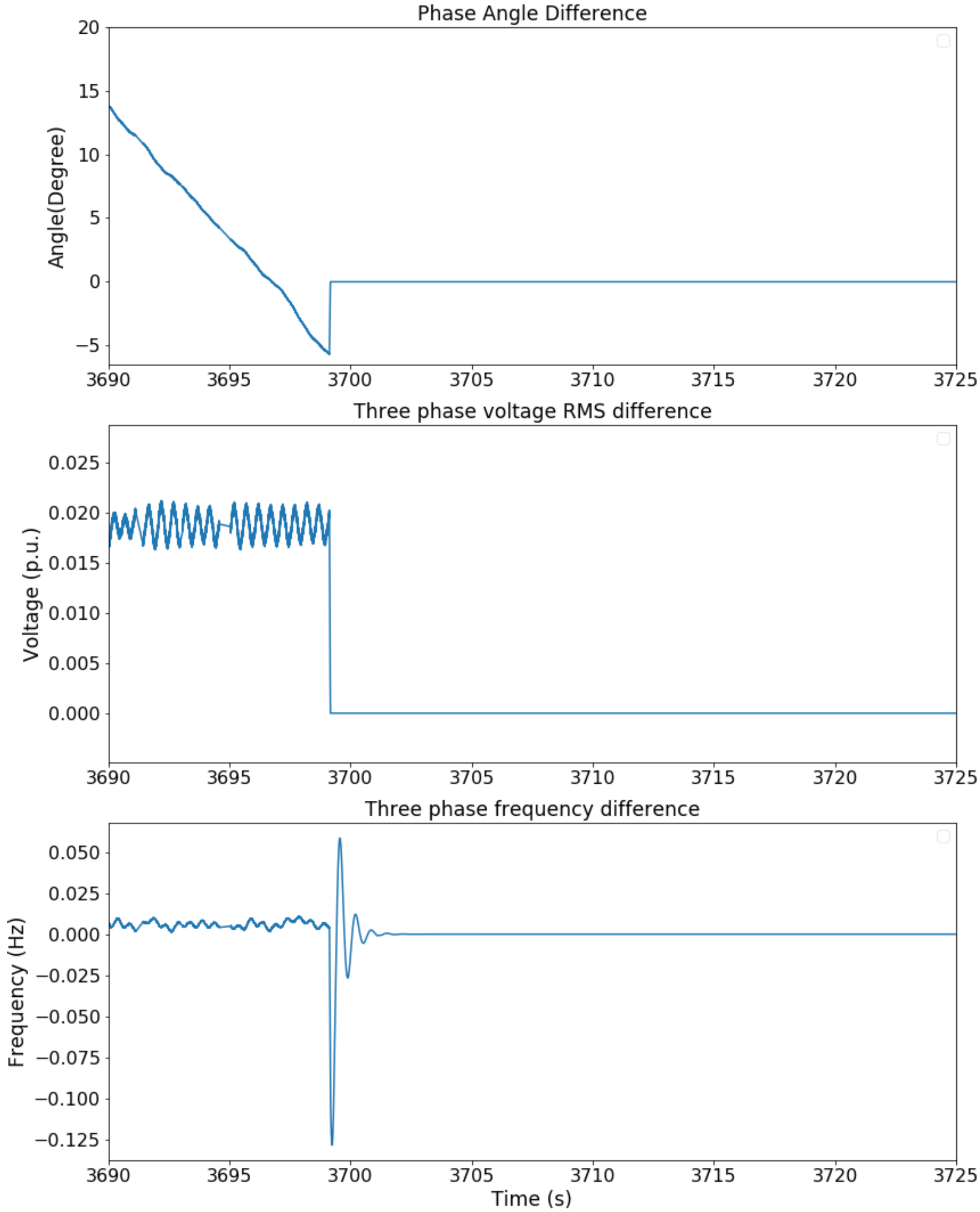
Similar to test case D1.1, the microgrid controller sends a pulse signal. Once this pulse is received, the PCC circuit breaker logic waits for 180 seconds for the voltage phase angle, magnitude, and frequency to fall within the limits. In Figure A-58, the trace at the top shows the microgrid controller disconnect signal and the PCC circuit breaker status. The microgrid controller disconnect signal is zero, indicating that the Wave microgrid controller had previously issued a signal to reconnect. The second trace shows both the area grid and microgrid voltages for Phase A, and the third trace shows the current through the PCC circuit breaker. The fourth and fifth traces show the measured output current of the hardware battery storage inverter and PV inverter. Figure A-59 and Figure A-60 show the simulation results for a longer period of 20 seconds. The microgrid was successfully reconnected to the area grid in this test case.

Figure A-59: Simulation Results for Test D1.2 (reconnection) during a Longer Period



Source: San Diego Gas & Electric Company

Figure A-60: Voltage Phase Angle, RMS, and Frequency Difference between Grid and Microgrid Voltage



Source: San Diego Gas & Electric Company

APPENDIX B: Metrics for Microgrid Controller Evaluation

The metrics by which dispatch and resiliency were evaluated are described in the following sections.

Survivability of Critical Loads

The survivability metric will reflect whether sufficient resources (for example, generation and/or energy storage) are operating and available to support the microgrid's seamless transition to island mode, and it will be calculated as follows:

$$S_n = \frac{P_{loads,crit,n}}{P_{avail,n}}$$

where $P_{loads,crit,n}$ is the total active power of all loads that are identified as critical by the community and San Diego Gas & Electric during time step n, and $P_{avail,n}$ is the total power available from all dispatchable generation[5] during time step n. For energy storage systems, the calculation of $P_{avail,n}$ will consider the available state-of-charge of the batteries. The survivability metric should be less than 1 at all time steps.

Economic Operation

The cost of operating the microgrid for the duration of the scenario simulated, C, will be calculated as follows:

$$C = \sum_{N} P_{grid,n} \cdot \tau \cdot c_{grid,n} + \sum_{k} \left\{ \sum_{N} P_{DER,k,n} \cdot \tau \cdot c_{DER,k,n} \right\} + c_D \cdot \max(P_{grid,n} \cdot \tau)$$

where P_{grid} is the power supplied by the grid, c_{grid} is the cost of grid power, $P_{DER,k}$ is the power supplied by the k^{th} DER resource within the microgrid, $c_{DER,k}$ is the cost of supplying power from the k^{th} DER resource within the microgrid, c_D is the demand charge associated with grid power and τ is time step. The cost to operate the DER, $c_{DER,k}$ was assumed to be zero for PV and battery energy storage systems; and it was calculated based on representative efficiency data and diesel fuel costs for the diesel generators.

Environmental Performance

The estimated carbon dioxide (CO_2) emissions associated with operating the microgrid for the duration of the scenario simulated, ϑ, will be calculated as follows:

[5] For accelerated tests, only steady-state values that are achieved after assets have been dispatched for each time step are used.

$$\vartheta = \sum_{N} P_{grid,n} \cdot \tau \cdot \xi_e + \sum_{k} \left\{ \sum_{N} P_{DER,k,n} \cdot \tau \cdot \xi_g \right\}$$

where ξ_e is the electricity emissions factor for the grid, and ξ_g is the diesel emissions factor. Note that ξ_g is zero for photovoltaic (PV) systems and battery energy storage systems (BESSs). The electricity and gas emissions factors provided in Attachment 12 of PON-14-301 (CEC 2014) shown here in Table B-1, will be used for the grid.

Table B-1: Emission Factors in Carbon Dioxide Equivalent (CEC 2014)

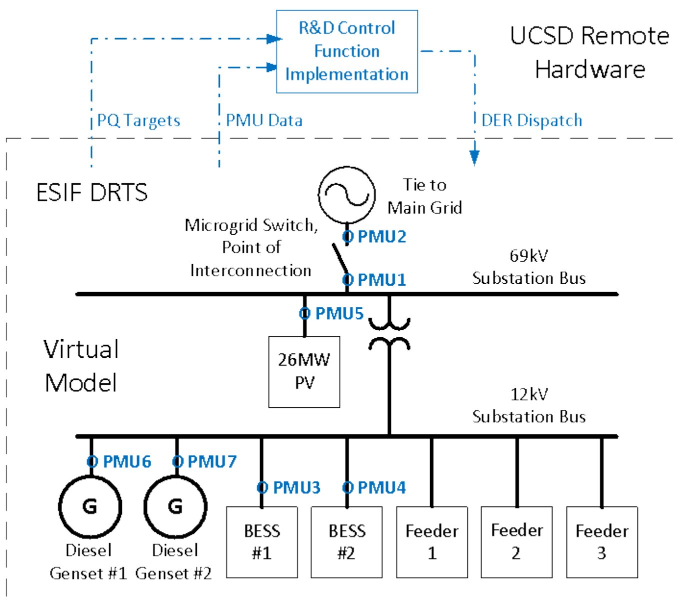
	Emissions Factor (CO_2e[a])	**Emissions Factor (CO_2e[a])**
Electricity	0.588 lbs/kWh saved	0.000283 metric tons/kWh
Gas	11.7 lbs/therm saved	0.0053 metric tons/therm

[a] Carbon dioxide equivalent

APPENDIX C: Results of Advanced Research and Development Control Functions Evaluation

This phase of testing evaluated the performance of the OSISoft/UCSD implementation of the advanced R&D microgrid control functions called ACT. The test setup shown in Figure C-1 was used, and the RTDS ran the reduced-order model in real time for Borrego Springs. The microgrid was operating while connected to the utility.

Figure C-1: Borrego Springs Test Setup for Evaluation of Advanced R&D Control Functions



Source: San Diego Gas & Electric Company

For all the test cases shown here, the National Renewable Energy Laboratory (NREL) used 300 steps of changes that were updated approximately every 2 to 3 seconds. These changes are load steps, PCC reference set points, and solar irradiation profiles.

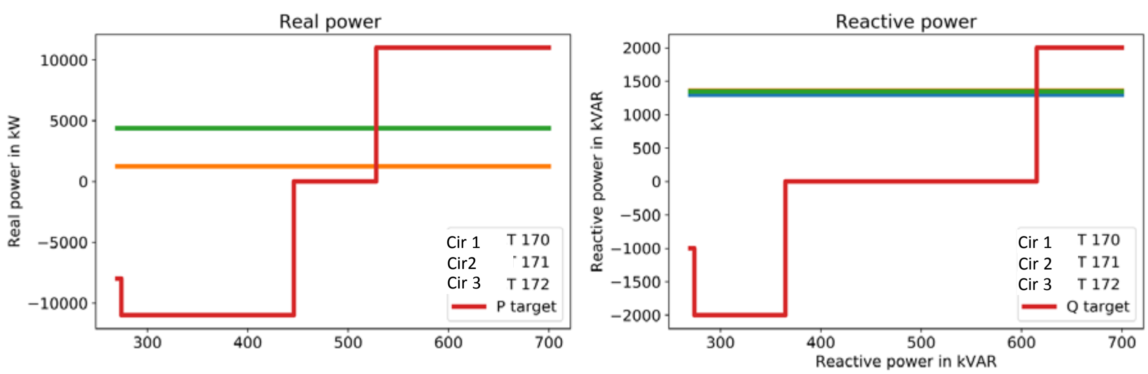
Results from Test Case ACT1: Real and Reactive Power Tracking

The purpose of this test case was to demonstrate the ability of the ACT functions to ensure that the real and reactive power flow (P,Q) across the PCC can track (follow) P,Q reference signals (P_R,Q_R) under steady-state conditions. For these test cases, the loads and solar irradiance are constant, and the reference signals are changing.

Results for Test ACT1.1: Real and Reactive Power Tracking with High Load and High PV Generation

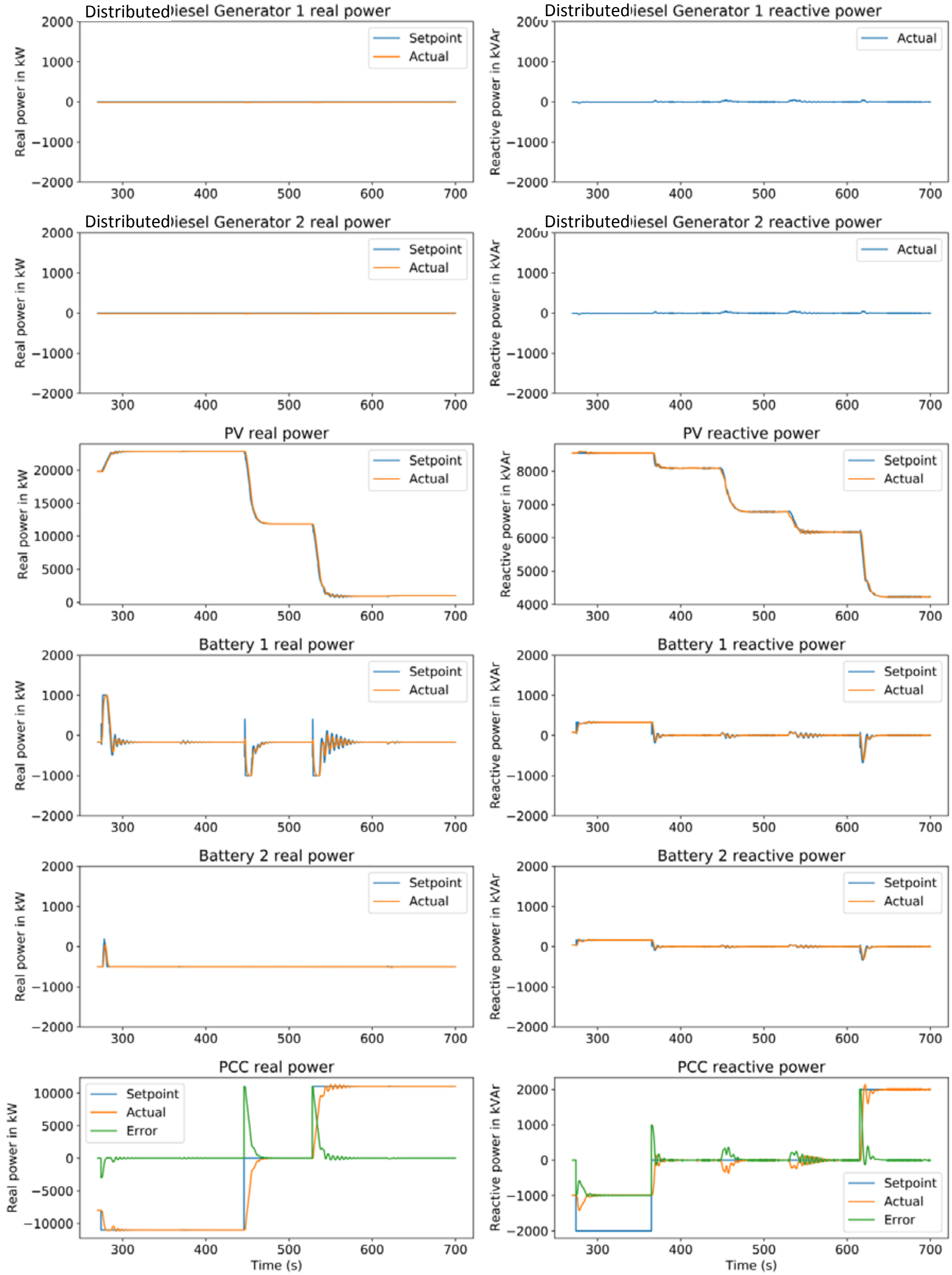
The load profiles and target power flows across the PCC are shown in Figure C-2. A constant solar irradiance of 900 W/m^2 was used. The results shown in Figure C-3 show the set points and the actual values of the simulated power flow across the PCC (P, Q) and the error between the P_R,Q_R and the P, Q. It also shows the set points and simulated power of the two distributed generators, the battery and the PV. The ACT was able to meet the real power set points throughout the experiment. The reactive power set point from 270 to 370 seconds was not met. It can be observed that the ACT was dispatching all the assets to its max. However, the distributed generators were not able to provide any reactive power support because they were not dispatched to provide any real power. But once the set point was changed, the DERs were able to provide enough reactive power support to meet the set point. The instantaneous errors were up to 11 MW and 2 MVAR respectively and the root mean square errors (RMSEs) over the duration of the experiment were 1.583 MW and 0.484 MVAR respectively.

Figure C-2: Load and Target Power Flow across the PCC for Test ACT 1.1



Source: San Diego Gas & Electric Company

Figure C-3: Power flow Across the PCC for Test ACT 1.1

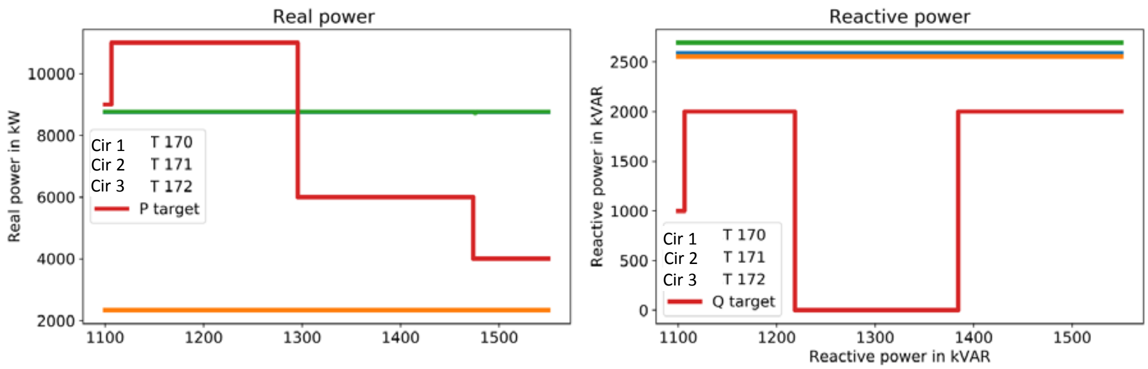


Source: San Diego Gas & Electric Company

Results for Test ACT1.2: Real and Reactive Power Tracking with High Load and Low PV Generation

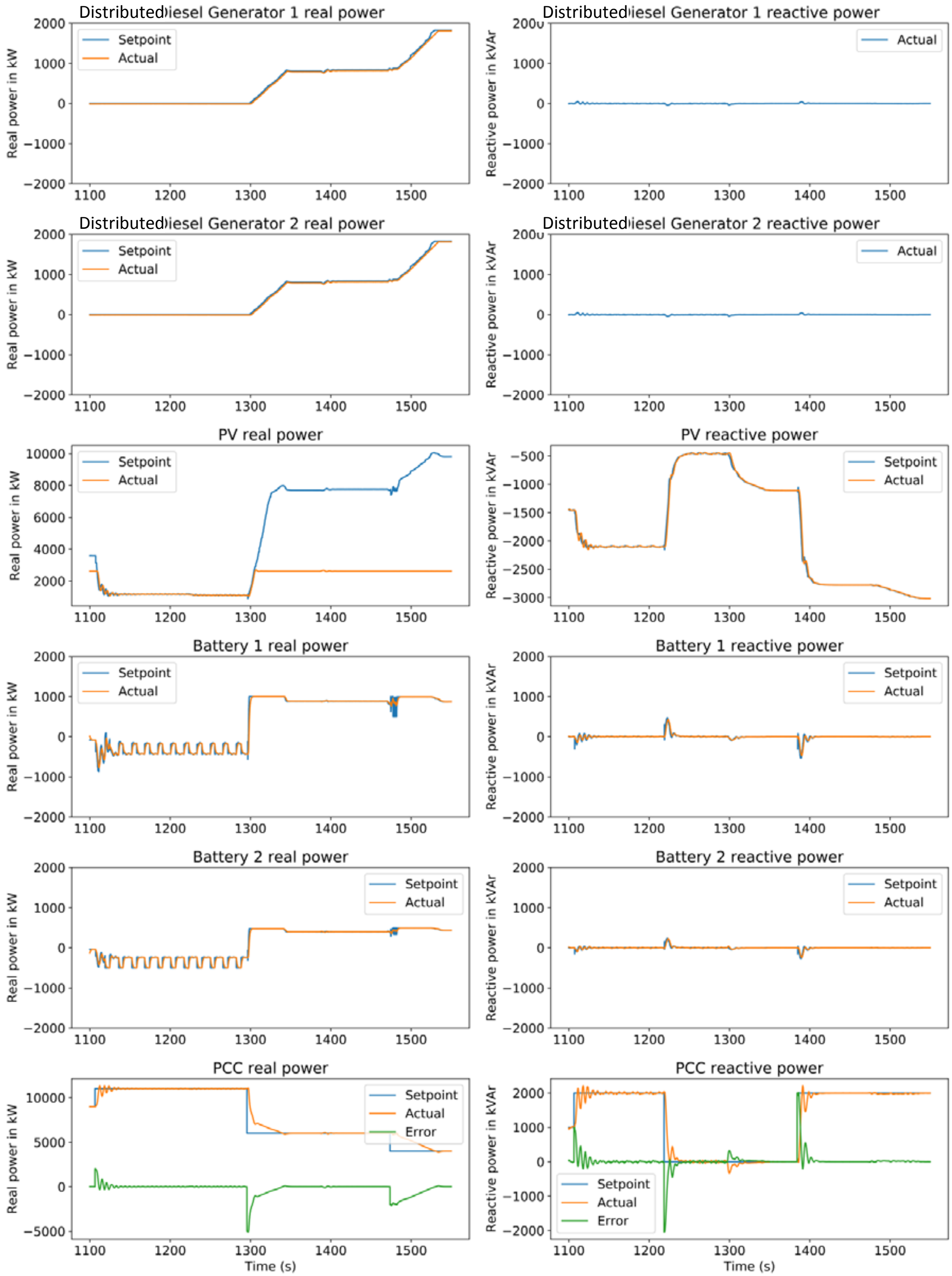
The load profiles and target power flows across the PCC are shown in Figure C-4. A constant solar irradiance of 100 W/m^2 was used. The ACT is able to track the reference signal, as shown in Figure C-5, with peak instantaneous errors of 5 MW and 2 MVAR respectively and RMSEs of 0.697 MW and 0.255 MVAR respectively. The ramp rate of the distributed generators, which is accounted for in the ACT, was a significant contributor to the active power error.

Figure C-4: Load and Target Power Flow across PCC for Test ACT 1.2



Source: San Diego Gas & Electric Company

Figure C-5: Power Flow across the PCC for Test ACT 1.2

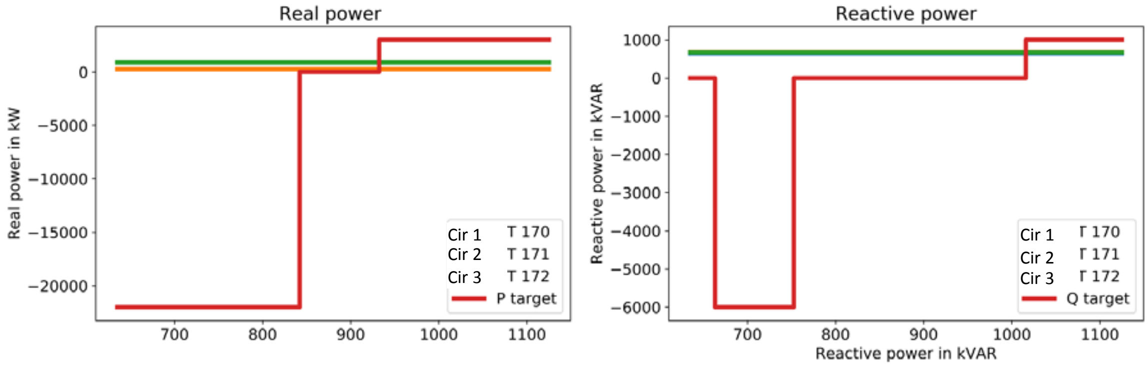


Source: San Diego Gas & Electric Company

Results for Test ACT1.3: Real and Reactive Power Tracking with Low Load and High PV Generation

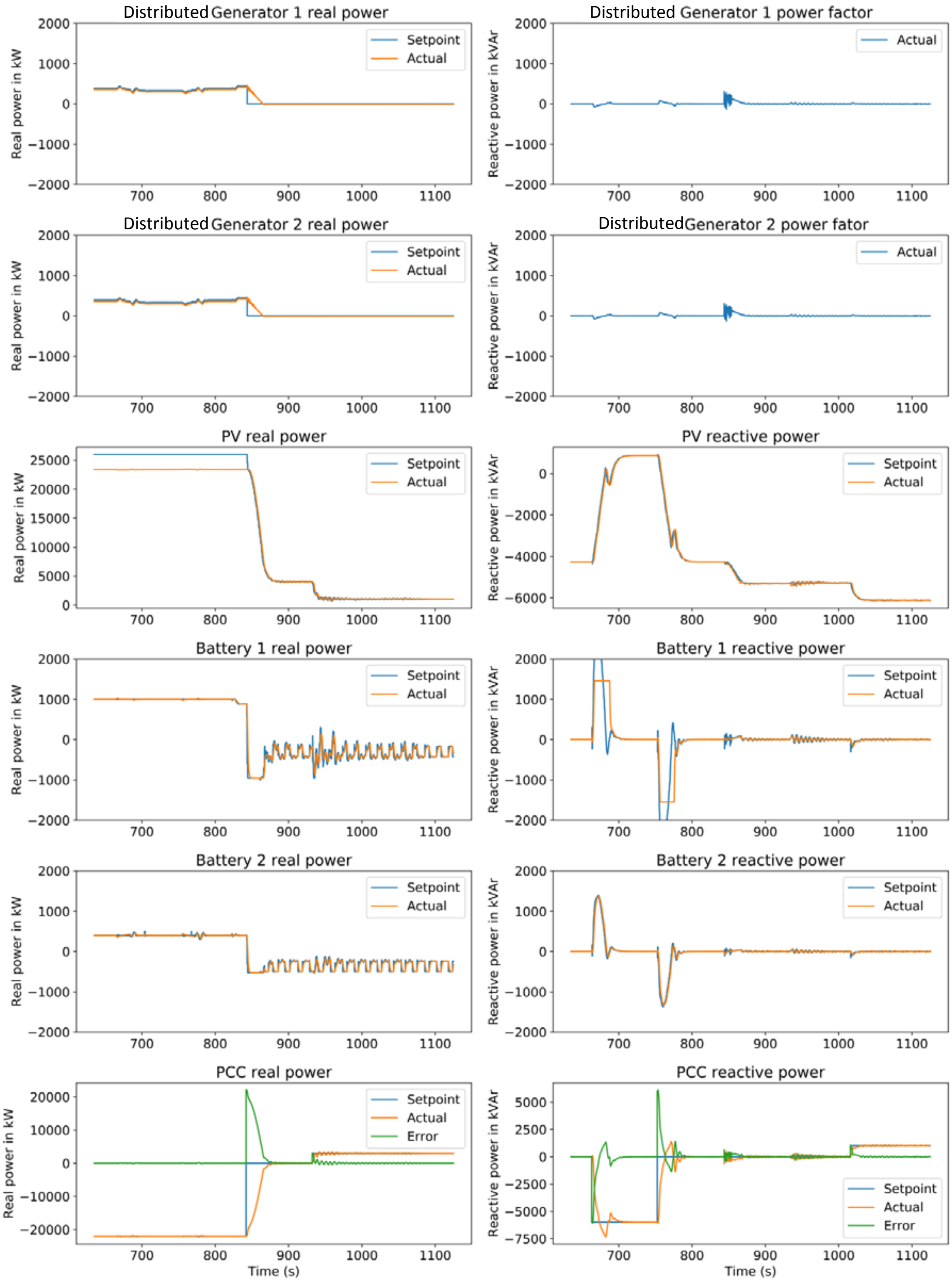
The load profiles and target power flows across the PCC are shown in Figure C-6. A constant solar irradiance of 900 W/m[2] was used. The ACT was able to track the real and reactive power set points in this test with the help of the distributed generators, as shown in Figure C-7. The peak instantaneous errors were 20 MW and 6 MVAR respectively and the RMSEs over the test duration were 3.259 MW and 0.742 MVAR respectively.

Figure C-6: Load and Target Power Flow across the PCC for Test ACT 1.3



Source: San Diego Gas & Electric Company

Figure C-7: Load and Target Power Flow across the PCC for Test ACT 1.3



Source: San Diego Gas & Electric Company

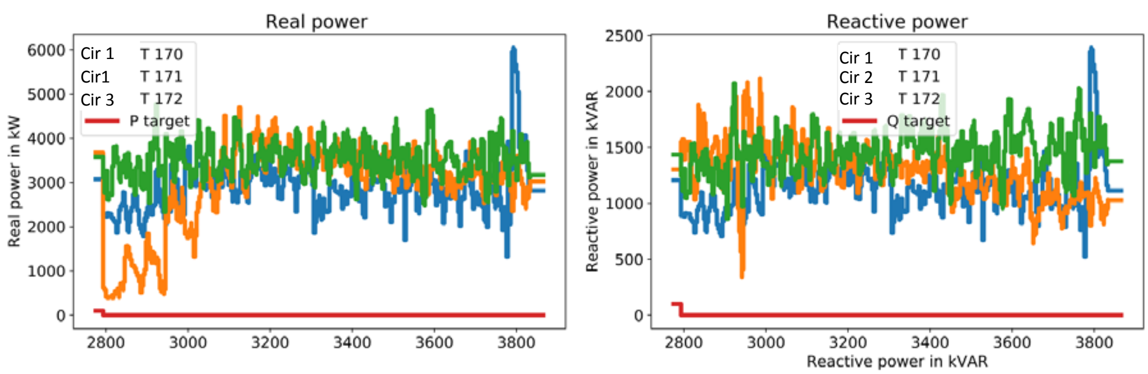
Results from Test Case ACT2: Real and Reactive Power Disturbance Mitigation

The purpose of this test case was to demonstrate the ability of the ACT functions to ensure that the P,Q across the PCC can track (follow) P_R,Q_R when subjected to changing microgrid load and generation conditions. For this test case, the reference signals are constants and the load or solar irradiance is changing.

Results for Test ACT2.1: Real and Reactive Power Disturbance Mitigation with High Load Variability and High PV Generation

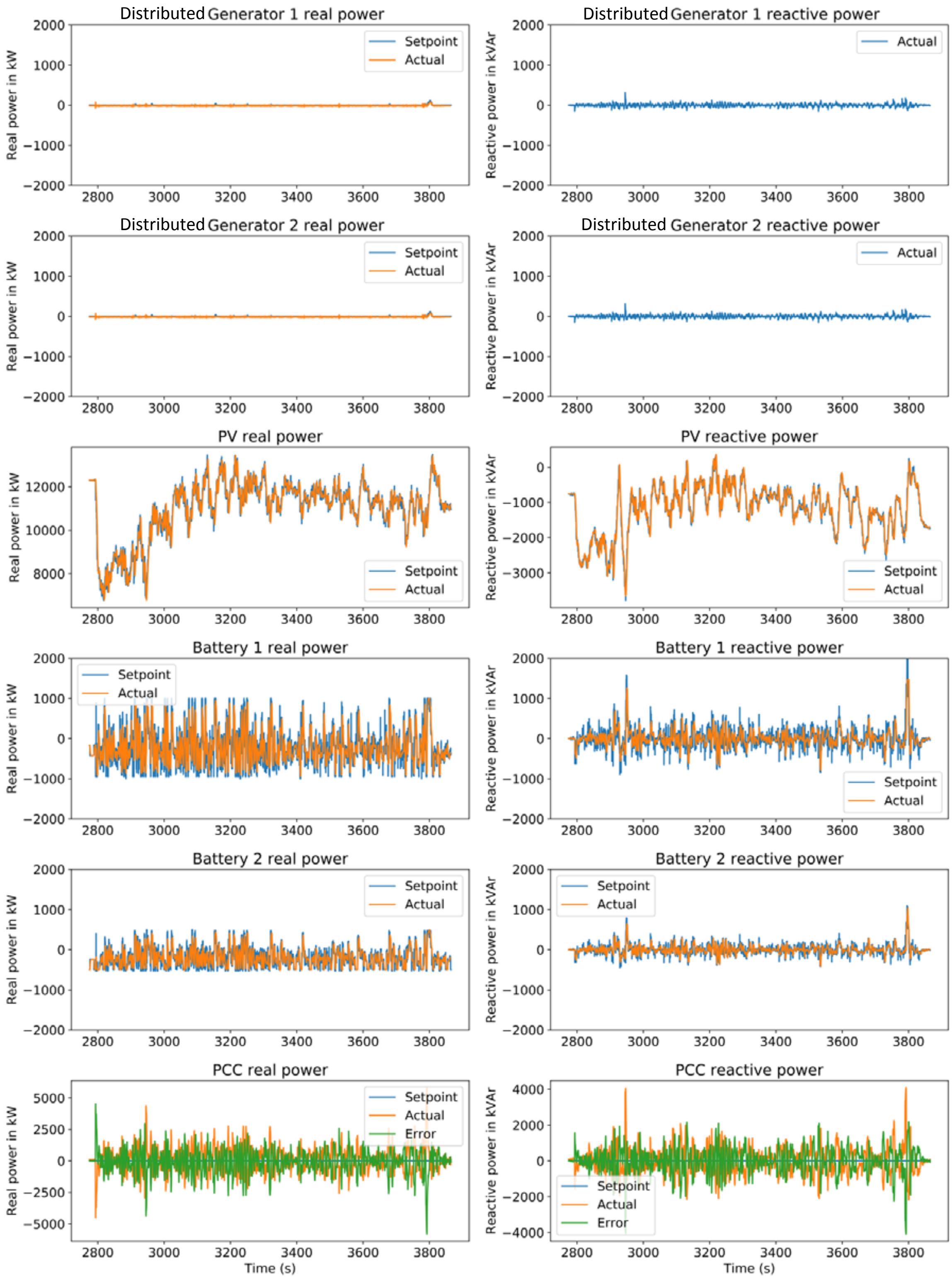
The load profiles and target power flows across the PCC are shown in Figure C-8. These load profiles have high variability because the ratio of the perturbation in load power to the mean of the load power is high. These load profiles are based on actual load profiles and variability was added to it. A constant solar irradiance of 900 W/m^2 was used. The ACT was able to minimize the change in the power flow across PCC to within 5 MW and 4 MVAR instantaneously as shown in Figure C-9. The RMSEs over the duration of the experiment were 0.935 MW and 0.713 MVAR respectively.

Figure C-8: Load and Target Power Flow across the PCC for Test ACT 2.1



Source: San Diego Gas & Electric Company

Figure C-9: Power Flow across the PCC for Test ACT 2.1



Source: San Diego Gas & Electric Company

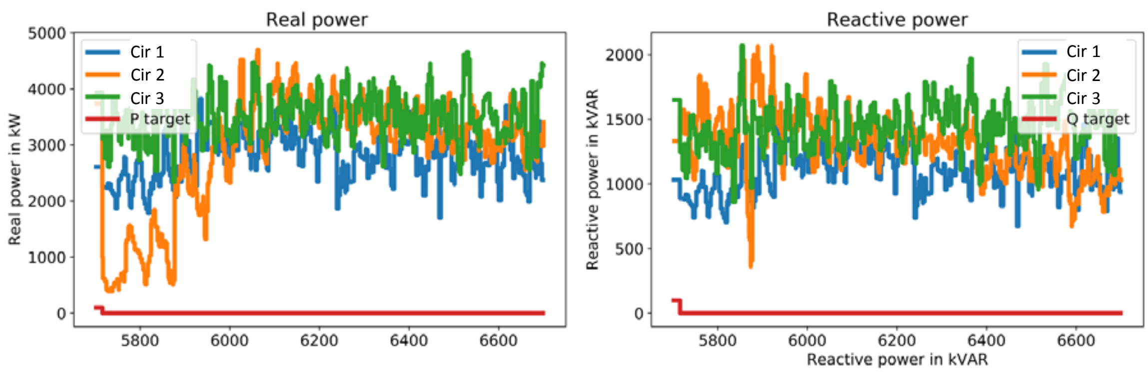
Results for Test ACT2.2: Real and Reactive Power Disturbance Mitigation with High Load Variability and Low PV Generation

The load profiles and target power flows across the PCC should be the same as for Test ACT2.1 and a constant solar irradiance of 100 W/m^2 should be used so that the PV generation is low. Due to time constraints, this test was not simulated.

Results for Test ACT2.3: Real and Reactive Power Disturbance Mitigation with Low Load Variability and High PV Generation

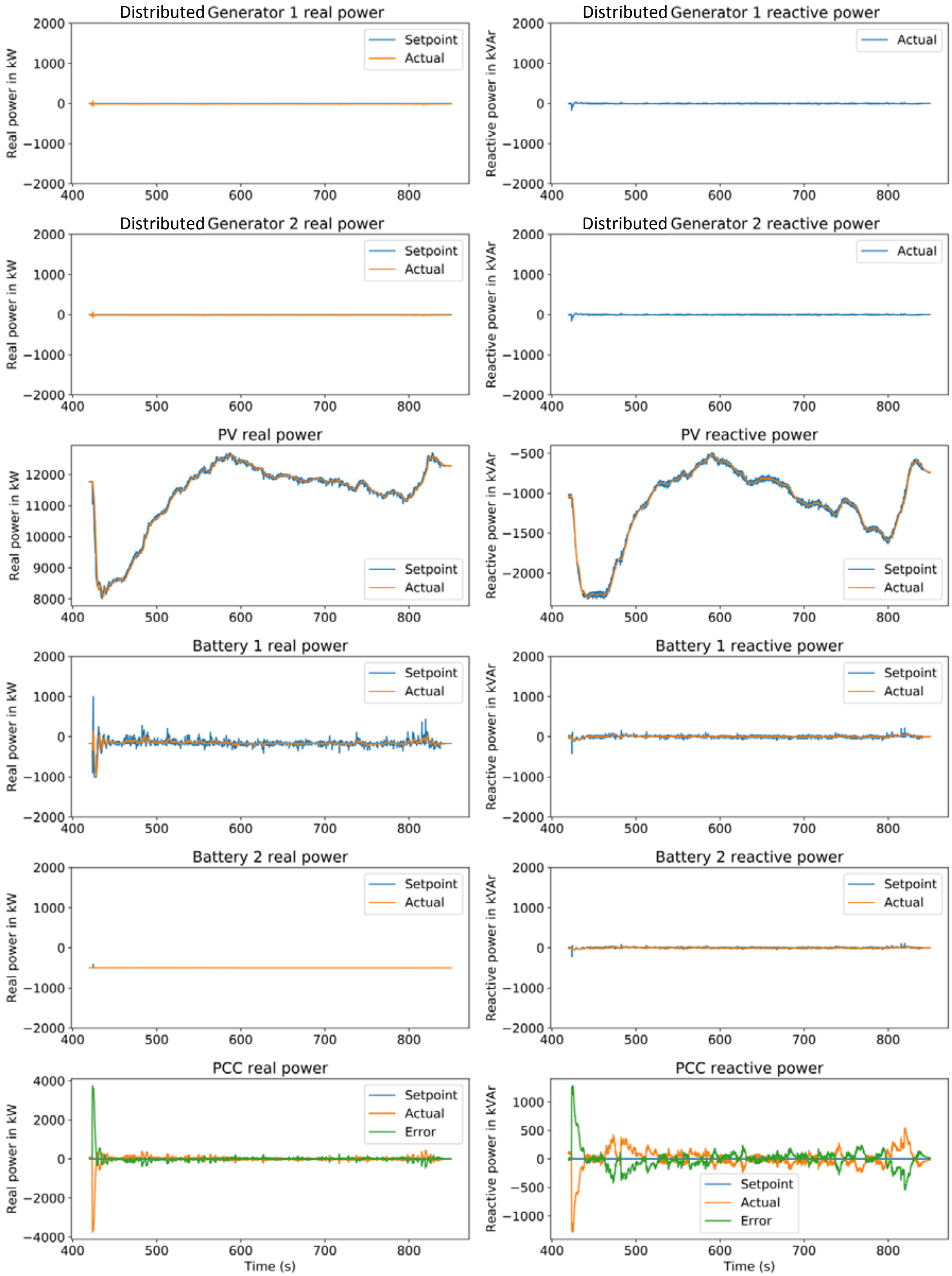
The load profiles and target power flows across the PCC are shown in Figure C-10. These load profiles have low variability. A constant solar irradiance of 900 W/m^2 was used so that the PV generation could be high and therefore the PV was primarily used to support the load. The ACT was able to mitigate the load variability, as shown in Figure C-11 with peak instantaneous errors of 4 MW and 1 MVAR respectively and RMSEs over the test duration of 0.286 MW and 0.172 kVAR respectively.

Figure C-10: Load and Target Power Flow across the PCC for Test ACT2.3



Source: San Diego Gas & Electric Company

Figure C-11: Power Flow across the PCC for Test ACT 2.3

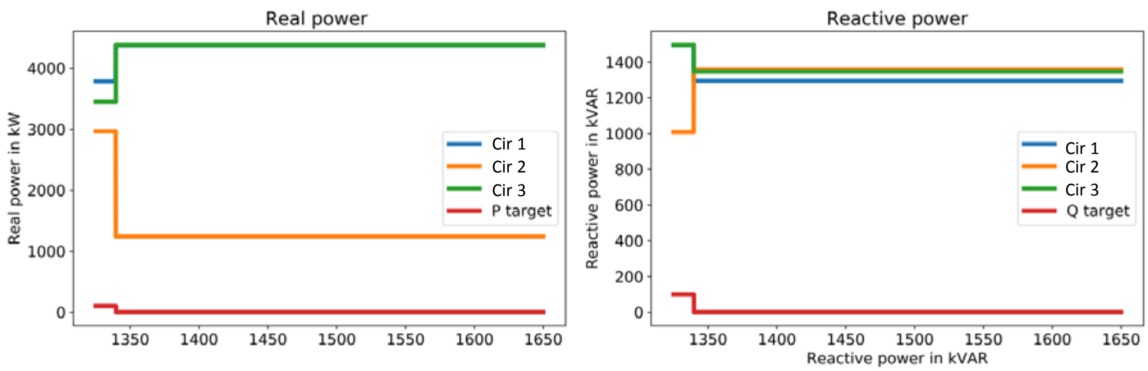


Source: San Diego Gas & Electric Company

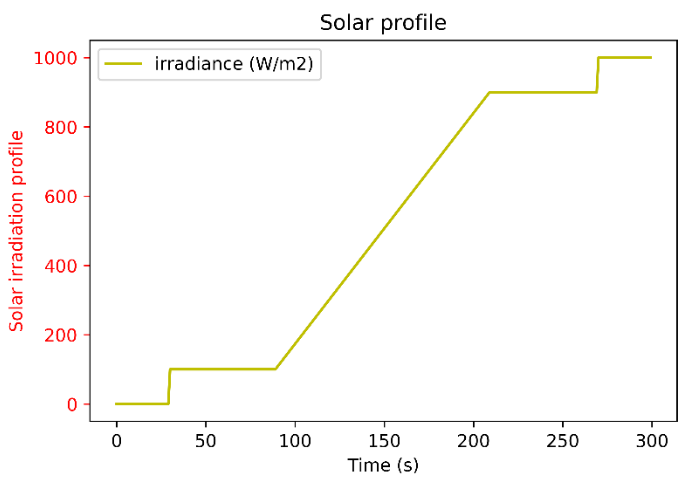
Results for Test ACT2.4: Real and Reactive Power Disturbance Mitigation for a Low to High PV Generation Change under High Load

The load profiles, solar irradiation, and target power flows across the PCC are shown in Figure C-12. The loads are constant and the solar irradiation changes. The ACT dispatched the distributed generators until the PV generation was high enough to support the load. However, the distributed generators could not support all of the load, so there was a significant error in active power at the start of the experiment. Once enough PV was available, the ACT was able to mitigate the solar irradiance changes, as shown in Figure C-13. However, there was an abrupt change in active power set points to the generators at about 1,550 seconds, and after that, there were significant fluctuations in the PV and battery power until the generators turned off.

Figure C-12: Load, Solar Irradiance, and Target Power Flow across the PCC for Test ACT 2.4



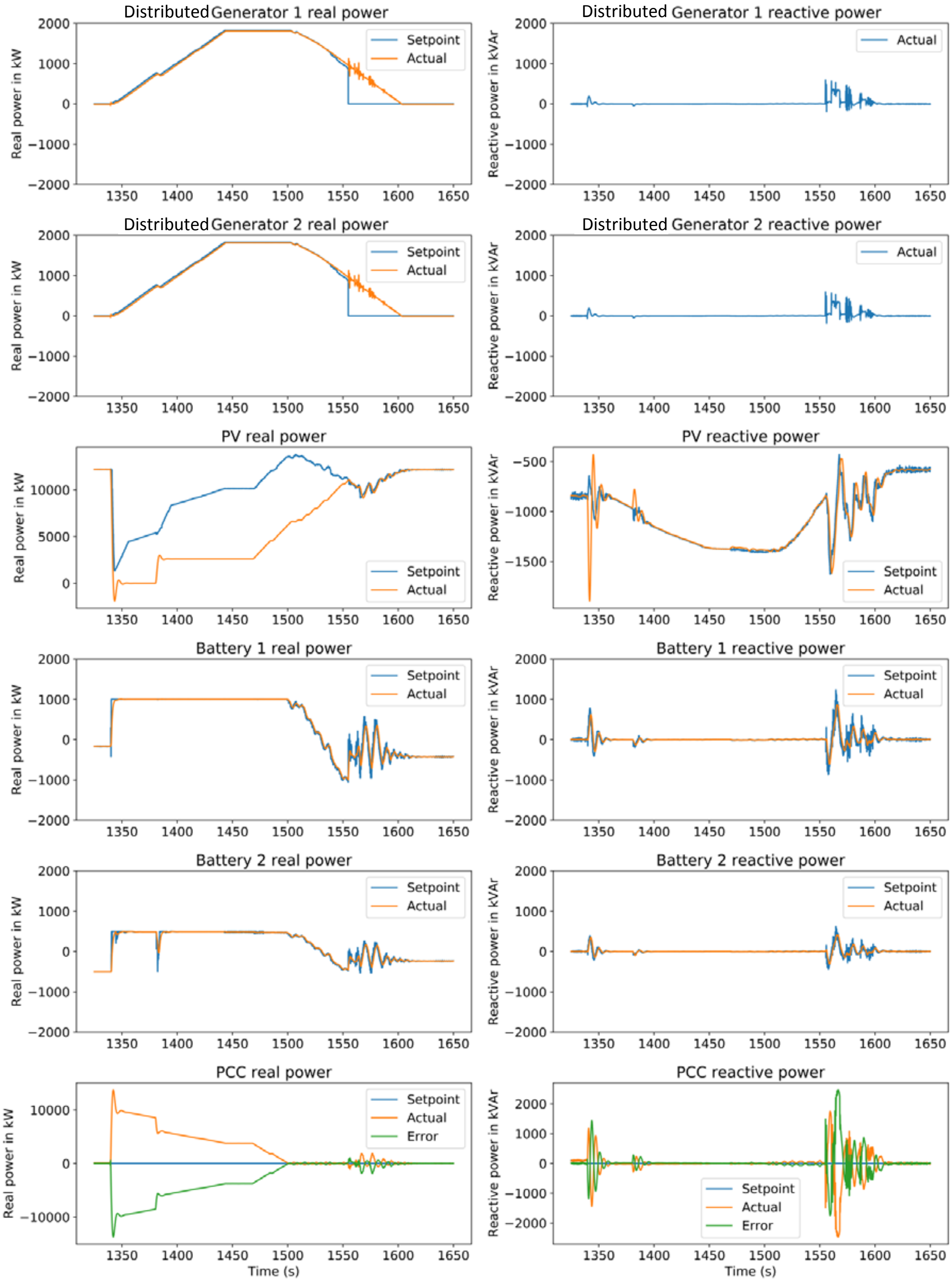
(a) Real and reactive power load with PCC target



(b) Solar Irradiance Profile

Source: San Diego Gas & Electric Company

Figure C-13: Power Flow across the PCC for Test ACT 2.4



Source: San Diego Gas & Electric Company

Results from Test Case ACT3: Frequency Disturbance Mitigation

This test case should demonstrate the ability of the ACT functions to reduce frequency fluctuations at the PCC of the microgrid. This capability was not available in the ACT at the time of testing and therefore this test case was not simulated.

APPENDIX D:
Technology / Knowledge Transfer Activities

Table D-1: Information Activities 2015-2018

#	Year	Date	Tech Transfer Product	Presented / Organized by:	Location	Description	Comments/Notes/URL	# of Est. People Reached	Tour Guests
1	2015	17-Feb	SDG&E Gets $5M Grant to Expand Borrego Springs Microgrid	PR Newswire		SAN DIEGO, Feb. 17, 2015 /PRNewswire/ -- The California Energy Commission (CEC) recently awarded San Diego Gas & Electric (SDG&E) a nearly $5 million grant to expand the innovative Borrego Springs Microgrid…	http://www.prnewswire.com/news-releases/sdge-receives-5-million-grant-to-expand-borrego-springs-microgrid-300037273.html	-	-
2	2015	17-Feb	SDG&E Gets $5M Grant to Expand Borrego Springs Microgrid	KPBS	San Diego	San Diego Gas & Electric announced Tuesday that a $5 million state grant will allow the utility to expand a solar-powered microgrid in the …	http://www.kpbs.org/news/2015/feb/17/sdge-gets-5m-grant-expand-borrego-springs-microgri/	-	-
3	2015	17-Feb	SDG&E obtains $5 million grant to expand Borrego Springs Microgrid	Allen Matkins Firm Website		San Diego Gas & Electric (SDG&E) announced Tuesday that a $5 million state grant will allow the utility to expand a solar-powered microgrid in the desert to provide for all of the electricity needs in Borrego Springs.	http://www.allenmatkins.com/en/Publications/Newsletters/Renewable-Energy-Update/2015/02/February-20-2015.aspx	-	-
4	2015	17-Feb	SDG&E Gets $5M Grant to Expand Borrego Springs Microgrid	SDG&E Newsroom	San Diego	SAN DIEGO, Feb. 17, 2015 – The California Energy Commission (CEC) recently awarded San Diego Gas & Electric (SDG&E) a nearly $5 million grant to expand the innovative Borrego Springs Microgrid…	http://www.sdge.com/newsroom/press-releases/2015-02-17/sdge-receives-5-million-grant-expand-borrego-springs-microgrid	-	-
5	2015	17-Feb	SDBJ: SDG&E Receives $5 Million Grant to Expand Microgrid	San Diego Business Journal	San Diego, CA	San Diego Gas & Electric (SDG&E) announced it has received a $5 million grant from the California Energy Commission to expand the Borrego Springs Microgrid…			

#	Year	Date	Tech Transfer Product	Presented / Organized by:	Location	Description	Comments/Notes/URL	# of Est. People Reached	Tour Guests
6	2015	18-Feb	Californian utility awarded $5m grant for solar microgrid expansion	pv magazine		San Diego Gas & Electric will use the monies awarded by the California Energy Commission to expand the Borrego Springs Microgrid to enable it to operate entirely on renewable energy.	http://www.pv-magazine.com/news/details/beitrag/californian-utility-awarded-5m-grant-for-solar-microgrid-expansion_100018271/#axzz45uibGh2H	-	-
7	2015	18-Feb	SDG&E to Create One of Largest Renewable Energy Microgrids in the US	Microgrid Knowledge		San Diego Gas & Electric plans to create one of the largest renewable energy microgrids in the United States with the help of a $5 million state grant it received earlier this month.	http://microgridknowledge.com/sdge-create-one-largest-renewable-energy-microgrids-us/	-	-
8	2015	18-Feb	San Diego Gas and Electric gets $5M to expand Borrego Springs Microgrid	SmartGrid News. com		San Diego Gas and Electric (SDG&E) has been awarded nearly $5 million from the California Energy Commission (CEC) to expand their Borrego Springs Microgrid.	http://www.smartgridnews.com/story/san-diego-gas-and-electric-gets-5m-expand-borrego-springs-microgrid/2015-02-18	-	-
9	2015	20-Feb	SDG&E receives $5 million grant to expand Borrego Springs Microgrid	PowerUp - SDG&E Internal Website	San Diego	On Feb. 17, SDG&E announced that the California Energy Commission (CEC) recently awarded San Diego Gas & Electric (SDG&E) a nearly $5 million grant to expand the innovative Borrego Springs Microgrid.	http://powerup.sdge.com/news/2015-0220-sdge-receives-5million-grant-expand-borrego-springs-microgrid.cfm	-	-
10	2015	20-Feb	SDG&E obtains $5 million grant to expand Borrego Springs Microgrid	California Carbon.info		(Source: KPBS) San Diego Gas & Electric (SDG&E) announces its receipt of a $5 million state grant that will enable the expansion of a solar-powered microgrid in Borrego Springs	http://californiacarbon.info/2015/02/20/sdge-obtains-5-million-grant-expand-borrego-springs-microgrid/	-	-
11	2015	20-Feb	Microgrids, SDG&E and NRG Demonstrate the Future	Microgrid Knowledge		Momentum is building for alternative utility business models, and California is once again a leading state.	http://microgridknowledge.com/microgrids-sdge-nrg-demonstrate-future/	-	-

#	Year	Date	Tech Transfer Product	Presented / Organized by:	Location	Description	Comments/Notes/URL	# of Est. People Reached	Tour Guests
12	2015	23-Feb	SDG&E Integrates Electric Vehicles and Energy Storage Systems into California's Energy and Ancillary Service Markets	PR Newswire		... and Borrego Springs Microgrid," added Avery. "Those innovative projects demonstrated that aggregating diverse resources like solar, energy …	http://www.prnewswire.com/news-releases/sdge-integrates-electric-vehicles-and-energy-storage-systems-into-californias-energy-and-ancillary-service-markets-300040007.html	-	-
13	2015	25-Feb	San Diego Gas and Electric gets $5M to expand Borrego Springs Microgrid	NTS-AT Advanced Technology		San Diego Gas and Electric (SDG&E) has been awarded nearly $5 million from the California Energy Commission (CEC) to expand their Borrego Springs Microgrid.	http://smartgrid.testing-blog.com/2015/02/25/san-diego-gas-and-electric-gets-5m-to-expand-borrego-springs-microgrid/	-	-
14	2015	27-Feb	SDG&E's James Avery on the Promise of EVs and the Pitfalls of Solar	Greentech Media		SDG&E is also investing millions in a distributed energy resources management system and an expansion of the Borrego Springs Microgrid …	http://www.greentechmedia.com/articles/read/Jim-Avery-on-the-Promise-of-EVs-and-the-Pitfalls-of-Solar	-	-
15	2015	3-Mar	Micro-grid sprouting on outskirts of San Diego	San Diego Union-Tribune		San Diego Gas & Electric is expanding an experimental micro-grid at Borrego Springs that is designed to run on renewable energy independently of the regional power grid.	http://www.sandiegouniontribune.com/news/2015/mar/03/borrego-micro-grid-expands/	-	-
16	2015	6-Mar	Current and Future Role of Microgrids	Tom Bialek, Chief Engineer, SDG&E	Sacramento, CA	Presented at the Staff WorkshopMicrogrid Assessment and Recommended Future RD&D Investments for theState of California	http://www.energy.ca.gov/research/notices/2015-03-06_workshop/2015-03-06_agenda.pdf	50	
17	2015	11-Mar	Borrego Springs Microgrid Demonstration Overview	Neal Bartek SDG&E	San Diego, CA	Presentation for the Society of American Military Engineers	http://samesandiego.org/wp-content/uploads/2015/05/March11PresentationBorregoSpringsMicroGridProject1.pdf	65	-
18	2015	16-Mar	Borrego Springs Microgrid Tour - Arizona Hopi Indian Tribe (Brian Roppe)	Neal Bartek SDG&E	Borrego Springs, CA	Gave tour to Hopi Tribe Council Members	5 Guests + 3 SDG&E = 11 Total	11	11

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19	2015	25-Mar	Clean Technica: San Diego Microgrid Expanding	Clean Technica		With help from a grant from California, SDG&E is expanding a renewable micro grid near San Diego to provide renewable power for up to 2,800 customers.			
20	2015	8-Apr	2015 Earth Day @ - DER Team Booth highlights Borrego Springs Microgrid and other projects	SDG&E Green Team	SDG&E Century Park Campus - San Diego, CA	Over +1,000 attendees at SDG&E's Century Park Campus - Discussed Borrego Springs Microgrid and other DER Team Projects	+1000 attendees to the Earth Fair	1000	
21	2015	11-Apr	ABDNHA - Water & Energy: Desert Living 2015	ABDNHA	Borrego Springs, CA	On the topic of energy: Tom Bialek, Chief Engineer of Smart Grid Technologies, Sempra Energy, is among the most knowledgeable engineers in America directly working with the technologies and the science behind the energy issues of today and the future: solar, microgrids, smart grids, distributed generation, transmission, renewables, and battery storage.	http://www.abdnha.org/desertliving/	60	
22	2015	11-Apr	KPBS Calendar Post - Water & Energy: Desert Living 2015	KPBS	San Diego, CA	On the topic of energy: Tom Bialek, Chief Engineer of Smart Grid Technologies, Sempra Energy, is among the most knowledgeable engineers in America directly working with the technologies and the science behind the energy issues of today and the future: solar, microgrids, smart grids, distributed generation, transmission, renewables, and battery storage.	http://www.kpbs.org/events/2015/apr/11/water-energy-desert-living-2015/?et=48814		
23	2015	13-Apr	Northern Arizona University	Neal Bartek SDG&E	Northern Arizona University, AZ	Presentation about DG and electric vehicles, and microgrids to students at NAU	Over +20 Guests	20	
24	2015	13-Apr	Hopi Indian Tribal Council - Arizona - Microgrid Presentation by Neal Bartek	Neal Bartek SDG&E	Northern Arizona University, AZ	Borrego Springs Microgrid Presentation given by Neal Bartek to several tribal members followed by a meeting to discuss next steps	Over +15 Guests	15	

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25	2015	16-Apr	Borrego Springs Microgrid an important part of utility's future	SmartGrid News. com		In September 2013, a large thunderstorm rolled through the Borrego Springs area of California, adding to a year that was filled with several natural disasters -- including wind storms and flash flooding.	http://www.smartgridnews.com/story/borrego-springs-microgrid-important-part-utilitys-future/2015-04-16		
26	2015	27-Apr	Utilities explore the microgrid value proposition	Intelligent Utility		Utility distribution microgrids (UDMs) are emerging as a new ... a distribution feeder in Borrego Springs while energizing a large solar PV farm, ...	http://www.intelligentutility.com/article/15/04/utilities-explore-microgrid-value-proposition	-	-
27	2015	27-Apr	Borrego Springs Microgrid Tour - SEPA USC - Solar Electric Power Association - Utility Solar Conference	Tom Bialek & Neal Bartek - SDG&E	Borrego Springs, CA	The Utility Solar Conference (USC) is a utility-only forum to learn from experts, exchange ideas, and talk through various strategies and service solutions in an intimate environment free from outside industry pressures and influences.	Over +35 Guests	35	35
28	2015	1-May	When Will We Get Smart Grids?	MIT Technology Review		In the United States, these "microgrids" currently exist mainly at ... million to connect a microgrid in Borrego Springs to a solar facility with battery ...	https://www.technologyreview.com/s/537046/when-will-we-get-smart-grids/	-	-
29	2015	7-May	EPC-14-060 Kickoff Meeting Borrego Springs	Tom Bialek & Neal Bartek - SDG&E	Borrego Springs Chamber of Commerce	Kick-Off Meeting & Tour as part of the CEC EPC-14-060 Project	18 Guests attended	18	18
30	2015	7-May	Borrego Springs Community Sponsor Group Presentation	Neal Bartek SDG&E	Borrego Springs, CA	Presentation given to the Borrego Springs Community Sponsor Group - The principal function of a sponsor group is to be an information link between the community and the County of San Diego on matters dealing with planning and the use of land in their community	15 Guests attended	15	
31	2015	22-May	Microgrid and Water Recurrent Worries for Borrego Springs	Borrego Sun Newspaper	Borrego Springs, CA	Two informational presentations were given to the Borrego Springs Community Sponsor Group on May 7. The first was a briefing on the microgrid from representatives of SDG&E. The microgrid is a subset of the larger electrical grid,	http://www.borregosun.com/story/2015/05/21/news/microgrid-and-water-recurrent-worries-for-borrego-springs/194.html	-	-

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32	2015	28-May	National Town Meeting on Demand Response and Smart Grid - Washington, DC - Microgrids from a Utility's Perspective	Neal Bartek SDG&E	Washington, DC	As the forum in the U.S. for all things demand response and smart grid, the National Town Meeting on Demand Response and Smart Grid® features speakers who take the measure of the state of the industry, indicate what's to come in the year ahead, and report on best practices and projects in the field.	Over +100 Guests	100	
33	2015	29-May	Smart Grid and DR Conference: We Need New Business Models to Spur Integration of Microgrids and Distributed Energy Resources	Powerit Solutions		Neal Bartek, distributed energy resources manager for San Diego Gas & Electric, talked about the utility's experience with its Borrego Springs demonstration microgrid	http://www.poweritsolutions.com/blog/?detail=yes&id=1102		
34	2015	1-Jun	Microgrid Powers Borrego Springs to Avoid Major Outage	SDG&E Newsroom		(SDG&E) Microgrid powered the entire community of Borrego Springs during ... on the Borrego Springs Microgrid to avoid the impact of a major outage. The Borrego Springs Microgrid uses ... launch the Borrego Springs Microgrid. By avoiding a lengthy outage, the Microgrid demonstrated its …	http://www.sdge.com/newsroom/press-releases/2015-06-01/microgrid-powers-borrego-springs-avoid-major-outage	-	-
35	2015	1-Jun	Electric Light & Power: VIDEO - Microgrid powers Borrego Springs to avoid power outage	Electric Light & Power		Video & Article - In late May, San Diego Gas & Electric's (SDG&E) microgrid powered the entire community of Borrego Springs during planned grid maintenance, thus avoiding major service interruptions to customers.	http://www.elp.com/articles/2015/06/microgrid-powers-borrego-springs-to-avoid-power-outage.html		
36	2015	1-Jun	Borrego Springs Microgrid Averts Long Outage During Lightning Strike Repair	Microgrid Knowledge		San Diego Gas & Electric reported today that the Borrego Springs Microgrid averted a major outage for an entire community in late May as the utility repaired damage from a lightning strike.	http://microgridknowledge.com/borrego-springs-microgrid-averts-long-outage-during-lightning-strike-repair/	-	-
37	2015	1-Jun	Microgrid powers Borrego Springs for 9-hours	Fox 5 News	San Diego	SAN DIEGO – All the electricity delivered to Borrego Springs during a nearly nine-hour period last month came from a nearby "microgrid," in …	http://fox5sandiego.com/2015/06/01/microgrid-powers-borrego-springs-for-9-hours/	-	-

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38	2015	1-Jun	Microgrid Powers Borrego Springs To Avoid Major Outage	PR Newswire		SAN DIEGO, June 1, 2015 /PRNewswire/ -- In late May, San Diego Gas & Electric's (SDG&E) Microgrid powered the entire community of Borrego Springs during planned grid maintenance…	http://www.prnewswire.com/news-releases/microgrid-powers-borrego-springs-to-avoid-major-outage-300091750.html	-	-
39	2015	2-Jun	Entire Borrego Springs Community Now Powered by Microgrid	KPBS		All the electricity delivered to Borrego Springs during a nearly nine-hour period last month came from a nearby "microgrid," in what's believed to be the first time that such a facility powered an entire community in the U.S., according to San Diego Gas & Electric.	http://www.kpbs.org/news/2015/jun/01/entire-borrego-springs-community-now-powered-micro/	-	-
40	2015	2-Jun	Microgrid Power Borrego Springs to Avoid Major Outage	Smartgridobserver.com		In addition to onsite generation and energy storage systems, SDG&E used NRG Energy's nearby 26-megawatt Borrego Solar facility to supply electricity to all 2,800 customers in the area for ten hours.	http://smartgridobserver.com/n6-2-15-Borrego-Springs-microgrid.htm	-	-
41	2015	3-Jun	SDG&E microgrid uses solar, storage to avoid outage in small town	Utility Dive		The utility used the Borrego Springs Microgrid after the transmission line that usually feeds the community was damaged by lightning. SDG&E …	http://www.utilitydive.com/news/sdge-microgrid-uses-solar-storage-to-avoid-outage-in-small-town/400147/	-	-
42	2015	3-Jun	Borrego Springs first community fully-powered by microgrid	SmartGridNews. com		San Diego Gas & Electric (SDG&E) has continued to use their microgrid in the Borrego Springs community and, in May, had to use it to power the entire community during a planned grid outage.	http://www.smartgridnews.com/story/borrego-springs-first-community-fully-powered-microgrid/2015-06-03	-	-
43	2015	3-Jun	Borrego Springs first community fully-powered by microgrid	FACEBOOK PAGE - UPME Unidad de Planeación Minero Energética - República de Colombia		San Diego Gas & Electric (SDG&E) has continued to use their microgrid in the Borrego Springs community and, in May, had to use it to power the entire community during a planned grid outage.	https://www.facebook.com/permalink.php?story_fbid=1064433486920144&id=374839812546185	-	-

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44	2015	3-Jun	SDG&E microgrid powers Borrego Springs to avoid service interruptions	California Carbon.info		(Source: Benzinga) San Diego Gas & Electric's (SDG&E) microgrid powered the entire community of Borrego Springs, during planned grid maintenance, in late May, thus avoiding service interruptions to customers.	http://californiacarbon.info/2015/06/03/sdge-microgrid-powers-borrego-springs-avoid-service-interruptions-2/	-	-
45	2015	4-Jun	Borrego Springs' Microgrid Powers the Town Successfully	Borrego Sun Newspaper	Borrego Springs, CA	The Borrego Springs Microgrid was tested on May 21 during a nine hour period that was required to repair transmission poles. SDG&E said it was able to use the microgrid to deliver electricity to Borrego Springs from the nearby 26-megawatt Borrego Solar facility during the...	http://www.borregosun.com/story/2015/06/04/news/borrego-springs-microgrid-powers-the-town-successfully/261.html	-	-
46	2015	8-Jun	Borrego Springs first community fully-powered by microgrid	eiXtra - Newsletter of Electrical Equipment & Medical Imaging Manufacturers - Feature Story		San Diego Gas & Electric (SDG&E) has continued to use their microgrid in the Borrego Springs community and, in May…	https://www.nema.org/news/EiExtra/20150608eiXtra.htm	-	-
47	2015	10-Jun	Industrial Environmental Association - Speaker	Neal Bartek, SDG&E	San Diego, CA	The Industrial Environmental Association (IEA) is a non-profit association based in San Diego, California, that promotes responsible environmental laws and regulations, provides a voice on a variety of environmental issues, and offers educational opportunities for manufacturers and associated organizations in the region.	8 Guests	8	
48	2015	6-Jul	Inside the nation's first renewables-plus-storage microgrid	Utility Dive		Borrego Springs, California, sits less than 100 miles from San Diego, but in terms of electric reliability the two places were once worlds apart…	http://www.utilitydive.com/news/inside-the-nations-first-renewables-plus-storage-microgrid/401476/	-	-
49	2015	7-Jul	Borrego Springs Microgrid - First of Its Kind	Borrego Sun Newspaper	Borrego Springs, CA	Borrego Springs is served by a transmission line that traverses sixty miles, making it susceptible to wild weather and wildfires. According to SDG&E's chief development officer, Jim Avery, it was after wildfires knocked out power in 2007 for two days that they began looking for	http://www.borregosun.com/story/2015/07/02/news/borrego-springs-microgrid-first-of-its-kind/505.html	-	-

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50	2015	7-Jul	California's Distributed Energy Grid Plans: The Next Steps	Greentech Media		SDG&E is planning demonstrations at its Borrego Springs Microgrid and at other unspecified locations, and PG&E is targeting solar-rich Fresno …	http://www.greentechmedia.com/articles/read/californias-distributed-energy-grid-plans-the-next-steps	-	-
51	2015	8-Jul	SDG&E DER Lunch & Learn Presentation: Borrego Springs May 21 Planned Outage Case Study	Justin Arakaki & Alfonso Orozco - SDG&E	SDG&E Lightwave - San Diego, CA	Overview, update and lessons learned presented at an in-house presentation series	55 Guests	55	
52	2015	9-Jul	Presentation - Utility Role in Microgrids	Tom Bialek, Chief Engineer, SDG&E	Golden, Colorado	Part of NREL Advanced Grid Control Technologies Workshop Series	40 Guests	40	
53	2015	13-Jul	NRG Tour/Meeting - Borrego Springs Microgrid - CEC EPC-14-060	Tom Bialek & Neal Bartek - SDG&E	Borrego Springs, CA	Meeting & Tour of both the NRG Solar Farm and Borrego Springs Microgrid by NRG & SDG&E employees to discuss CEC EPC-14-060	13 Guests	13	13
54	2015	15-Jul	Moving Microgrids Beyond R&D	Alternative Energy Stocks		A microgrid is an electrical supply and use system that can operate ... such as San Diego Gas and Electric's Borrego Springs CA microgrid …	http://www.altenergystocks.com/archives/2015/07/moving_microgrids_beyond_rd.html	-	-
55	2015	23-Jul	SDG&E fires up solar-based microgrid to avoid 9-hour maintenance outage	Chartwell's Best Practices Report		San Diego Gas & Electric (SDG&E) reached a significant milestone in its continuing work with microgrid technology on May 21, when the SDG&E Borrego Springs Microgrid Demonstration Project in California powered the entire community of Borrego Springs…	-	-	-
56	2015	27-Jul	Scottish & Southern Energy - Microgrid Operations Discussions	Neal Bartek, SDG&E	San Diego, CA	Discussion on Borrego Springs Microgrid with some SSE utility leaders who are interested in the project. Set-up by Bradley Williams (VP – Oracle)	12 Guests	12	

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57	2015	29-Jul	2nd Microgrid Development for Public and Private Sectors WEST Coast (Marcus Evans)	Speaker Neal Bartek, SDG&E Organizers Marcus Evans	Irvine, CA	Conference - Establishing a Microgrid Framework through Innovative System Designs, Technological Advances, and Regulatory Comprehension	75 Guests	75	
58	2015	29-Jul	Why the future of microgrids won't look like the past	Utility Dive		According to GTM Research, total microgrid capacity in the United States ... and San Diego Gas & Electric has 26 MW serving Borrego Springs).	http://www.utilitydive.com/news/why-the-future-of-microgrids-wont-look-like-the-past/403093/	-	-
59	2015	30-Jul	Warming up to microgrids	energybiz		Still, most microgrids in the United States serve army bases, remote ... In 2013, the transmission line to Borrego Springs was taken out several …	http://www.energybiz.com/article/15/06/warming-microgrids	-	-
60	2015	15-Aug	SDG&E Microgrid Uses Solar Facility to Avoid Outages	Electrical Contractor Power & Integrated Building Systems		San Diego Gas & Electric's (SDG&E) microgrid supplied electricity to 2,800 customers in Borrego Springs in San Diego County, Calif., on May 21, 2015, during planned grid maintenance. This marked the first time a U.S. microgrid used renewable energy to power a community, according to SDG&E.	http://www.ecmag.com/section/your-business/sdge-microgrid-uses-solar-facility-avoid-outages	-	-
61	2015	19-Aug	CPUC - ENERGY STORAGE WORKSHOP - IOU Presentations on Safety of Energy Storage	Neal Bartek, SDG&E	San Francisco, CA	Energy Storage presentations given which included the Borrego Springs Microgrid	What are the utilities' experiences installing and operating storage devices for a wide variety of applications?		
62	2015	19-Aug	CEC-Mexico Conf - EFFICIENCY, RENEWABLES AND GRID MANAGEMENT CONFERENCE	Jim Avery, SDG&E Chf Dev Ofcr of SDG&E, Development & Clean Transp	UCSD La Jolla, CA	"The Future of Microgrids" - presentation gave overview of the Borrego Springs project	Technical workshop on efficiency, renewables and grid management.		
63	2015	19-Aug	Borrego Springs Microgrid Video	Jim Avery, SDG&E Chf Dev Ofcr of SDG&E, Development & Clean Transp		Used in conjunction with Jim Avery's "The Future of Microgrids" presentation	http://www.sdge.com/smartgrid/borrego-springs-microgrid		

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64	2015	19-Aug	SDG&E Smart Grid Website - Borrego Springs Microgrid (Includes link to video)	SDG&E Smart Grid Team		The Borrego Springs Microgrid offers a powerful example of what new Smart Grid technology can do. When this experimental project was used during an actual power emergency, it gave us and our customers a glimpse of a possible “utility of the future”…	http://www.sdge.com/smartgrid/borrego-springs-microgrid		
65	2015	21-Aug	Borrego Springs Microgrid Tour - CEC-Mexico Clean-Tech Conference	Neal Bartek & Tom Bialek, SDG&E	Borrego Springs, CA		20 Attendees	20	20
66	2015	24-Aug	California Climate Change Symposium 2015 - The premier forum for the sharing of cutting-edge research addressing the impacts of climate change on the state.	Neal Bartek, SDG&E	Sacramento, CA	Presentation - "Microgrids for Energy Resiliency"	150 Attendees	150	
67	2015	25-Aug	The 10 Questions to Ask When You Hear the Word “Microgrid”	RMI Outlet - Rocky Mountain Institute		Both SDG&E’s demonstration project in Borrego Springs, CA, (recently heralded for keeping the lights on during a transmission line problem) and Konterra’s solar-storage project at its Maryland corporate headquarters have made headline news as microgrids...			
68	2015	3-Sep	Power Grid Summit - 2015	Tom Bialek, Chief Engineer, SDG&E	San Diego, Ca	Presentation - "The Future of Microgrids to Solve Resilience Challenges"	30 Attendees	30	
69	2015	10-Sep	10 questions to ask before you build a microgrid	GreenBiz		For example, the Borrego Springs Microgrid serves that community and is owned and operated by the local San Diego utility, SDG&E. The U.S. …	https://www.greenbiz.com/article/10-questions-ask-you-build-microgrid	-	-

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70	2015	14-Sep	Four Good Reasons for Community Microgrids	Energy Collective		When it islands, the microgrid turns on its on-site generation to send ... in Borrego Springs, the site of a microgrid that serves 2,800 customers.	http://www.theenergycollective.com/darekobg/2270755/four-good-reasons-community-microgrids	-	-
71	2015	15-Sep	SDG&E North County Spotlight Event - met with community leaders from several chambers and economic development organizations from North County.	DER Team	Escondido, CA	Event highlighted updated the community on SDG&E's innovative programs. This is a partnership with the following Chambers of Commerce and the San Diego North Economic Development Council - Discussed Borrego Springs Microgrid and other DER Team Projects at the DER Booth	Over 150 business owners, politicians and community leaders	150	
72	2015	23-Sep	Skin in the Game: New Case Studies Illuminate Best Practice	Energy Collective		... accelerate early deployment of new technologies, as in the case of the California Solar PV Program (SPVP) and Borrego Springs Microgrid.	http://www.theenergycollective.com/americaspowerplan/2274718/skin-game-new-case-studies-illuminate-best-practices-der-ownership-and-ope	-	-
73	2015	23-Sep	Skin in the Game: New Case Studies Illuminate Best Practice	Power Plan (Reposted Energy Collective article)		The utility-owned and operated model may be able to demonstrate and accelerate early deployment of new technologies, as in the case of the California Solar PV Program (SPVP) and Borrego Springs Microgrid.	http://americaspowerplan.com/tag/distributed-energy-resources/	-	-
74	2015	28-Sep	Inverter Capabilities Are the Biggest Limitation Facing All-Renewable Microgrids	Greentech Media		All-renewable microgrids such as the one powering Borrego Springs are likely to remain scarce for years because of inverter shortcomings, ...	http://www.greentechmedia.com/articles/read/why-the-all-renewable-microgrid-is-still-a-way-off	-	-
75	2015	28-Sep	Duke simplifies microgrid development process for NC fire department	Utility Dive		Duke Energy has developed a microgrid serving Charlotte Fire Station ... and San Diego Gas & Electric's 26 MW grid serving Borrego Springs…	http://www.utilitydive.com/news/duke-simplifies-microgrid-development-process-for-nc-fire-department/406326/	-	-

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76	2015	Oct	SDG&E A Utility-Owned Microgrid - A Case Study on Borrego Springs	Association for Demand Response + Smart Grid		ADS chose SDG&E forthis case study for thefollowing reasons:1. The utility had adesire to exploreoptions outside ofits normalbusiness model…	http://www.demandresponsesmartgrid.org/resources/Documents/Case%20Studies/SDGE%20Borrego%20Springs%20Case%20Study%20FINAL.pdf	-	-
77	2015	5-Oct	Borrego Springs Microgrid Tour Guide Training of the DER Team	Neal Bartek, SDG&E	SDG&E Lightwave - San Diego, CA	Due to the popularity of BSM Tours…we are training other DER Team members to be tour guides - thorough overview given	3 Guests - Neal Bartek, Alfonso Orozco, Jeff Mucha	3	
78	2015	7-Oct	CEC RESCO Workshop @ SANDAG - The Energy Commission's Renewable Energy Secure Communities (RESCO) program aims to address issues with the deployment and integration of renewable energy at the community scale.	Neal Bartek, SDG&E	SANDAG Offices, San Diego, CA	Borrego Springs Microgrid Project Overview - Discussion of the efforts in the Borrego Springs effort to serve as a case study, especially since the Energy Commission is helping to fund the next phase of the project.	http://www.energy.ca.gov/research/notices/2015-10-07_workshop/presentations/03_SDG_and_E_BorregoSprings_10-7-15.pdf	30	
79	2015	9-Oct	Borrego Springs Microgrid	SDG&E Newsroom		View the Borrego Springs Microgrid video to see how SDG&E's Microgrid leveraged ... to the local community through its onsite resources.	http://www.sdge.com/smartgrid/borrego-springs-microgrid		
80	2015	14-Oct	Honey, I shrunk the grids: The emergence of 'nanogrids'	Utility Dive		Duke Energy, San Diego Gas & Electric, and Central Hudson -- along with many other utilities -- have all been working to integrate microgrids into their systems…	http://www.utilitydive.com/news/honey-i-shrunk-the-grids-the-emergence-of-nanogrids/407283/	-	-
81	2015	15-Oct	National Action Plan on Demand Response Case Study #6 - Case Study on utility-owned microgrid	ADS - Association for Demand Response Smart Grid		Report - pdf	http://www.demandresponsesmartgrid.org/resources/Documents/Case%20Studies/SDGE%20Borrego%20Springs%20Case%20Study%20FINAL.pdf	-	-

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82	2015	16-Oct	Borrego Springs Microgrid Tour - China Energy Storage Alliance (CNESA)	Josh McIlvoy, Jeff Mucha and Alfonso Orozco, SDG&E	Borrego Springs, CA	"CNESA is China's energy storage industry association who represent over 100 Chinese and international companies across the energy storage value chain.	8 Chinese Delegates	8	8
83	2015	23-Oct	Case study on utility-owned microgrid released by the Association for Demand Response & Smart Grid	PR Newswire		The Association for Demand Response & Smart Grid (ADS) released a new case study today that examines how San Diego Gas & Electric's Borrego Springs Microgrid was…	http://www.prnewswire.com/news-releases/case-study-on-utility-owned-microgrid-released-by-the-association-for-demand-response--smart-grid-300165400.html	-	-
84	2015	24-25 Oct	2015 Borrego Days - Neal Bartek on Saturday, Frank Goodman on Sunday	Neal Bartek, Frank Goodman SDG&E	Borrego Springs, CA	Borrego Days is an annual community event that spans 3 days with food, entertainment, booths and events. SDG&E has a booth and talks to the community about the local microgrid project	DER Team provided a Microgrid Spokesperson to share progress and info on the Microgrid with the community		
85	2015	25-Oct	San Diego Gas & Electric's Borrego Springs Microgrid Studied by ADS	Transmission and Distribution World		ADS released a new case study that examines how San Diego Gas & Electric's Borrego Springs Microgrid…	http://tdworld.com/distribution/san-diego-gas-electrics-borrego-springs-microgrid-studied-ads	-	-
86	2015	26-Oct	Study: SDG&E's Borrego Springs Microgrid proves useful, but complicated	SNL		San Diego Gas & Electric Co.'s Borrego Springs Microgrid started out as a research and development project, but violent storms and extreme desert heat have made the effort a real-world necessity.	https://www.snl.com/InteractiveX/article.aspx?CdId=A-34271985-12583	-	-
87	2015	26-Oct	Microgrid Conference - EUCI in Chicago Illinois - Microgrid Deployment Session	Neal Bartek, SDG&E	Illinois Institute of Technology in Chicago, IL	This conference will bring together the industry's most knowledgeable microgrid professionals to share their experiences and vision for the microgrid marketplace.	70 Attendees		
88	2015	27-Oct	Utility microgrid: Lessons learnt from California's SDG&E	Metering and Smart Energy International		Utility microgrid: Lessons learnt from California's SDG&E ... how San Diego Gas & Electric's Borrego Springs Microgrid was developed.	http://www.metering.com/utility-microgrid-lessons-learnt-from-californias-sdge/	-	-

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89	2015	28-Oct	GreenBiz VERGE Conf - Off the Grid: Microgrid Owner/Operator Perspectives - presentation by Neal Bartek	Neal Bartek SDG&E	San Jose, CA	VERGE is GreenBiz Group's global event series focusing on the technologies and systems that accelerate sustainability solutions across sectors in a climate-constrained world. The event brings together the world's largest companies, technology innovators, utilities and cities, creating a broad ecosystem of players to accelerate opportunities for business, the environment and society.	60 attendees. The operator of the VERGE Interconnect microgrid leads a presentation on how microgrids are being deployed and operated. The session will examine actual results and benefits being realized through the operation of various types of microgrids, including the equipment required to implement a system, power systems control technology, timing and complexity of the build and benefits to both savings and resiliency. Featured speakers include owners and operators from Necker Island and other innovative microgrid developments.	60	
90	2015	28-Oct	Microgrid Recognized as Innovative	Borrego Sun Newspaper	Borrego Springs, CA	A new case study highlighting SDG&E's Borrego Springs Microgrid has been released by the Association for Demand Response & Smart Grid (ADS) and the Demand Response Coordinating Committee last week examining how the site was developed…	http://www.borregosun.com/story/2015/10/28/news/microgrid-recognised-as-innovative/1308.html	-	-
91	2015	28-Oct	Key Lessons from San Diego Gas & Electric's Utility-Owned Microgrid	Smartgridobserver.com		A recently published case study by the Association for Demand Response & Smart Grid (ADS) examines the latest updates and lessons learned from SDG&E's Borrego Springs Microgrid project.	http://smartgridobserver.com/microgrids.htm	-	-
92	2015	29-Oct	Borrego Springs Microgrid Tour - Borrego Water District & SDG&E Business Optimization and Financial & Strategic Analysis Departments	Neal Bartek & Josh McIlvoy, SDG&E	Borrego Springs, CA		12 Business Optimization & Financial Depart + 3 DER Team + 2 Borrego Water District = 17 Total	17	17

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93	2015	29-Oct	Dispatches from San Diego, Pt. 4 Article - CNESA - Energy Storage North America Conference and Expo . (CNESA - China Energy Storage Alliance is a non-profit industry association dedicated to promoting energy storage technology in China)	CNESA - (China Energy Storage Alliance	San Diego, CA	We wanted to make the most of our San Diego trip, and so scheduled a trip to Borrego Springs, a community two hours away hosting a 26 megawatt solar facility and a 4.5 MWh lithium-ion battery energy storage system owned and operated by San Diego Gas & Electric... (BSM Tour was given on Oct 16, 2015)	http://en.cnesa.org/latest-news/2015/10/29/dispatches-from-san-diego-pt-4	-	-
94	2015	30-Oct	Borrego Springs Microgrid Tour Guide Training	Neal Bartek, SDG&E	SDG&E Lightwave - San Diego, CA	Due to the popularity of BSM Tours…we are training other DER Team members to be tour guides - thorough overview given	Meeting - 6 Guests - Neal Bartek, Frank Goodman, Kelvin Ellis, Jeff Mucha, John Holmes, Josh McIlvoy	6	
95	2015	30-Oct	Here's how microgrids and utilities are getting along	GreenBiz		SDG&E is undertaking a project to build a microgrid in Borrego Springs, a town on the outskirts of San Diego County, which is isolated by …	https://www.greenbiz.com/article/heres-how-microgrids-and-utilities-are-getting-along	-	-
96	2015	12-Nov	Borrego Springs Microgrid Tour - City of Chula Vista (4 Guests), Groundwork SD - Cholas Creek Earth Lab Collaboration (3 Guests) and SDG&E Project Management Team (4 Guests)	Neal Bartek & Josh McIlvoy, SDG&E	Borrego Springs, CA		15 Guests Total - SDG&E and Community Leaders	15	15
97	2015	19-Nov	2015 Energy Career Connections & Sustainability Fair (Title 1 High School Event for Borrego Springs High School and 5 other schools)	SDG&E DER Team and ABDNHA	SDG&E Energy Innovation Center San Diego, CA	Community event done in conjunction with the Anza-Borrego Desert Natural History Association - DER Team organizes this event as part of our commitment to the Borrego Springs Community		200	

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98	2015	30-Nov	A Timeline of California's Distributed Energy Future, 2015	Greentech Media		SDG&E has proposed using its existing Borrego Springs Microgrid for demonstration project E, but wants to seek out high-value circuits across ...	https://www.greentechmedia.com/squared/read/A-Timeline-of-Californias-Distributed-Energy-Future-2016-and-Beyond	-	-
99	2015	2-Dec	ACWA 2015 Fall Conference & Exhibition (Assoc. of California Water Agencies)	Neal Bartek, SDG&E	Indian Wells, CA	Presentation - "Energy Committee Program - Getting Off the Grid: Microgrids"	60 Attendees	60	
100	2015	3-Dec	2015 EPIC Innovation Symposium - Data Analytics in Support of Advanced Planning and System Operations	Neal Bartek, Frank Goodman & Yvette Oldham, SDG&E	Folsum, CA	Shared info on the Borrego Springs Microgrid-Frank Goodman was Session Organizer and gave Report to Final Plenary. Bartek & Oldman gave a presentation on the Borrego Springs Microgrid	150 Attendees	150	
101	2015	11-Dec	Borrego Springs Microgrid Tour - AMEREN Electric Utilities (Illinois) & SDG&E Emergency Operations Team (Kris Bourbois)	Neal Bartek, Josh McIlvoy, Gil Montes, SDG&E	Borrego Springs, CA		21 Guests on Tour	21	21
102	2015	11-Dec	SDG&E Emergency Operations Team - Meeting with Sheriff Billy Painter and Linda Haddock Chamber to discuss emergency plans and critical load report	Neal Bartek, SDG&E	Borrego Springs, CA	Discussion about the BSM Critical Load Report as well as meeting with the Emergency Operations Team	15 Guests at this meeting	15	
103	2015	22-Dec	7 Energy Storage Stories You Might Have Missed in 2015	Greentech Media		San Diego Gas & Electric's Borrego Springs Microgrid project was put into motion long before AB 2514. The USDOE-funded project brings …	http://www.greentechmedia.com/articles/read/7-Energy-Storage-Stories-You-Might-Have-Missed-in-2015	-	-

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							Tech Transfer Summary 2015	2,527	158
2016									
1	2016	20-Jan	Microgrids - Berkley Lab Website	Berkley		Lists all the microgrids in the U.S.	https://building-microgrid.lbl.gov/borrego-springs	-	-
2	2016	20-Jan	Cal Poly - San Luis Obispo - Borrego Springs Microgrid Presentation by Neal Bartek	Cal Poly - San Luis Obispo Alumni - presentation by Neal Bartek, SDG&E - San Diego, CA		Overview of the Borrego Springs Microgrid	15 Guests	15	
3	2016	9-Feb	DistribuTECH - Utility Owned Microgrid Best Practices - Panel Presentation	David L. Geier - Vice President, Electric Transmission and System EngineeringSDG&E	Orlando, Florida	Microgrids are increasingly popular for adding resiliency to transmission and distribution grids. Join this panel discussion to learn about best practices for the planning, design and construction of different types of microgrids. Projects to be discussed include: the Borrego Springs Microgrid that received a recent California Energy Commission (CEC) grant for expansion...	DistribuTECH is the leading annual smart grid event. Presentation attended by over 100 Guests	100	
4	2016	10-Feb	How Arizona Public Service is preparing for the grid of the future	Utility Dive		The need for a good DERMS system to control multiple DERs is not unique to APS. At the microgrid forum on Tuesday, Jeff Geier, vice president for transmission and system engineering at SDG&E, spoke about the Borrego Springs Microgrid, one of the first renewables-plus-storage microgrids in the nation.	http://www.utilitydive.com/news/how-arizona-public-service-is-preparing-for-the-grid-of-the-future/413667/	-	-

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5	2016	9-Feb	Electricity Use in Rural and Islanded Communities: A Workshop Supporting the Quadrennial Energy Review's Public Outreach - Presentation on "Microgrids"	Tom Bialek, Chief Engineer, SDG&E	Washington, DC	**40 Guests - Microgrids**: Discuss the potential for microgrids to improve resilience and operations. Consider new technologies and business models for decentralized generation and their implications for rural and islanded communities.	-	40	
6	2016	16-Feb	UCSD - SNU Korean Delegation Conference - 2 presentations: Borrego Springs Microgrid and SDG&E Projects	Frank Goodman, SDG&E	UCSD La Jolla, CA	This group consist of a cross-section of Korean industry, universities, and governmental agencies, their focus will be on microgrids and power system automation.	Over 25 Guests	25	
7	2016	18-Feb	Borrego Springs Microgrid Tour - UCSD SNU Korean Delegation	Neal Bartek, Tom Bialek & Jeff Mucha, SDG&E	Borrego Springs, CA	This group consist of a cross-section of Korean industry, universities, and governmental agencies, their focus will be on microgrids and power system automation.	22 Guests	22	22
8	2016	18-Feb	Borrego Springs Microgrid Tour - So Cal Edison Team	Neal Bartek, Tom Bialek & Jeff Mucha, SDG&E	Borrego Springs, CA		6 Guests	6	6
9	2016	24-Feb	New report reviews top US projects	Energy Storage Report		Only one of the three projects reviewed, the 1.6MW, 4.7MWh Borrego Springs Microgrid implemented by San Diego Gas & Electric (SDG&E), appears to have functioned satisfactorily from the outset.	http://energystoragereport.info/grid-scale-energy-storage-projects-usa/		
10	2016	24-Feb	US Energy Storage Projects and Prospects Guide 2016	Energy Storage Report		The guide focuses on the Borrego Springs, Tehachapiand, and Notrees energy storage projects and examines the long-term impact that they will have on the future project pipeline in the United States…	http://energystoragereport.info/grid-scale-energy-storage-projects-usa/#sthash.GMnU0UO0.dpuf		

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11	2016	24-Feb	US Energy Storage Projects and Prospects Guide 2016	Energy Storage Report	Report pdf file	The guide focuses on the Borrego Springs, Tehachapi and, and Notrees energy storage projects and examines the long-term impact that they will have on the future project pipeline in the United States…	**Error! Hyperlink reference not valid.**		
12	2016	25-Feb	Energy Delivery Public Policy EAC Meeting - Hyatt Regency La Jolla	Neal Bartek, SDG&E	La Jolla, California		Over 25 Guests	25	
13	2016	3-Mar	Report: Mighty Microgrids	ILSR - Institute for Local Self-Reliance		Borrego Springs is a rural town of 2,800 people in southern California. Connected to the larger grid by a single, aging transmission line, Borrego Springs was a natural demonstration site for a microgrid.	https://ilsr.org/report-mighty-microgrids/		
14	2016	3-Mar	Report: Mighty Microgrids	ILSR - Institute for Local Self-Reliance		pdf file	https://ilsr.org/wp-content/uploads/downloads/2016/03/Report-Mighty-Microgrids-PDF-3_3_16.pdf		
15	2016	16-18 Mar	Microgrids Markets Summit East - Conference - Panel Presentation	Neal Bartek, SDG&E	Arlington, VA	Panel Discussion: Advanced Inverter Alternatives Available to Distribution Planners • Energy Storage • Grid-side Energy Efficiency and Demand Response • Customer demand management • Relationship of advanced inverters to storage and the grid	Over 100 Guests	100	
16	2016	22-Mar	Emerging Microgrid Business Models	POWER Magazine		In California, San Diego Gas & Electric (SDG&E) developed the Borrego Springs Microgrid project (see photo below) on its own initiative, ...	http://www.powermag.com/emerging-microgrid-business-models/		
17	2016	23-Mar	Borrego Springs Chamber Meeting - Microgrid Discussion	Neal Bartek, SDG&E	Borrego Springs, CA	Neal met with some of the Borrego Springs Chamber members and board to give an update on the project	Over 50 Guests	50	

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18	2016	25-Mar	Borrego Springs Microgrid Tour - City of San Diego - Scott Chadwick and Team (Frank Urtasun)	Neal Bartek & Tom Bialek, SDG&E	Borrego Springs, CA		8 of Guests Total	8	8
19	2016	25-Mar	Borrego Springs Microgrid Tour - So Cal Edison and Pacific Gas & Electric Team	Neal Bartek & Tom Bialek, SDG&E	Borrego Springs, CA		11-So Cal Edison + 3-Pacific Gas & Electric	14	14
20	2016	30-Mar	What the Internet of Things Means for Local Governments	Public CEO		...home to more than 2.3 million smart electric meters, plus an advanced **microgrid** at **Borrego Springs**. And Walnut Creek is experimenting with ...	http://www.publicceo.com/2016/03/what-the-internet-of-things-means-for-local-governments/	-	-
21	2016	31-Mar	Utility Role in Microgrids - "Microgrids - the Next Big Thing"	Tom Bialek, Chief Engineer, SDG&E	La Jolla, California		Over +40 Guests	40	
22	2016	6-Apr	SDG&E Earth Day @ CP - DER Team Booth	SDG&E	SDG&E's Century Park Campus - San Diego, CA	Over +1,000 attendees at SDG&E's Century Park Campus - Discussed Borrego Springs Microgrid and other DER Team Projects	+1000 attendees to the Earth Fair	1000	
23	2016	18-Apr	Stationary Energy Storage Meeting - Panelist on BESSs Lessons Learned and Future Solutions	**Neal Bartek**	**La Jolla, California**	Neal is a "panelist at the Stationary Energy Storage meeting. Their topic is "BESSs Lessons Learned and Future Solutions" Primary audience will be battery R&D chemists and electrical engineers.	Over 50 Guests	50	
24	2016	22-Apr	Borrego Springs Microgrid - DER Team - Tour Guide Training	Neal Bartek, SDG&E	Borrego Springs, CA	Training DER Team members	9 Guests	9	9

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25	2016	22-Apr	Borrego Springs Microgrid Tour - SDG&E Federal Regulatory & Compliance Team (Andrey Komissarov) and VP, Patrick Lee - Major Project Controls, Project Controls & Analysis	Neal Bartek, SDG&E	Borrego Springs, CA	Tour for internal SDG&E employees	8 Guests	8	8
26	2016	26-27 Apr	CEATI Conference - Intelligent Distribution Systems of the Future	Smart Grid Discussions on the Borrego Springs Microgrid conducted by Marvin Zavala-Iraheta and Steven Prsha	Atlanta, GA	The Centre for Energy Advancement through Technological Innovation (CEATI) is a user-driven organization committed to providing technology solutions to its electrical utility participants, who are brought together to collaborate and act jointly to advance the industry through the sharing and developing of practical and applicable knowledge.	70 Guests	70	
27	2016	27-Apr	Long live competition (Page 2)	Energy Biz		Maybe they can do it as part of their regulated business as SDG&E did with its Borrego Springs Microgrid project…	http://www.energybiz.com/article/16/04/long-live-competition-part-2		
28	2016	28-Apr	California Community Colleges- IOU ENERGY EFFICIENCY PARTNERSHIP - Campus Forum -	Neal Bartek, SDG&E	Oceanside, CA	Presentation given on SDG&E's Advanced Energy Storage projects (such as Borrego Springs, Canyon Crest, etc…)	Over +60 Guests	60	
29	2016	2-May	Overcoming Market Challenges to Microgrids -	AutomatedBuildings.com		They may have unusually high failure rates in their power supply. Borrego Springs is an example, a growing community at the end of a long single distribution line into the desert…	http://www.automatedbuildings.com/news/may16/columns/160429104808considine.html		
30	2016	3-May	2016 IEEE T&D Conference and Exposition	Tom Bialek, Chief Engineer, SDG&E	Dallas, TX	Presentation - "Forecasting & Mitigating Intermittent DER Impacts on Electric Distribution Systems" - Information on the Borrego Springs Microgrid included	Over 100 guests	100	

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31	2016	4-May	EERE National Lab Impact Summit	EERE - Energy Efficiency & Renewable Energy	NREL Campus, Golden, CO	Neal Bartek served on breakout panel about "Energy Systems Integration" - Information on the Borrego Springs Microgrid included		75	
32	2016	20-May	SDG&E Green Careers Conference at the Energy Innovation Center	SDG&E and Strategic Energy Innovations (SEI)	SDG&E Energy Innovation Center - San Diego, CA	Daniel Spaizman, Engineer II discussed the Borrego Springs Microgrid and SDG&E's ability to island the entire town with the support of the NRG solar farm	High school students present about energy education projects, interact with industry professionals about green careers in renewables, energy efficiency, engineering, design and manufacturing, and more. Connect with environmental education institutions, non-profits, and future employers. 30 (Students, teachers & industry professionals)	30	
33	2016	2-Jun	KPBS - Interview & Tour at the Borrego Springs Microgrid Yard	KPBS	Borrego Springs, CA	Neal Bartek, DER Manager was interviewed by KPBS at the Borrego Springs Microgrid yard about the project	News story is pending	3	3
34	2016	12-Jun	Forester Daily News - Energy Storage Systems in Microgrids	Forester Daily News	na	Jun 12, 2016 - The Borrego Springs Microgrid is perhaps the best-known microgrid in the energy industry, and it is being expanded.	http://foresternetwork.com/weekly/energy-storage-solutions-weekly/energy-storage-systems-in-microgrids/		
35	2016	24-Jun	SDG&E's IT Tech Expo 2016 - Distributed Energy - Connecting Renewables to the Grid	Neal Bartek & Tom Bialek, SDG&E	SDG&E Energy Innovation Center, San Diego, CA	Discuss specific DER innovations/projects that are being managed to compensate for the changing industry environment - Includes Borrego Springs Microgrid information and video		175	
36	2016	29-Jun	CPUC Public Workshop on DRP Demonstration Projects - San Francisco, CA -	Neal Bartek	San Francisco, CA	Neal Bartek - Speaker - Describe SDG&E's planned demonstration projects and coordinate with other IOUs/stakeholders		50	

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37	2016	Misc.	Borrego Springs Microgrid Project (Posting Date is Unknown)	Green Energy Corp	na	green energy corp has a website page dedicated to the Borrego Springs Microgrid Project	http://www.greenenergycorp.com/borrego-springs-microgrid-project/		
38	2016	1-Aug	Borrego Springs Microgrid Tour for Sumitomo Team	Neal Bartek & Tom Bialek	Borrego Springs, CA	SDG&E is working with Sumitomo on an AES project		12	12
39	2016	4-Aug	KPBS - ARTICLE: San Diego Leads Way in Reshaping Nation's Power Grid by Eric Anderson	Neal Bartek & Hanan Eisenman	Borrego Springs, CA	Borrego Springs sprawls across a mostly flat desert valley about 80 miles east of San Diego.	KPBS Website Article - http://www.kpbs.org/news/2016/aug/04/san-diego-leads-way-reshaping-nations-power-grid/		
40	2016	4-Aug	KPBS - VIDEO: San Diego Leads Way in Reshaping Nation's Power Grid by Eric Anderson	Neal Bartek & Hanan Eisenman	Borrego Springs, CA	Borrego Springs sprawls across a mostly flat desert valley about 80 miles east of San Diego.	KPBS Website Article - http://www.kpbs.org/news/2016/aug/04/san-diego-leads-way-reshaping-nations-power-grid/		
41	2016	4-Aug	KPBS - Radio News PT 1: San Diego Leads Way in Reshaping Nation's Power Grid by Eric Anderson	Neal Bartek & Hanan Eisenman	KPBS - San Diego	Borrego Springs, a small desert community about 80 miles east of San Diego, is shining a light on a future that could completely change how power is delivered to homes and businesses.	KPBS Radio News - http://www.kpbs.org/news/2016/aug/04/san-diego-leads-way-reshaping-nations-power-grid/		
42	2016	4-Aug	KPBS - Radio Midday News: San Diego Leads Way in Reshaping Nation's Power Grid by Eric Anderson	Neal Bartek & Hanan Eisenman	KPBS - San Diego	San Diego Leads Way in Reshaping Nation's Power Grid	KPBS Midday Edition - http://www.kpbs.org/news/2016/aug/04/san-diego-leads-way-reshaping-nations-power-grid/		
43	2016	5-Aug	KPBS - Radio News PT 2: San Diego Leads Way in Reshaping Nation's Power Grid by Eric Anderson	Neal Bartek & Hanan Eisenman	KPBS - San Diego	Borrego Springs, a small desert community about 80 miles east of San Diego, is shining a light on a future that could completely change how power is delivered to homes and businesses.	KPBS Radio News - http://www.kpbs.org/news/2016/aug/04/san-diego-leads-way-reshaping-nations-power-grid/		

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44	2016	9-Aug	WNYC - Rural Towns Create Sustainable Energy, Digital Sanctuaries (12-minute audio file & article)	WNYC.org	WNYC.org	Through community cooperatives and microgrids, small towns are ... local lights on in Borrego Springs while the power lines were repaired. KPBS Reporter Erik Anderson explains how this remote town created a ...	http://www.wnyc.org/story/creating-sustainable-energy-island/		
45	2016	30-Aug	TAC Meeting - CEC EPIC - 14-060	Tom Bialek, Chief Engineer, SDG&E&Tisha SmithProject Mgr	Via Webex	**Agenda for the TAC Meeting:**1) Review historical Borrego Microgrid activities2) Review scope of CEC project aka Borrego 2.03) Update on progress4) Update on issues5) Review islanding events6) Review key lessons learnedPresented via webex	PowerPoint Slide Deck - 8 Total - TAC Members and SDG&E Team	8	
46	2016	6-Sep	CEC Staff Workshop on Microgrids	Tom Bialek, Chief Engineer, SDG&E	Sacramento, CA	Enhance the Borrego Springs Microgrid to be more flexible and automated in responding to a variety of potential outage situations, and leverage various new technologies and Distributed Energy Resources for increased Microgrid capabilities.	http://www.energy.ca.gov/research/epic/documents/2016-09-06_workshop/presentations/06%20SDG&E-Borrego%20Springs.pdf	50	
47	2016	3-Oct	Singapore Power Team - Meeting to discuss the Borrego Springs Microgrid	Laurence Abcede, SDG&E DER Manager & Tisha Smith BSM Project Mgr	SDG&E Lightwave Office, San Diego, CA		5 SDG&E Team members and 8 Singapore Power Team Members. PowerPoint Slide Deck	13	
48	2016	22-23-Oct	2016 Borrego Days Community Event	Laurence Abcede, Tisha Smith & Frank Goodman SDG&E	Borrego Springs, CA	Borrego Days is an annual community event that spans 3 days with food, entertainment, booths and events. SDG&E has a booth and talks to the community about the local microgrid project	DER Team provided a Microgrid Spokesperson to share progress and info on the Microgrid with the community	45,000	
49	2016	22-Oct	Borrego Springs Microgrid Fact Sheet - Community (2-page Flyer)	SDG&E Communications & DER Team	n/a	Fact Sheet about the Borrego Springs Microgrid - High-level for the Community			
50	2016	1-Nov	Seeker: Cities Are Building Disaster-Proof Green Microgrids	Seeker.com					

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51	2016	2-Nov	Borrego Sun - "Borrego Microgrid in the News"	Borrego Sun Newspaper	n/a	Borrego's Microgrid hit the news recently with a piece by Eric Niiler for Seeker and interview with local resident Sylvana Meeks			
52	2016	4-Nov	DER Team Building & Borrego Springs Microgrid Tour	Laurence Abcede, SDG&E DER Manager & Tisha Smith BSM Project Mgr	Borrego Springs, CA	SDG&E's DER Team building event. Update the team on the latest upgrades to the microgrid yard		16	16
53	2016	17-Nov	Borrego Springs Microgrid Tour - PA Consulting	Laurence Abcede, SDG&E DER Manager & Tisha Smith BSM Project Mgr	Borrego Springs, CA	The Reliability Delegates from PA Consulting took a tour of the Borrego Springs Microgrid	Ulises Ochoa, Elect Anlys & Solutions Mgr, Techlgy Sols & Relibty - POC at SDG&E and organized tour with PA Consultant	50	50
54	2016	1-Dec	Borrego Springs Microgrid Tour & Safety Evaluation/Assessment	Laurence Abcede, SDG&E DER Manager & Tisha Smith BSM Project Mgr	Borrego Springs, CA	Tour and Safety Evaluation/Assessment by various key members of our DER Emergency Planning Team - Field Safety Advisor, Fire, Environmental, Engineers - feedback and guidance on signage, etc…		10	10
55	2016	19-Dec	Borrego Springs Microgrid Branding & Community Emergency Signs Installed	Tisha Smith BSM Project Mgr	Borrego Springs, CA	IAS Signs Installed 1 Branding Sign on the Command Center and 3 Community Emergency Signs at the 3 entrances to the microgrid yard			
56	2016	19-Dec	Borrego Springs Microgrid Tour for new interim SDG&E Public Affairs Manager, Addie Woodard	Tisha SmithBSM Project Mgr	Borrego Springs, CA		Addie Woodard toured the microgrid yard, learned more about our project and we also facilitated a meeting with Linda Haddock, Executive Director from the Borrego Springs Chamber of Commerce.	7	7

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57	2016	21-Dec	INSIDE ENERGY: Microgrids Power Desert Community and Urban Campus (Includes 2 audio interviews)	Inside Energy		Borrego Springs sprawls across a mostly flat desert valley about 80 miles east of San Diego. When the afternoon wind blows in the summer it feels like …	http://insideenergy.org/2016/12/21/microgrids-power-desert-community-and-urban-campus/#		
58	2016	21-Dec	INSIDE ENERGY - Erik Anderson Author Post - Microgrids Power Desert Community and Urban Campus (Includes 2 audio interviews)	Inside Energy		Author Post - Erik Anderson - Borrego Springs sprawls across a mostly flat desert valley about 80 miles east of San Diego. When the afternoon wind blows in the summer it feels like …	http://insideenergy.org/author/erik-anderson-kpbs/		
59	2016	21-Dec	Wyoming PBS Facebook - Microgrids Power Desert Community and Urban Campus	Wyoming PBS		Borrego Springs sprawls across a mostly flat desert valley about 80 miles east of San Diego. When the afternoon wind blows in the summer it feels like …	https://www.facebook.com/WyomingPBS/		
60	2016	22-Dec	Video Shoot - Production for a 3-minute Borrego Springs Microgrid Video that will be presented at the Sempra Shareholders Meeting - Aerial shots, installation of the Ultracapacitor, interviews and b-roll footage. All b-roll footage and BSM video will be on a hard drive for our use. Ultracap was installed - Tisha has photos of that as well	Maria McGregor - Comms Mgr, Corporate Communications	Borrego Springs, CA	Maria McGregor is coordinating the video production of a 3-minute video about the Borrego Springs Microgrid Project for a Sempra Shareholders meeting. Included interviews with SDG&E Engineer, Daniel Spaizman and Borrego Springs Chamber of Commerce, Executive Director - Linda Haddock. A drone also took aerial shots of the microgrid yard		10	
61	2016	19-20 Dec	PRE-TEST - GENERATORS - Hawthorne	Tisha SmithBSM Project Mgr	Borrego Springs, CA	Run generators as a pre-test for the SDAPCD testing which will be conducted on 12/21-22		8	

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62	2016	21-22 - Dec	SOURCE TEST for PERMITS: San Diego Air Pollution Control (Coordinated with SDG&E's Brian Yim)	SDG&E Tisha Smith BSM Project Mgr & Daniel Spaizman Engineer	Borrego Springs, CA	San Diego Air Pollution Control District (SDAPCD) conducts all-day testing on Dec 21st and Dec 22nd. The Source Test is an annual emissions test conducted on the two generators to demonstrate compliance with the emission limits.		8	
63	2016	25-Dec	Borrego Springs Microgrid: From Proof of Concept to Project Development Showcase - Andrew Burger	Microgridmedia.com		Backed by a power purchase agreement with San Diego Gas & Electric (SDG&E), NRG Energy commissioned the first utility-scale solar energy facility at the edge of town in 2013.	http://microgridmedia.com/borrego-springs-microgrid-proof-concept-project-development-showcase/		
							Tech Transfer Summary 2016	47,267	165

#	Year	Date	Tech Transfer Product	Presented / Organized by:	Location	Description	Comments/Notes/URL	# of Est. People Reached	Tour Guests
2017									
1	2017	16-Jan	INTERVIEWS Scheduled for the Sempra Shareholders Meeting video about the Borrego Springs Microgrid	Maria McGregor - Comms Mgr, Corporate Communications	Borrego Springs, CA	Maria McGregor is coordinating the video production of a 3-minute video about the Borrego Springs Microgrid Project for a Sempra Shareholders meeting. Included interviews with SDG&E Engineer, Daniel Spaizman and Borrego Springs Chamber of Commerce, Executive Director - Linda Haddock. A drone also took aerial shots of the microgrid yard		10	
2	2017	19-Jan	Borrego Springs Microgrid Discussion with	Tj Kirk, NRECA - National Rural Electric Cooperatives Association	San Diego, CA	PEER TO PEER DISCUSSIONS – NRECA's group is comprised of Project Managers who would not only like a tour of SDG&E's AES sites but would also like the opportunity to have candid discussions with our DER Team about the various projects we are working on.	Discussion took place at SDG&E's Advanced Energy Storage yard at Canyon Crest Academy	15	

#	Year	Date	Tech Transfer Product	Presented / Organized by:	Location	Description	Comments/Notes/URL	# of Est. People Reached	Tour Guests
3	2017	30-Jan	UU 101: DMS Solutions for Modern Distribution SystemsMonday, January 30, 2017: 8:00 AM - 5:00 PM*Tom Bialek represented SDG&E on a DistribuTECH Panel	DistribuTECH Conference & Exhibition	San Diego, CA	The course will provide information needed for electric utilities to plan, integrate and commission modern distribution systems. The course will feature presentations by representatives of Duke Energy and San Diego Gas & Electric, which have recently deployed DMS. These speakers will describe their implementation experiences, major challenges and solutions, and implementation lessons learned. Time will be allotted during each electric utility presentation to allow for Q&A between the electric utility speakers and attendees.	http://events.pennwell.com/DTECH2017/Public/SessionDetails.aspx?FromPage=Speakers.aspx&SessionID=16569&nav=true&Role=U%27	40	
4	2017	31-Jan	Keynote Session - DistribuTECHTuesday, January 31, 2017: 9:00 AM - 11:00 AM*Scott Drury, incoming President, represented SDG&E on a DistribuTECH Panel and mentioned the BSM	DistribuTECH Conference & Exhibition		The DistribuTECH 2017 keynote session will continue the tradition of featuring highly-respected industry experts who will share their views on the challenges and opportunities utilities face. You'll hear what these experts believe utilities must do to not just survive, but thrive now and in the future. They will share their thoughts about the digital transformation that is redefining utilities and their customers.	http://events.pennwell.com/DTECH2017/Public/SessionDetails.aspx?FromPage=Sessions.aspx&SessionID=17465&SessionDateID=498#	5000	
5	2017	31-Jan	Customer-owned Microgrids: Ignore Them? Fight Them? Partner with Them? T Tuesday, January 31, 2017: 3:00 PM - 4:30 PM* Tom Bialek represented SDG&E on a DistribuTECH Panel	DistribuTECH Conference & Exhibition	San Diego, CA		http://events.pennwell.com/DTECH2017/Public/SessionDetails.aspx?FromPage=Speakers.aspx&SessionID=16783&nav=true&Role=U%27	150	
6	2017	1-Feb	Planning for a Modern Grid: Lessons from California and New YorkWednesday, February 01, 2017: 10:00 AM - 11:30 AM*Tom Bialek represented SDG&E on a DistribuTECH Panel	DistribuTECH Conference & Exhibition	San Diego, CA	Grid modernization has become the leading topic of discussion in the utility industry. This panel of experts will explore the early pilots of New York's Reforming the Energy Vision (REV) and California's Distribution Resource Plans (DRP). Panelists will discuss grid modernization and how new technologies including DER, storage, EV charging and DSM programs are being applied.	http://events.pennwell.com/DTECH2017/Public/SessionDetails.aspx?FromPage=Speakers.aspx&SessionID=16693&nav=true&Role=U%27	300	

#	Year	Date	Tech Transfer Product	Presented / Organized by:	Location	Description	Comments/Notes/URL	# of Est. People Reached	Tour Guests
7	2017	7-Feb	Microgrids on the March: Utilities Are Building Out New Business Models to Make Islanding Work	Greentech Media	DistribuTECH Conference - San Diego, CA	San Diego Gas & Electric delivers power to the town of Borrego Springs via a single radial transmission line running through the desert. Lightning strikes and desert flash floods threaten that line, resulting in historically poor reliability, Chief Engineer Thomas Bialek explained at the DistribuTECH panel.	https://www.greentechmedia.com/articles/read/DistribuTECH-roundup-microgrids-on-the-march		
8	2017	8-Feb	5th Annual - Energy Career Connections & Leadership Conference	ABDNHA - Betsy Knaak	Jacobs Center - San Diego, CA	165 Students, 60 Mentors attended event - Borrego Springs Microgrid was mentioned during the How Energy Works presentation given by Gabe Leggett. Borrego Springs High School was in attendance as well as 5 other Title 1 High Schools. DER Team also had a booth at the career fair and discussed the BSM project		225	
9	2017	27-Feb	Borrego Springs Microgrid Tour - The Electric Cooperatives of South Carolina, Inc.	Tisha SmithBSM Project Mgr	Borrego Springs, CA	Tour for the Electric Cooperatives of South Carolina, Inc.	Tour Group Objectives: This field trip is about seeing what a successful microgrid looks like. The cooperatives of South Carolina serve 70% of the geography of the state and a third of the population. There are areas we serve that we cannot get transmission lines permitted - a microgrid could help alleviate significant reliability issues. Seeing a microgrid such as yours helps us answer viability questions, and can encourage us to pursue non-traditional solutions.	4	4
10	2017	24-Mar	Borrego Springs Tour - SPAWAR & SDSU / UCSD / SDG&E / So Cal Edison	Tisha SmithBSM Project Mgr&Daniel SpaizmanEngineer II	Borrego Springs, CA	5 Groups take a tour of the microgrid because they are all considering microgrids for their facilities/companies		20	20
11	2017	10-Apr	The Value of Energy Storage in Microgrids	Microgrid Knowledge		San Diego Gas and Electric installed a microgrid in Borrego Springs, CA to help with solar smoothing and energy shifting, and it has the capabilities to fully support its community during a power outage.	http://microgridknowledge.com/value-energy-storage-microgrids/		

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12	2017	20-Apr	SDG&E Earth Fair - Borrego Springs Microgrid	DER Team	SDG&E Century Park Campus	DER Team booth at SDG&E's Earth Fair's Innovation Corridor to discuss green technologies. Featured information about the Borrego Springs Microgrid & DERMS in all presentations to event guests.		400	
13	2017	12-May	Sempra Energy Annual Shareholders Meeting - Borrego Springs Microgrid video shown	Maria McGregor - Comms Mgr, Corporate Communications	San Diego, CA	Short video shown during the Sempra Shareholders meeting	Annual Shareholders Meeting on May 12, 2017, at the Island Hotel in Newport Beach, California. They delivered reports/presentations on their financial and operational targets.		
14	2017	16-May	Borrego Springs Microgrid - Aerial Shots by Drone	Christine Asaro, SDG&E Aviation Services	Borrego Springs, CA	Christine Asaro took aerial photos and video of the Borrego Springs Microgrid yard.	Loaded up on the Distributed Energy Resources Z: Drive		
15	2017	16-May	Borrego Springs Microgrid - Video - Verite Production Studios	Maria McGregor - Comms Mgr, Corporate Communications	San Diego, CA	Maria McGregor is coordinating the video production of a 3-minute video about the Borrego Springs Microgrid Project for a Sempra Shareholders meeting. This is the B-Roll Footage on the Ultracap installation	Loaded up on the Distributed Energy Resources Z: Drive		
16	2017	21-Jun	DER Lunch & Learn - Borrego Springs Microgrid Project	Tisha SmithBSM Project Mgr&Daniel SpaizmanEngineer II	SDG&E CP East Auditorium	Update on the Borrego Springs Microgrid Project 2.0 phase.	1 hour presentation with PPT - photos taken of attendees - guests attended in person and via Skype	80	
17	2017	29-Jun	The Economist Magazine - Borrego Springs Microgrid Tour and interview with Caroline Winn, SDG&E's Chief Operating Officer	Colleen Windsor, SDG&E Communications	Borrego Springs, CA	A reporter from the Economist Magazine interviewed Caroline Winn and taking a tour of the Borrego Springs Microgrid.		5	5

#	Year	Date	Tech Transfer Product	Presented / Organized by:	Location	Description	Comments/Notes/URL	# of Est. People Reached	Tour Guests
18	2017	30-Jun	Borrego Springs Microgrid - Interviews with DER Team - Video Shoot - Verite Production Studios	Maria McGregor - Comms Mgr, Corporate Communications	San Diego, CA	Interviews with Tom Bialek, Daniel Spaizman, Gabe Leggett and Laurence Abcede			
19	2017	13-Jul	TOUR - Borrego Sun Newspaper - Suzanne Howarth - Guest Editor	Laurence Abcede, DER Manager & Helen Gao, Communications	Borrego Springs, CA	Updating the Borrego Sun on the progress of the Borrego Springs Microgrid with Tour	New SDG&E Public Affairs Manager, Joseph Gabaldon also attended	5	5
20	2017	18-Jul	2017 IEEE PES General Meeting - Super Session on Energy Storage by Frank Goodman, SDG&E	Frank Goodman, SDG&E Team Lead - EPIC Projects	Chicago, IL	Frank Goodman was part of a panel and did a 30-minute presentation on energy storage. One of the main projects featured was the Borrego Springs Microgrid along with a short video clip of the microgrid yard. Copy of slide deck available online for all participants	The IEEE Power & Energy Society (PES)held its 2017 General Meeting in Chicago, IL USA. The technical program theme of “Energizing a More Secure, Resilient & Adaptable Grid” will provide a platform to offer new insights, innovative ideas and answers to some of the most intriguing and important questions facing the power industry today	50	
21	2017	26-Jul	Debating the future of energy	Idaho Mountain Express and Guide	Idaho	She said that the city of Borrego Springs, Calif., which is east of San Diego, has ... Myers said the microgrid offers a dependable alternative solution.	http://www.mtexpress.com/news/blaine_county/debating-the-future-of-energy/article_503484f0-7192-11e7-877c-6fa5693f8483.html		
22	2017	27-Jul	Dr. Arni McKinley and Kevin McKinley - 7/27 - MEETING & 7/28 TOUR with interns	Tisha Smith, Project Mgr	San Diego, CA	Meeting to discuss the Borrego Springs Microgrid	Dr. McKinley is from the University College London in the Electronic & Electrical Engineering department - he is participating in a study in South Australia this summer - Goal - looking at the design and development of residential and commercial microgrids. Kevin McKinley used to work at SDG&E	4	

#	Year	Date	Tech Transfer Product	Presented / Organized by:	Location	Description	Comments/Notes/URL	# of Est. People Reached	Tour Guests
23	2017	28-Jul	SDG&E Summer Interns - Borrego Springs Microgrid Tour	Connie Liu, Engineer	Borrego Springs, CA	Interns from various departments will tour the Borrego Springs Microgrid - DERMS demonstration as well as a site tour given		37	37
24	2017	28-Jul	Dr. Arni McKinley and Kevin McKinley - 7/27 - MEETING & 7/28 TOUR with interns	Tisha Smith, Project Mgr	Borrego Springs, CA	Tour the Borrego Springs Microgrid with DERMS demonstration	Dr. McKinley is from the University College London in the Electronic & Electrical Engineering department - he is participating in a study in South Australia this summer - Goal - looking at the design and development of residential and commercial microgrids. Kevin McKinley used to work at SDG&E	2	2
25	2017	28-Jul	James Dodenhoff - Regional Director of Business Development-Western U.S. IPERC	Tisha Smith, Project Mgr	Borrego Springs, CA	Tour the Borrego Springs Microgrid with DERMS demonstration	IPERC was founded with the central mission of advancing the power of energy to provide a more intelligent and efficient control system capable of reducing costs, enhancing security and providing continuous power when failure is not an option.	5	5
26	2017	9-Aug	A Small-Scale Power Solution Could Pay Big Dividends Across the U.S.	Time.com		Microgrids used as a way to deliver power to the 2,800 residents of Borrego Springs, Calif - (mention)	http://time.com/4894986/small-scale-power-solution-pay-big-dividends-across-us/		
27	2017	21-Aug	California Awarding $45 Million for Microgrids	RTO Insider - (Subscription Service)		California is offering $45 million in grants for the development of microgrids on a variety of siting categories to stimulate development of new distributed energy resources	https://www.rtoinsider.com/california-microgrids-distributed-energy-resources-47923/		

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28	2017	24-Aug	SDG&E COO Highlights Power of Energy Storage Innovation	sdgenews.com		... proud of is our microgrid, located in the town of Borrego Springs about 90 miles from here. It leverages solar energy, storage, and …	http://sdgenews.com/clean-innovative/sdge-coo-highlights-power-energy-storage-innovation		
29	2017	24-Aug	Microgrid and Big Problems	Borrego Sun Newspaper	Borrego Springs, CA	Borrego's microgrid is being classed as a leading light in waging the war on developing sustainable electricity for homeowners…	-		
30	2017	5-Sep	Microgrids: Small But Mighty	sdgenews.com		Over the past decade, SDG&E has been continually perfecting one of the first large, utility-scale microgrids in the United States – the Borrego Springs Microgrid	http://sdgenews.com/reliable/microgrids-small-mighty		
31	2017	15-Sep	California Energy Markets - Top 10 California Microgrids Listing	California Energy Markets - Energy News Data Corporation		Microgrids are becoming widespread in California,with military bases, ports, tribes, disadvantagedcommunities, rural areas, industrial complexes anduniversities and schools eyeing the technology forgeneration, redundancy and reliability.	Subscription energy news service		
32	2017	Sept	Case Study: Borrego Springs Microgrid	Governor's Office of Planning and Research		Adaptation-oriented case studies for the Governor's Office of Planning and Research - SDG&E Chief Engineer Tom Bialek worked with GOPR on this paper			
33	2017	3-Oct	California Microgrid Program Advances	RTO Insider		The PUC's "Distributed Resources Plans" proceeding has authorized development of two microgrids: one in Borrego Springs, in San Diego Gas & Electric territory, and another in Mono County, in Southern California Edison's area.	https://www.rtoinsider.com/california-microgrids-76595/		
34	2017	3-Oct	Borrego Springs Microgrid Tour & Interview by Michael Sadler, Borrego Sun	Borrego Sun Newspaper	Borrego Springs, CA	Michael is putting together some FAQ's about the Borrego Springs Microgrid as well as taking a tour, writing an article - wait for his write-up	Laurence Abcede, DER Manager, Gabe Leggett, DER Engineer and Helen Gao, Communications Manager gave the tour	4	4

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35	2017	19-Oct	Borrego Springs Microgrid FAQ's - by Michael Sadler	Borrego Sun Newspaper	Borrego Springs, CA	1 page of FAQ's about the Borrego Springs Microgrid			
36	2017	19-Oct	Testing the Advanced Technologies of the Future	sdgenews.com		.. energy storage systems. Technology which enabled the Borrego Springs Microgrid was also tested and perfected at the lab before it was …	http://sdgenews.com/clean/testing-advanced-technologies-of-the-future		
37	2017	27-28-Oct	2017 Borrego Days Community Event	Tisha Smith, Donna Miyasako-Blanco, Joe Gabaldon SDG&E	Borrego Springs, CA	Borrego Days is an annual community event that spans 3 days with food, entertainment, booths and events. SDG&E has a booth and talks to the community about the local microgrid project	SDG&E Sponsored, DER Team had a double booth and shared it with ABDNHA, Borrego Desert Energy Center and the Friends of the Library. Recruited and conducted the DRP Borrego Springs Microgrid Survey	45,000	
38	2017	28-Oct	Borrego Springs Microgrid Awareness Survey	Donna Miyasako-Blanco, SDG&E	Borrego Springs, CA	Recruited and conducted a simple awareness survey about the Borrego Springs Microgrid with 49 total part-time and full-time residents in attendance to the Borrego Days event		49	
39	2017	15-Nov	DER Lunch & Learn - Borrego Springs Microgrid - Case Study - Island 2	Daniel Spaizman, Michelle Menvielle and Mehrdad Yazdanibiouki	SDG&E Century Park Campus	On the morning of October 4, the DER-Distributed Energy Resources and DERMS - Distributed Energy Resource Management Systems Teams conducted a successful event at the Borrego Microgrid to test "Island #2" and validate automation and system protection settings. These tests involved black start, islanding, and transition to the utility grid. The entire test was conducted and managed with the DERMS Wave controller. (Distributed Energy Resource Management System)			
40	2017	15-Nov	Borrego Springs Microgrid Video	Produced in-house for the DER L&L presentation	San Diego, CA	Aerial shots and Microgrid yard video & photos shown in a loop during the event			

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41	2017	17-Nov	Borrego Springs Microgrid Video	Produced by Verite					
42	2017	4-Dec	Microgrids Keep These Cities Running When the Power Goes Out	Inside Climate News		Microgrids Keep These Cities Running When the Power Goes Out Inside Climate News It was put to the test in September 2013, when lightning and flooding knocked out the same critical transmission line that connects Borrego Springs with outside power…			
43	2017	20-Dec	TOUR - DER Lunch & Learn - Borrego Springs Microgrid Project	Daniel Spaizman, Michelle Menvielle and Mehrdad Yazdanibiouki	Borrego Springs, CA	25 Total Tour Participants		25	25
44	2017	*2017	Modernizing Our Grid and Energy System - ESIF 2017	NREL		37 Page Report - The Energy Systems Integration Facility (ESIF) is thenation's premier facility for the research, development,and demonstration of the integrated technologies andstrategies shaping our energy system.			
							Tech Transfer Summary 2017	51,430	107
2017									
1	2018	5-Jan	Borrego Springs' Claim to Energy Fame: A Microgrid That Enhances Reliability	sdgenews.com	Borrego Springs, CA	Most recently, Inside Climate News featured the Borrego Springs Microgrid in an article titled "Microgrids Keep These Cities Running When the Power Goes Out."	http://sdgenews.com/reliable/borrego-springs%E2%80%99-claim-energy-fame-microgrid-enhances-reliability		

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2	2018	5-Feb	Microgrids: From Niche to $100 Billion Market by Fereidoon Sioshansi	theenergycollective.com		(SDG&E) project in Borrego Springs utility distribution microgrid. Others, however, have confronted regulatory skepticism and rejection, including Baltimore Gas & Electric Co.	http://www.theenergycollective.com/fereidoonsionshansi/2421442/microgrids-niche-100-billion-market		
3	2018	13-Feb	Modern Marvel: The Brains Behind Reliable Renewable Energy	sdgenews.com		... largest utility microgrids. Built by SDG&E, the Borrego Springs Microgrid can independently provide power to the remote desert ... near future.	http://sdgenews.com/reliable/modern-marvel-brains-behind-reliable-renewable-energy		
4	2018	1-Mar	ABDNHA - Borrego Desert Energy Educational Project - Introduction Event & Project Launch	ABDNHA	Borrego Springs, CA	Introduction event to launch the Borrego Desert Energy Educational Project - BDEP includes community outreach into the city and schools to promote the impact of energy generation and use on the environment and to advocate efficient energy management to reduce carbon footprint	Photos were taken of the event	65	
5	2018	1-Mar	BSM Tour - Jamie Patterson, CEC	Alisha Stamps, SDG&E	Borrego Springs, CA	Tour of the BSM for CEC Senior Electrical Engineer and CEC EPIC-14-060 program manager, Jamie Patterson. Other guests included: SDG&E's Morgan Justice-Black, Alisha Stamps, Tom Bialek, Donna Miyasako-Blanco & the DER Team			10
6	2018	1-Mar	Energy and Nature: The Dynamic Duo at the Center of the Borrego Springs Energy Education Project	sdgenews.com	Borrego Springs, CA	Today, the Anza-Borrego Desert Natural History Association (ABDNHA), one of our long-time partners in environmental education, celebrated the completion of its new energy education project. We joined about 30 residents and community leaders to mark the occasion.	http://sdgenews.com/clean/energy-and-nature-dynamic-duo-center-borrego-springs-energy-education-project		
7	2018	1-Mar	ABDNHA - Borrego Desert Energy Center Website- Features information about the Borrego Springs Microgrid	Mike McElhatton - ABDNHA	Borrego Springs, CA	The Borrego Springs Microgrid is featured as a local sustainable project on the ABDNHA's BDEC website	http://www.abdnha.org/energycenter/SustainableBorrego/index.html		
8	2018	7-Mar	SDG&E President Highlights Leadership and Innovation	sdgenews.com		... generation to meet the unique needs of the community of Borrego Springs about 90 miles from here. And finally, one of our latest efforts …	http://sdgenews.com/clean-community-innovative-reliable-safe/sdge-president-highlights-leadership-and-innovation		

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9	2018	9-Mar	ABDNHA Desert Energy Project	Borrego Sun Newspaper	Borrego Springs, CA	If there are Borregan's who doubt the possibility of members of non-profit organizations, government agencies, and the private sector all working together in harmonious synchronization towards a common public goal, they should have attended the kick-off meeting of our Desert Energy Project March 1, held at the Anza-Borrego Desert Natural History Association	http://www.borregosun.com/story/2018/03/01/news/abdnha-desert-energy-project/4267.html		
10	2018	19-Mar	Borrego Springs Microgrid Tour: Tom Roberts from ORA	Jose L. Cardenas, SDG&E	Borrego Springs, CA	Tom Roberts from the ORA visited the Borrego Springs Microgrid to see the progress of the work for the two budgets in the GRC .	Alan Colton and various members from SDG&E and the SDG&E DER Team accompanied Tom Roberts	9	9
11	2018	23-Mar	Borrego Springs Microgrid Awareness Survey	Donna Miyasako-Blanco, SDG&E	Borrego Springs, CA	Recruited 33 more survey participants at the local Borrego Springs Farmer's Market at Christmas Circle - Partnering with ABDNHA and the Dark Skies Local Volunteer Team		33	
12	2018	4-Apr	2018 SDG&E Earth Fair @ SDG&E's Century Park Campus	SDG&E Green Team	San Diego, CA	The DER Team had a booth at SDG&E's Earth Fair and discussed the Borrego Springs Microgrid and other DER projects to fair attendees. The theme was SDG&E's commitment to environmental sustainability.	http://powerup.sdge.com/departments/green/2018EarthFairRecap.cfm	400	
13	2018	8-Jun	CEC Team Tour of the Borrego Springs Microgrid	Laurence Abcede, DER Team	Borrego Springs, CA	The CEC is taking a tour of the Borrego Springs Microgrid to see how it is progressing. The CEC awarded nearly $5 million to SDG&E to expand the Microgrid to use the nearby 26-megawatt (MW) Borrego Solar facility to power the entire community,			
14	2018	26-Jun	Borrego Springs Microgrid Overview Presentation	Tom Bialek, Chief Engineer	Borrego Springs, CA	Tom Bialek gave a historic overview and progress update of the Borrego Springs Microgrid project to Japan's NEDO Team and Sumitomo Electric's Team.			12

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15	2018	26-Jun	NEDO and Sumitomo Electric tour of the Borrego Springs Microgrid	Laurence Abcede, DER Team	Borrego Springs, CA	DER Team gives Japan's NEDO Team and Sumitomo Electric's Team a tour of the Microgrid yard			12
16	2018	13-Jul	Borrego Springs Microgrid Fact Sheet (Updated)	Donna Miyasako-Blanco, SDG&E		CEC needed an updated fact sheet on the Borrego Springs Microgrid that contained more technical specs			
							Tech Transfer Summary for April - July 2018	507	43

Tech Transfer Summary 2015	2,527	158
Tech Transfer Summary 2016	47,267	165
Tech Transfer Summary 2017	51,430	107
Tech Transfer Summary for April - July 2018	507	43