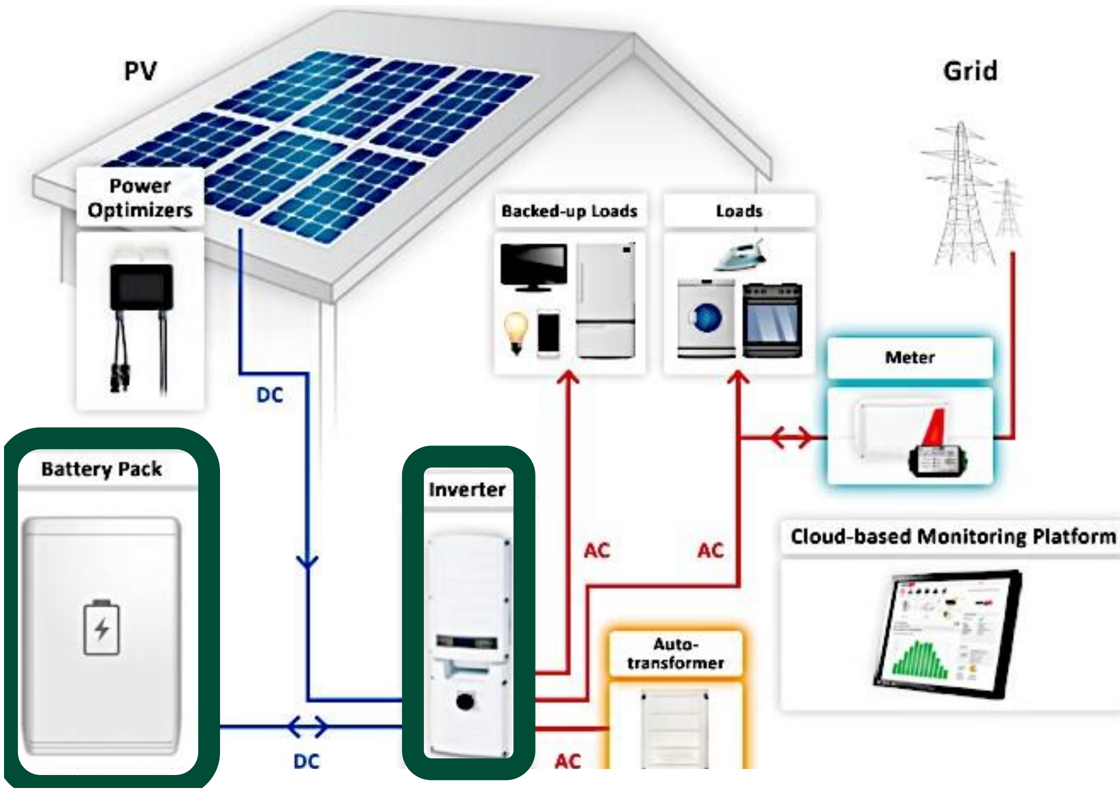
RESIDENTIAL ENERGY STORAGE STUDY (RESS) FINAL REPORT

DR18.05



Prepared by Kliewer and Associates, LLC for

Emerging Products, Customer Programs & Services
Southern California Edison

February 17, 2022

Acknowledgements

Southern California Edison's (SCE) Emerging Products, Customer Programs and Services group, is responsible for this project. It was developed under internal project number DR18.05. Navniel Pillay conducted this technology evaluation, with overall guidance and management from Dave Rivers. Kliewer and Associates conducted the research and field work on behalf of SCE. For more information on this project, please contact navniel.n.pillay@sce.com.

EXECUTIVE SUMMARY

Residential Battery Energy Storage Systems (BESSs) have become a popular solution marketed by the storage industry for electric grid[1] resilience, mostly due to recent grid interruptions originating from fires and high wind events from Public Safety Power Shutoffs (PSPS). Utility program incentives have supported widespread customer adoption by reducing the cost of purchase and installation.

The BESS project is the next research phase following SCE's Retail Automated Transactive Energy System (RATES) program, which studied an experimental subscription transactive tariff (completed 2020).[2] In this project, four residential BESS systems were installed, three of which had existing solar Photovoltaic (PV) arrays. Incentives and marketing have accelerated the growth of residential battery storage systems.

The research objective was to demonstrate monitoring and automated control of four Behind-the-Meter (BTM) residential BESS systems, to provide real-time grid congestion support and demonstrate price responsiveness. These installations were located at three homes in the Moorpark, Thousand Oaks, and Westlake Village areas. In addition, "Site E" was in the Smart Energy Experience (SEE) Exhibit at SCE's Irwindale Energy Education Center (EEC).

The project investigated and assessed how new, enabling Demand Response (DR) technologies could be provided by residential BESS in a way that enables SCE to leverage the asset value to customers and the electric grid.

This project also studied how customer resources could be deployed to automatically respond to grid needs while minimizing customer costs during peak pricing via Time-of-Use (TOU) schedules, which serve as an indicator of grid congestion.

Barriers of implementation were investigated to employ current BESS designs in a manner that provides the greatest value and resilience to the grid and the customer (co-optimization). The program balanced the benefits (cost savings and power backup capacity) while also relieving grid congestion.

It also investigated the integrated value of customer-owned BESS resources for Energy Efficiency (EE), DR, and other services that provide comprehensive value. BESS provides grid benefits, but also increases the complexity of controlling these systems. The project attempted to take BESS control to the next level by employing autonomous management through the manufacturer's proprietary encrypted cloud-based Application Programming Interface (API). This interface was first designed for aggregators to leverage control of a virtually unlimited number of systems and develop specialized software to execute control commands, typically in a batch process.

A major goal was to study how SCE might share API control of the BESS. This innovative project proved more complex than anticipated, as described the Results and Discussion section of this report. The intent was to align BESS with grid pricing signals (proxy for grid

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[1] "Grid" in this context refers to the Electrical Service Grid throughout this document.

[2] https://www.energy.ca.gov/publications/2020/complete-and-low-cost-retail-automated-transactive-energy-system-rates

congestion) and for autonomous real-time response, thus expanding the value of API control via pricing signals.

The project encountered certain challenges, some of which were resolved, and others that will be the subject of future research. Implementation problems included delayed equipment supply, equipment reliability issues identified during installation and attempted operation, permit inspector and installer training gaps, and changes to equipment design and firmware not documented or communicated by the manufacturer.

On a positive note, the TOU-D-Prime rate tariff was found to help maximize customer savings for BESS, whether or not it was paired with PV generation.

DEFINITIONS

Application Programing Interface	Enables management and monitoring Distributed Energy Resources with commands used to create instructions.
Battery Energy Storage System	Systems that use battery technology to store electrical energy for later use. Typically used for solar PV systems, they can also be employed for non-PV applications. These systems enable alignment with TOU tariffs and provide backup power sources during grid.
Commissioning	A systematic verification process to ensure all building systems perform interactively, according to design intent.
Distributed Energy Resources	Small-scale units of power generation that operate locally, connected to a larger power grid at the distribution level.
Inverter	Equipment used to change Direct Current to Alternating Current; a critical component for solar Photovoltaic systems.
ISY	**I**ntelligent **Sy**stem: An OpenADR 2.0b-certified automation platform developed and manufactured by Universal Devices Inc. (UDI), The ISY is used to provide integration and automation of all things behind the meter.
Lithium Ion Battery	A type of high-density rechargeable battery in which lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging.
Open Automated Demand Response	An industry standard interface language for sending information and signals to control electricity use.
Photovoltaic Array	A set of solar panels configured to convert sunlight into electricity.
PolisyPro	Intelligent System: An OpenADR 2.0b-certified automation platform developed and manufactured by Universal Devices Inc. (UDI), The PolisyPro is similar to the ISY but adds increased functionality including polyglot.
Polyglot	A device that supports multiple languages.
Public Safety Power Shutoff	A power outage intentionally initiated by the utility to mitigate possible disasters, such as wildfires due to high winds.
Residential Energy Storage Study	Ongoing work on select Battery Energy Storage Systems previously installed as part of the Retail Automated Transactive Energy System project.
Retail Automated Transactive Energy System Project	CEC GFO 15-311/Group 2; Solutions that Allow Customers to Manage Their Energy Demand, March 2016.
Secure Socket Layer	A protocol for establishing authenticated and encrypted links between networked computers.
Energy Education Center	SCE’s immersive public education center featuring the future of Energy Efficiency and smart grid technologies.

TOU-D-PRIME	An SCE rate tariff with a fixed daily basic charge equivalent to approximately $12 per month, which allows for lower Super Off-Peak and Off-Peak rates.
Transactive Energy	Economic and control techniques used to manage the flow or exchange of energy within an existing electricity power system regarding economic and market-based standard energy values.

ABBREVIATIONS AND ACRONYMS

AC	Alternating Current
API	Application Programming Interface
APIC	API for Controls
APIM	API for Monitoring
BESS	Battery Energy Storage System
BTM	Behind the Meter
CAISO	California Independent System Operator
CEC	California Energy Commission
CPUC	California Public Utility Commission
Cx	Commissioning
DC	Direct Current
DER	Distributed Energy Resource
DR	Demand Response
EE	Energy Efficiency
EEC	Energy Education Center
EIA	Energy Information Association
ELP	Essential Loads Panel
EM&T	Emerging Markets and Technologies
EPIC	Electric Program Investment Charge
EV	Electric Vehicle
HERS	Home Energy Rating System
HOA	Homeowner's Association
IoT	Internet of Things
IOU	Investor-Owned Utility
ISY	**I**ntelligent **Sy**stems
K&A	Kliewer & Associates, LLC

Li-Ion	Lithium Ion
NEM	Net Energy Metering
OpenADR	Open Automated Demand Response
PSPS	Public Safety Power Shutoff
PTO	Permission to Operate
PV	Photovoltaic
RATES	Retail Automated Transactive Energy System
RESS	Residential Energy Storage Study
RESU	Residential Energy Storage Unit
SCE	Southern California Edison
SEE	Smart Energy Experience
SEGS	SolarEdge Grid Services
SGIP	Self-Generation Incentive Program
SOC	State of Charge
SSL	Secure Socket Layer
TE	Transactive Energy
TOU	Time of Use
UDI	Universal Devices Inc.
URL	Uniform Resource Locator
USGS	United States Geological Survey
VAR	Volt-Amp Reactive
VTN	Virtual Top Node

CONTENTS

INTRODUCTION

For more than 10 years, SCE has been the statewide lead in program design, planning, implementation, policy input, and program evaluation for this statewide program, designed to investigate and assess emerging technologies and enhance customer engagement of DR and dynamic pricing programs. SCE's Emerging Markets and Technologies (EM&T) group is charged with accelerating the availability of cost-effective enabling DR technologies and their communication protocols for wholesale market tariffs and retail programs.

This document provides a briefing on the Residential Energy Storage (RESS) project. This work is a collaboration among SCE, the CPUC, the California Energy Commission (CEC), and other partners. This final report pertains to work that Kliewer & Associates (K&A), LLC performed in 2018-2021 on behalf of SCE.

The RESS project described herein is authorized by the California Public Utilities Commission through the year 2022.

The RESS project builds on the $3.2M that the California Energy Commission invested in the RATES project.

The research objective was to demonstrate the potential ability of SCE to control BTM residential BESS, to demonstrate customer price responsiveness and provide real-time grid congestion support. The project studied a retail tariff with highly-dynamic prices and automated BESS dispatch. The purpose was to investigate the technical feasibility of such controls, as well as customer economics and grid benefits. The TOU rate used in this project was the experimental tariff developed in the RATES project.[3] Other tariffs could be applied as events dictate.

Key elements studied in this project were aggregation of loads from customer-owned BESS systems, TOU pricing (as per the RATES project) and the ability of customers to respond to PSPS events.

[3] The RATES tariff used in the RESS pilot was submitted to the CPUC by SCE in advice letter 3837-E (https://www1.sce.com/NR/sc3/tm2/pdf/3837-E.pdf).

Aggregation	API interface can be used by aggregators to control many BESS simultaneously. Specialized software executes controls in a in a batch process.
TOU Pricing	The RESS project aligned control of the API of BESS systems with retail TOU pricing signals, thus expanding the value of API control of battery systems to the grid as pricing signals are a proxy for grid congestion.
PSPS	The project began to investigate how the autonomous signaling could be applied to respond to emergency signals such as Public Safety Power Shutoff (PSPS) events.

This report describes BESS systems installed at four locations – three residential homes, and at the SEE Exhibit ("Smart Home") at SCE's Irwindale EEC. It reviews each of the installations to identify obstacles and solutions that could be helpful and informative to any similar future programs. The report demonstrates how smart inverter APIs can facilitate monitoring and automated control of BTM residential batteries.

The project delves into the overarching issues surrounding dynamic load management, resource co-optimization, and comprehensive value achievement. The communications architecture is studied to understand how to optimize the transactive exchange between customers. The report concludes with a discussion about future programs to consider.

Project History

The RESS project builds on the RATES project, which set out to test whether it was possible to stabilize participant bills and utility revenue streams via a special rate program. The RESS project described herein leverages this earlier work. Of interest in this new project were LG RESU lithium-ion (Li-Ion) batteries and controllers purchased by SCE through the RATES project. The batteries were installed and commissioned at three homes in the Moorpark, Thousand Oaks, and Westlake Village areas. Another BESS was installed at the SCE Energy Education Center (EEC), located in Irwindale, CA.

The EEC Smart Home Display provided the framework to highlight this technology to the public. A key goal of the new RESS project, which is the focus of this report, was to demonstrate monitoring and automated control of four BTM residential batteries for grid support and price responsiveness. A secondary goal was to explore control of BESS systems for coordination with the SCE PSPS emergency alert system for high winds and wildfires.

Customer-Sited BESS

Distributed energy storage in the form of BESS is regarded as an important solution to support increased distributed solar power in California, while minimizing operational stress on the grid. SCE, along with other utilities, the California Independent System Operator (CAISO), and the CPUC have been exploring novel approaches to dispatching virtual generation capacity, thereby compensating BTM customers to provide support for this cost-effective resource.

> Four residential BESS systems were installed by SCE, three of which had existing solar PV arrays. The systems included batteries, smart inverters, and manufacturer's cloud portal for remote monitoring and rudimentary control.
>
> The systems are located at three homes in the Moorpark, Thousand Oaks, and Westlake Village areas. In addition, Site E was the SEE exhibit at SCE's Irwindale EEC.

In-home BESS paired with PV is growing in popularity, with rapidly-accelerating California installations. However, non-PV systems are also beneficial to customers and the power grid. In this investigation, one residence without PV performed well.

Moorpark home has a pool pump controller (on/off), thermostats, PV, and BESS

Thousand Oaks home has controllable thermostats and lighting, PV, and BESS.

Westlake Village home has controllable lighting, thermostats, pool pump, and BESS but no PV.

The flexibility of batteries to charge and discharge on short notice helps the power grid. Automated, controlled battery dispatch can stabilize the distribution system as more variable solar generation comes online.

This project examined the application of retail tariffs with highly-dynamic prices to energy storage equipped with finely-controlled dispatch capabilities. The approach can potentially offer good customer value and power grid operational support.

In late 2020, software upgrades were implemented, and testing was conducted, and the project team used data developed via remote test plan execution to complete a final report detailing design validation, use case selection, test plan development, and test plan execution, in accordance with SCE's COVID-19 safety protocols.

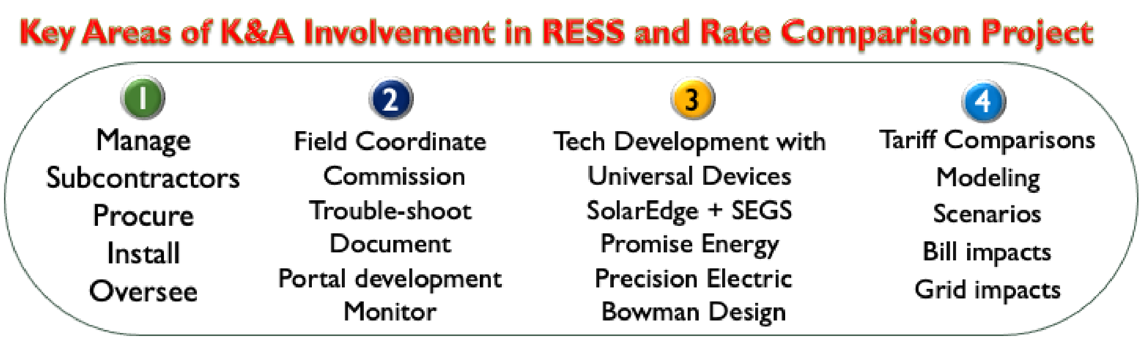
BACKGROUND

Project Evolution

The RESS project leveraged previous work performed through the RATES project (described earlier in this report) on three residential participant homes. These installations were performed through a CEC Electric Program Investment Charge (EPIC) grant project. Each of these homes had a BESS, including a SolarEdge smart inverter system and an LG Chem Residential Energy Storage Unit (RESU) BESS, installed by a third-party systems integrator. After the residential installations were complete, another installation was conducted to retrofit the existing PV system at SCE's SEE exhibit, with the LG Chem RESU BESS and inverter replaced with SolarEdge StorEdge model.

Kliewer and Associates, LLC (K&A)

K&A facilitated customer agreements with the homeowners and SCE's Legal department, and coordinated the BESS installations, commissioning (Cx), and inspections at each home. They also managed the grid-interactive API integration to allow remote BESS mode control, which enabled automated BESS dispatching for grid-responsive flexibility testing.



The project was wholly funded by SCE's EM&T program, with no co-funding or cost sharing with other utilities, private industries, governments, or other third-party groups. The following research team stakeholders contributed to the project tasks:

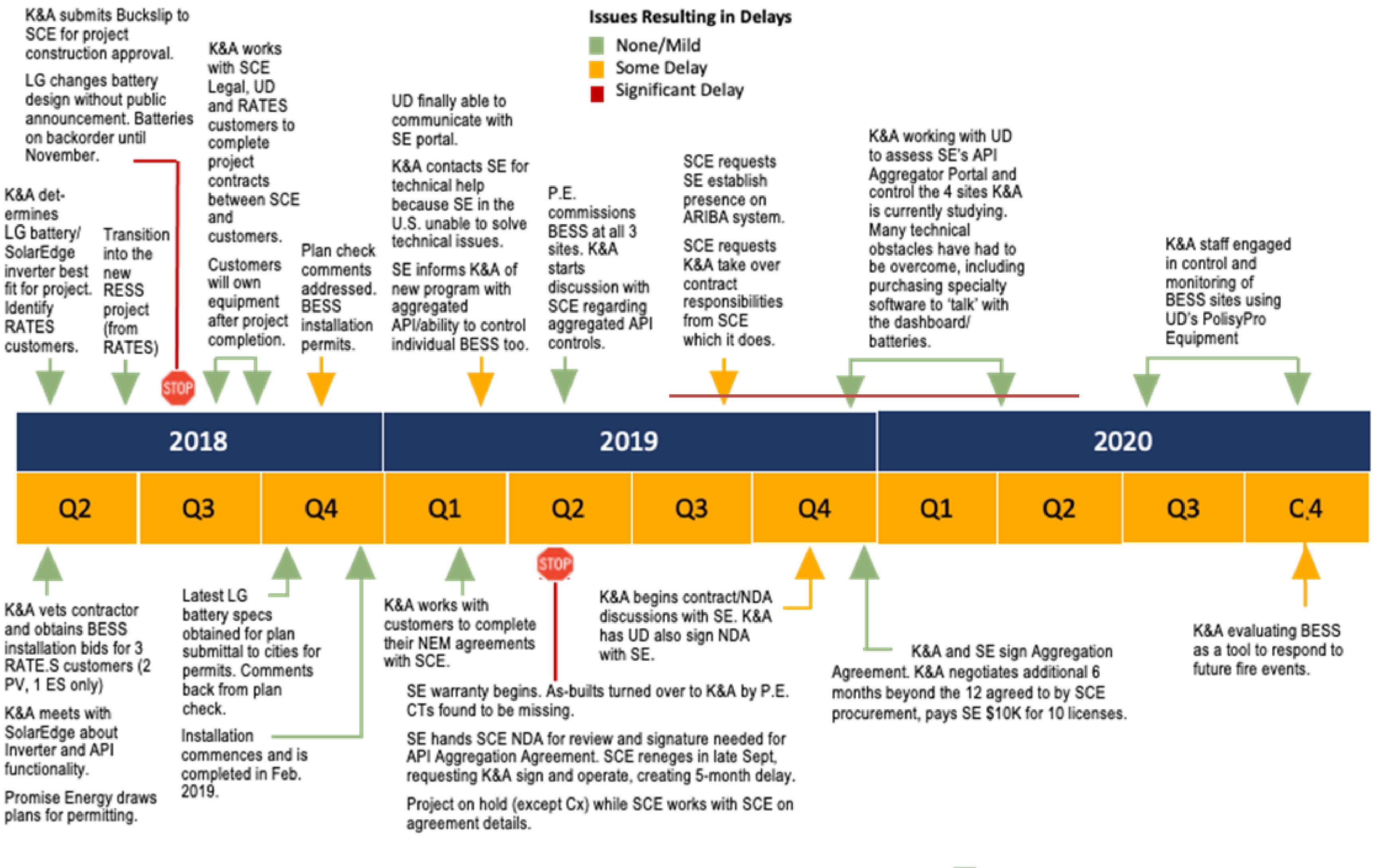
Universal Devices Inc. (UDI) and TeMix

UDI and TeMix served as contractors on this project. Each provided platforms and interfaces required to enable the BESS to respond to market price signals. UD developed its ISY and Polisy device platforms to receive the pricing signals and apply automated decisions to induce a BESS response. TeMix developed the cloud-based interface services, which monitor pricing signals from CAISO and relay this information to customer platforms.

Initially, the ISY platforms were installed at the three residences to control PV systems under RATES. SolarEdge had advertised API functionality for their StorEdge BESS inverters, but after installation, we discovered this "functionality" meant projecting dashboard information to a kiosk, without any command-and-control functionality.

However, when these systems were upgraded with BESS, the API used to control from SolarEdge Grid Services required additional security certificates. Fortunately, UD had just released its Polisy platform (a polyglot) which allowed the APIs to communicate to the SolarEdge and TeMix clouds for automated control. Another Polisy platform was installed at a remote location, to control BESS operation at the EEC. This was done as a response to SCE IT firewall security requirements.

Timeline and Milestones



ASSESSMENT OBJECTIVES

California's IOUs, CAISO, and the CPUC have been exploring approaches to dispatching flexible BTM demand resources to support grid resilience and appropriately compensate participating customers.

SCE recognizes the potential of BESS systems that store energy for later discharge upon instruction to support more variable solar generation on the grid. The BESS project was intended to improve understanding of the system's technical performance and benefits, as well as impacts to customers and grid operators.

The project studied how smart inverter APIs can facilitate monitoring and automated BTM residential battery control for grid support, DR, and price elasticity to dynamic tariffs. Many valuable lessons emerged, as described later in this report. K&A's research addressed these overarching issues about BTM:

- Dynamic Management: Customer resources can be developed to respond to grid resiliency needs and minimize market energy prices during peak pricing, which reflects grid supply and demand availability.
- Resource Co-Optimization: Design in a manner that provides the greatest value and resilience to the grid and customers, balancing benefits for cost savings and power backup capacity.
- Integrated Value: Using customer-owned resources for EE, DR, and other services provides comprehensive value. The inherent distributed resources provide benefits but increase the complexity of coordinating effective control.

This project intended to inform and prepare SCE and its technical stakeholders about the opportunity for leveraging customer energy storage resources, with consideration of tariff compliance, customers, and grid economics, and additional technical grid service support from coordinated operation of customer-owned flexible assets.

BESS charge and discharge setpoints were established and evaluated along with scheduled commands for BESS charge and discharge. A retail energy time shift is viable when BESS can be used to reduce electric bills through judicious energy dispatch. Utility tariffs are factors that include the marginal costs of providing power. This clearly benefits the distribution system, but it can also maximize customer benefits on the TOU-D PRIME rate. RESS management provides customer demand charge management to flatten load profiles and eliminate grid spikes.

TECHNOLOGY EVALUATION

Technologies and Integration

To control the batteries and facilitate participation in DR programs, SolarEdge integrated with third-party software interfaces through a dedicated grid services API control, which enabled the following control and data logging:

PRIMARY EQUIPMENT CONTROL

LG Batteries

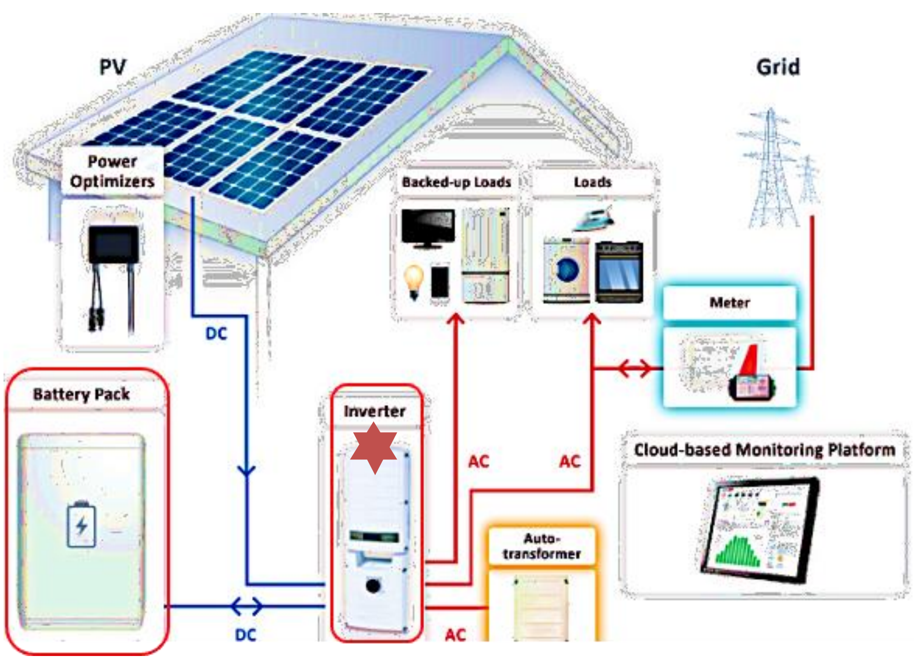
- Charge/discharge at a set power for a set duration
- Set battery modes
  - Backup
  - Maximize self-consumption
  - Disable
- Set battery energy reserve

SolarEdge Inverters

- Set power flow configurations & limits
- Set operating curve settings or limited-time events
- Volt-Var and Volt-Watt operating curves
- Dynamic Power Factor
- Frequency regulation settings
- Report fleet metrics
- Grid Voltage measurements
- Current export/import readings

STOREDGE INVERTER FEATURES

SolarEdge's StorEdge series specialized power inverters were used to manage and monitor PV arrays and provide the fundamental BESS framework. In this project, BESSs were used to control excess PV power export, for TOU shifting to maximize peak grid demand reduction capabilities, and to provide backup power.

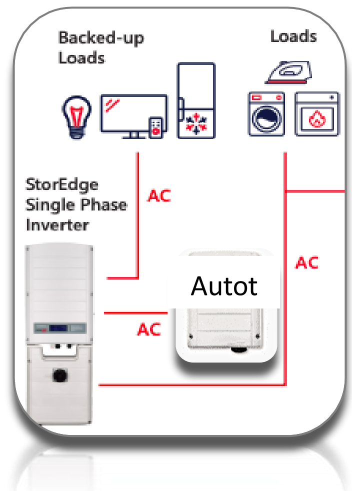


Inverters are devices that regulate electricity flow and convert Direct Current (DC) power into Alternating Current (AC) power. Rooftop solar PV arrays generate DC power, and optimizers maintain constant voltage to balance the PV module array strings’ production.

BESS inverters also communicate with optimizers to provide quick PV array shutdown in grid outages (a building code-required safety system).

For one installation, no PV system had been installed because the location’s Homeowner’s Association (HOA) prohibited rooftop PV installations. This can be a barrier for widespread BESS adoption. However, the same BESS components were successfully deployed to operate a non-generating installation. In this case, the BESS was charged from the grid during low price times. In these situations, the BESS provides additional value as a backup power supply during PSPS events.

SOLAREDGE TRANSFORMERS



SOLAREDGE AUTO TRANSFORMER

The SolarEdge 5kW auto transformer was connected to the inverter. This device continuously monitored grid voltage and sent solar and stored power to the essential loads (backup) service panel.

It was designed to work with the inverter as a transfer switch for battery storage. The auto transformer is required for the inverter to operate properly and isolate power to the main electric panel when the grid is down.

BESS Sites

The BESS sites (shown on the next page) included other energy-saving features in addition to the BESS systems:

Site A: Moorpark home, fitted with a pool pump controller, smart thermostats, and PV.

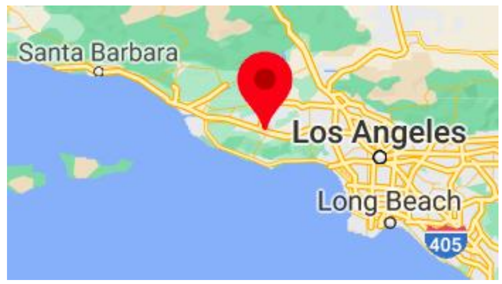
Site C: Thousand Oaks home, fitted with smart thermostats, lighting controls, and PV.

Site E: SCE’s Smart Home demonstration, with ENERGY STAR® appliances, smart thermostats, and PV.

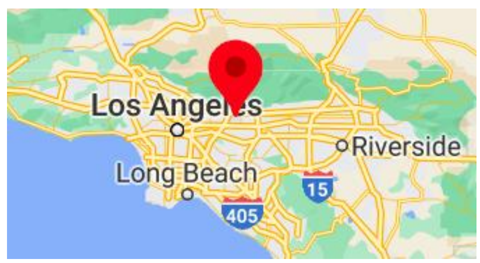
Site H: Westlake Village home, with smart thermostats, lighting controls, and pool pump controls (PV was not installed at this private community).

SITE A: MOORPARK

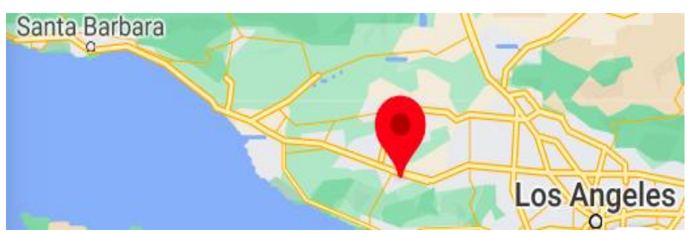
SITE C: THOUSAND OAKS



SITE E: IRWINDALE ENERGY EDUCATION CENTER



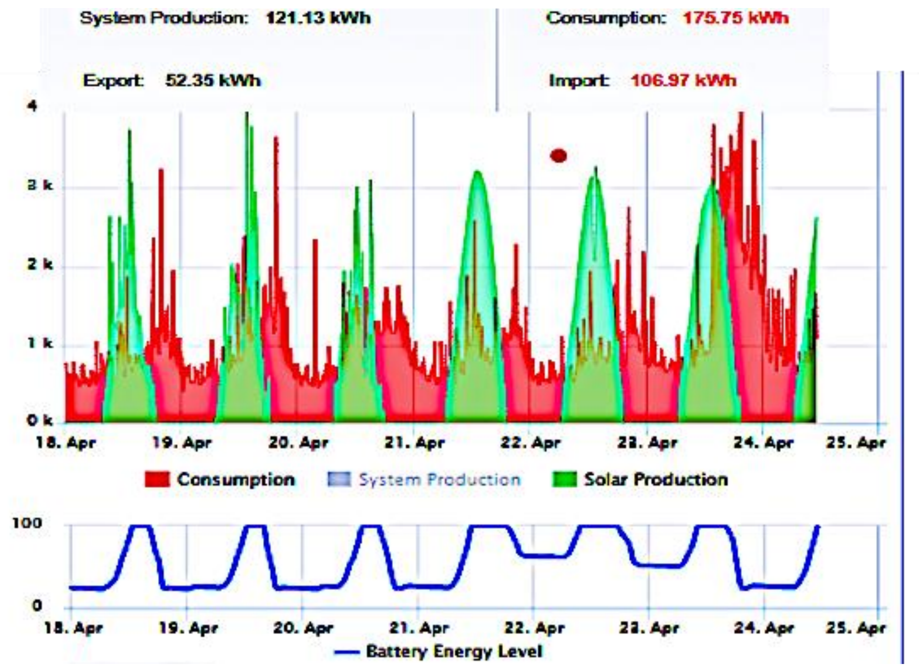
SITE H: WESTLAKE VILLAGE



BESS Site A

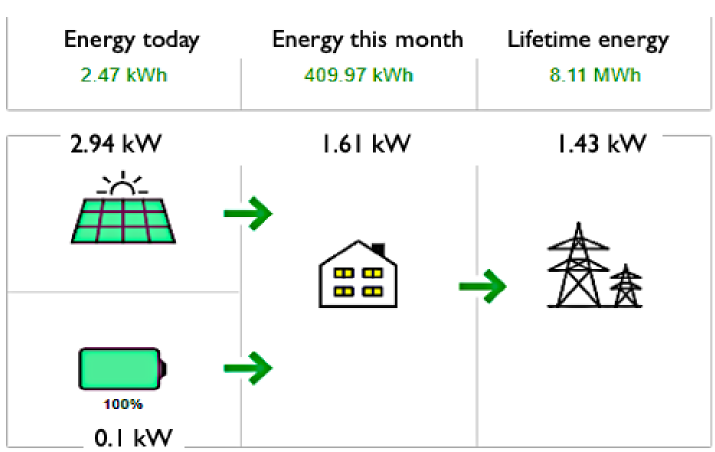
The BESS at this residence responded well to scheduling based on the TOU-D-Prime tariff. PV overproduction was successfully sent back to the grid after the battery was charged. During mid-peak hours (4 – 9 p.m.) the battery discharged to serve the home's load, to minimize grid consumption. A BESS minimum charge of 30% was maintained, to ensure optimum battery life.

Site A



The dashboard at Site A is accessed through a secure web portal. The administrator assigns access rights, and an invitation is sent to the user's email address, including a link the user clicks to access the portal. Administrators can navigate from site to site.

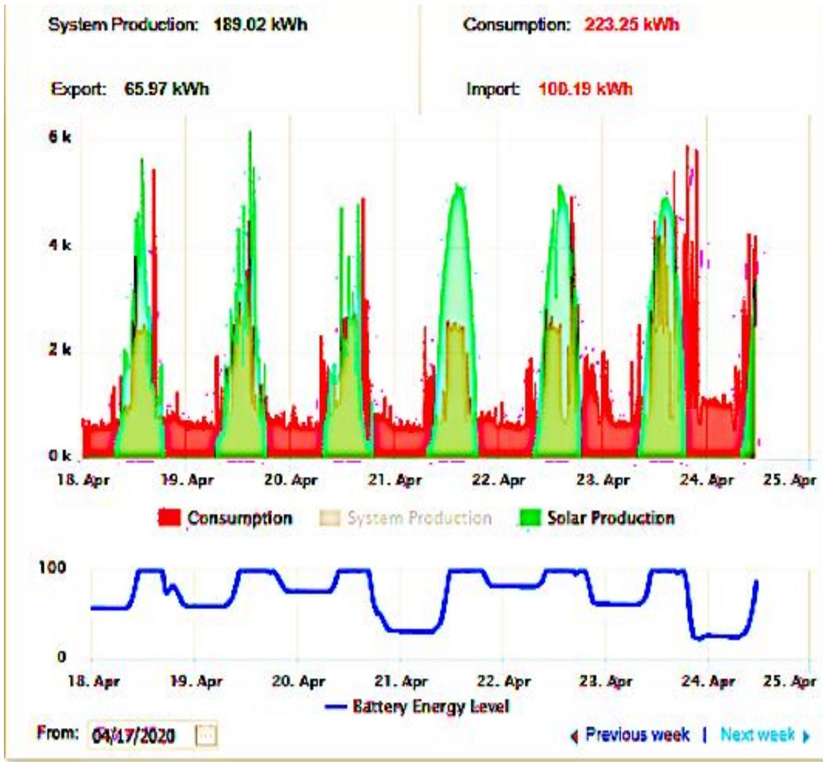
Site A Dashboard



BESS SITE C

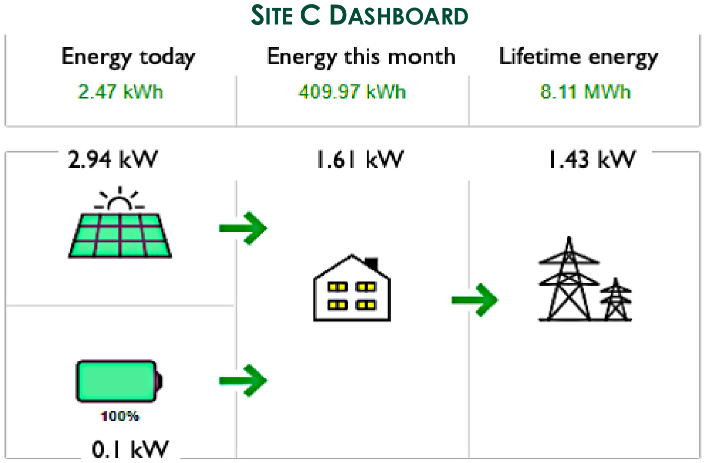
The BESS at Site C responded well to scheduling based on the TOU-D-Prime tariff. PV overproduction was sent back to the grid after the BESS was charged. During mid-peak hours (4 – 9 p.m.) the BESS discharged, to minimize grid consumption. A BESS minimum charge of 30% was maintained, to ensure optimum battery life.

SITE C



The dashboard is accessed through a secure web portal. The administrator assigns access rights, and an invitation is sent to the user's email address, including a link the user clicks to access the portal. Administrators can move from site to site.

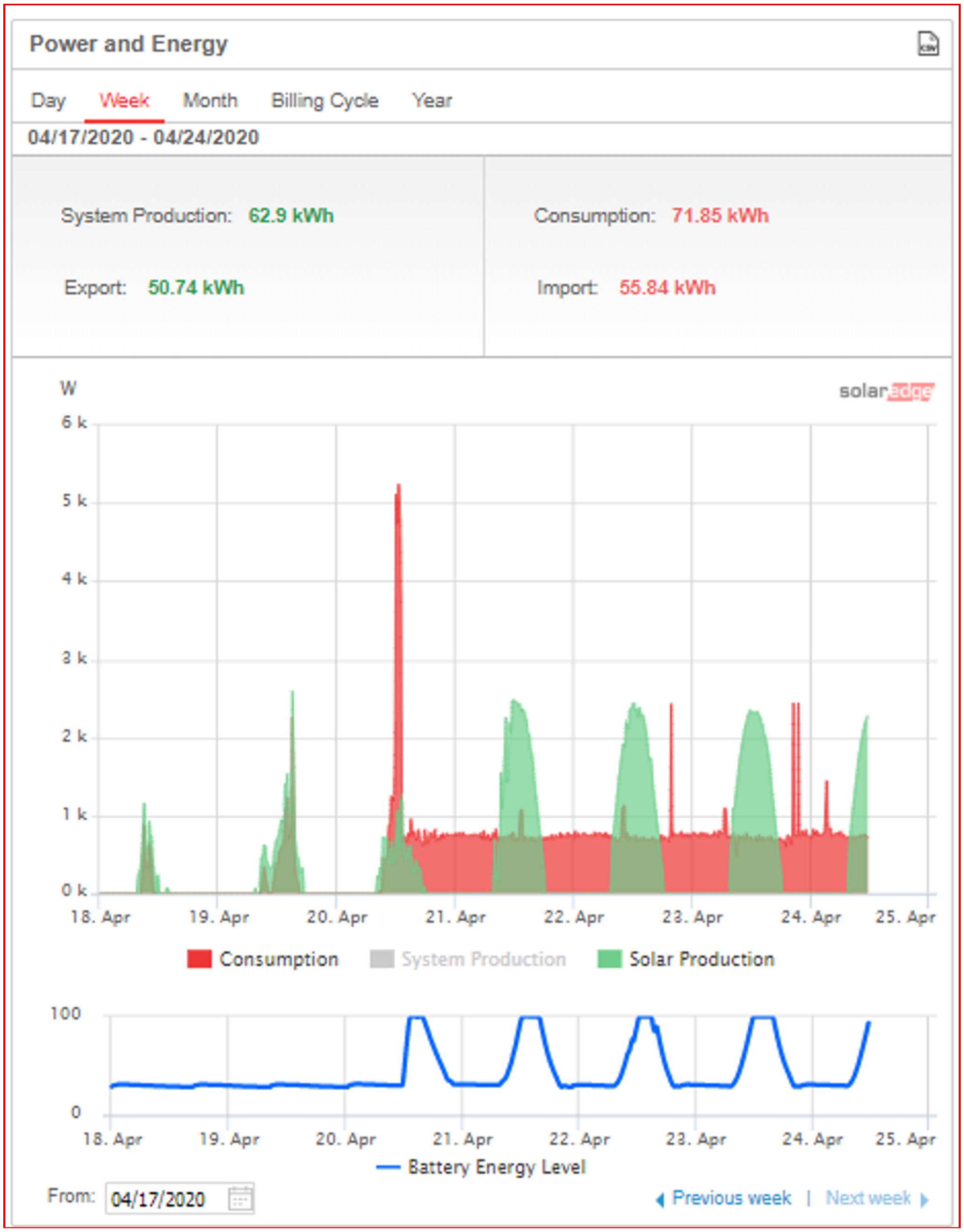
SITE C DASHBOARD



BESS Site E

The BESS at Site E responded well to scheduling based on the TOU-D-Prime tariff. This site was lightly occupied for five days a week. Charging and discharging the BESS was scheduled only during the occupied period.

Site E

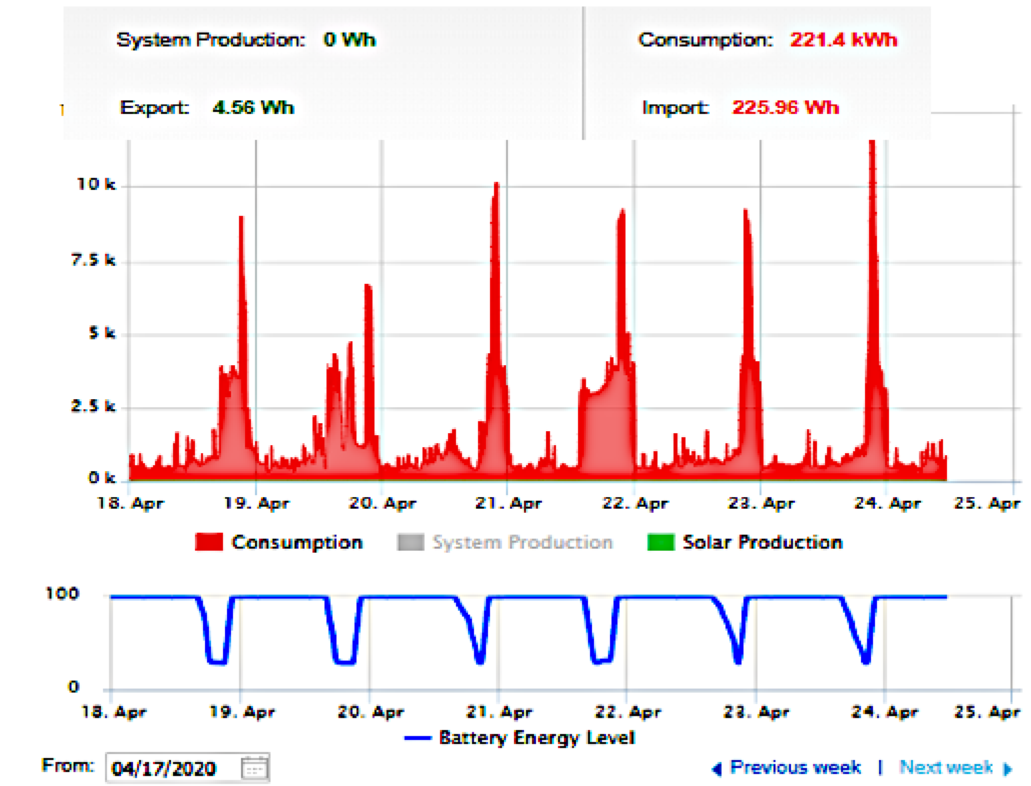


The figure above uses a screen shot from the SolarEdge portal. There was not an actual rate tariff applicable to this SCE site, so residential tariffs from the other sites were substituted for rate analyses, to simulate a typical residential site.

BESS Site H

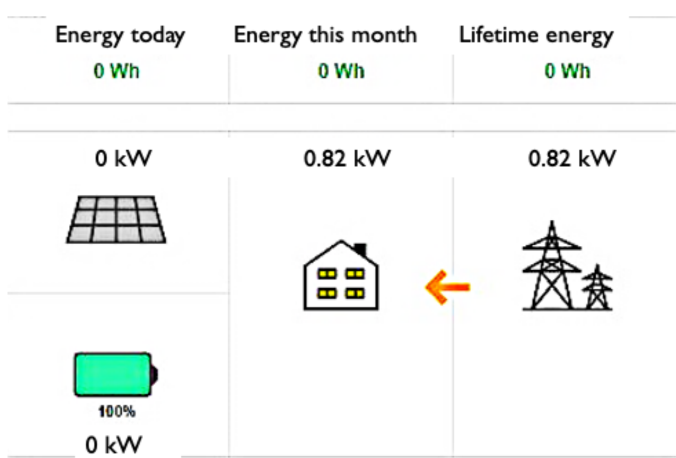
The BESS at Site H responded well to scheduling based on the TOU-D-Prime tariff. This site had no PV production. During off-peak hours, the BESS charged from the grid. During mid-peak hours (4 – 9 p.m.) the BESS discharged, to minimize grid consumption. A BESS minimum charge of 30% was maintained, to ensure optimum battery life.

Site H



The dashboard for Site H is accessed through a secure web portal. The administrator assigns access rights, and an invitation is sent to the user's email address, including a link to access the portal. Administrators can move from site to site.

Site H Dashboard

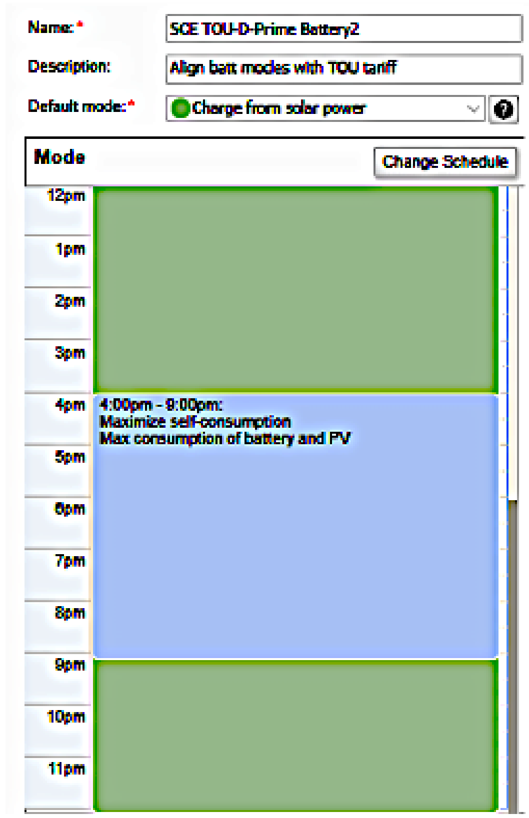


SCE TOU Rate Tariff and Operation

K&A developed storage profiles (schedules) for operating the BESS and uploaded them to the inverter at each site.

Storage profiles included daily and seasonal profiles that supported the SCE TOU-D-Prime tariff.

Daily Profile Details



Rate Analysis

A rate analysis using a simplified spreadsheet model was conducted for each site after their BESS installations. As a result, all of the residential customers switched to the TOU-D-Prime rate, and they are enjoying additional cost savings. The EEC is controlled in a manner similar to the residential sites.

Grid Outage Operation

Code Compliance: During a grid outage, the PV system must be quickly isolated and shut down for safety. The autotransformer performs this function.

PV Offline: The inverter senses grid failures, and initiates a transfer switch, taking the PV systems offline. PV system optimizers isolate each PV module string.

Essential Loads Panel (ELP): The battery provides power to the inverter, to control the output current to the ELP, where select loads are served by the BESS.

Low Battery Limit: When the inverter senses the battery or charge falls below an adjustable setpoint (typically 30%) the inverter isolates the BESS from the ELP, to prevent battery damage. Li-Ion batteries cannot be allowed to fully discharge, as they do not accept a charge after a complete discharge, rendering them useless.

TECHNICAL APPROACH

Contractors

K&A worked with two companies – Promise Energy and Precision Energy – to support the project installations. At each residential site, Promise Energy designed and installed the BESS, including all engineering calculations, drawings, materials, and installation labor. The equipment included:

- One LG Chem RESU 10H backup battery
- One StorEdge SE7600A-US battery inverter
- One 5kVA auto transformer
- Additional system materials (ELP, SolarEdge meter and Current Transformers [CTs], wiring, conduit, and appurtenances) to complete the BESS

SCE hired Precision Electric to design and install the BESS at the EEC, including calculations, drawings, materials, and installation labor. The equipment included:

- One LG Chem RESU 10H backup battery
- One SolarEdge StorEdge SE7600A-US battery inverter
- One 5kVA auto transformer
- Additional system materials (ELP, SolarEdge meter and CTs, wiring, conduit, and appurtenances) to complete the BESS

Commissioning (C_x)

K&A coordinated Cx for each BESS system, including:

- Coordinating customer and subcontractor site access
- Witnessing and documenting the subcontractor's on-site Cx work
- Conducting a follow-up Cx evaluation on the SolarEdge site portals
- Coordinating SolarEdge's technical services to identify, confirm, and correct operational issues
- Requiring the subcontractor to complete Cx documents, including as-built documents, and Cx forms, as well as letters of attestation, permit signoffs from building departments, and interconnection permits from SCE's Net Energy Metering (NEM) program and Rule 21 Distribution group.

Site Installations

This section describes each site installation. An important purpose of this project was to identify obstacles and offer solutions to inform future programs.

BESS Site A

The Site A installation was completed, but with certain challenges.

The battery inverter had not been properly equipped to respond to remote DR dispatch capabilities. This issue was remedied during Cx for the SolarEdge Grid Services API upgrade.

SITE A

SITE A INSTALLATION DIARY

Nov. 6, 2018 – Day 1
- Inverter delivered
- Battery not delivered

Nov. 8, 2018 – Day 2
- Existing inverter removed
- New inverter connected
- Battery delivered and installed

Nov. 9, 2018 – Day 3
- Power wiring and conduit installed to existing panel

Nov. 12, 2018 – Day 4
- Communication from battery to inverter
- Clean up conduit and wiring

Nov. 13, 2018 – Day 5
- Pulled breakers and reinstalled into essential load panels
- Cut access into back of breaker panel to pull essential load circuits

Nov. 19, 2018 – Day 6
- Inspection completed
- Commissioning scheduled

Dec. 3, 2018 – Day 7
- Commissioning.
- Battery/inverter communication error cleared.
- Portal integration initiated in the background.
- **Issues with battery and inverter communication identified.**

Jan. 21, 2019 – Day 8
- **Battery firmware required a downgrade** to communicate with new inverter.
- **Special battery charger shipped** to charge battery and prepare for download.

BESS Site C

Site C has an installed BESS, plus controllable thermostats, lighting, and PV. This house responded well to scheduling based on the TOU-D-Prime tariff.

Solar PV overproduction was successfully sent back to the grid after the BESS was charged.

Site C

Site C Installation Diary

Nov. 27, 2018 – Day 1

- Delays in receiving equipment.
- Inverter and battery delivered.
- Both installed on wall by end of day.
- Backboard required.

Nov. 28, 2018 – Day 2

- **Inverter found to be defective.**

Dec. 3, 2018 – Day 3

- **Inverter replaced.**

Dec. 4, 2018 – Day 4

- Essential loads panel breakers relocated from main service panel.

Dec. 5, 2018 – Day 5

- **Inspection – not passed**; needed main breaker upgraded per plan.
- **Breaker replaced**; photo sent to inspector; sign off at end of day at office.
- **Communication issues between battery and inverter remain.**

Dec. 6, 2018 – Day 6

- Commissioning by electrician (late).
- **Cannot remedy communication issue.**
- **Background firmware up/downgrade required.**

BESS Site H

Site H

Site H does not have PV generation. Some difficulties were encountered at this site, one of which was poor cellular reception for the inverter to communicate with the cloud and respond to control signals. This issue was remedied during Cx for the SolarEdge Grid Services API upgrade, which also upgraded the cellular plan.

Another challenge was that this site required Rule 21 approval. This was difficult to acquire, as this represents a non-standard installation charged from the grid rather than a PV system. Additionally, the LG RESU battery replaced a failed "Electriq" storage battery.

Site H Installation Diary

Jan. 9, 2019 – Day 1

- Demolition (remove existing battery and inverter).
- New battery and inverter arrive and are installed.
- Wiring of components are completed.
- Battery was turned off to save charge until the firmware upgrade can be performed.

Jan. 21, 2019 – Day 2

- Battery firmware upgrade successful.
- **Firmware downgrade was required to communicate with the inverter.**
- **Initial condition was diagnosed as a (fault).**

BESS Site E

Site E

In addition to the three residential installations, a BESS was installed the SEE exhibit at SCE's Irwindale EEC.

This installation provides SCE customers and building professionals the opportunity to experience a functioning BESS up close, and the project team to evaluate API controls without disturbing customers.

The installed smart meter was unable to connect with the EEC meter, so K&A devised a solution to remotely site the UD Polisy platform, providing an essential proof-of-concept of data acquisition via the inverter portal platform.

Technology Integration

UD Intelligent Systems Platform

The project evaluated the UD ISY, and later the PolisyPro platforms. This enabled integrating and automating everything BTM, including:

- Smart Meter integration
- Off-the-shelf device integration
- Cloud-based device integration
- Smart Speaker integration
- OpenADR 2.0a/2.0b certification
- Native communication with the Virtual Top Node (VTN)
- TOU price reception from the VTN

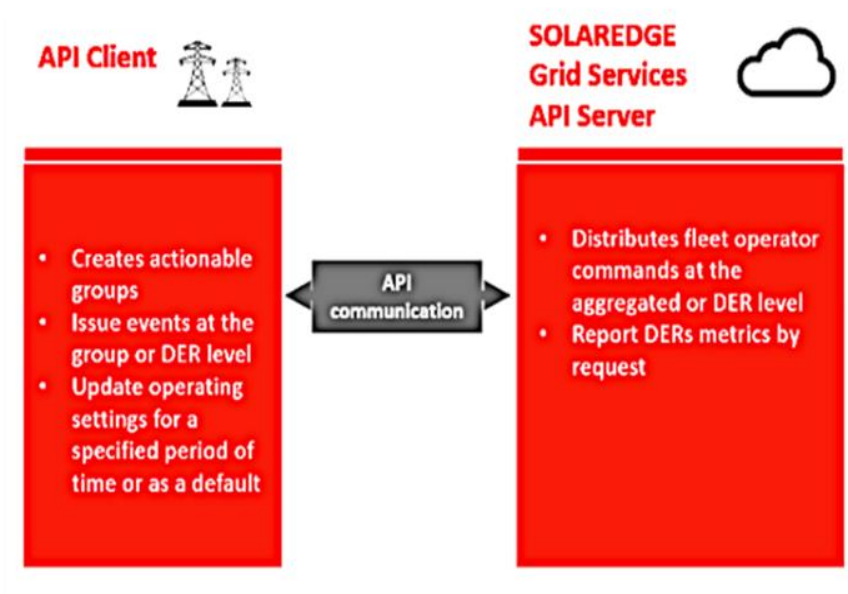
SolarEdge API

SolarEdge

Initial integration was performed using SolarEdge cloud-based public APIs, via the cloud on the Polisy platform. The customer had administrative rights to access a required API_KEY from the SolarEdge Grid Services website.

Initially, commands could not be sent (they were read only) and only one query was permitted per 30-minute period. To address these limitations, K&A used APIs from SolarEdge Grid Services. This required K&A signing a contract and subscribing to the service (enrollment required a minimum of 10 licenses). K&A coordinated with SCE's Legal department to facilitate this effort.

SolarEdge API Structure



SolarEdge API

The batteries and inverters were integrated with third-party software interfaces through a dedicated API, which enabled managing and monitoring Distributed Energy Resources (DERS) according to the specified objectives. It allowed granular data elements at five-minute intervals through an upgraded cellular inverter connection.

Commands were used to create instructions to execute tasks at a set time, for a set duration (≥1 second). Sites were configured to accept up to one new command per minute. The API server was intended to be responsible for mediating between the fleet operator and end-use devices. The server managed communication with individual DERs and operator control command execution.

Each API operation that modified any type of content was performed by posting to a web Uniform Resource Locator (URL). The API communication used 4096-bit RSA encryption. Each user executing API calls was pre-registered and authenticated via a pre-shared user ID and password.

SolarEdge markets their product as having API functionality. However, their API is for monitoring only (APIM). API for control (APIC) required a specific contract with SolarEdge Grid Services (SEGS) which had just established in California. With a subscription and fees, the agreement provided exclusive access to the SolarEdge cloud servers. This project was the first installation in California to receive a SEGS API (normally, the subscription is only offered to aggregators).

The basic API BESS commands were Charge and Discharge, with additional controls such as a discharge rate not to exceed local consumption if grid export is prohibited. API control modes included Maximize Self-Consumption, Storage Profile (configured), Backup Only, Storage Reserve (percent of capacity), and State of Charge Limit.

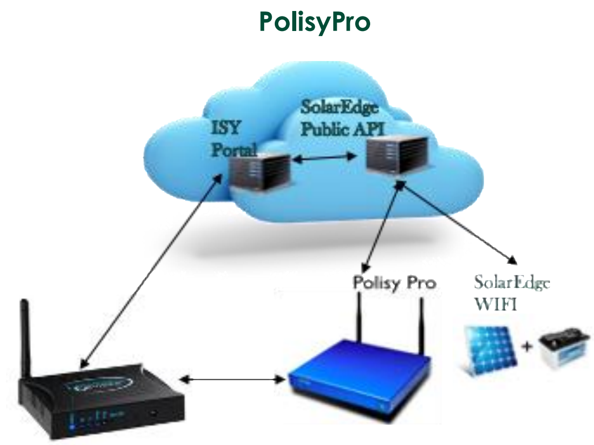
The following information was available to the ISY/Polisy platforms through the SEGS cloud, and exceeded what a typical SolarEdge BESS was capable of monitoring:

- **Allow Grid Export:** Allowed or prohibited export energy to the grid. If grid export is not allowed, forced discharge commands were limited, and could not exceed local consumption.
- **Charge Storage using PV only:** Eliminated charging storage from the grid.
- **Fixed Power Factor:** Set a fixed power factor when the inverter was over- or under-excited.
- **Charge/Discharge**
- **Volt-VAR Curve:** Provided over- or under-excited Volt-Amp Reactive (VAR) compensation as a function of measured voltage.
- **Volt-Watt Curve:** Limits real power output as a function of measured voltage.
- **Frequency-Watt Curve:** Limits real power output as a function of measured frequency.
- **Limit Active Power:** Limits inverter active power to a percentage of its nameplate rating.

To integrate with SEGS, it was necessary to first register and go through the process of obtaining a 4096-bit RSA certificate. Each user obtained a unique certificate, then the password was changed. Once registered, no additional sites could be added. Each site had a collection of resources identified by the DER's ID, such as the PV system, BESS, and Electric Vehicle (EV) chargers.

POLISYPRO

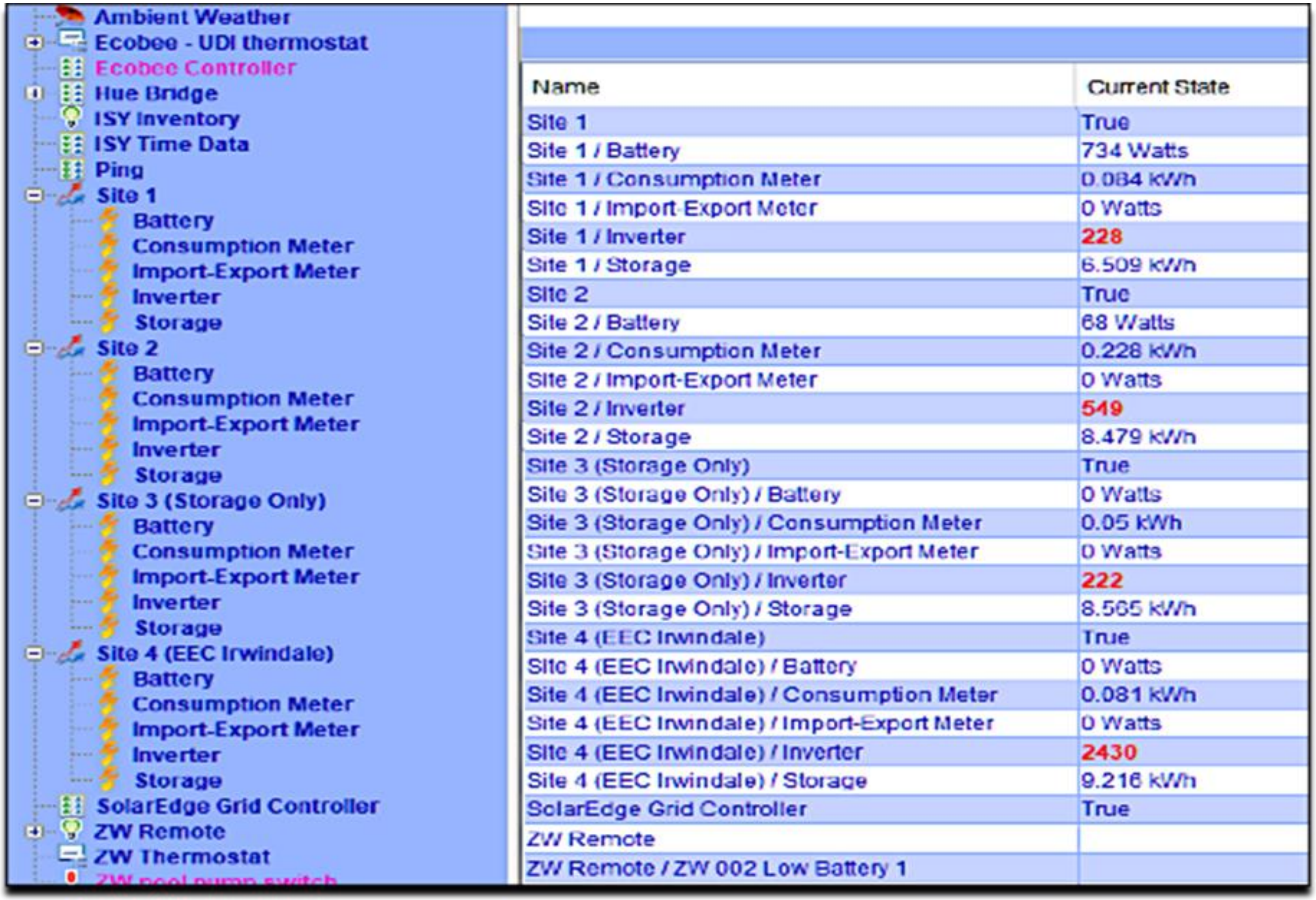
K&A purchased Polisy Pro (Polisy) as an Internet of Things (IoT) integration platform for the ISY.



Storing security certificates in the cloud was deemed insecure, so Polisy is where the certificates are stored. Also, the certificates required the Unix programming language to develop and manage. Polisy is a polyglot (a device that supports multiple languages) and was able to support the SEGS cloud API server's security requirements.

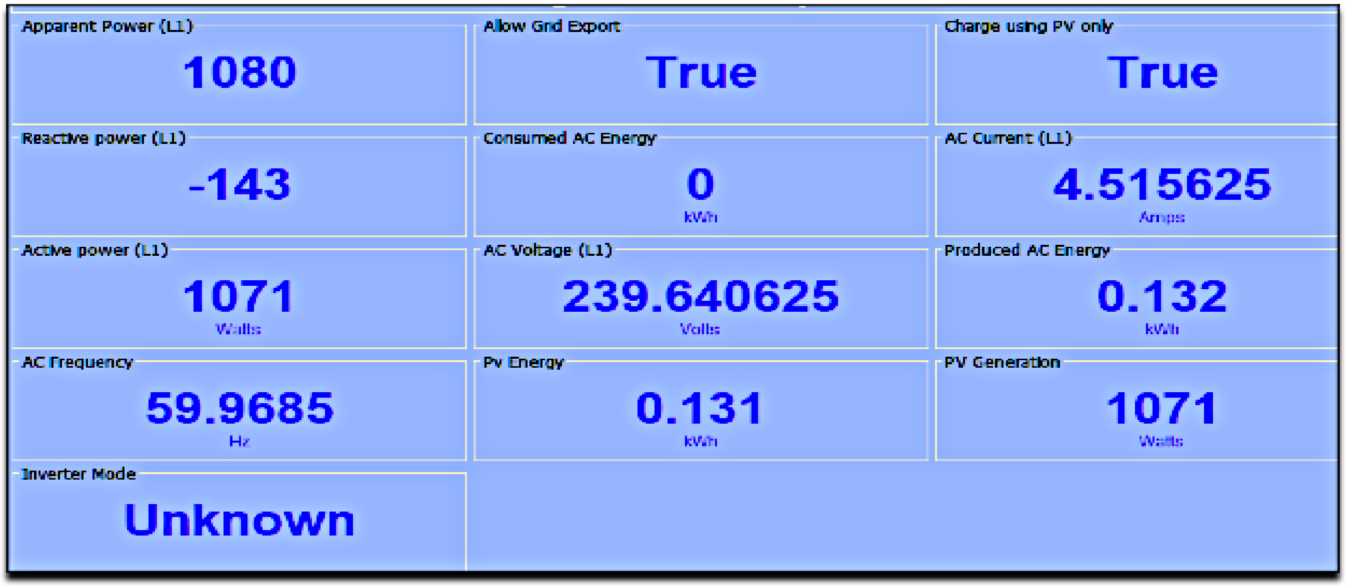
Polisy Pro integrates with local and cloud-based IoT and communicates with SolarEdge Grid Services. It updates the ISY with SolarEdge data points and executes ISY commands against the SolarEdge cloud server, which then transmits the commands to the SolarEdge inverter for processing.

REPRESENTATION OF SOLAREDGE SITES



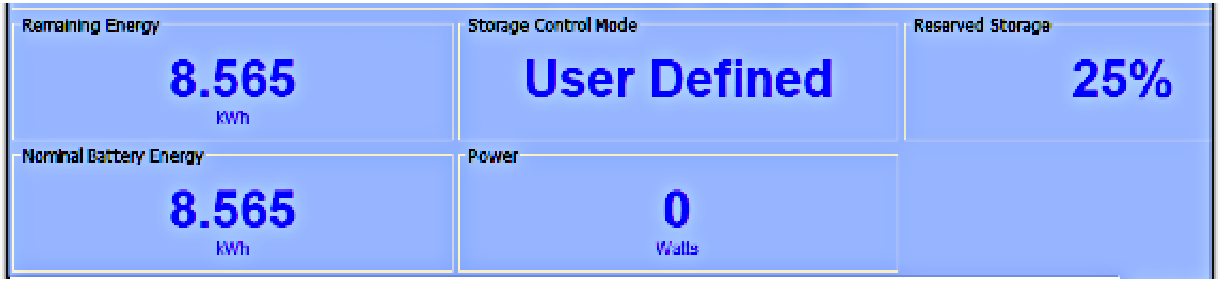
Name	Current State
Site 1	True
Site 1 / Battery	734 Watts
Site 1 / Consumption Meter	0.084 kWh
Site 1 / Import-Export Meter	0 Watts
Site 1 / Inverter	228
Site 1 / Storage	6.509 kWh
Site 2	True
Site 2 / Battery	68 Watts
Site 2 / Consumption Meter	0.228 kWh
Site 2 / Import-Export Meter	0 Watts
Site 2 / Inverter	549
Site 2 / Storage	8.479 kWh
Site 3 (Storage Only)	True
Site 3 (Storage Only) / Battery	0 Watts
Site 3 (Storage Only) / Consumption Meter	0.05 kWh
Site 3 (Storage Only) / Import-Export Meter	0 Watts
Site 3 (Storage Only) / Inverter	222
Site 3 (Storage Only) / Storage	8.565 kWh
Site 4 (EEC Irwindale)	True
Site 4 (EEC Irwindale) / Battery	0 Watts
Site 4 (EEC Irwindale) / Consumption Meter	0.081 kWh
Site 4 (EEC Irwindale) / Import-Export Meter	0 Watts
Site 4 (EEC Irwindale) / Inverter	2430
Site 4 (EEC Irwindale) / Storage	9.216 kWh
SolarEdge Grid Controller	True
ZW Remote	
ZW Remote / ZW 002 Low Battery 1	

Inverter Parameters (representation from one site)



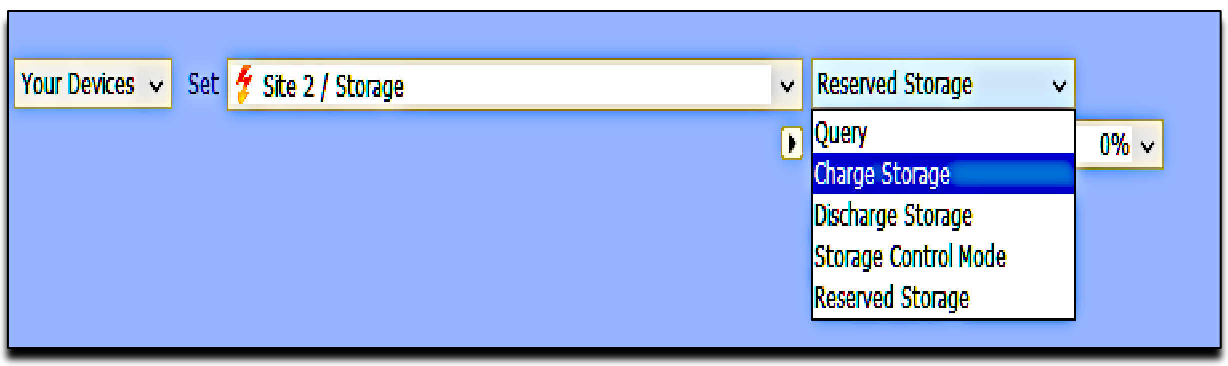
Battery Parameters

STORAGE OPERATIONS PARAMETERS

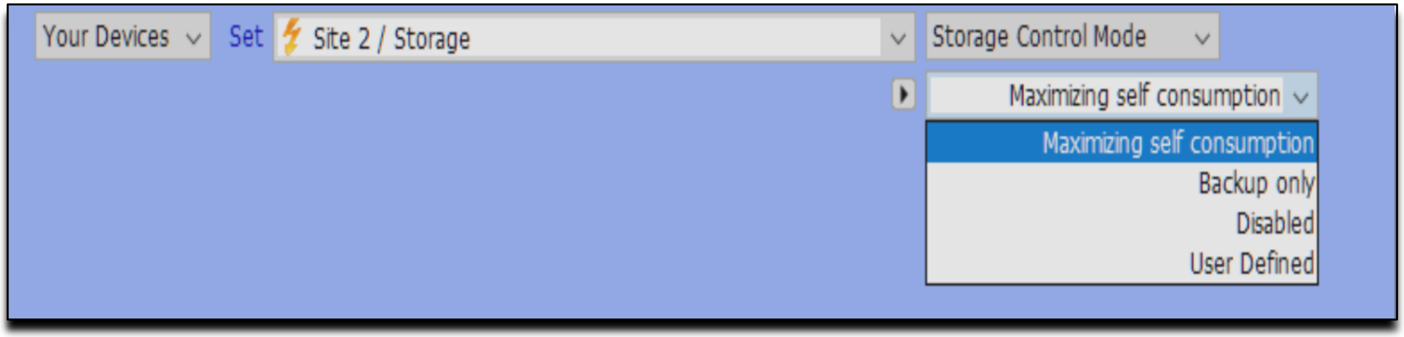


INVERTER SETTABLE MODES

STORAGE SETTABLE MODES

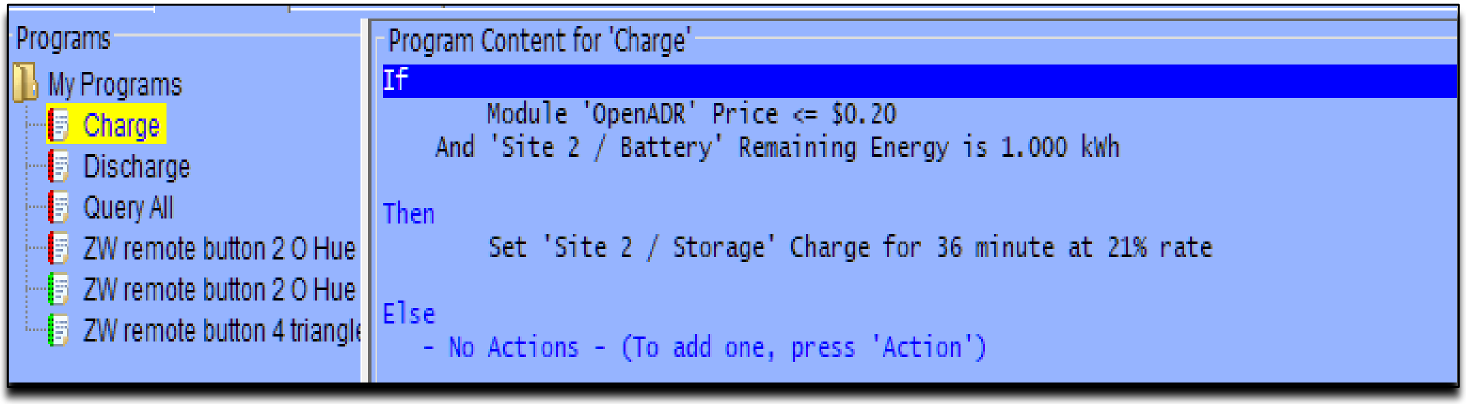


STORAGE CONTROL MODE

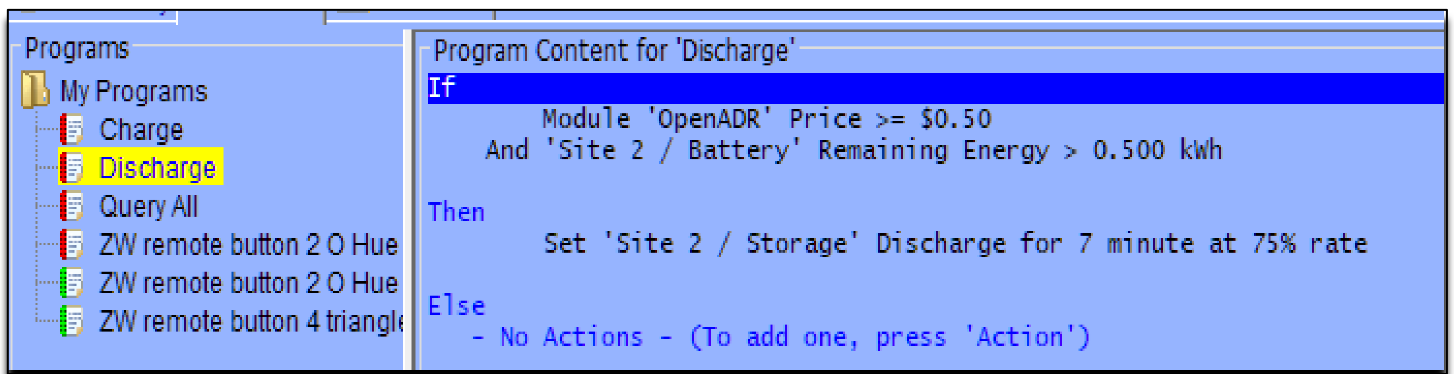


SET RESERVED STORAGE PERCENTAGE

Charge Based on TOU



Discharge Based on TOU



Communication Architecture

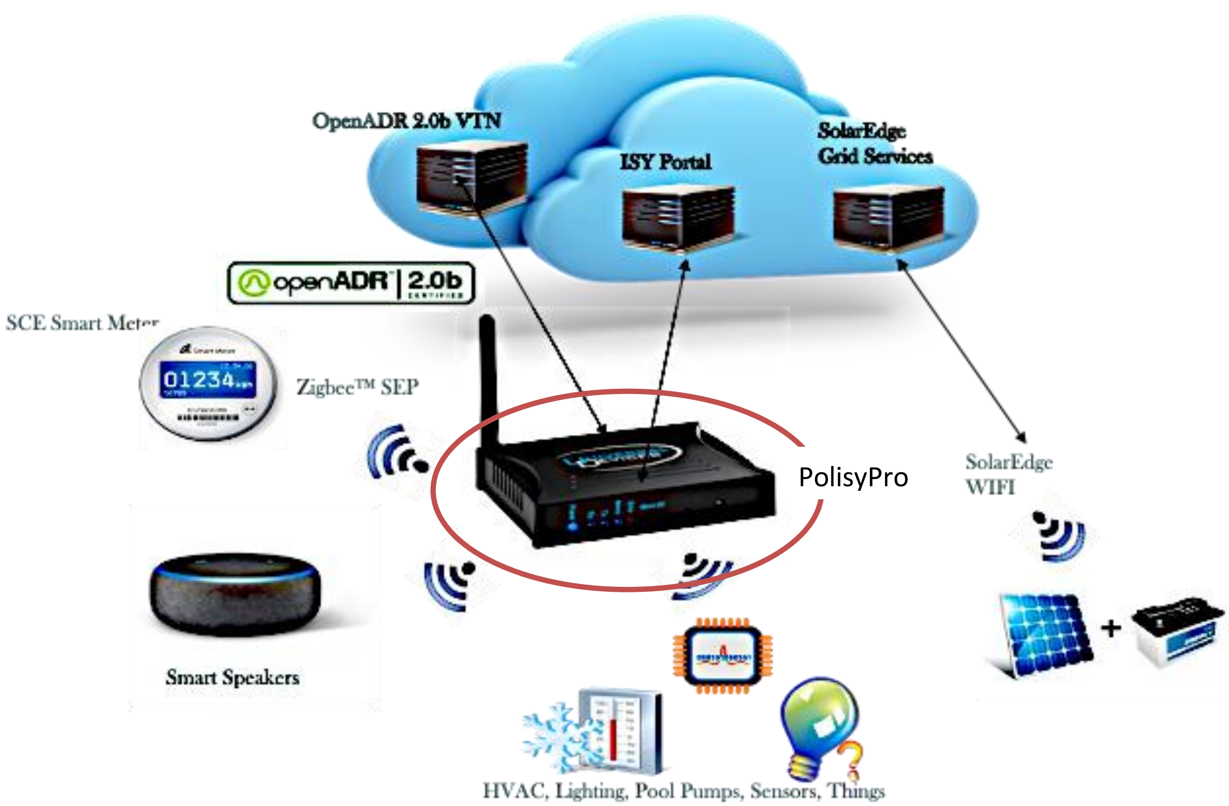
The architecture for sites A, C, E, and H includes connection to an internet cloud-based portal to record PV and BESS operations data. API control of these sites was not initially completed due to various issues, as described in the Universal Devices and TeMix section of this document.

As the purpose was to understand how to optimize transactive exchange between customers with DERs, K&A set up Site E to evaluate API control. Although this site had a smart meter installed at the time, it was unable to make connection with the SCE/EEC meter. Therefore, an ISY and PolisyPro setup at a remote office was used to control the BESS. This alternative solution achieved essential proof of concept.

After some site troubleshooting, K&A corrected BESS operations at Site E. Effective API control was accomplished and successfully followed pricing signals, as delivered through the cloud from the PolisyPro device.

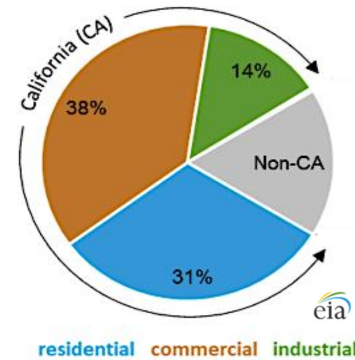
Later, PolisyPro installations were performed at sites A, C, and H. These installations allowed full transactive control using APIs pushed through the SEGS cloud and co-aligned with pricing signals from the UD cloud.

TYPICAL CONTROL TYPOLOGY



RESULTS AND DISCUSSION

The importance of this project to SCE and California is underscored by the state's outsized role in advancing residential BESS. Indeed, the state accounts for 83% of installed small scale BESS nationwide, and over 30% of this is residential.



Li-ion batteries are the most energetic rechargeable batteries available. The California market for residential BESS is driven by the import of low-cost solar panels. According to the Energy Information Association (EIA), BESS capital costs fell by 72% between 2015 and 2019, a 27% per year rate of decline.

Yet this implementation project revealed there is work yet to be done. One positive, important outcome is the SCE TOU-D-Prime rate tariff was identified as an effective mechanism for maximizing customer savings. This was achieved through an alignment of BESS scheduling with tariffs and was found to be feasible with or without PV generation.

The team encountered numerous challenges, some of which could be resolved, and others that require future attention. The hope is that these project results serve as a useful resource to guide future work in this area.

The project encountered, among other problems, delivery constraints, installed equipment that did not perform properly, gaps in training (among permit inspectors, electricians, and installers), equipment design issues, and undocumented manufacturer firmware changes. Support for BESS equipment control was not as comprehensive as advertised.

SUMMARY OF INSTALLATION CHALLENGES

Site	Installation	Installation Issues
A	Jan. 21, 2019	Issues involving battery inverter communication that required a firmware download and the need for a battery charger.
C	Dec. 6, 2018	Defective inverter needed replacing. Communication issues between battery and inverter. Project failed initial inspection.
H	June 21, 2019	Battery inverter communication issues that required a firmware download.

Because the BESS equipment was proprietary, customers and SCE contractors were restricted from controlling the system. For example, expensive licensing costs were not apparent at the outset, and firewalls were not aligned with equipment protocols.

Installation Issues

The project team encountered difficulties at all three sites, starting in mid-2018 when the project was getting underway. One purpose of this report is to document such challenges and inform programs going forward. These challenges included:

- At the outset, SolarEdge batteries and inverters were sold out, resulting in a five-month delivery delay.
- After the BESSs were installed, there were lengthy delays in obtaining the required Permission-to-Operate (PTO) from SCE (the last PTO was granted at the end of 2019).
- Inspectors had neither sufficient training nor adequate time to understand what they were looking for.
- Site H required Rule 21 approval, which was difficult to acquire for a non-standard installation (this designation was due to charging from the grid rather than a PV array).
- UD's ISY platform integrated pricing signals from the cloud using OpenADR 2.0b. However, the base functionality of the inverters using an API key supported monitoring only (the manufacturer over-promised on what it could deliver).
- The BESS systems were consequently ill equipped to perform flexible transactive control. Inverters were unable to charge or discharge in response to API commands.
- Additional equipment was needed (either purchased or upgraded) to allow the BESS to perform essential functions by command.
- It required considerable effort on the part of K&A to revise the BESS control interface and align contracts with SEGS.
- This project was the first in California to use the full API functionality the manufacturers claimed. The manufacturer told K&A the API "push" control was to be released soon, with a U.S. office to be co-located in San Francisco with SolarEdge. Further licensing contract negotiations with SEGS took months, partly due to the manufacturer and partly due to utility legal reviews.
- After PolisyPro platforms were installed at all sites in late 2020, K&A attempted to integrate a PSPS response capability similar to the transactive responses we were providing. K&A found that while it was possible to initiate a response from the UD cloud server to the BESSs, the interface to receive signals from SCE's PSPS system would be a major hurdle requiring additional funding beyond initial project scope. Still, the capability to automate responses from PSPS event notifications would be complementary to effectively control a BESS set up to respond to transactive energy pricing signals.
- Finally, as the project was wrapping up, LG sent a notice of recall for all the BESS installations in this project. As a result, the batteries were limited to charge only to 50% remotely by LG. Logistical issues have delayed replacement battery delivery (as of February 2022, the replacements have not been received).

Integration with SolarEdge Services

Observations

K&A offers these positive observations about integration with SolarEdge services:

- Granular readings were available up to once every five minutes.
- After the quirks of security certificates and communications were resolved due to Grid Services requirements, readings became very stable.
- Charge/Discharge commands worked well.
- The team was able to send commands to a group but could not fully assess this functionality (this is an opportunity for future research).

Considerations

A few issues from this experience provide ideas about the process of API certificate creation, for consideration:

- User registration and adding sites is time consuming.
- API functionality was targeted to aggregators. The API implementation process was beyond the residential customers' technical capabilities and requires additional specialized equipment.
- The API control's licensing cost is expensive and is only available for multiple installations (a minimum of 10 at the time of the project) targeted to aggregators and (potentially) utilities.
- There was no user-friendly interface, so secure communications management had to be performed using Unix command line utilities.
- UD's PolisyPro had to be used as a polyglot, to provide the interface required to set up and manage the secure encryption interface for API communications. It was fortunate that this device was available.
- BESS operation documentation was general, cryptic at best, and incomplete at worst. Support improved as time passed.
- Commands took time to update in the SolarEdge monitoring site, especially for installations using cellular data plans prior to the Grid Services upgrade. Most sites had to transition to direct ethernet connections, to avoid long command response times.

Questions

How will deployments work in the future, considering:

- API access is granted to a user in an organization.
- An organization may have multiple users and multiple certificates.
- It is unclear which certificate is used for deployment. Where is the documentation?
- The entire process of gathering and submitting security certificates was complex and time consuming, beyond normal customer abilities. Again, where is the documentation?

Is there a future role for aggregating site views, such as?

- Aggregated reactive power.

- Aggregated available storage.
- Aggregated export potential (solar + storage).
- BESS State of Charge (SOC) and other system data diagnostics.

Looking Ahead

Future integration with SolarEdge Grid Services should review and consider:

- Moving to a secure cloud portal, so PolisyPro is not necessary.
- Data charting functions.
- Sending group commands.
- Aggregation from a customer point of view.
- Other forms of optimization, based on available data:
  - TOU single-hour pricing.
  - Climate conditions and forecasts, including PSPS events.
  - Occupancy/vacation modes; remote control and monitoring.
  - Scheduling loads, such as car charging.

Implications of Title 24 Standards

To qualify for compliance credit under the Performance Approach, BESSs must now comply with Joint Appendix JA12 Qualification Requirements for Battery Storage Systems.

- K&A developed and implemented TOU profiles in alignment with these requirements. Certain modes available from the SolarEdge portal do not appear to operate exactly as described, which could potentially compromise strict compliance.
- More work is necessary to confirm the proper control modes for TOU profiles are working properly and are fully aligned with JA12 requirements.
- Credit under JA12 is available for Advanced DR Control, in response to signals from the utility or aggregator. However, current functionality is not demonstrated or available.
- The BESSs are on track to eventually earn credit under JA12 for Advanced DR Control, but not at this time. They would have to be able to respond to an OpenADR signal.
- Appendix H – Demand Responsive Controls specifies the systems must use OpenADR 2.0 or 2.0b to communicate with the entity initiating the DR Signal. The system must also use specified communication pathways. The approach involving the ISY and PolisyPro equipment described above complies with this requirement.
- All new residential projects must employ PV systems as a mandatory requirement. Therefore, additional compliance credits available for BESSs are expected to generate strong demand for fully-compliant BESS credits.
- Lessons from the RESS project indicate technological issues may prevent BESSs from fulfilling TOU and DR expectations of improved resiliency.

Rate Tariff Analysis

Various residential rate tariffs (TOU-D-5-8, TOU-D-4-9, and TOU-D-Prime) were used to develop a simplified rate analysis spreadsheet to quantify estimated cost savings. This rate analysis also applied to the EEC site. Data from each site's BESS system were analyzed to determine the effectiveness of these rate tariffs.

Rate Analysis Procedure

- In late 2019 and early 2020, data logged by the inverter was used to select a representative day for each site.
- Energy consumption and solar generation data from the BESS was analyzed by spreadsheet and forecasted to represent a year of operation.
- Three operation profiles were modeled:
  - Base Facility Load
  - Facility Load + PV Generation
  - Facility Load + PV + BESS
- Three TOU rate tariffs were applied to the annual forecasted model, to quantify and compare the rates' cost effect.
- Optimum BESS control to roughly align with the TOU rates was analyzed and quantified for comparison.

Analysis Results

The results shown below indicate the TOU-D-Prime tariff aligns best with all load profiles, regardless of PV or BESS technology. Simply moving to TOU-D-Prime is cost effective for all the base load profiles.

For Site H, which does not have a generating component, savings were significant with the TOU-D-Prime rate, largely because of the customer's load profile (most loads occur in the late evening). This site experienced a minor cost increase on TOU-D-Prime under BESS control. This may be due to the BESS exhausting capacity prior to completing the late-evening part of the discharge schedule. This indicates more storage capacity may be required to optimize savings.

As would be expected, PV generation has the most impact, using an essentially free cost generation component to offset energy use.

Profile (site)	Description	TOU-D-4-9 Cost	TOU-D-5-8 Cost	TOU-D-Prime Cost
A-1	Base Load	$11,283.06	$11,449.64	$8,358.40
A-2	Base Load + PV Generation	$6,951.87	$7,147.73	$4,783.59
A-3	Base Load + PV Generation + BESS	*$4,816.73*	*$4,975.20*	*$3,362.84*
C-1	Base Load	$16,228.84	$16,493.48	$13,933.63
C-2	Base Load + PV Generation	$7,902.92	$8,114.35	$6,920.18
C-3	Base Load + PV Generation + BESS	$4,254.15	$4,417.01	$3,076.45
H-1	Base Load	$21,695.63	$22,310.85	$14,645.45
H-2	N/A	N/A	N/A	N/A
H-3	Base Load + BESS	$20,819.91	$21,449.20	$15,053.32
EEC-1	Base Load	$6,515.86	$6,549.20	$5,114.16
EEC-2	Base Load + PV Generation	$2,969.77	$3,080.08	$1,928.93
EEC-3	Base Load + PV Generation + BESS	$2,300.68	$2,385.30	$1,513.01

PSPS Analysis

PSPS events are now more common across California, to support wildfire mitigation. Toward the end of monitoring the BESS installations, SCE requested an additional task to explore the barriers to aligning the automation developed for pricing response to include PSPS response. This would enable the BESS systems to change modes prior to potential PSPS events, and to maximize storage capacity to extend critical loads backup service times.

Upon developing an automated response, the K&A team found it was not possible to interface directly with PSPS notifications, as SCE's IT policy prohibited access to its servers. Other means (primarily requiring subscription services) may be used in the future. Investigating and deploying these other means is beyond the scope of this project, but they would be a valuable addition to BESS control.

Tesla has a technology called "Stormwatch" which notifies users of severe weather forecasts via smartphone app.

Stormwatch uses United States Geological Survey (USGS) weather reports of potentially-severe local weather events and sends the user a message asking them to consider switching to backup mode (the message can be customized to switch automatically).

The K&A team appreciates Tesla's forward-thinking use of Stormwatch technology with their BESS systems. However, it lacks the more definitive PSPS system interface, which may call PSPS events outside of severe weather circumstances. More work is needed to bring PSPS responses into the mainstream of BESS control.

OpenADR protocol integration is maturing and expanding into utility DR programs and customer-purchased appliances. This may be the most productive path to explore integrated PSPS BESS control in the near term, and K&A recommends more research in this direction.

STORMWATCH APP

Automated pricing signal response for BESS control has been demonstrated and validated in this project, and researcher consensus indicates PSPS response integration is within reach, since technical barriers can be overcome.

Project Recommendations for Discussion

These recommendations are offered for discussion based on the results described above:

1. Careful BESS installations, accompanied by BESS system Cx, is required for optimal control and savings. Every system had an issue that needed to be corrected after the BESS installations were "complete" to achieve proper operation and control. Consider, for example, adopting a requirement (rule) for a third party, such as a Home Energy Rating System (HERS) rater, to certify BESS installations.

2. Most homeowners (and many installation contractors) are unable to troubleshoot BESS installations for optimal control. Inspectors do not have the time or training to know what to look for and may often miss deficiencies. Certification to qualify each manufacturer's product installations would be helpful; an independent third party may be necessary but would require sanctioning to be effective.

3. Unintended consequences, such as BESS system charging, can occur during grid congestion. More safeguards may be required to prevent such issues, including hardware or software lockouts.

4. IOU support with special TOU tariffs was helpful and should continue for future technology growth and innovation. The TOU-D-Prime tariff was highly effective in reducing energy costs, as long as the BESS was aligned with the rate schedule. Transactive real-time market pricing response was also successfully demonstrated. More work is required to fully understand and document customer BTM savings as well as the grid-supporting effect of BESS customer aggregation.

5. Single-battery (Li-Ion) BESS systems frequently did not have enough capacity to last the entire TOU peak pricing window. Additionally, after completing the discharge cycle, they had little reserve to provide meaningful backup power in the event of a grid outage. Controls to adjust the rate of charge/discharge would help schedule reliable BESS operation to support the grid. Additionally, storage mode modeling tools would aid in proper BESS system design. The Electric Power Research Institute (EPRI) developed StorageVET®, a storage value estimation tool. StorageVET[4] analysis is recommended prior to planning BESS installations.

6. PSPS event response should be a fundamental BESS strength. However, if the PSPS timing coincides with late BESS TOU discharge, little if any reserve capacity is available for critical loads backup. Anticipating and automatically responding to PSPS events is critical for customers to optimally use BESSs for backup load response. Barriers to this functionality currently exist, and more research and testing is required to enable it.

7. In late summer 2021, LG notified the BESS installers of a recall on the RESU batteries at all of our project sites due to an overheating concern. The recall included a reinstatement of the 10-year original battery upon replacement. LG then unilaterally limited the maximum battery charge to 75% through remote access (we were not aware they had this capability). As of February 2022, the batteries, which are manufactured in Korea, have not been replaced due to logistical shipping delays.

[4] EPRI developed a publicly available, open-source, optimization-based BESS energy valuation and planning tool, providing an understanding of where to place and install energy storage, optimum size, and control options. https://www.storagevet.com/home/

CONCLUSIONS

Project Success

The project successfully demonstrated monitoring and automated control could be used on four BTM residential BESSs for grid support and price responsiveness. It also intended to identify problems with installations, Cx, and technology integration. Significant project delays were encountered because of factors outside these project task areas.

COVID restrictions limited K&A's building access to perform engineering work, but this was eventually resolved. Delays occurred due to contracting and equipment procurement issues. At the outset, batteries and inverters were sold out, resulting in a five-month delay.

Although all three residential installations involved significant complications as described in this report, the project demonstrated BESS feasibility. The installation at SCE's Irwindale SEE exhibit offers the public as well as building professionals an opportunity to view a functioning BESS up close, and for K&A to assess API control without disturbing customers.

Many lessons were learned for the future development of BESS as an emerging technology.

Lessons for Future Program Design

Manufacturer Product Integration Issues: Multiple delays were encountered in bringing BESS sites online and functioning properly. This is an innovative technology, and the BESS integrated equipment release seemed premature. The K&A team encountered significant firmware deficiencies, including batteries that over-discharged immediately after installation, which is a serious risk of permanent failure.

Shipment Delays: The team waited nearly five months for the BESSs to arrive, resulting in a significant project holdup (procurement was reportedly delayed due to market demand).

Training Deficits: Every installation suffered from a deficit of professionally-trained solar installation technicians. These professionals have been in high demand and were not adequately prepared to install BESS systems.

Manufacturers Oversold Functionality: Solar manufacturers provided misleading information to installation subcontractors about BESS API functionality. The subcontractors were insufficiently familiar with the new BESS equipment, and therefore did not raise questions about manufacturer claims.

Manufacturer Unprepared to Troubleshoot: The SolarEdge manufacturer's online support team was ill equipped to troubleshoot BESS issues. This eventually improved, but response times remained excessive.

Inadequate Documentation: BESS mode control documentation and actual performance do not coincide. For example, the team was unable to get the "discharge to minimize grid input" mode to operate properly.

Meter Installation Errors: Almost every installation suffered from errors in the manufacturer's suggested metering installation. CTs were often wired incorrectly, and some sites were missing CTs altogether, which probably would not have been corrected without K&A's oversight.

Warranty Replacement Delays: Some sites suffered equipment failures shortly after installation, requiring warranty replacements. The team encountered delays in receiving these replacements, because of reportedly high BESS demand.

Internet Cloud Communication Latency: This was an issue at all sites. Baseline cellular communications were inadequate, taking 30 minutes to several hours, even at the site with the best signal. The poorest reception commonly resulted in delays of four to eight hours.

Sequential Delays: The issues described above resulted in delayed troubleshooting during Cx. Prior to the SEGS upgrade, inverters had to be directly connected to the internet, which sometimes required additional equipment. The SEGS upgrade improved cellular and internet latency, which is mandatory and perhaps just adequate for any transactive control.

Manufacturer's Deficient Internal Communication: SEGS is a new SolarEdge business unit. Almost all of the SolarEdge online tech support team was unaware the SEGS existed, resulting in serious troubleshooting delays.

Out-of-Scope Equipment Purchase: Unbeknownst to anyone at the outset, ISY and PolisyPro platforms are now mandatory equipment to support the SEGS security and protocol administration required for API control.

Lengthy Security Certificate Process: The process of obtaining SEGS security certifications was slow. Initializing the certificates was difficult and required advanced coding and network skills.

Departure from Industry Standard: At the time of procurement and installation, SEGS did not use the industry-standard SunSpec communication protocol. Recent publications indicate SunSpec may be supported by select SolarEdge inverters equipped with the latest firmware updates. It is not known whether the RESS sites have inverters that can be updated to SunSpec. If so, it would make the security certification process easier.

Contracting Delays: The team encountered significant contract delays, both to and from SEGS and SCE legal, creating project setbacks.

SEGS licensing costs were significant, at roughly $1,000 per site annually, with a ten-site minimum contract. This introduced a cost burden for aggregators and utilities.

Self-Generation Incentive Program (SGIP) Rebate Processing: Solar subcontractors waived SGIP rebate incentives, missing the opportunity to receive $3,500 per site because the application process was time consuming.

Rule 21 Permit Review: Requiring a Rule 21 permit review on a non-PV BESS did not fit the current structure. This rule is more appropriate for large generating projects.

Battery Recalls: At the end of the project, LG recalled batteries at all of our BESS installations due to safety concerns. This is not the first time LG has recalled BESS batteries for this reason, and it casts a shadow on BESS Li-Ion safety and reliability.

Inverter Communication Disruptions: At the end of the project, SolarEdge notified us that T-Mobile would no longer support communications built into StorEdge inverters, meaning the devices had to use a direct ethernet connection to communicate via the portal. Most systems were already using an ethernet connection, as it decreases command and data acquisition response times (one site has to be upgraded).

RECOMMENDATIONS

In addition to the Lessons for Future Program Design described above, we are making these recommendations for BESS system functionality to support grid resilience:

1. Explore the Dynamic OpenADR Signal

- Implement the TOU-D-Prime tariff in the OpenADR server.
- Configure multiple residential sites on the TOU-D-Prime tariff using pricing to drive BESS.
- Run four different test cases, and compare them on a weekly basis during summer:
    - Existing maximize-self-utilization BESS modes.
    - Simple charge/discharge (such as via SolarEdge portal) based on TOU rates.
    - Optimization based on smart meter data, state of charge, occupancy, price, and device state (load shift/shed).
    - Simulation of grid distress (PSPS events) and BESS response to utility-generated event notices.

2. Investigate Granular Pricing Schemes

Apply pricing schemes (at as small as five-minute intervals) to investigate response timing and validate the flexibility to respond dynamically to various pricing scenarios.

3. Investigate the Impact of Power Factor Correction via BESS

This requires 50 – 100 customers on the same distribution circuit and demonstrates the ability to improve the power factor of the grid by mobilizing BESS aggregation.