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U.S. Department Of Energy

Electric Access System Enhancement (EASE)

DEPARTMENT OF ENERGY AWARD NUMBER: DE-EE0008004

Effectively connect and manage a high penetration of DERs by enhancing customer interconnection process to the grid, improving access to information from DER, and optimize the usage of DER so they can provide services to the grid and other customers.

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Project Overview

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The Enabling Extreme Real-Time Grid Integration of Solar Energy (ENERGISE) funding program develops distribution planning and operation solutions to enable dynamic, automated, and cost-effective management of distributed and variable generation sources, like solar, onto the grid.

Leading innovative utility with significant solar installed and progressive State energy policy.

Grant administrator for the EPIC program funds contributing to Customer Acquisition, DER integration and service platforms performed by Kitu.

TEAM MEMBERS:

- **SCE Team :** Juan Castaneda (Principal Investigator), Alexandria Vallejo (Project Manager), Andrew Ioan (Engineering Lead) and Peter Kim (Computer Scientist/Engineer)
- **Smarter Grid Solutions (SGS):** DERMS platform & real-time voltage & thermal (current) constraint management system
- **Opus One Solutions:** Market Services for simulation of DSO and ISO markets
- **Kitu Systems Inc**: Customer acquisition, DER aggregation & dispatch via IEEE 2030.5
- **Clean Power Research, Inc**: Developer of DER provisioning portal
- **NREL:** Solar PV forecasting expertise and large-scale testing experience
- **City of Santa Ana**: Municipal participant for portal development and integration

PROJECT OBJECTIVE

To effectively connect and manage a high penetration of DERs by enhancing customer interconnection process to the grid, improving access to information from DER, and optimize the usage of DER so they can provide services to the grid and other customers.

Southern California Edison's Goals for Carbon Neutrality

Present

15M
Customers serving
5M
Customer accounts

50,000
Square-mile service areas with Central, Coastal and Southern California

48%
Percentage of power delivered to customers originating from carbon-free sources in 2019

2045

+60% electrical demand
+40% peak load

Bulk System needs: 80 GW of wind/solar, 30 GW of storage

Distribution Level needs: 30 GW of customer-sited solar and 10 GW of storage

70%
Projected growth of electric space and water heating in homes and businesses

108 MMT

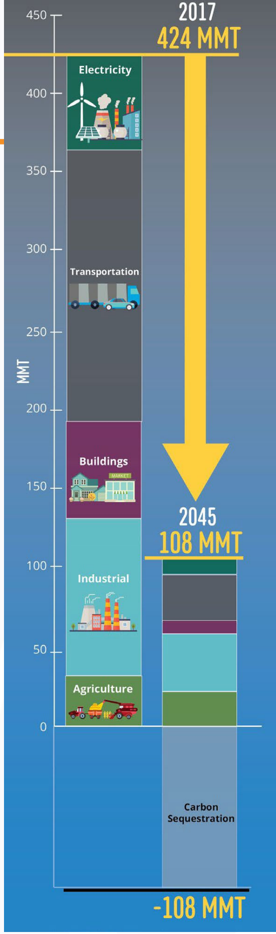
An Edison International (NYSE:EIX) company, Southern California Edison (SCE) is one of the nation's largest electric utilities

SCE is planning for an evolving power grid in the coming decades and is working to decarbonize its electric power supply.

Reimagining the Grid | Edison International
Pathway 2045 | Edison International

Compared to today, **2045 will see a 60% increase in electricity demand and 40% increase in peak load** that will have to be met by carbon-free generation sources.

Reimagining the Grid is a comprehensive assessment to address how the grid must change to support California's greenhouse gas reduction goals and the imperative for power to be carbon-free by 2045



Greenhouse gas emissions reductions to meet California targets (in million metric tons)

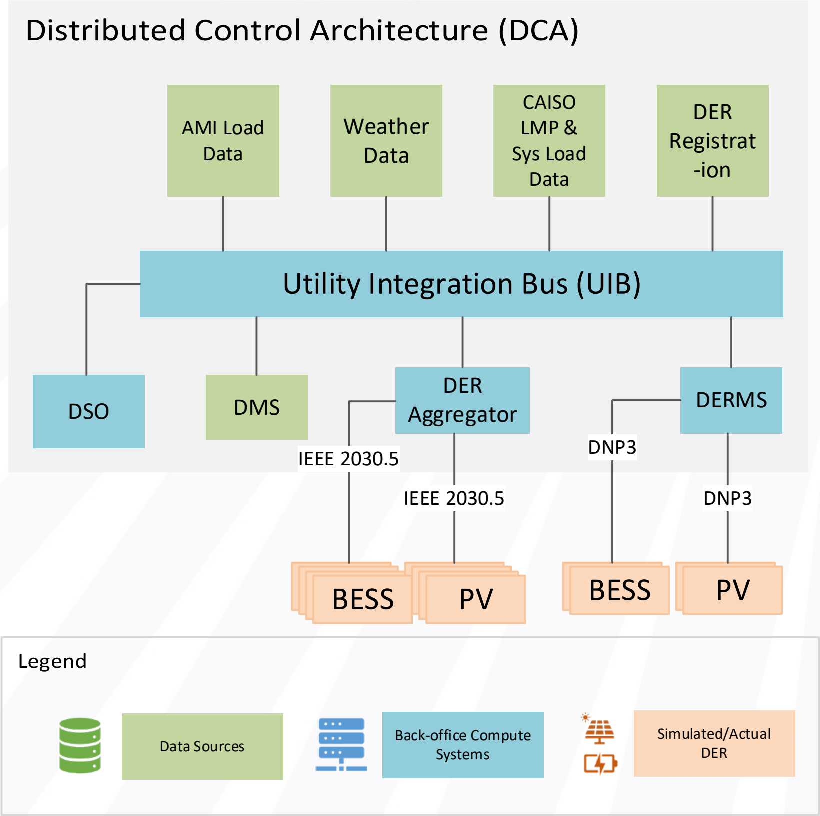
Architecture: Components

Distributed Energy Resource Management System (DERMS) Real-time Control Platform of DERs is provided by Smarter Grid Solutions. Manages DER Dispatches and performs constraint management to mitigate circuit constraints.

3rd Party Aggregator
Interface between customer owned DER and the utility provided by Kitu Systems.

Data Bus/Utility Integration Bus (UIB)
- CAISO Locational Marginal Pricing (LMP) data to inform DER dispatches for the day-ahead and 15-minute intra-day markets
- Weather data for PV generation forecasting
- Historical AMI Load data for load forecasting
- DMS circuit measurement & device data

Distribution System Operator (DSO)
Provided by Opus One Solutions, the DSO uses optimal power flow analyses to calculate DER dispatches informed by data to provide market services that benefit the utility, ISO, and customers. Dispatches sent to DERMS.



Network Model & Provisioned DER

Goal was to simulate a future-state of a local substation distribution grid that **needed to be managed by a DERMS/DSO system**. Project use-cases would then be re-tested in a field demonstration

Camden Substation

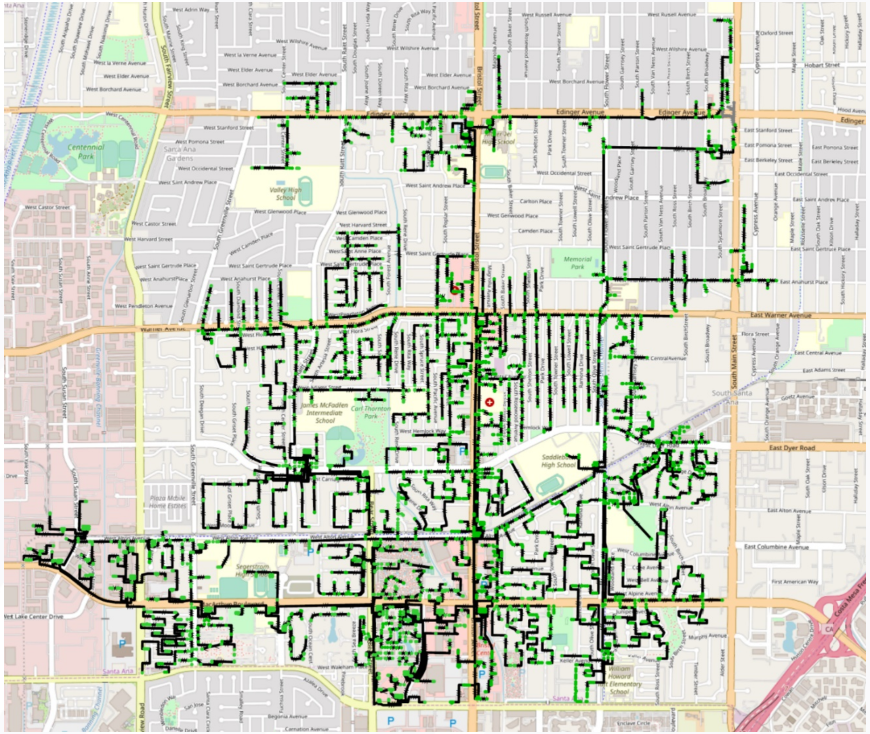
- x7 12kV circuits
- ~18,000 customers
- 10,000 DER represented in the model
- Average substation load of 20 to 40 MW. Varies by season
- ~1000 transformers with multiple customers per structure. Each transformer is an aggregated load

Total BESS rating of 39.9MW;

- 22.25MW capacity is from the behind-the-meter aggregated 2-hour energy storage
- Individual energy storages with total capacity of 17.65MW.
- 80 MWh of energy storage capacity total

Total PV capacity of 30.75 MW;

- 22.25MW capacity is from the behind-the-meter aggregated PVs
- 8.5MW of individually controlled PVs throughout the substation



Distribution System Operator (DSO) Use-cases

DER are providing services to the Utility, CAISO, and to other customers by participating in the wholesale electricity market via the Distribution System Operator (DSO).

Simulating DER Services during the Intra-Day Energy Services Market

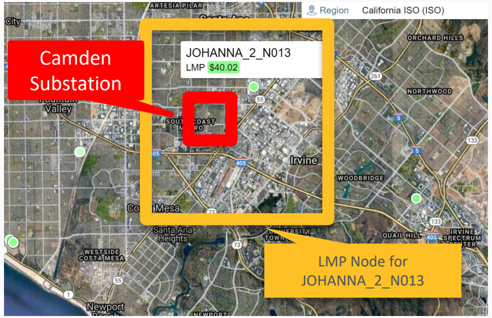
Objective: DSO is to minimize losses but use the LMP price for optimizing DER dispatches in the day-ahead and intra-day markets via a constrained unbalanced AC cost optimization.

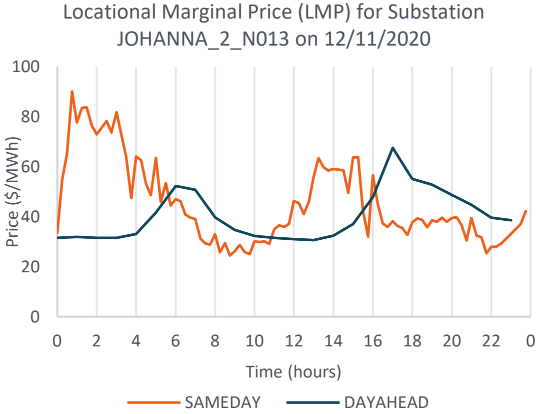
- **Benefit:** DER dispatches benefit the bulk system LMP node (Johanna_2_N013). Note Camden substation is one of several under the Johanna 220/66kV system.
- **Day-ahead analysis:** Performed by DSO System on 9/25/20
- **Test Day:** Real-time test was executed on September 26, 2020 using live market data and time-series load flow simulations (system load calculated every 15-seconds).

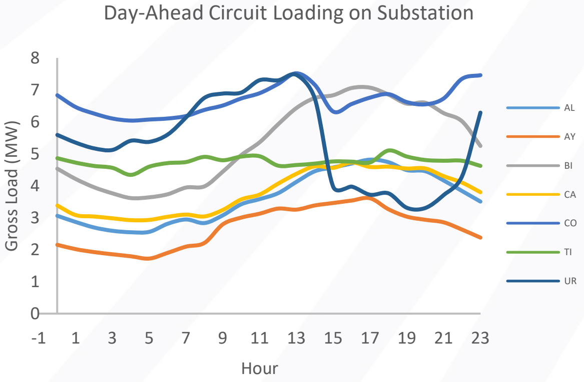
Load & PV Gen Forecasting: The given day-ahead loading, and day-ahead and intra-day forecasted PV generation profiles are shown below.

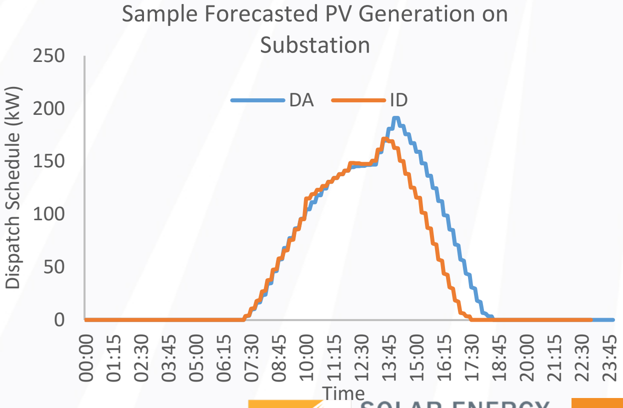
Forecasted LMP is used to perform a cost optimization to determine the optimal dispatch of DERs versus importing power from the grid.

Bids & Offers: All PV bid into the market at $-100 by default, and all BESS bid $0 by default as well so they're always selected to operate throughout the day by the DSO.









DER Dispatches at an Aggregate Level Simulated per Circuit

Circuit Impact: DSO was successful minimize losses while using the LMP+D price for to optimize DER dispatches for day-ahead and intra-day markets.

1. **Aggregate PV** generation allowed to operate at maximum throughout the day to reduce gross load and charge BESS.
2. **Aggregate BESS** were largely influenced by the relative LMP at the Bulk system level.
   a) Attempted to smoothen the ramp-up and ramp-down of PV generation
   b) Charged when LMP prices were relatively low
   c) Discharged when LMP prices were relatively high
3. **Feeder net load**
   1. Roughly equivalent to the gross loading in morning/evening.
   2. is lower overall during the day
4. **Gross Feeder Load:** customer load (not including DER load/generation)
   1. Roughly equivalent to the gross loading in morning/evening

Total Potential Payment to DERs = $39,711.91

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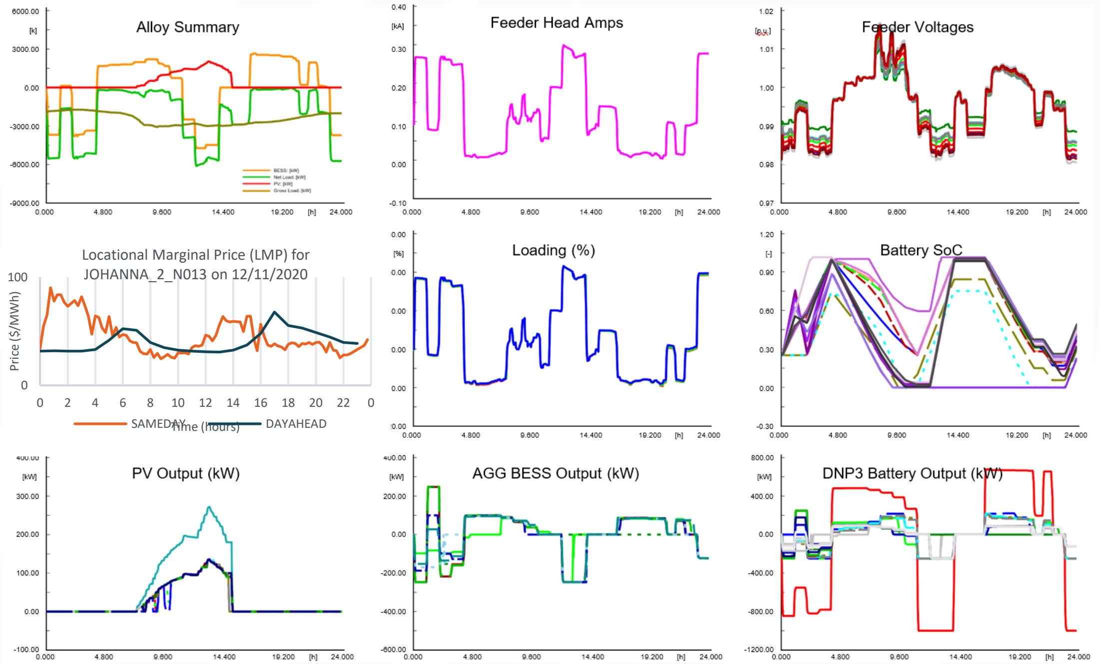
Validating Simulated Grid Impact per Feeder

VALIDATED LMP+D AND DLMP Optimal Power Flow
Each feeder on Camden was assessed to ensure GridOS' optimal power flow will dispatch considered DER nameplate ratings and feeder constraints to ensure no limits were breached.

- Feeder voltages were between the 1.06 and 0.94 p.u. limits from GridOS
- Feeder loading remained below 90% per phase
- Batteries were charged and discharged within 0% and 100% state of charge (SoC) limits.
- GridOS dispatched DER within their nameplate ratings.

LMP price node largely influenced battery energy storage system (BESS) dispatch.

- PV generation allowed to operate at maximum throughout the day to reduce gross load and charge BESS.
- BESS discharged when LMP was relatively high and charged when LMP was relatively low.
  - Global LMP peak at 18:00 is when the BESS discharge their most energy.
  - All BESS reach ~0% SoC around 22:00
- DSO ensures there's no reverse-flow for the feeder's net load.



Realtime Constraint Management & Net Load Management Use-cases

The utility can use DER via the DERMS to manage real-time voltage or thermal (current) constraint violations on the grid without requiring traditional utility equipment to manage voltage & load (i.e. capacitors, switches, voltage regulators, etc.).

Real-time Constraint Management

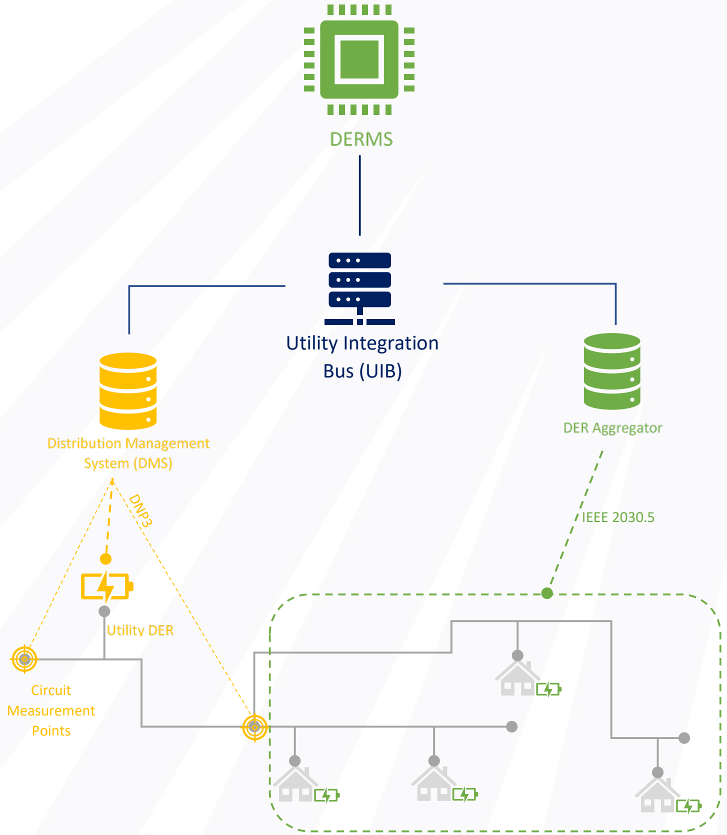
Utility systems can provide the DERMS with voltage and current measurements along the circuits to **mitigate unplanned high-loading or voltage rises or sags that weren't expected** in the DSO's day-ahead or intra-day DER unbalanced AC cost optimization.

Circuit measurement points are used by the DERMS to monitor network conditions for any thermal or voltage constraints that exceed the defined threshold for those measurement points.

The DERMS can select which DER can be used to alleviate a thermal constraint at the circuit measurement point. This system acts independently of the DSO and serves as a safety net utilizing the same pool of customer DERs.

Control Strategy

- Identify measurement points on the circuit
- Implement DER controls
- Set thresholds
- Perform a sensitivity analysis on the network given the provisioned DER to assess how much a DER could influence the voltage or current at its point of connection
- Control DER by overriding any existing PV generator and energy storage controls in order to alleviate the constraint

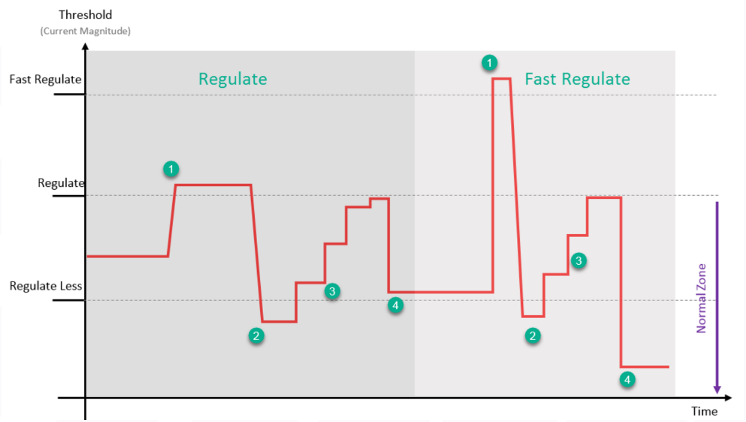


Feeder Constraint Management | Current Regulation

Fast Regulate: Setpoints are issued to the corresponding DERs for the measurement value to reach the Regulate Less Margin threshold. This threshold is set to a higher magnitude and shorter time duration than the Regulate threshold.

Regulate: Setpoints issued to associated DERs to reach the Regulate Less Margin threshold. This threshold is set to a lower magnitude and longer time duration than the Fast Regulate threshold.

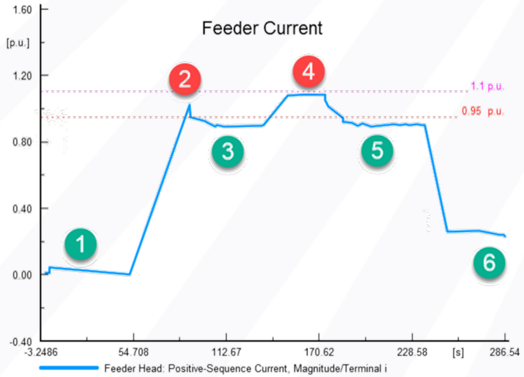
Regulate Less Margin: Target measurement level after a threshold has been breached.

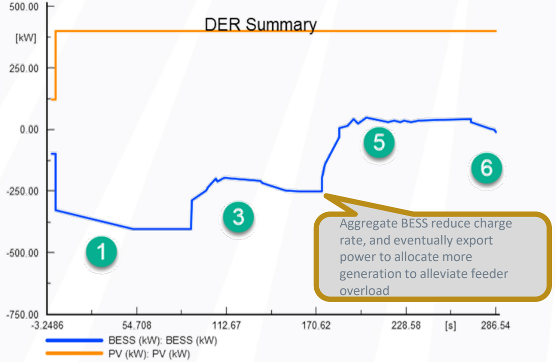


Lab Simulation Results – Current Overload scenario

DERMS uses all PV and BESS to alleviate a current overload at the feeder head.

1. DER Normal Operation. No constrains on feeder
2. Current exceeds 0.95 p.u. at feeder head
3. Less BESS charging to reduce feeder loading
4. Current exceeds 0.95 p.u. at feeder head
5. BESS discharging to reduce feeder loading





Feeder Constraint Management | Voltage Regulation

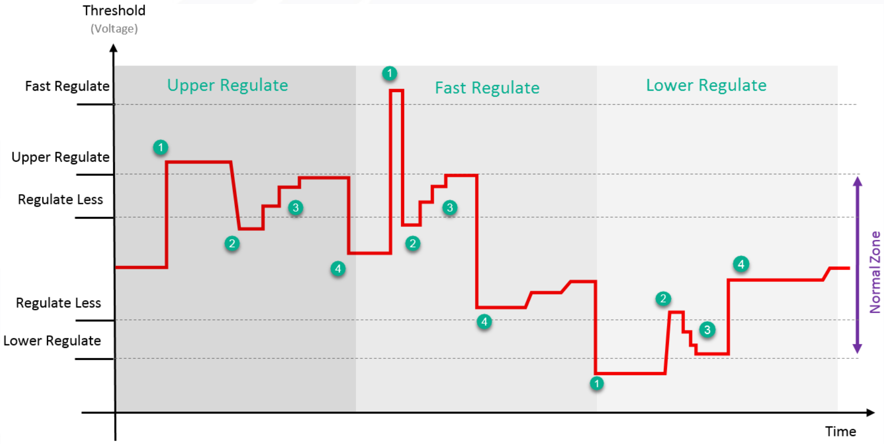
Fast Regulate: Set points issued to associated DERs to reduce the circuit voltage measurement value to below the Release Upper threshold. Setpoints issued immediately after limit is breached.

Upper Regulate: Set points issued to associated DERs to reduce the circuit voltage measurement value below the Release Upper threshold. Setpoints issued after a specified duration after limit is breached

Release Upper: Reference measurement level to fall below after a breach of the Upper Regulate threshold.

Release Lower: Reference measurement level to go above after a breach of the Lower Regulate threshold.

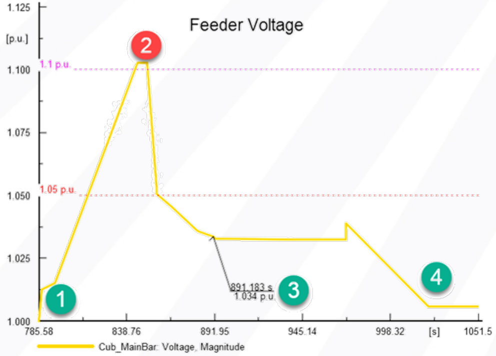
Lower Regulate: Set points issued to associated DERs to increase the circuit voltage measurement above the Release Lower threshold. Setpoints issued after a specified duration after limit is breached

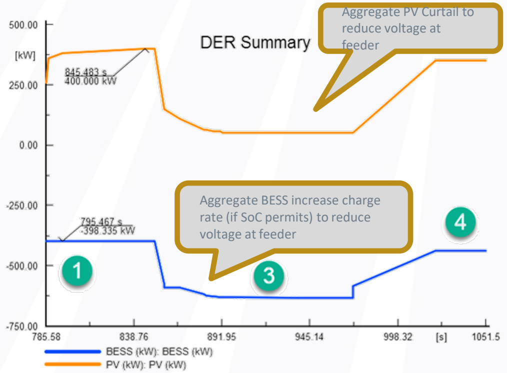


Lab Simulation Results – Current Overload scenario

DERMS uses all PV and BESS to alleviate a current overload at the feeder head.

1. DER Normal Operation
2. Regulate Over voltage > 1.10 p.u.
3. BESS charge and PV curtail to reduce feeder voltage
4. DER Normal Operation



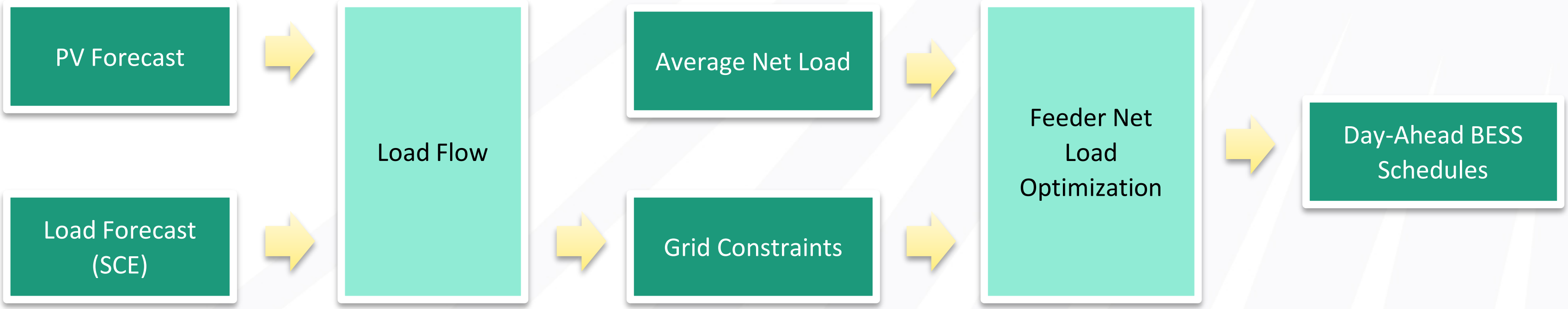


Feeder Net Load Management

Objective: Manage the feeder net load through scheduling BESS to enact a desired feeder load profile.

Day-ahead conditions are forecasted over 24 hours at 15-minute time steps, using PV generation and load forecasts.

- Inputs: Day-ahead PV & load forecast
- Output: Day-ahead BESS schedules that would level the load per feeder.



Feeder Net Load Management Data Flow

Methodology published in 2020 IEEE Conference on Technologies for Sustainability (SusTech),

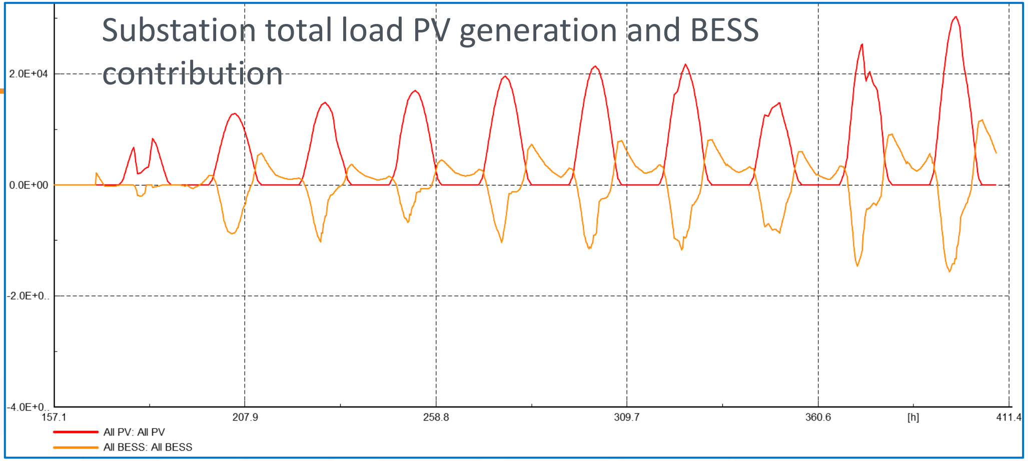
K. Morrissey, S. Kahrobaee and A. Ioan, "Optimal Energy Storage Schedules for Load Leveling and Ramp Rate Control in Distribution Systems," 2020 IEEE Conference on Technologies for Sustainability (SusTech), 2020, pp. 1-4, doi: 10.1109/SusTech47890.2020.9150516.

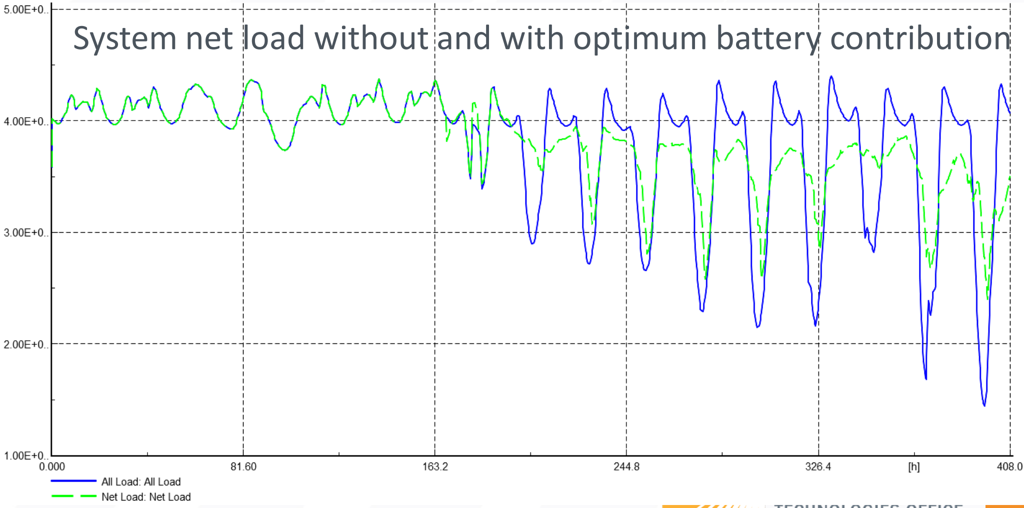
Feeder Net Load Management

DERMS function that does not require any pricing signals, and just leverages historical data in DMS.

Case-Study: 10-day Load Leveling Test

- Average substation load of 40 MW
- Total BESS rating of 39.9MW; where 22.25MW capacity is from the behind-the-meter aggregated 2-hour energy storage on 13 different locations on each circuit, and the remaining capacity is from individual energy storages with total capacity of 17.65MW.
- Total PV capacity of 30.75 MW; where 22.25MW capacity is from the behind-the-meter aggregated PVs on 13 different locations on each circuit, and the remaining capacity is 8.5MW of individually controlled PVs throughout the substation.





Next Steps

Project Next Steps

- Perform Cost-benefit Analyses using lab simulation platform with GridOS

- Field Demonstration with up to 100 customer-owned DER
  - Re-evaluate use-cases studied in the lab simulations using real customer DER
  - Demonstrated a scalable and interoperable means of integrating DERs in the field
  - Perform cost-benefit analysis for utility and consumers using optimal power flow studies
  - Validate DERMS thermal and voltage constraint management use-cases

Long-term at SCE

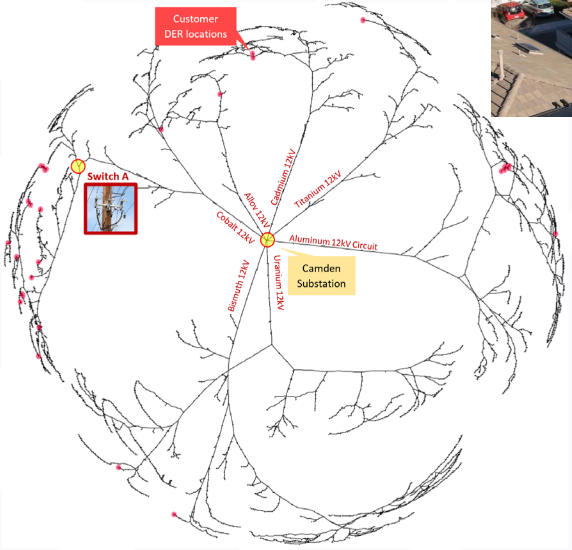
- Integrate Transactive Market findings into SCE's Grid Management System (GMS) for global optimization of DERs

Future areas to investigate

- <u>Validity of use-case assumptions and objectives</u> of dispatching DER to minimize overall costs for customers & utility

- <u>DER settlement payouts</u> to customers/DER Aggregators for delivering during their committed time windows

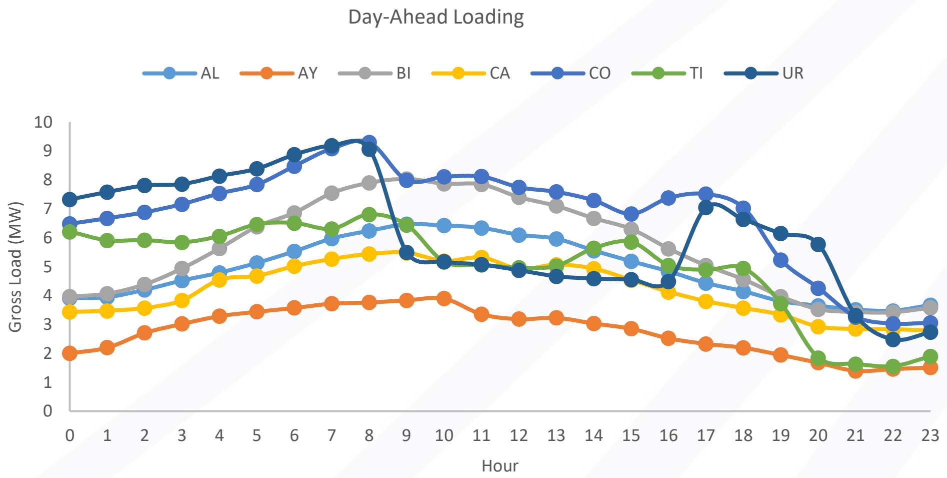
- <u>Locational Marginal Price zones</u>, and how they may change over time with the concept of Distribution Locational Marginal Price (DLMP) or Locational Marginal Price + Distribution factors (LMP+D)

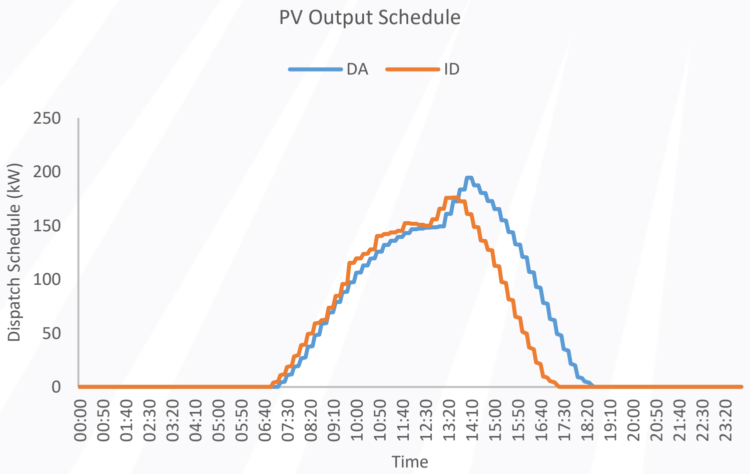


Customers DERs online today, and our Voltage & Current Constraint Management locations

Appendix Use Case 6

Use Case 6 | DER Services to the Investor-Owned Utility (IOU)





**PV profile is for AGG_1_AL_PV and is used as a sample to show the difference between the day-ahead forecasted PV profile and the PV profile observed during the intra-day. Note that all PV on Camden will have a similar profile waveshape but may vary in magnitude depending on the capacity of the PV system.*

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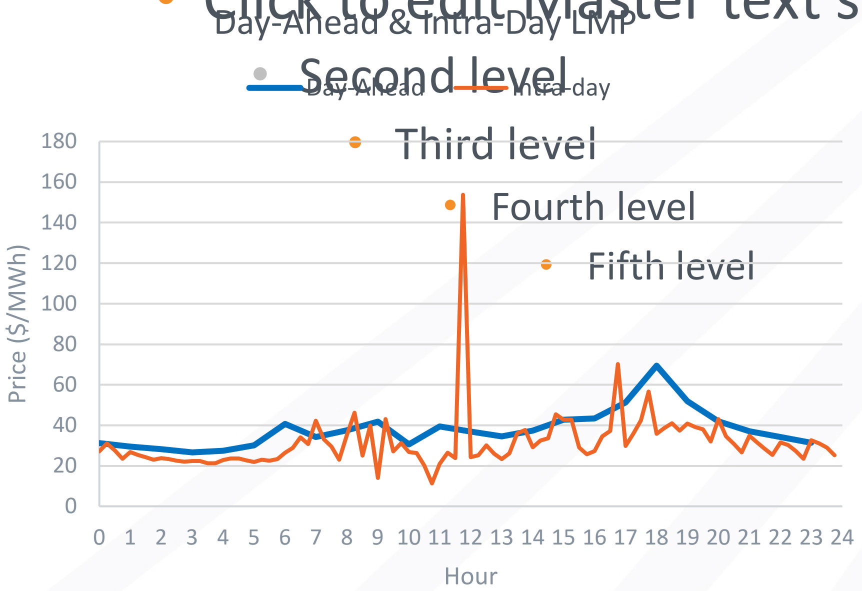
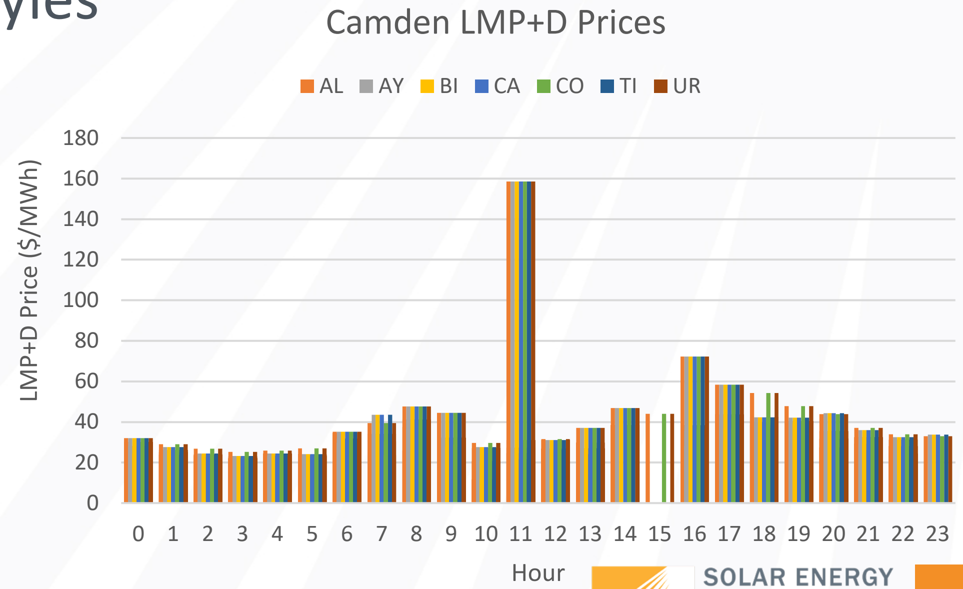
Use-Case 6 | UIB Data Source Inputs

- Click to edit Master text styles
  - Second level
    - Third level
      - Fourth level
        - Fifth level





Use Case 6 | Circuit Impact

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Use Case 6 | Loss Reduction Assessment

- Click to edit Master text styles
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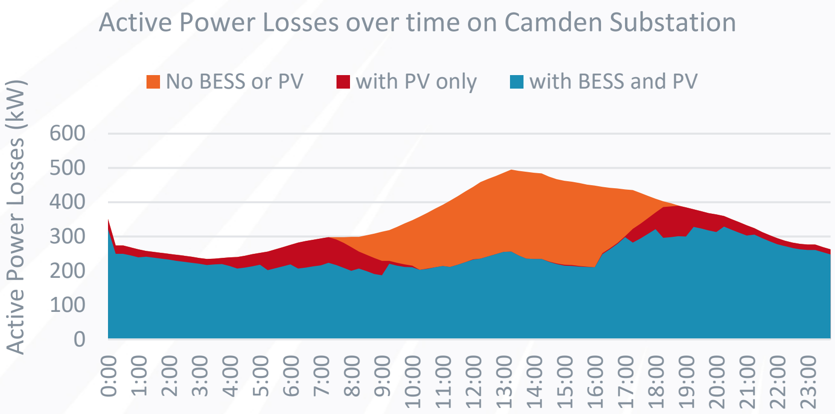
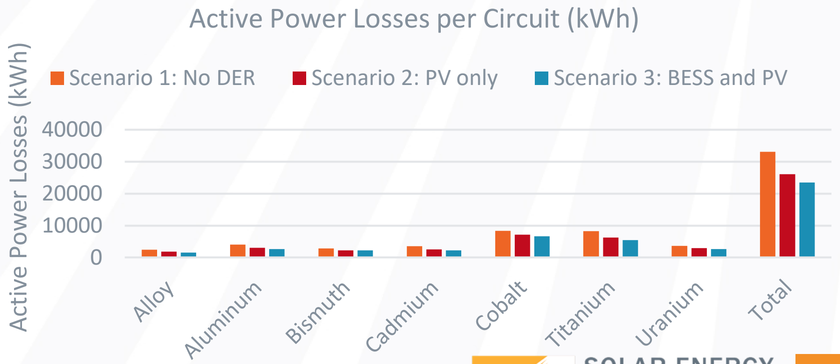
        - Fifth level





Use Case 6 | Battery Capacity Limit Validation

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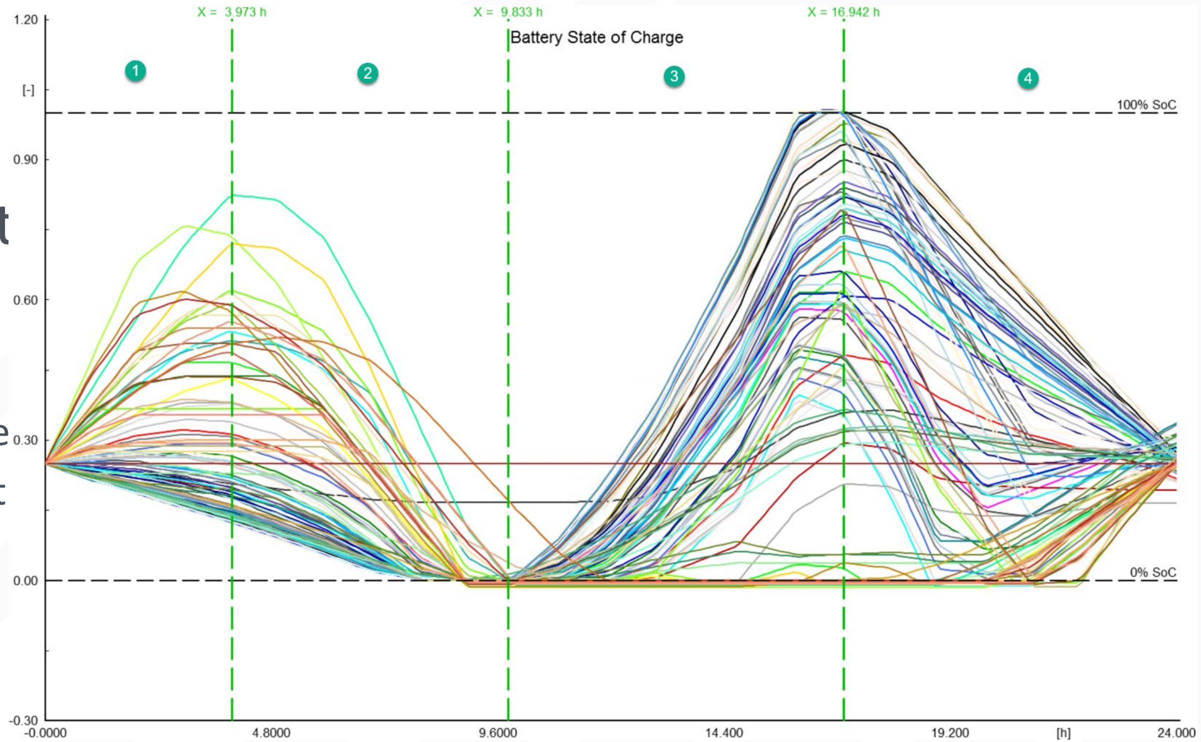
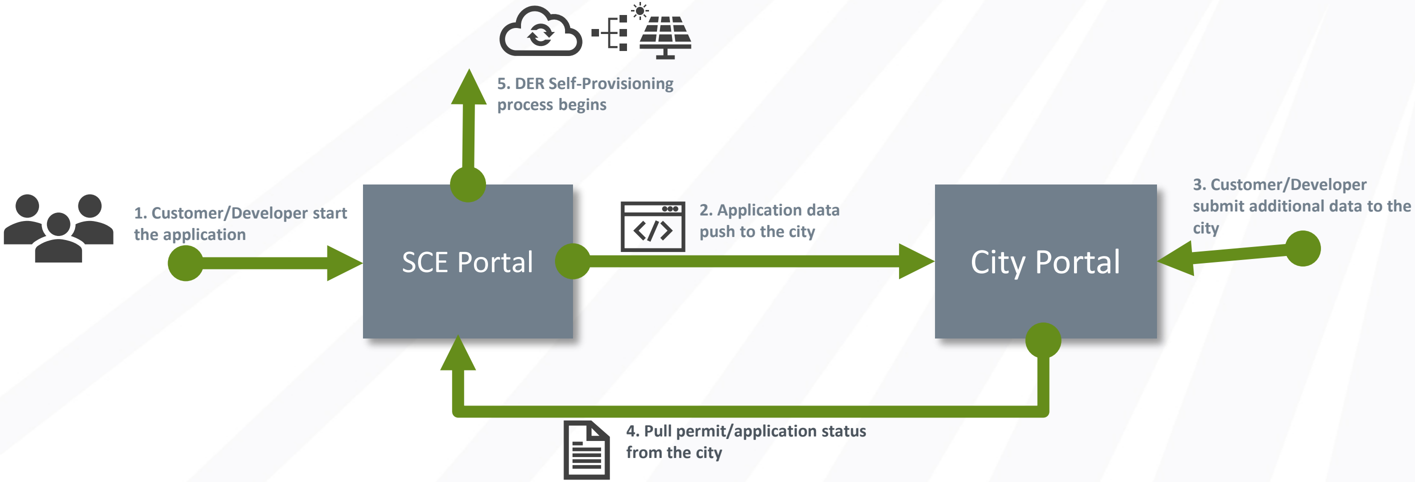


Appendix
Budget Period 1: DER Registration Portal
Use-cases 1 & 2

DER Registration Portal

Goal: Demonstrate permitting and interconnection approval process between Utility and City through implementation of a DER registration portal in the lab

Primary Scenario: Developer logs into the portal and enters site/DER information. Information is reviewed by utility and local jurisdiction. Appropriate building permit and utility interconnection agreement is issued.



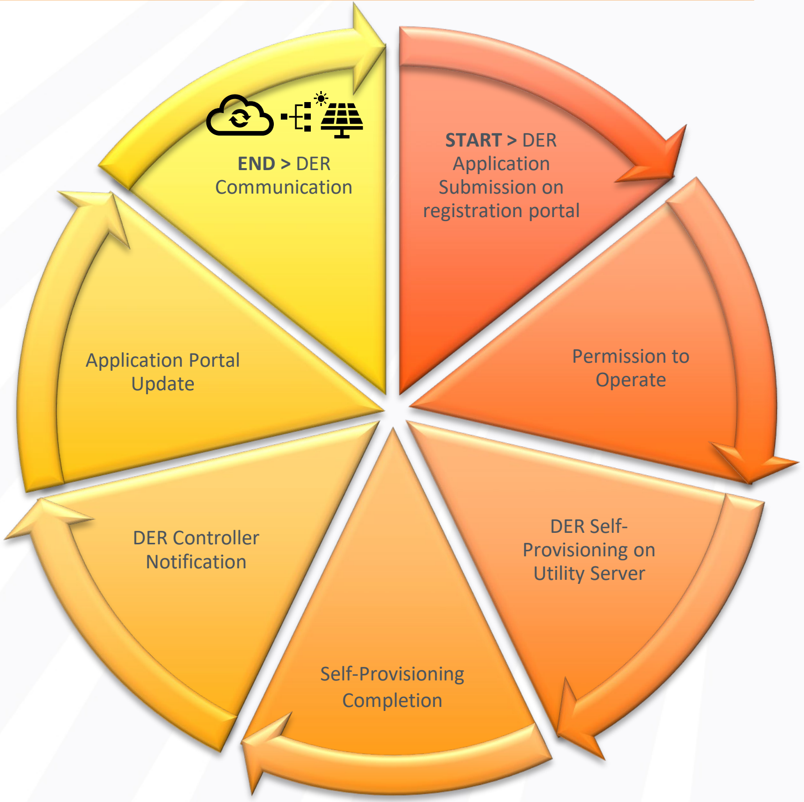
DER Self-Provisioning

Goal: Demonstrate registration of a new device into the lab DER control system and make DER available for control scheme interaction.

Primary Scenario: Utility approves the interconnection application. DER Provisioning data is pulled from registration portal by the Utility Integration Bus. A provisioning service configures the control system with new DER data. DCA establishes communication with DER.

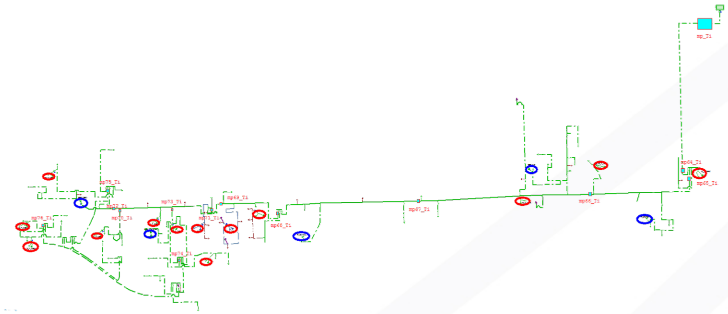
Provisioning Data

- DER type
- Equipment ratings
- Location information
- Control Device ID

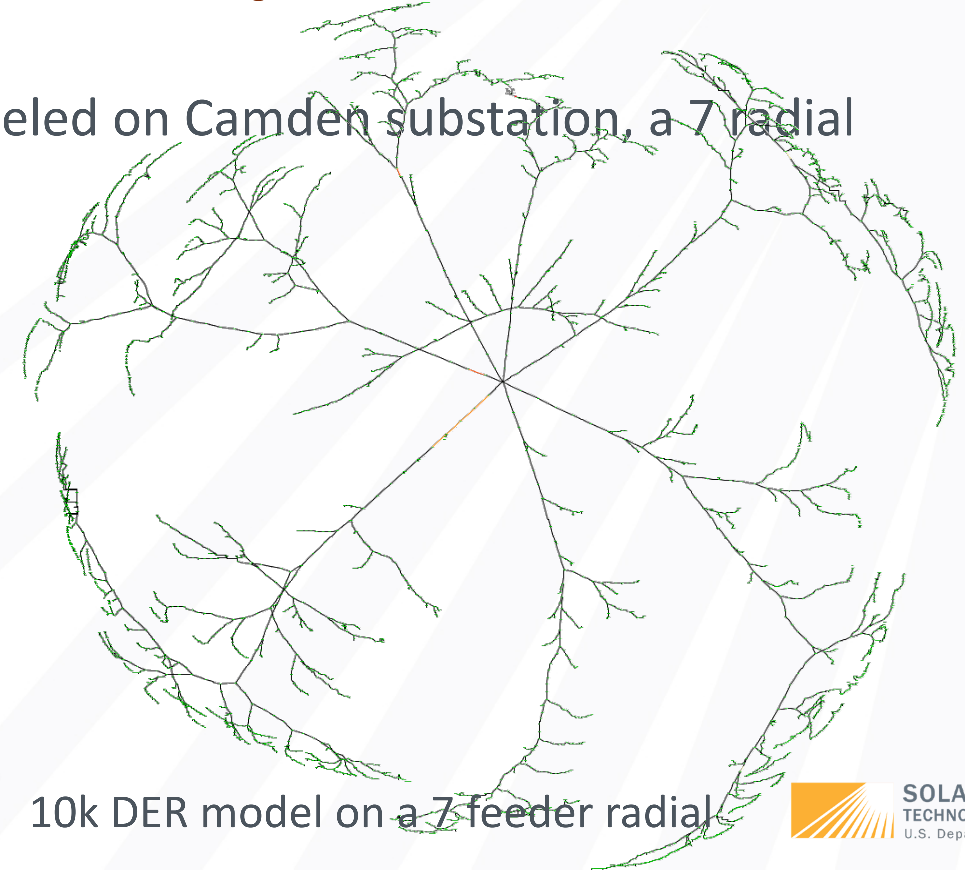


Scalability Testing Environment

- Advanced Distribution Controls for High-Penetration PV to Increase Hosting Capacity
- 10k DER model was modeled on Camden substation, a 7 radial configured circuit.



1k DER model



10k DER model on a 7 feeder radial