Integrated Modeling Tool for Regulators

Distribution Grid Locational Performance Modeling:
Developing a Foundational Integrated Modeling Tool for Regulators

Proof of Concept and Prototype

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Executive Summary

This report presents the results of the first phase of a multi-phased project to develop an Integrated Modeling Tool for Regulators (IMT) that supports decision-making for regulatory proceedings on integrated resource planning, grid modernization proceedings, rate cases and other state and federal dockets involving the integration of distributed energy resources (DER) into the power delivery system. This first phase of the project focused on defining the scope, performance goals, and technical requirements, and conducting a *proof of concept* by creating a demonstrative software *prototype* – the first technical component of the IMT.

The need for an IMT is motivated by a recognition of the impact of DER on distribution networks and their value as dispatchable and flexible resources to the grid. These DER are interconnected to distribution networks as individual resources, aggregated resources, and microgrids.

Modeling tools are available today to evaluate the economics of interconnected DER to inform regulatory decision-making on issues such as net-metering. Other modeling tools are available to evaluate the impacts on the distribution circuits to which DER are interconnected, such as local constraints and voltage support. However, there is no tool to demonstrate via power flow how economic incentives and tariffs can be used to leverage DER for local grid support, considering both planning and operations. Such a tool requires economic, DER build-out capability, and power flow analysis to assess locational performance on the distribution system.

The IMT recognizes the locational performance value of DER for providing grid supportive services and will help regulators and stakeholders (including developers, independent power producers, aggregators, microgrids, utilities and, most importantly, rate-payers) better understand the contribution of DER to reliability and resiliency.

The prototype has the ability to assess the impact of DER on distribution systems by demonstrating the effect of energy tariff variations on investments in behind-the-meter DER technologies and analyzing the impact of these DER deployments on the distribution grid. It does this by leveraging existing state-of-the-art tools for both behind-the-meter DER cost-optimization and distribution power flow analysis, along with new integration, automation, and visualization capabilities. The prototype can be used today to demonstrate the utility of the IMT. For instance, it can be configured to estimate whether DER penetration goals can be met under current tariffs and incentives, or estimate the percentage of new DER capacity additions in distribution systems that could serve as dispatchable resources, thus providing valuable information to support proceedings of integrated resource planning.

The integration of power flow calculations with economic analysis brings to tariff design evaluation capabilities that go beyond its current state by identifying the most challenging points of operation of the distribution grid, quantifying possible violations of network constraints, locating problematic nodes and lines, as well as detecting critical periods associated with each tariff scenario. By doing so, the IMT helps regulators better understand the locational performance of DER at the distribution level, individually, and in concert as part of the distribution system.

The proof of concept was demonstrated using a representative 119 bus feeder model, and energy load data for a set of representative residential and commercial building models in San Francisco, along with PG&E natural gas and electricity tariffs. Three distinct use cases were analyzed, demonstrating the impact of

1. tariffs on the aggregate system-wide deployment of behind-the-meter DER;
2. DER interconnection on distribution system voltage profiles; and
3. tariff modifications on DER investment and operations for specific consumer segments.

Each of these use cases was evaluated for three distinct DER investment options: (i) DER generation without storage, (ii) DER with storage, and (iii) DER generation with storage and combined heat and power units.

Analysis of the impact of DER on the distribution network shows that deployments motivated by increasing peak TOU rates can have a positive impact during periods of high network loads. This can be observed when peak TOU rates lead to increased levels of distributed generation and corresponding self-consumption. However, new challengers can also be introduced, particularly in periods of reduced loads and high power injection into the distribution network, where overvoltage events may occur. When high DER deployments are combined with storage, the risks to network operations were found to be mitigated for the tariff scenarios analyzed, and maximum voltages on the network were found to decrease.

This analysis illustrates the prototype capabilities that make it possible to quantify the impacts of DER on the distribution network for different tariff scenarios, which can be beneficial in in moderate DER penetration levels, or can create needs for additional distribution investments to operate safely in cases of very high DER deployment levels.

As illustrated by the prototype, the integration of power flow calculations with economic analysis in the IMT brings to the tariff design process the capability of identifying problematic locations on the distribution grid, quantifying possible violations of network constraints, as well as detecting the most critical hours for each tariff scenario.

The analysis made possible by the IMT can therefore provide an objective basis for decision-making on the grid impact of DER (individual and aggregated) and microgrids (with various configurations of generation, storage and loads). It provides a tool to support grid integration of DER that recognizes their potential as a dispatchable resource that can improve resiliency and contribute to the stability and reliability of the distribution system.

With respect to utility infrastructure investments motivated by new DER deployments, the IMT capabilities will provide an objective assessment of distribution network upgrades, and consider their contribution to grid resiliency and reliability. This analysis will be helpful for decision-making by regulators with respect to utility filings related to DER.

The value introduced by IMT in integrating DER economic analysis and build-out scenarios with grid analysis and planning can benefit several regulatory proceedings, including integrated resources planning, grid modernization, rate case and DER-related dockets. These contributions extend to multiple regions across the country, as illustrated in Annex I by a list of 23 regulatory proceedings in 16 jurisdictions, with brief descriptions and references.

This report includes a timeline and work plan for fully developing the IMT to deliver additional capabilities for enhancing the usefulness of the tool for regulators. These capabilities include multi-year planning consistent with the needs of different proceedings, adoption-rate modeling to adequately estimate DER build-out scenarios, extended power flow modeling capabilities to address the optimal power flow problem, locational valuation metrics that quantify the impact of DER in utility investment deferral, advanced load data analytics, and integration with wholesale markets.

1. Introduction

This report introduces a proof of concept and prototype for an Integrated Modeling Tool for Regulators (IMT) to support decision-making for the design of tariffs and other financial incentives that recognizes the locational value of distributed energy resources (DER) for grid supportive services and local constraints and imbalances. DER is modeled as interconnected to the grid either as an independent resource, aggregated as a generation resource, or as a microgrid.

The IMT is designed to assist regulators in understanding: (1) the technical and economic locational performance of DER as a supply resource on the distribution grid (e.g. a resource's increased or decreased performance in addressing proximate imbalances or constraints, or its role in the local utility's advanced distribution system network); (2) non-dispatchable and dispatchable DER capacity buildout dynamics (including projections for available supply-side and networked capacity); (3) distributional utility advanced DER-related infrastructure investments enabling them to optimally leverage DER (e.g. advanced control rooms, DERMS controls, networks of master microgrid controllers, advanced sensors, etc.) and deliver a smart grid.

1.1. Need for an Integrated Modeling Tool

Distributed Energy Resources (DER), defined as generation, storage, and/or demand-side assets located near or at the energy end user, are quickly proliferating throughout distribution networks, in many cases in the form of advanced applications such as microgrids, where multiple DER can operate in concert and under a common controlling entity. A key driver for this proliferation is the value proposition of DER and microgrids to meet customer needs for economic, high-quality, and resilient power, leveraged by endogenous and clean renewable energy resources.

The value proposition for DER and microgrids revolves around products and applications such as energy arbitrage and load reduction through self-generation, load shifting, or peak shaving, and direct revenue streams resulting from feed-in and net-metering agreements, and advanced microgrid applications that have the potential to provide products to wholesale power markets, as well as custom products and services to distributional utilities.

By leveraging on-site generation, storage, and bidirectional power flow, microgrids can be a valuable resource to the grid, while having the capability to operate independently of it. One of the defining characteristics of microgrids is the ability to operate either connected to the grid or in islanded mode. This offers value in terms of resiliency and reliability within the microgrid itself, while also enabling microgrids to provide unique services at the distribution level. Among these services is the capability to provide support to coordinated grid restoration following forced islanding events or for relieving local grid congestion. In addition, microgrids and DER aggregations have the potential to provide services at the wholesale level not only by participating in capacity and energy markets, but also by offering ancillary services such as frequency regulation, and spinning and non-spinning reserve.

In the context of distribution networks, the *location* of DER and microgrids within the grid at a specific point of interconnection plays a key role in shaping the products and services they can provide to support utilities, and determines their potential to form aggregations to deliver high performing products that enhance competition in wholesale markets.

While the potential for DER products and services to be made available has been identified, the extent to which these can be offered to the grid is still unclear, largely because the grid impacts of large scale DER penetration are largely unknown, and tools to assess the locational value of DER are inadequate. Regulatory authorities such as state public utility commissions (PUC) seeking to integrate and take advantage of advanced applications for DER need a better understanding of distribution grid locational performance factors, and how regulatory proceedings can be tailored to best capture benefits from DER and microgrids and improve service to populations. Specifically, structuring DER-related tariffs and utility procurement procedures requires an understanding of DER performance and costs when compared to traditional generation resources and distribution assets.

Regulators need comprehensive and objective tools that recognize and capture the locational performance of interconnected DER and microgrids. Current models typically rely on simplistic heuristics that disregard resource performance, coordination and optimization at the distribution level. Current constraint modeling is helpful for identifying problems in planning, but does not model differences in resource performance (technical or financial) among specific locations within the distribution system. The IMT is constructed to recognize these operational values to the grid as well as the economic value for customers.

1.2. Objectives

Through this work, we are taking the first step towards developing an IMT which can assist regulatory authorities in identifying and assessing the value of DER, advanced DER applications, and microgrids with respect to their location throughout distribution networks, and provide the capabilities required to adequately build and evaluate compensation mechanisms required to capture the economic and operational benefits of DER and microgrids.

Specifically, we have undertaken to identify the fundamental performance goals for an IMT to support regulatory decision-makers with respect to assessing the benefits of DER, aggregated DER, and microgrids, and objectively quantifying their locational performance value. Further, we have identified the technical requirements of an IMT to meet performance goals, and propose a multi-phased development plan to build this tool by progressively implementing new capabilities targeting specific regulatory needs, ultimately leading to an IMT with capabilities for evaluating a full range of deployment scenarios.

Finally, to illustrate the outcomes of developing the IMT, we have built a software prototype leveraging state-of-the-art DER and microgrid modeling capabilities, and carry out a representative demonstration.

2. Integrated Modeling Tool for Regulators

Developing an IMT – one that successfully addresses the underlying complexities of capturing locational DER performance factors and integrates them in regulatory proceedings – is a long-term effort that requires careful planning.

In this context, the first contribution of this work is to clearly identify the performance goals of the IMT and lay out the foundation for its development.

2.1. Performance Goals

The main reason for developing an IMT is to deliver a software tool for the integrated analysis and evaluation of the impact of advanced applications for DER and microgrids on the distribution system by regulators – state public utility commissions, as well as the Federal Energy Regulatory Commission (FERC), the North American Electric Reliability Corporation (NERC), Independent System Operators (ISO), Regional Transmission Organizations (RTO), grid operators, and other relevant stakeholders.

The IMT comprises a model and algorithms for analysis of the *locational performance of distribution level resources* across a range of grid impacts, products, and services, relevant both at the distribution and transmission levels. This analysis must be available across multiple grid scenarios (both in distribution and transmission), and accommodate various rates of DER penetration and risks associated with different sources of uncertainty.

At the *distribution level*, the IMT must be able to assist in various public utility commission proceedings, including rate cases, integrated resource planning, distribution system planning, resource requirements (renewable portfolio standards, alternative energy portfolio standards, energy efficiency portfolio standards, demand side management, environmental performance, etc.), and tariff proceedings. For all of these proceedings, the IMT must allow modeling either representative or real distribution networks.

Several regulatory proceedings that could be supported by an IMT were identified as part of Phase I research. Among these are Integrated Resources Plans in California, Virginia, and Oregon; Grid Modernization dockets such as *NextGrid* in Illinois, *PowerForward* in Ohio, and *Reforming the Energy Vision* in New York State; and Rate Case and DER Dockets such as the California *Microgrid Roadmap Proceeding* and the *Review of Residential TOU Trial & Demand Rate Pilot* in Colorado. A list of 23 regulatory proceedings in 16 jurisdictions, with brief descriptions and HTML links is available in Annex I.

Tariff proceedings, for instance, can be effectively assessed using representative networks with representative consumer data. These allow estimating how different rate structures (such as real-time pricing, critical peak pricing, or time of use rates) may impact the overall behavior of network users, and further assess how those behaviors may impact ratepayers and markets. In the long run, the IMT should permit starting from a reference tariff to effectively calculate how the adoption of DER may affect total system costs, and use that information to further refine the tariff. This can be achieved through convergence of a feedback process, updating tariff components to reflect DER system costs, and using the updated tariffs to re-assess DER adoption. With this capability, public utility commissions can analyze the effect of rate modifications on DER adoption and understand the overall contribution to achieving regulatory goals.

Conversely, proceedings on rate cases or distribution system planning may require modeling real distribution networks. In this case, either real network models or representative models resulting from advanced data processing (e.g., prototypical feeder models obtained from k-means clustering analysis) must be used to analyze how distribution level resources may impact the planning process and system-wide utility costs. Network models must provide enough diversity to be representative of the respective service territories, while allowing appropriate scalability. Thus, the results can be used to estimate the impact of DER on costs, losses, and quality of service when deciding on appropriate incentives for utilities in rate cases.

Distribution level products and services from advanced applications for DER, and microgrids incorporated in the IMT will include peak shaving, load curtailment, retail demand response, coordinated islanding and support to grid restoration, energy exports, and profile products – custom load and generation profiles assumable as dispatched by the distribution utility.

At the *transmission level*, the IMT can provide information that supports NERC in advancing towards more spatially-granular measures of reliability, or support FERC to advance in capacity mechanism regulation, following the trend of recognizing and rewarding performance.

In addition to estimating locational constraints and avoided (or incremental) costs resulting from DER penetration, the IMT will capture the physical and economic performance of resources in the context of the entire distribution system, and integrate those into sub-transmission and transmission areas, considering the participation of aggregated DER in wholesale markets, thus enabling the collective optimization of resources across different levels (merit-order across the entire system). Wholesale products and services provided directly or through aggregators to ISOs/RTOs will include energy (including wholesale demand response), capacity, and ancillary services such as frequency regulation, VAR support, operating and spinning reserves, or fast/black-start.

Furthermore, the IMT will provide a framework upon which to build toward using real-time operational data as more sensory equipment is deployed at the distribution level. This will enable supporting the analysis of "transactive" sub-areas of the distribution grid and impacts on the rest of the distribution grid, as well as ultimately supporting ISO/RTO grid operators / control area operators in dispatching day-ahead and real-time markets with merit-order consideration of distribution level locational resource performance factors in addition to transmission. This will provide more visibility of DER performance below the node across distribution level sub-nodes, and more accurate pricing in the transmission system (e.g. impact Locational Marginal Prices).

Finally, the IMT will help mitigate data security concerns with a secure area for utilities and regulators to provide granular distribution system data (e.g., feeder topology, load information) to map into the model, and offer regulators the opportunity to play a more active role in system planning, integrated resources planning, and rate proceedings, rather than being presented with a model by the utility.

2.2. Technical Requirements

As detailed further below, the key technical requirements of the IMT consist of:

a) Running physical power flows over entire distribution systems,
b) Allowing long-term analysis compatible with the needs of different regulatory proceedings,
c) Considering the economics of grid planning and operations,
d) Estimating DER and microgrid deployment throughout distribution networks based on behind-the-meter economic optimization, and
e) Integrating transmission and distribution power flow models to assess impacts of DER in the bulk electric system.

In the early stages, the overall model relies on a deterministic architecture, while in later stages it will include a probabilistic approach based on scenario analysis. These scenarios will enable capturing the uncertainty associated with different data, such as the deployment cost of DER technologies, weather resources, and load forecasts. In specific cases, such as the adoption rate for DER, other advanced techniques will be evaluated.

a) Running physical power flows over entire distribution networks

Running power flows over entire distribution networks makes it possible to identify and address constraints and imbalances under various grid conditions, scenarios for DER penetration, and the provision of different products and services including dispatchable and flexible DER.

Further, the ability to perform power flow simulations on distribution networks makes possible the quantification of key physical properties such as line loading in different grid elements, and understanding how voltage profiles may be impacted by power injection from DER installations as a consequence of modifying tariffs and other economic incentives. This process allows identifying specific locations or nodes within the grid where DER may either have a negative impact or, on the other hand, provide benefits such as improving voltage conditions near the end of the feeder through power injection.

b) Long-term analysis

Capturing the dynamics of investment and deployment trajectories for DER and microgrids over multiple planning and regulatory proceedings requires that the IMT is capable of analysis over long time periods – up to 25 years. This long-term time horizon requires analytical capabilities that can process large amounts of data and deal with multiple scenarios associated with data uncertainty, using advanced methods, with a very high number of computations, optimization processes and simulation processes, potentially requiring the use of high-performance computing.

c) Economics of grid planning and operations

Running power flows over distribution networks must be integrated with the economics of distribution system planning and operations as well as behind-the-meter DER. Hence, the IMT includes a specific module capable of quantifying the costs of distribution system planning and operation during the scope of the analysis, while considering the dynamics of DER adoption.

This allows determining the most economic options for distribution networks to maintain safe operation under different DER penetration scenarios, including new grid investments, line upgrades, DER installation and maintenance costs, demand response, or DER service provision at the distribution level. This analysis is supported by specific methods such as Optimal Power Flow (OPF) formulations with grid reconfiguration and reinforcements.

d) DER and microgrid economic optimization and adoption-rate modeling

The analysis of DER and microgrid deployment is supported by DER-CAM, a state-of-the-art behind-the-meter DER and microgrid modeling and optimization tool developed by LBNL. DER-CAM is used to find the most cost-effective DER investment solutions for different loads and locations throughout distribution networks, and to drive DER adoption and deployment models.

In the initial phases, DER deployment is supported by probabilistic methods to estimate adoption based on expected benefits. In future phases, other advanced modeling methods will be explored, in which DER adoption rates are estimated in time according to the success of previous adoption during the time horizon. In addition, the ability to forecast DER and microgrid deployment throughout distribution networks will be included. This dynamic modeling approach will enable analyzing different investment cycles common to the electricity sector.

e) Integration of distribution and transmission models

Capturing the overall impact of DER, as well as DER-provided products and services, requires integrating transmission flow models with distribution level flow models, while overlaying the economic components. This enables modeling the participation of DER aggregations and microgrids in wholesale markets at the transmission level. Distribution and transmission models are linked by DER resource optimization and the creation of supply curves among adjacent circuits and substations, used as an input data for transmission modeling. Further, the integration of distribution and transmission models will target the aggregation methods required to estimate DER and microgrid impacts at the transmission level, and estimate flexibility services delivered at the boundary nodes between transmission and distribution.

2.3. Development timeline

The Proof of Concept and Prototype described in this report are the first of eight technical components (TC) of a multi-phase project. Each phase is structured to deliver additional technical components for a fully developed IMT that addresses the full range of performance goals and satisfies the technical requirements to achieve them. Each phase includes developing specific case studies and demonstrations validated by user engagement and outreach to guarantee the successful completion of the project and development of the IMT (Figure 1).

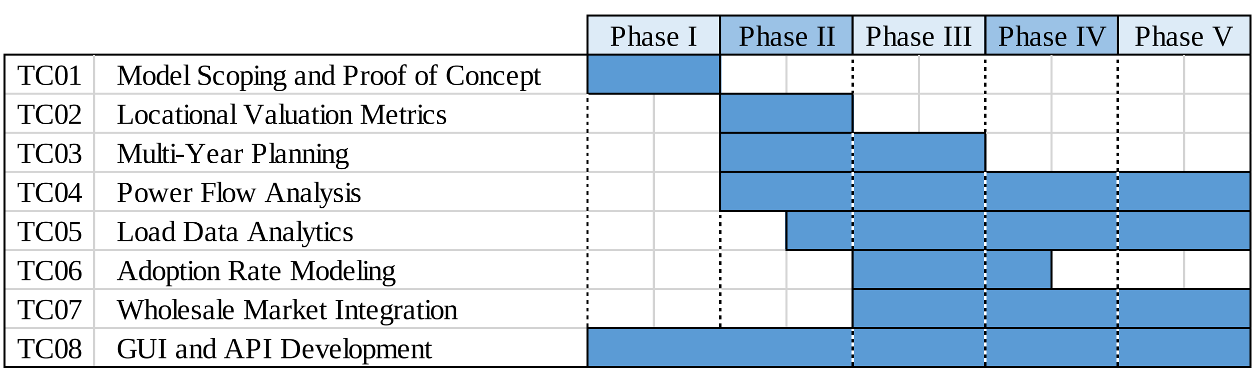

Figure 1. Development timeline

The eight Technical Components (TC) are described in the table below.

TC-01 – Model Scoping and Proof of Concept
Description: Define range of performance goals for the Integration Modeling Tool; Define technical requirements; Develop proof of concept and prototype.
TC-02 – Locational Valuation Metrics
Description: Define objective locational valuation metrics, accounting for different DER products and services at the distribution level, as well as participation in wholesale markets; Implement the valuation metrics in the overall system analysis.
TC-03 – Multi-Year Planning
Description: Develop core multi-year planning capabilities to accommodate relevant industry planning cycles, technology cost evolution, and regulatory proceedings; Address both deterministic and robust / stochastic modeling approaches; Develop core data analytics to process large model input datasets.
TC-04 – Power Flow Analysis
Description: Develop capabilities to import and convert data from open source and proprietary distribution power flow models; Incorporate utility operation and expansion costs in the tariff calculation process; Develop OPF model including utility assets and operation costs; Develop linearized power flow capabilities for streamlined analysis.
TC-05 – Load Data Analytics
Description: Develop different methodologies to process large customer load datasets (advanced metering infrastructure data) and develop accurate behind-the-meter DER investment and dispatch decisions; Develop data clustering capabilities for model reduction; Develop optimization based load aggregation algorithms for model reduction; Develop machine learning based algorithms to find optimal DER investment and dispatch decisions while bypassing explicit optimization analysis.
TC-06 – Adoption Rate Modeling
Description: Develop capabilities to forecast load growth scenarios, DER costs and performance values; Develop adoption rate models based on existing best practices (e.g. Bass adoption models); Explore and integrate advanced modeling capabilities such as system dynamics, feedback models, and agent-based models in the multi-year planning model.
TC-07 – Wholesale Market Integration
Description: Develop DER flexibility models to estimate locational potential for DER participation in wholesale markets; Develop aggregation models to aggregate DER flexibility to boundary nodes between transmission and distribution; Develop core functionalities to enable integration with Transmission models; Develop system-wide merit-order model.
TC-08 – GUI and API Development
Description: Develop Graphical User Interfaces and Application Programming Interfaces required to elegantly display complex data and model features and capabilities, as well as ensure interoperability between the different model components.

Presented below is a representative flow-chart of the fully developed IMT.

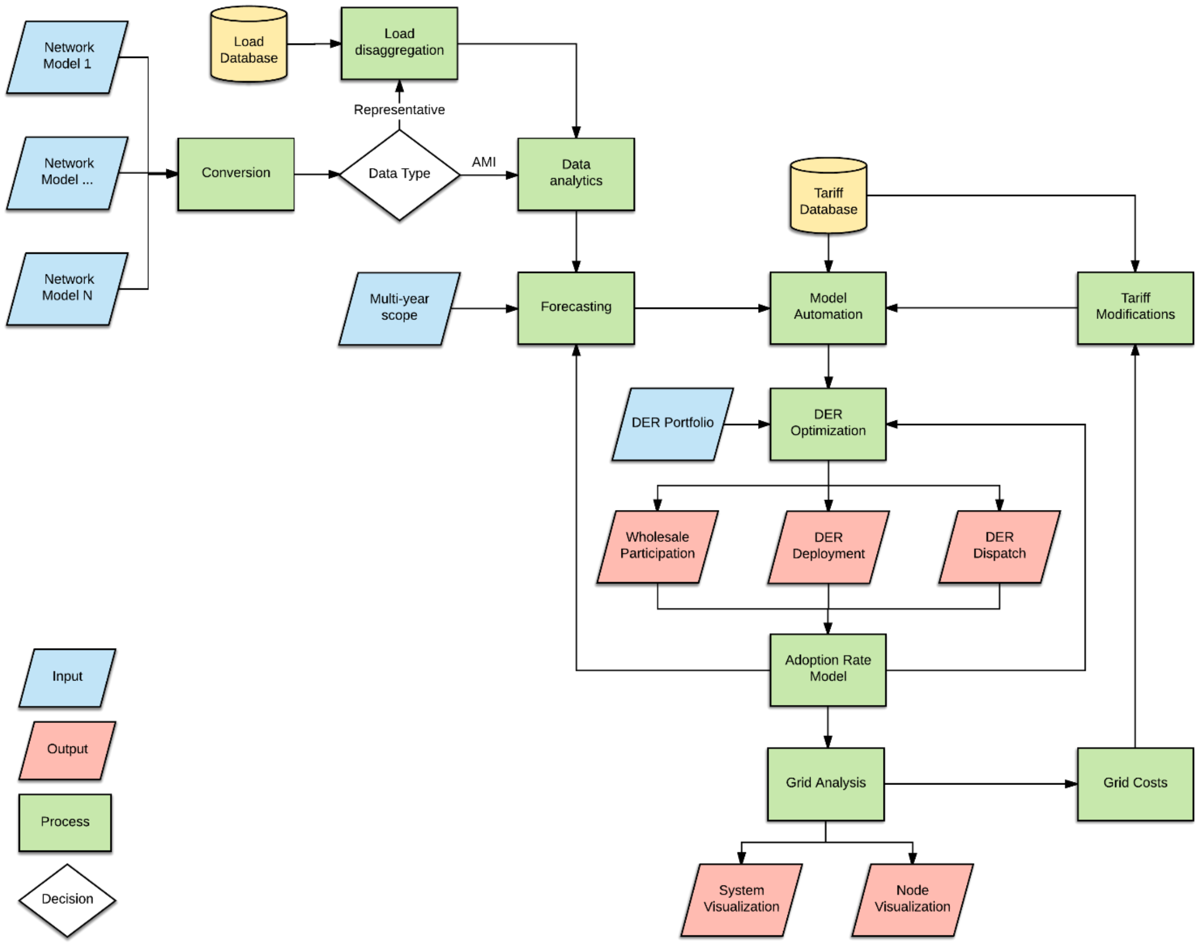

Figure 2. Representative IMT Flowchart

3. Proof of Concept

Through this project, we are building an IMT that can support the varying needs of regulatory authorities for objective, comprehensive, and long-term analysis for decision-making on behind-the-meter DER and microgrids that considers the optimal balance of network impacts, physical power flows, the economics of grid planning and operations, and the interactions at the boundary of distribution and transmission networks. These are described in sections 2.1 Performance Goals and 2.2 Technical Requirements.

As a proof of concept, we developed a software prototype that features core capabilities of the IMT to demonstrate the feasibility, practicality, and potential for analyzing multiple use cases for the integration of DER and microgrids on distribution networks.

3.1. Prototype Development

3.1.1. Overview

To highlight potential applications of the IMT, a software prototype was developed that integrates behind-the-meter DER investment models[1] with distribution system power flow analysis and visualization capabilities under a wide range of loads, tariff scenarios, and DER investment portfolio options, as illustrated in Figure 3. The behind-the-meter models implemented in the software prototype leverage the Distributed Energy Resources Customer Adoption Model (DER-CAM).

DER-CAM is a state-of-the-art tool used extensively to address the problem of optimally sizing and scheduling distributed energy resources (DER) under multiple microgrid settings. It plays an important role in developing the IMT as the optimization backend to estimate both investment and operational decisions of different customers interconnected throughout distribution systems, recognizing their load specificities and their sensitivity to varying tariff schemes.

To consider distribution power flow analysis, the prototype leverages pandapower[2], an open-source Python package built around the PYPOWER power flow and OPF solver.

To enable the integration of these two key components, specific API were developed to establish linkage between DER-CAM and pandapower, and enable power flow analysis of the distribution

[1] The Distributed Energy Resources Customer Adoption Model (DER-CAM) has been enhanced over by the Grid Integration Group at LBNL to make it adaptable for applications such as the IMT.
[2] http://pandapower.readthedocs.io/en/v1.3.1/_downloads/pandapower.pdf

network while at the same time considering the economic analysis of DER deployment and dispatch for various loads, tariff scenarios, and DER portfolio options.

When integrating DER-CAM and pandapower, the software prototype developed automation features to expedite data processing and enable sequential analysis for a variety of load types under varying tariff levels and different DER investment portfolio scenarios.

Finally, the prototype development included creating visualization capabilities to allow an intuitive understanding of results across the distribution network, for various tariffs and investment portfolio scenarios. This included the creation of a Graphical User Interface and specific results visualization capabilities.

The core modules of the software prototype are described in greater detail in the following sections.

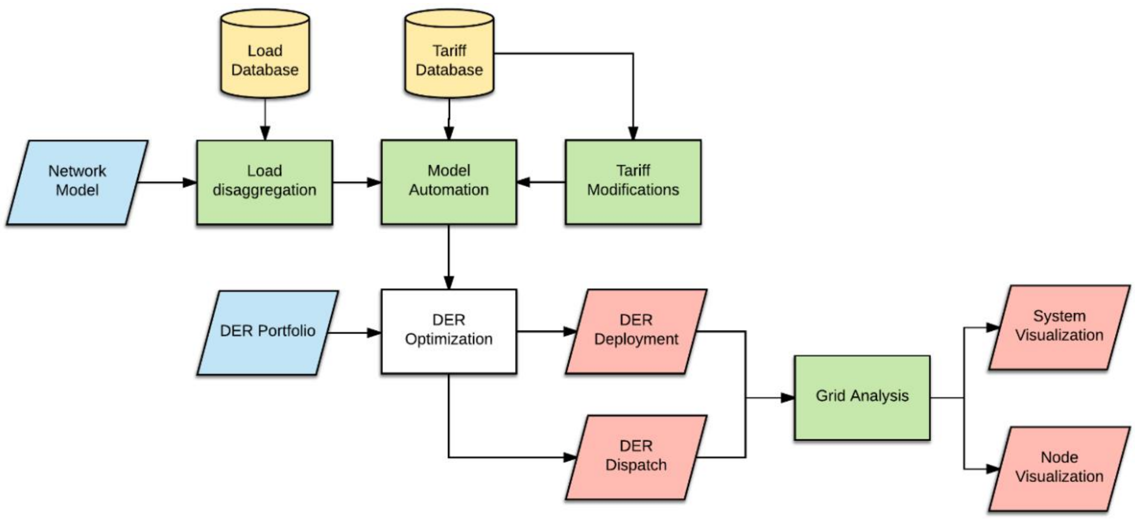

Figure 3. IMT prototype flowchart

3.1.2. DER-CAM

DER-CAM[3] is a state-of-the-art decision support tool developed at LBNL with funding by the DOE Office of Electricity Delivery and Energy Reliability. It is used extensively to address the problem of optimally investing and scheduling DER under multiple settings.

The model is formulated as a mixed integer linear program (MILP), and the key inputs in DER-CAM are customer loads, market tariffs including electric and natural gas prices, techno-economic data of distributed generation technologies (including capital costs, operation and maintenance

[3] https://building-microgrid.lbl.gov/projects/der-cam

costs, electric efficiency, heat-to-power ratio, sprint capacity, maximum operating hours, among others).

Key outputs of DER-CAM include site-wide energy costs, the optimal installed onsite capacity and dispatch of selected technologies, and load management measures. The purpose of the model is to find the optimal combination of technology adoption and operation to supply all energy services required by the site under consideration, while optimizing the energy flows to minimize costs and / or CO_2 emissions.

The targeted user-groups of DER-CAM include microgrid owners and site operators, industry stakeholders including equipment manufacturers, and policy makers. Key applications for microgrid owners and site operators include optimized investment recommendations based on site-specific loads, tariffs, and objectives. Applications for industry stakeholders include identifying cost and performance characteristics that will lead to adoption of their technologies in diverse segments of the market. For policy makers, key DER-CAM applications include determining high-level impacts on distributed energy resource penetration levels, and anticipating customer adoption behaviors given changes in electricity rates, demand-response programs, and different regulations.

DER-CAM supports standard tariff designs found throughout the U.S. with time of use (TOU) rates, demand rates, and real-time pricing (RTP). Additionally, other specific programs can be analyzed, including feed-in tariffs, direct load control, and export.

3.1.3. pandapower

pandapower is an open-source Python package that combines the data analysis library pandas and the power flow solver PYPOWER to create an easy-to-use network calculation program aimed at automation of power system analysis and optimization in distribution and sub-transmission networks.[4]

pandapower is an element-based network calculation tool that supports the following components:

- lines
- two-winding and three-winding transformers
- ideal bus-bus and bus-branch switches
- static generators

[4] pandapower is a joint development of the research group Energy Management and Power System Operation, University of Kassel and the Department for Distribution System Operation at the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), Kassel.

- ZIP loads
- shunts
- external grid connections
- synchronous generators
- DC lines
- unsymmetrical impedances
- ward equivalents

Regarding network analysis, pandapower supports the following functions:

- power flow
- optimal power flow
- state estimation
- short-circuit calculation according to IEC 60909
- topological graph searches

3.1.4. Model Integration and Automation

Integrating DER-CAM with pandapower required developing new API and other specific algorithms to enable an integrated analysis as described in Figure 3. Specifically, importing data from distribution level circuits required developing parsers to extract load and grid topology data. Estimating the distribution of customers in each transformer node based on the information available in the circuit model required developing algorithms to address load disaggregation at each feeder node, and generating and handling data from the corresponding DER-CAM models required developing algorithms to automate the generation of DER-CAM input parameters, send job requests to the DER-CAM middleware server, parse and re-aggregate results at each node, perform pandapower power flow simulations, and parse and visualize the power flow results, as described further below:

Circuit data parsing: The first step in integrating DER-CAM with pandapower and enabling an integrated analysis consists of parsing distribution system data. This includes capturing the attributes of different network elements, such as load data from distribution transformers, or the length, impedance, and thermal limit from each line segment.

Load disaggregation: Given the scarcity of data typically found in distribution network models, an important step in enabling an integrated system analysis consists of creating disaggregated load profiles, particularly in cases where only representative data is available. We developed this capability starting both from "snapshot" data and time-series data, for a given set of user-defined assumptions (e.g. system peak timestamp, load classes, and customer distribution). Further, we implemented and tested several algorithms for disaggregation and optimized the process. This is illustrated in Figure 4, where the results obtained for different algorithms is presented (includes quadratic and mixed integer quadratic programming, with different rounding heuristics)

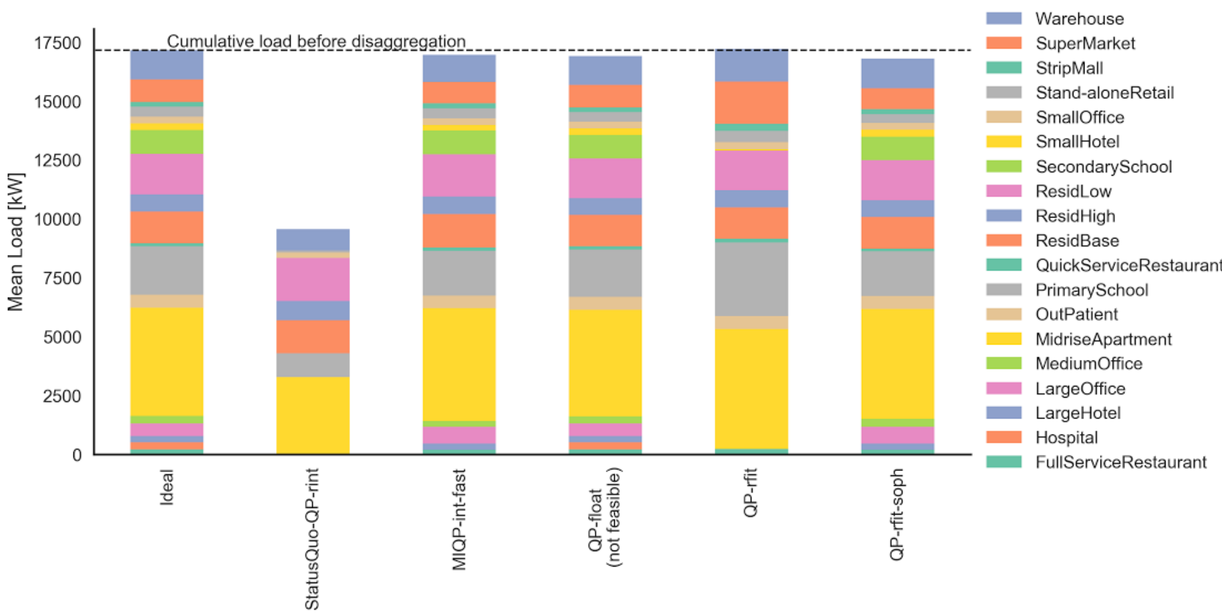

Figure 4. Results of disaggregation for aggregated PG&E load data using different algorithms

Generate DER-CAM input: The next step in the integrated analysis consists of generating the input parameters required to create and execute a DER-CAM model based on the disaggregation results. This was achieved by developing API endpoints that enable streamlining the use of information from the different DER-CAM databases (e.g. building load and weather data) and by developing a Python web-client for the DER-CAM server, both of which were integrated in the software prototype.

Parsing and aggregation of DER-CAM results: Following the process of creating DER-CAM jobs and sending requests to the server, a new step of data parsing is required. A single DER-CAM model typically consists of several hundred thousand to a few million equations and variables, naturally leading to a very lengthy set of results. To limit the set of results to those relevant for the integrated analysis, we developed a parser that allows extracting and aggregating all meaningful DER-CAM results back to the node level.

Power flow analysis: Following the DER-CAM results aggregation, the distribution system power flow analysis can be performed. For this purpose, we integrated the pandapower package in our prototype and built the functionality to run a steady state power flow analysis for all 864 time-steps used in the DER-CAM data format.

Parsing and visualization of power flow results: The final step to enable the system analysis consists of parsing and visualizing the power flow results, so that the impact of DER deployment and operation in the distribution system can be quantified and visualized. For this purpose, we built the algorithms to generate the structured parsing and collection of results, which are then loaded in the Graphical User Interface.

Model automation: Performing a comprehensive analysis around the impact of DER on distribution networks, and understanding how it may be influenced by different tariff levels, requires building and executing a very large number of models, both behind-the-meter and at the distribution system level. Different optimizations and simulations must be carried out for each modification made to each tariff of interest. To achieve this, we developed the API that enables executing an arbitrary number of DER-CAM runs and automate the respective power flow calculations.

3.1.5. Visualization

Capturing the locational value of DER and designing optimal rates that consider locational grid aspects requires both a spatial formulation of the problem and a spatial representation of results. The development of such capabilities is therefore a fundamental component of the prototype tool. Among other goals, visualization capabilities should enable users to understand the impact of varying tariff sets onto line-specific load-flows and local voltage levels.

Graphical user interface: To meet the goal of spatially visualizing results, we developed a graphical user interface (GUI) featuring the core of visualization capabilities required for the integrated analysis. This GUI allows visualizing the topology of the distribution system, and display the key power flow results for any time-step, and for any of the tariff modifications analyzed, as illustrated in Figure 5.

Results visualization: Further to the topology level visualization of power flow results, we developed additional visualization capabilities that provide an overall system perspective on results. Namely, this includes the generation of plots containing key results for each tariff modification, such as the aggregate capacity of DER deployment, overall DER generation levels, or specific grid impacts such as minimum and maximum voltage levels (Figure 6).

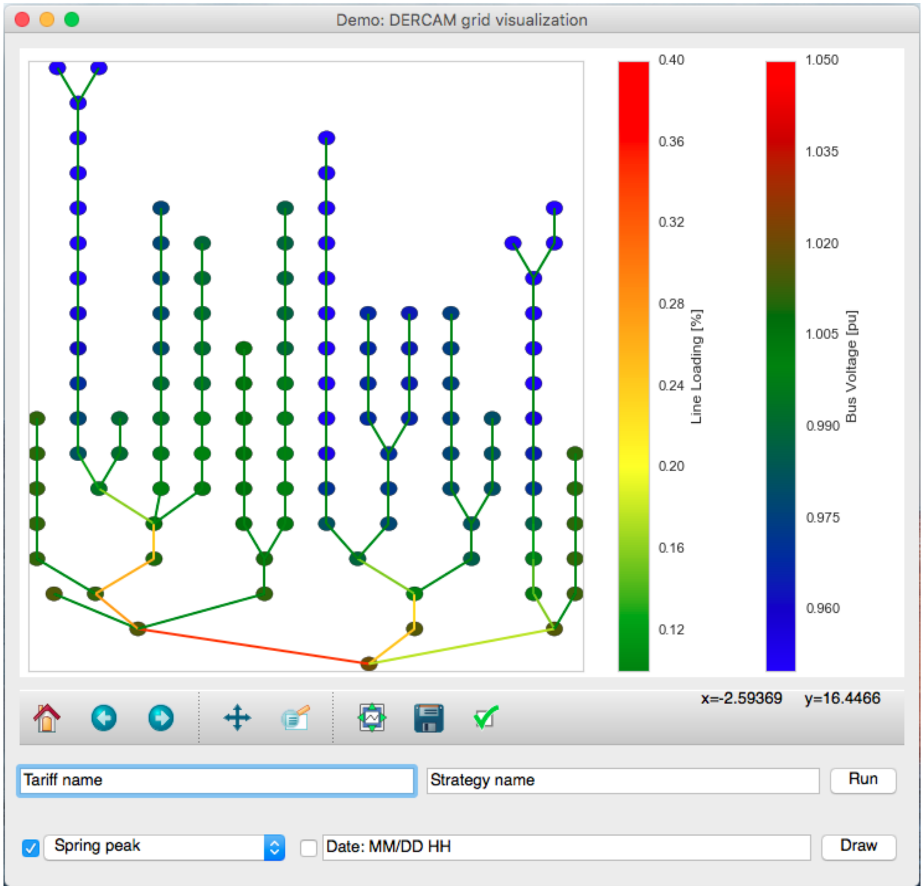

Figure 5 - Prototype GUI

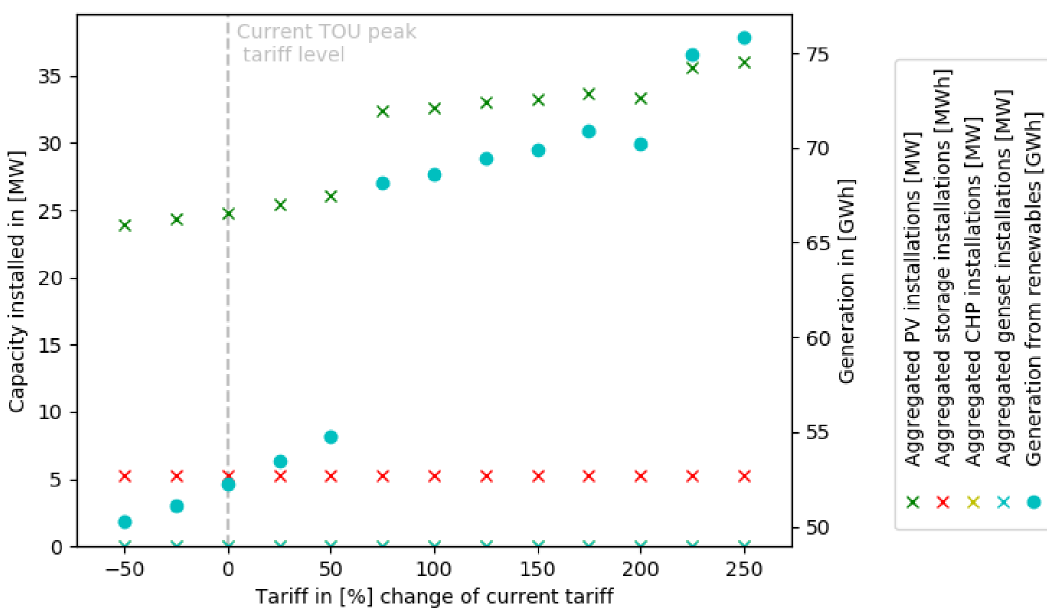

Figure 6 - Sample diagram for visualization of PV and storage installations depending on the tariff level

3.2. Demonstration

Further to developing a software prototype for the IMT, LBNL carried out a demonstration to illustrate potential applications of this tool. This demonstration comprised three use cases under three different DER investment portfolio options, as described in the following sections.

3.2.1. Use Cases

Three different use cases were explored to illustrate the core capabilities of the software prototype and provide preliminary insight on some of the questions to be addressed by the IMT:

Use Case 1 – Impact of tariffs on the aggregate system-level deployment of DER

This use case was designed to demonstrate the aggregate deployment of behind-the-meter DER in response to modifications in retail electricity tariffs. Specifically, the peak component of time-of-use tariffs was modified from a range of -50% to +250% to observe the effect on the cost-optimal aggregate deployment of DER in the distribution system as a whole, considering several DER investment portfolio options. This use case provides insights into how large-scale mandates and goals for renewable generation or DER capacity deployment may be affected by changes in tariffs.

Use Case 2 – Impact of DER on distribution system voltage

Use Case 2 was designed to analyze the impact of DER over the range of voltage levels occurring in the distribution system. For this purpose, power flow results were analyzed in each time-step, for each node, tariff modification, and DER investment portfolio option, and minimum and maximum voltage levels in the network were identified. Through this process, instances were found where PV injection levels driven by increasing tariffs may alleviate under voltage problems in specific sections of the network while creating over voltage problems in sections elsewhere.

Use Case 3 - DER investments and operation in reaction to tariff modifications

Use Case 3 was designed to see how optimal DER investment and dispatch decisions with respect to specific sets of buildings could be influenced by tariff modifications. To achieve this, the hourly dispatch of DER assets was analyzed for the different customer segments, for each tariff modification, and for each DER investment portfolio option. This use case gave an understanding the tradeoff between different DER investments within the context of specific consumer segments, and the corresponding impact on loads and power exports in response to tariff modifications.

The following DER portfolio investment options are considered in each of the three use cases:

PV Only: Since PV is the most predominant DER currently deployed in distribution networks, the first DER investment option focuses on PV installations, both at the residential and commercial level. In this case, different tariff options were analyzed, including Net Metering and different maximum power export levels.

PV and Storage: Following the analysis on PV-only installations, a second DER investment focused on the coupling of PV and storage solutions. The inclusion of storage introduces flexibility in the ability to participate in demand response programs (such as time-of-use rates and demand charges by shifting customer loads), address generation intermittency, and enables dispatching PV generation.

PV, Storage, and CHP. While PV and storage solutions may prove cost-effective in both the residential and commercial building sectors, it is more likely that conventional generators and CHP systems may play a significant role only for larger commercial and industrial loads, particularly in the presence of significant heating loads where CHP systems may become very cost-effective. To accommodate these scenarios, a third DER investment portfolio was considered where different conventional generators and CHP units were contemplated. Specifically, this included reciprocating engines, micro-turbines, combustion turbines, fuel cells, and different types of CHP units.

The tariff analysis carried out in the prototype demonstration relied on the model automation process described earlier in this document to explore each use case under each of the DER investment portfolio options.

3.2.2. Data sets

Conducting the demonstration requires using several data sets. This includes distribution network data, building energy loads, load disaggregation data, DER data, and tariff information, as described below.

Distribution Network Model: The feeder model used in the demonstration consists of a standard 119-bus radial distribution circuit. It consists of a 11kV distribution system with total power loads of 22.7 MW and 17.0 Mvar[(5)], illustrated in Figure 7.

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[5] The feeder is described in detail by Zhang et al. 2007, see http://dx.doi.org/10.1016/j.epsr.2006.06.005 .

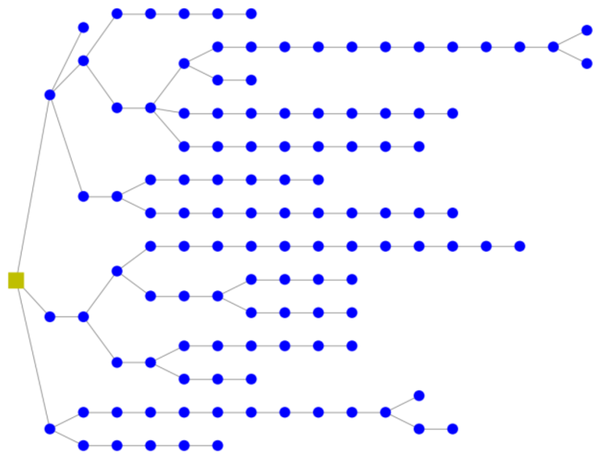


Figure 7 – 119-bus test network model

Customer loads: The datasets used to represent different customer segments consist of hourly loads for both commercial and residential buildings. Data for residential buildings is based on the U.S. DOE Residential Energy Consumption Survey (RECS), which contains hourly loads for all TMY3 locations in the United States, disaggregated into electricity, heating, and cooling loads for three different reference residential building categories – "base," "high," and "low" – to cover different residential building sizes and consumption profiles. Data for commercial buildings was collected from the U.S. DOE commercial reference building types, also consisting of hourly loads for all TMY3 locations throughout the country. In this demonstration, we selected data from the San Francisco Airport TMY3 location.

Combined, the residential and commercial DOE datasets include 19 different building categories or customer segments. Key information regarding these categories is summarized in Table 1.

Table 1 – Summary of building category data

	Building Type	Floor Area (ft^2)	Floors	Maximum electricity demand [kW]	Total electricity consumption [MWh]	Total gas consumption [MWh]
Commercial & Industrial	Large office	498,588	12	1,504	5,734	540
	Medium office	53,628	3	208	646	8
	Small office	5,500	1	16	59	5
	Warehouse	52,045	1	70	226	92
	Stand-alone retail	24,962	1	70	259	92
	Strip mall	22,500	1	68	257	95
	Primary school	73,960	1	281	801	244

	Secondary school	210,887	2	1,005	2,565	885
	Supermarket	45,000	1	309	1,581	554
	Quick–service restaurant	2,500	1	31	180	176
	Full-service restaurant	5,500	1	52	290	329
	Hospital	241,351	5	1,423	8,452	3,937
	Outpatient health care	40,946	3	267	1,182	789
	Small hotel	43,200	4	109	541	178
	Large hotel	122,120	6	425	2,302	1,999
Residential	Mid-rise apartments	33,740	4	52	215	82
	BASE	2,090	3	1.9	7.0	14.2
	LOW	1,045	2	0.9	3.7	0.8
	HIGH	3,135	4	2.6	9.7	19.2

Load disaggregation: Performing transformer load disaggregation was based on data collected from the U.S. Census Bureau American Housing Survey, and from the U.S. EIA Commercial Buildings Energy Consumption Survey (CEBECS). This data is summarized in Table 2.

Table 2 – Customer distribution per sector and building type.

Sector	Share of total demand [%]	Building type	Share of sector demand [%]
Commercial	50.9	Primary school	12.2
		Secondary school	2.0
		Hospital	0.2
		Outpatient care	2.7
		Large office	0.5
		Medium office	2.4
		Small office	24.0
		Warehouse	26.0
		Supermarket	3.6
		Quick-service restaurant	4.4
		Full-service restaurant	4.4
		Stand-alone retail	9.2
		Strip mall	4.5
		Large hotel	0.7
		Small hotel	3.2

Residential	49.1	Midrise	3
		High	10
		Base	25
		Low	62

DER Data: The DER data used in this demonstration includes information on key parameters such as capital costs, O&M costs, expected lifetime, rated output, operational limits, and conversion efficiency, among others. All techno-economic DER data used in this demonstration is available in the standard DER-CAM template[6].

Tariff Data: The demonstration relies on the use of PG&E electricity and natural gas tariffs. Table 3 illustrates the relevant PG&E tariffs applicable to each of the 19 building categories presented in Table 1.

These tariffs can be categorized as follows:

- Tiered energy tariffs: E-1, EM
- Time-of-Use energy tariffs: A1, A6, E-1-TOU
- Time-of-Use energy and power demand tariffs: A-10, E-19, E-20

Table 3 – Applicable tariffs per building category

Type	Building Type Name	PG&E Electricity tariff scheme applied	PG&E Gas tariff scheme applied	Monthly gas rate
Commercial & Industrial	Large office	E-20	G-NR1	D
	Medium office	A-10	G-NR1	A
	Small office	A-1, A-6	G-NR1	A
	Warehouse	A-10	G-NR1	C
	Stand-alone retail	A-10	G-NR1	C
	Strip mall	A-10	G-NR1	C
	Primary school	A-10	G-NR1	D
	Secondary school	E-19	G-NR1	E
	Supermarket	A-10	G-NR1	D
	Quick-service restaurant	A-10	G-NR1	C
	Full-service restaurant	A-10	G-NR1	C
	Hospital	E-20	G-NR1	E
	Outpatient health care	A-10	G-NR1	D

[6] https://building-microgrid.lbl.gov/projects/der-cam

	Small hotel	A-10	G-NR1	C
	Large hotel	A-10	G-NR1	E
Residential	Mid-rise apartments	E-1, E-1-TOU, EM	G-1	Res
	BASE	E-1, E-1-TOU	G-1	Res
	LOW	E-1, E-1-TOU	G-1	Res
	HIGH	E-1, E-1-TOU	G-1	Res

In the demonstration, we focused on tariffs containing Time-Of-Use components for both energy and power demand. Specifically, we tested tariff modifications by targeting the magnitude of applicable peak rate values (shown in red in Figure 8).

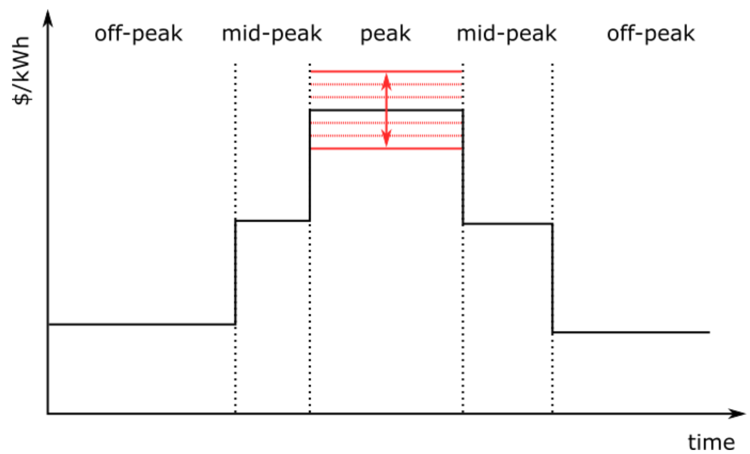


Figure 8 - Sensitivity analysis to tariff changes

3.2.3. Key Demonstration Results

In this section, the key results obtained during the prototype tool demonstration are presented. Specifically, we evaluate the effect of energy tariff variations on investments in behind-the-meter DER technologies and assess their impact on the distribution grid, considering the three use cases and data sets presented in previous sections. The results obtained by performing a sensitivity analysis on the peak component of residential tariff E-1-TOU are highlighted.

To understand the results and the capabilities of the prototype tool, it is important to keep in mind that to better reflect a real scenario, the prototype allows studying the impacts of modifying a single tariff – applicable to a set of building types and for a set of DER investment options – while still considering all the different tariffs that apply to all other building types where other DER investment options may be available. This capability is reflected in the discussion of results below.

In the analysis made around residential tariff E-1-TOU, two investment cases were considered: PV for residential applications where E-1-TOU applies, and PV with storage for commercial applications in all other cases. The sensitivity analysis made to tariff E-1-TOU consists of modifying the peak rate values in the range of -50% to +250% in steps of 25%, totaling 13 tariff variations.

Key system-wide results are shown in Figure 9, where the aggregate PV and storage capacity installation is displayed for all 119 distribution system nodes and for each of the 13 modifications made to the residential tariff (Use Case 1).

It can be observed that while electric storage deployment remains constant – as it is only allowed in cases not subject to the sensitivity analysis – increasing the peak E-1-TOU rate component creates favorable conditions for PV deployment, illustrating how a tariff design with high TOU peak rates can contribute to pursuing renewable policy targets as established by state regulators and legislators.

However, the increase of PV deployment does not scale linearly. For example, modifying the peak TOU component from +25% to +50% leads to only a 1 MW increase in system-wide PV deployment (from 24 MW to 26 MW), while a variation between 50% and 75% leads to an increase of 6.5 MW in residential PV (from 26 to 32.5 MW).

From a regulatory perspective, this suggests that a 50% increase in the peak TOU rates has a limited impact on residential PV adoption, while an increase of 75% represents meeting a threshold point, where a major increase in PV investments can be expected. Identifying such dynamics and thresholds that can lead to changing behaviors based on energy tariffs is one of the main capabilities of this software tool, providing valuable information for regulators and policy makers.

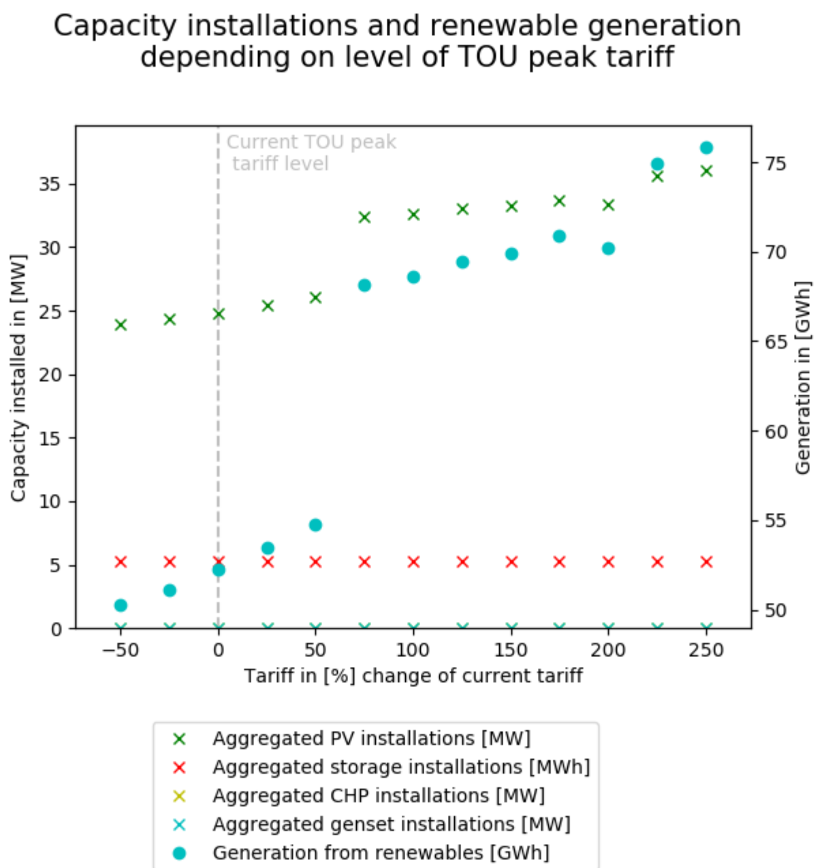


Figure 9 – Capacity installations and renewable generation: Residential PV only

Analysis of the impact of DER on the distribution network (Use Case 2) shows that increased levels of PV deployment motivated by higher peak TOU rates can have a positive impact during periods of high network loads, since PV generation for self-consumption has the potential to eliminate grid problems from physical constraints caused by high electricity demand at a specific point on the network.

This effect can be observed by analyzing the power flow results when maximum annual consumption occurs in the distribution system, for example during a hot summer day at 5 pm. This is illustrated in Figure 10 by comparing the voltage profiles with and without considering DER under a 25% increase in the peak TOU rate component. PV investments driven by this tariff variation lead to an overall increase in voltage levels that eliminates the risk of under-voltage events otherwise found in the upper right section of the network.

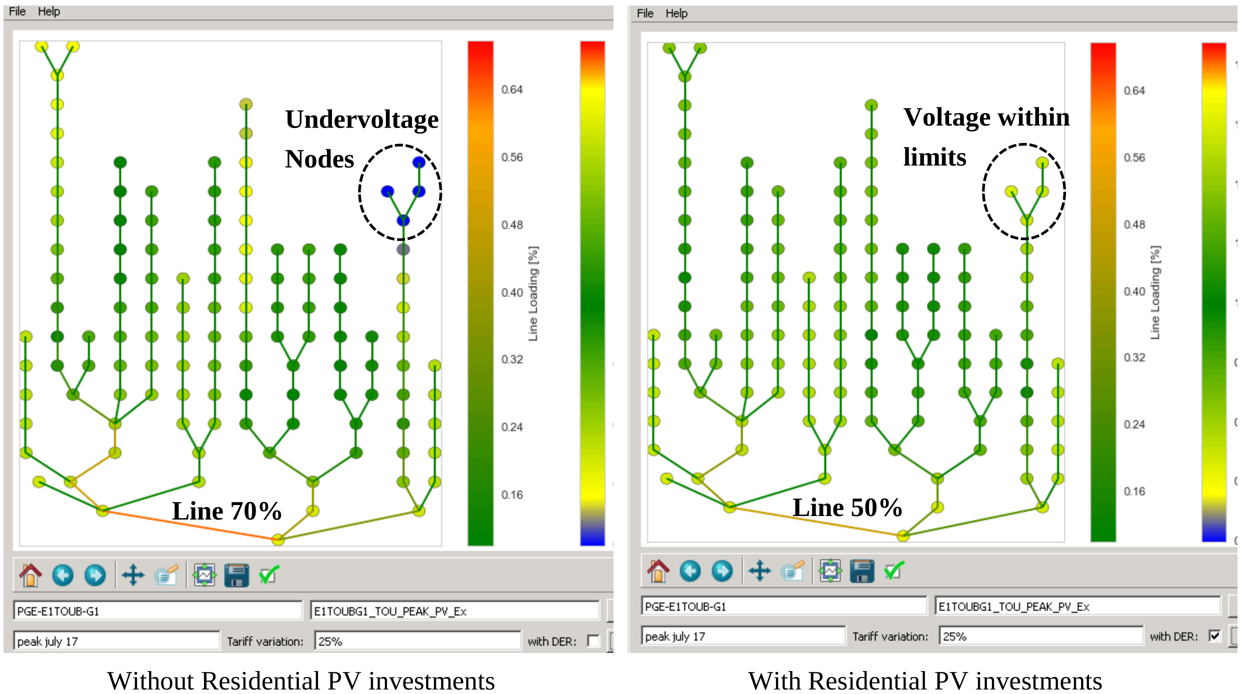
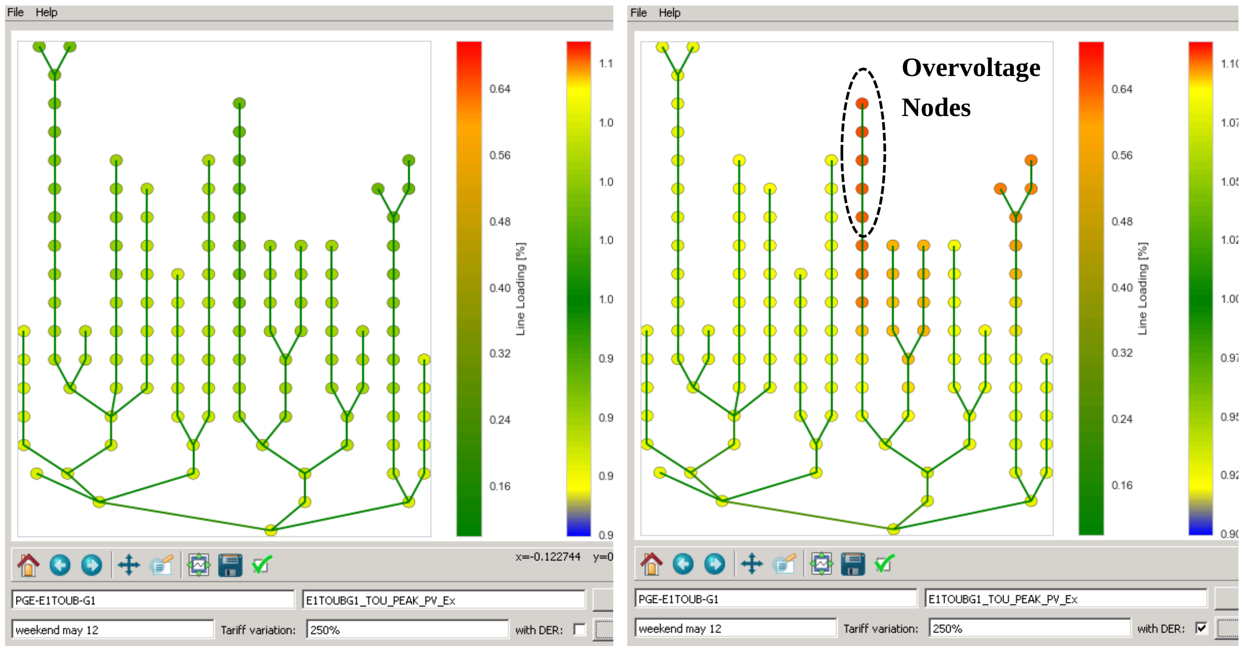


Figure 10 – Impact of PV generation during the peak scenario.

Further, because the increase in local generation leads to a reduction in power exchanges with the main grid, the line flows near the substation are reduced, mitigating the risk of thermal limit violations. In this case, the power rating in the line connecting the substation with the lower left side of the distribution grid decreased from 70% to 50% due to increased PV penetration motivated by the change in tariffs.

Although PV investments can have a positive impact on the grid operation during periods of high energy consumption, they can also introduce challenges to the system during periods of high solar output. This is particularly relevant in cases where tariffs create an incentive for very high penetration of PV, and correspondingly high levels of power injection to the distribution grid.

To illustrate this situation, consider a scenario with a 250% increase in the peak component of TOU residential tariffs and its consequent impact on the distribution grid. In this case, the strong incentive for PV deployment motivates high power injection levels during periods of low energy consumption. This introduces a serious risk of over-voltage in specific sections in the distribution grid, especially those with a high share of residential customers. This can be observed in Figure 11, where a snapshot of the grid power flow calculated at noon during a weekend day in May is presented, with and without the presence of DER.



Without Residential PV investments

With Residential PV investments

Figure 11 – Impact of PV generation during the valley scenario.

Overall, the analysis enabled by the prototype tool clearly shows the potential of the IMT to analyze the impacts of modifying retail tariffs and how incremental residential PV can be affected by changes in specific TOU components. Moreover, the power flow capabilities of the prototype enable quantifying impacts of DER on the distribution network, which can either be beneficial in scenarios with moderate PV penetration or pose risks to network operation in scenarios with very high PV deployment levels.

To illustrate Use Case 3 - DER investments and operation in reaction to tariff modifications, hybrid investment options – combining residential PV and storage – are analyzed.

Figure 12 presents a comparison between the two investment cases – residential PV versus residential PV and storage – for all tariff modifications to E-1-TOU analyzed. Here investments in residential storage become viable only when the peak TOU rate increases more than 100%, due to high investment costs of electric storage. However, after this threshold is met, electric storage deployments become dramatically more attractive.

Further, for high tariff values, PV deployment is higher when combined with electric storage, illustrating the interaction between these two technologies. Specifically, for peak TOU rate increases over 150%, PV investments are 8% higher when combined with storage than when only PV is allowed.

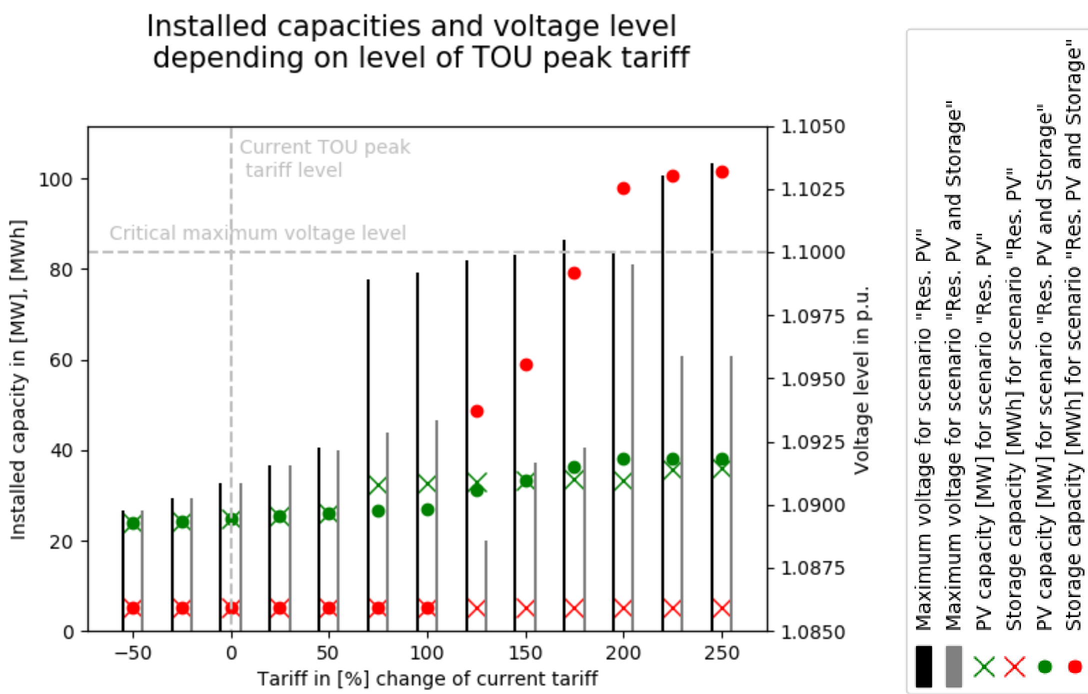


Figure 12 – Impact of PV generation during the valley scenario.

In this case, although residential PV increases when combined with storage, the higher deployment levels do not necessarily involve a higher risk for network operation. In fact, as illustrated in Figure 12, the maximum voltages of the network tend to decrease when storage investments are made. This can be explained by the ability of electric storage to shift the excess PV generation during noon hours to later periods in the day, when electricity rates are still high. This behavior can be observed, for example, in the DER dispatch of a typical mid-rise apartment building for the annual valley scenario (May, weekend). When DER investments are allowed only in solar (Figure 13), a significant PV injection occurs during noon hours. When the DER investment portfolio includes storage as an option, the battery is used to shift excess PV generation to evening periods (Figure 14).

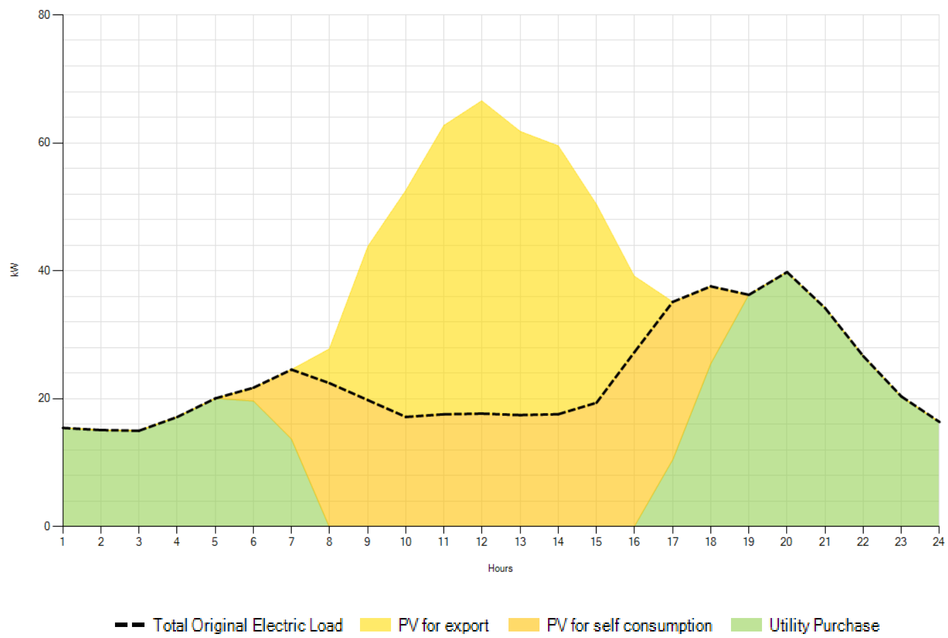


Figure 13 –Midrise apartment – PV generation during the valley scenario. DER investments in PV only.

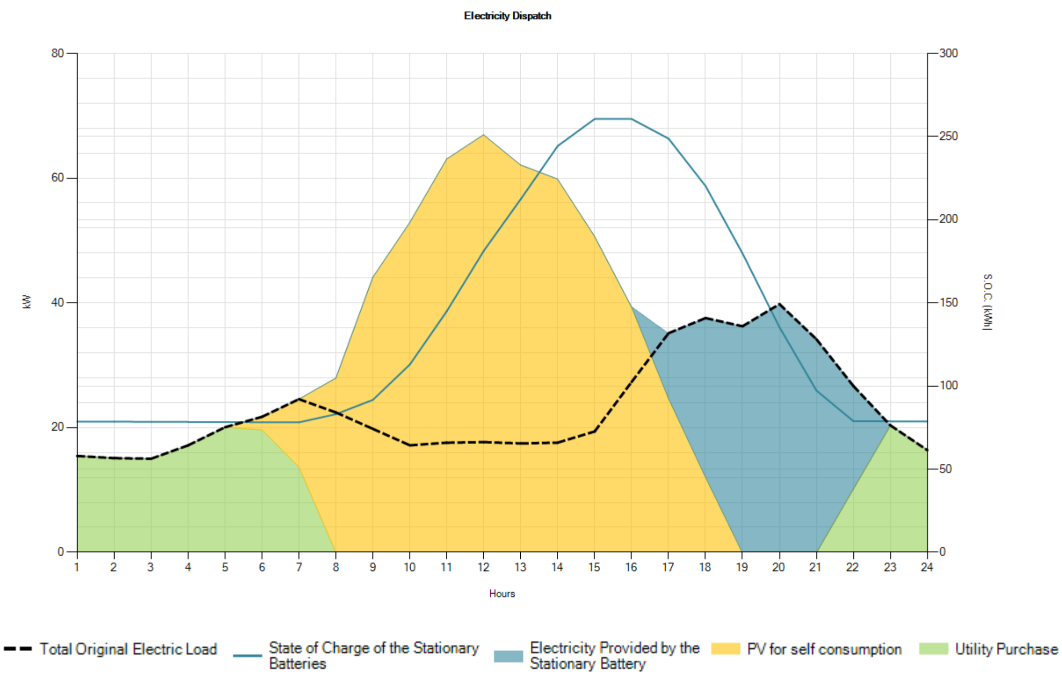


Figure 14 – Midrise apartment – PV generation during the valley scenario. DER investments in PV and Storage.

As shown in the use cases presented above, sensitivity analysis performed using the IMT prototype identified important threshold points in the TOU rate variations, providing important guidelines for tariff design toward the integration of generation from renewable resources at the distribution level.

The power flow module within the prototype provides regulators and policy makers with a simple and intuitively-useable tool to evaluate the hourly impact of various tariff rate scenarios on the distribution grid. In fact, the integration of power flow calculations with economic analysis brings to the tariff design process the capability of identifying the most challenging points of operation of the distribution grid, quantifying possible violations of the network physical constraints, locating problematic nodes and lines as well as detecting the most critical hours for each tariff scenario.

Finally, the multidimensional and dynamic analysis made possible by the IMT provides an objective basis for decision-making on the impact of DER (individual and aggregated) and microgrids (with various configurations of generation, storage and loads) on the grid. It provides a tool for grid integration that recognizes political goals for renewables and resiliency, while ensuring the stability and reliability of the distribution system. It helps regulators to balance the full range of benefits and costs for ratepayers with the technical requirements of the network to ensure the reliable operation of the distribution system by the utility which is ultimately responsible for power delivery.

4. Conclusion

This report documents the work conducted throughout Phase I of the project "*Distribution Grid Locational Performance Modeling: Developing a Foundational Integrated Modeling Tool for Regulators*".

During its initial phase, the project focused on defining the scope and performance goals of the Integrated Modeling Tool for Regulators (IMT), at both the distribution and transmission levels, as well as the technical requirements to meet those goals, including the ability to run power flow analysis over long-term periods while considering the economics of grid planning and operations, behind-the-meter DER deployment and economic optimization, and to integrate transmission and distribution power flow models to assess impacts of DER in the bulk electric system.

Further, the work done in this first phase of the project consisted of developing the timeline and planning for the remainder of the project, with the goal of developing the IMT incrementally and delivering tangible capabilities in each of the five yearly phases.

Finally, Phase I included the development of a proof of concept for IMT, where a software prototype was developed and used to carry out a demonstration. This prototype features some of the capabilities desired for IMT, and leverages existing state-of-the-art tools for both behind-the-meter DER cost-optimization (DER-CAM) and distribution power flow analysis (pandapower), along with new integration, automation, and visualization capabilities.

A demonstration was carried out using a representative 119 bus feeder model, and building energy-load data for San Francisco, with PGE's natural gas and electricity tariffs. Further, DER-CAM data templates were used to define the techno-economic characteristics of different DER, and three distinct use cases were analyzed, including the impact of tariffs in the aggregate deployment of behind-the-meter DER, the impact of DER on distribution system voltage, and DER investments and operation in reaction to tariff modifications. Each of these use cases was evaluated for three DER investment options: (i) DER generation without storage, (ii) DER with storage, and (iii) DER generation with storage and combined heat and power units.

The results obtained in the demonstration highlight how various tariff modifications can contribute to either alleviating or worsening voltage stability problems in specific nodes, mainly due to the impact of varying economic signals on how DER is dispatched (either for self-consumption or power exports). Further, these results highlight how specific tariffs and tariff modifications can contribute to achieving system-wide goals for the interconnection of renewables and reliability.

Annex I Regulatory Proceedings

Integrated Resource Planning, Grid Modernization, and Rate Case/DER Dockets

Integrated Resource Planning (IRP):

Arizona Public Service Integrated Resource Planning Process (2017 Integrated Resource Plan)

https://www.aps.com/library/resource%20alt/2017IntegratedResourcePlan.pdf

The Integrated Resource Plan is intended to be a 15-year plan to continue to "safely and efficiently generate and deliver reliable energy to meet the changing needs of our customers…by creating a portfolio of supply-and demand-side resources to manage the impacts of today's industry developments."

California Energy Commission, Integrated Resource Plans

http://www.energy.ca.gov/sb350/IRPs/

Senate Bill 350 of 2015 requires the Energy Commission to produce guidelines for and to review Integrated Resource Plans (IRPs) from publicly owned utilities (POUs). Workshops on the adoption of Publicly Owned Utility Integrated Resource Plan Submission and Review Guidelines are continuing through 2017.

Virginia State Corporation Commission and North Carolina Utilities Commission, Dominion Virginia Electric and Power Company 2017 Integrated Resource Plan

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiM1O_Js7bVAhWEbz4KHfUcBOMQFggoMAA&url=https%3A%2F%2Fwww.dominionenergy.com%2Flibrary%2Fdomcom%2Fpdfs%2Fcorporate%2F2017-irp.pdf&usg=AFQjCNGs9w0WMaewr9ET8S1mmByGmVBWlA

The Virginia Code and North Carolina General Statutes require utilities to prepare a long-range plan to meet energy needs.

Oregon Public Utility Commission, Docket No. LC 66 Portland General Electric Company 2016 Integrated Resources Plan

http://edocs.puc.state.or.us/efdocs/HAA/lc66haa144338.pdf

The Commission requires a plan compliant with their IRP guidelines detailing long term use of resources, implementation of new technology, and compliance with Oregon's goals on renewable resources and transferring off coal-fired electricity.

Grid Modernization Dockets:

California Public Utilities Commission, R141003 Order Instituting Rulemaking to Create a Consistent Regulatory Framework for the Guidance, Planning and Evaluation of Integrated Distributed Energy Resources

https://apps.cpuc.ca.gov/apex/f?p=401:56:23706437939969::NO:RP,57,RIR:P5_PROCEEDING_SELECT:R1410003

The Commission opened this rulemaking to consider the development and adoption of a regulatory framework to provide policy consistency for the direction and review of demand-side resource programs. They envision this framework to be a unified mechanism to authorize and direct the Commission-regulated electric and gas utilities to achieve demand reduction and load shaping using integrated demand-side management resources.

Colorado Public Utilities Commission, Proceeding 16A-0588E

The Commission approved a settlement agreement between Xcel, Commission Staff, the Office of Consumer Counsel and several other parties. The approved Advanced Grid Intelligence and Security plan includes: 1) a full advanced metering infrastructure roll-out beginning in 2020, 2) an integrated Volt-VAR Optimization program, 3) associated components of an advanced communications network (known as the Field Area Network or FAN), and 4) implementation of the Green Button Connect My Data web portal or another nationally adopted standard that is deemed superior at the time of implementation.

DC Public Service Commission, DC Formal Case No. 1130: Investigation into Modernizing the Energy Delivery System for Increased Sustainability (MEDSIS)

http://www.dcpsc.org/Newsroom/HotTopics/MEDSIS-Initiative.aspx

The Commission established MEDSIS to identify technologies and policies that can be implemented to modernize the distribution energy delivery system in the District of Columbia. The goal of MEDSIS is to increase sustainability for District consumers, and in the near-term, make the distribution energy delivery system more reliable, efficient, cost effective, and interactive.

Illinois Commerce Commission, NextGrid

https://www.icc.illinois.gov/NextGrid/

"NextGrid" is Illinois' Utility of the Future study. NextGrid is an approximately eighteen-month initiative that will be a consumer-focused effort to study ways to leverage the state's restructured energy market, investment in smart-grid technology, and significant expansion of renewables and energy efficiency as a result of the recently passed Future Energy Jobs Act. The study will be led and overseen by the Illinois Commerce Commission with the assistance of an independent facilitator who will seek input from all stakeholders on goals and guiding principles for the process.

Public Utilities Commission of Ohio, PowerForward

https://www.puco.ohio.gov/industry-information/industry-topics/powerforward/

PowerForward is the PUCO's review of the latest in technological and regulatory innovation that could serve to enhance the consumer electricity experience. Through this series, the PUCO intends to chart a clear path forward for future grid modernization projects, innovative regulations and forward-thinking policies

New Hampshire Public Utilities Commission, Grid Modernization Working Group and Grid Modernization Report (Docket No. IR 15-296)

http://www.raabassociates.org/Articles/NH%20Grid%20Mod%20Final%20Report%203-20-2017.pdf

The report (delivered March 2017) includes many areas of consensus among stakeholders, as well as distinct stakeholder viewpoints on areas of non-consensus. The proceeding covered distribution system planning, advanced metering functionality, rate design, customer data and education, and utility cost recovery and financial incentives.

New York State Department of Public Service, Docket No. 14-M-0101 Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision

http://energy.pace.edu/sites/default/files/REV%20TRACK%201%20ORDER.pdf

(Track 1) The "Track 1" order creates a framework for the shift from centralized generation to a customer-centric market that encourages adoption of clean distributed energy resources. The commission said that business as usual is no longer a viable option for utilities in meeting their statutory responsibilities to New Yorkers.

New York State Department of Public Service, Docket No. 14-M-0101 Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7bD6EC8F0B-6141-4A82-A857-B79CF0A71BF0%7d

(Track 2) REV's Track 2 intends to provide a framework for utilities to remain financially sound while offering customers greater choices to interact with third parties through an Order adopting a ratemaking and utility revenue model policy framework.

Maryland Public Service Commission, Public Conference No. 44

http://webapp.psc.state.md.us/intranet/AdminDocket/CaseAction_new.cfm?CaseNumber=PC44

The Maryland Public Service Commission (PSC), as part of the Exelon-PHI merger condition, initiated a grid modernization proceeding to make sure that the electric distribution system in Maryland is customer-centric, affordable, reliable, and environmentally sustainable. The proceeding is addressing rate design, electric vehicles, competitive markets and customer choice, the interconnection process, energy storage, and distribution system planning.

Minnesota Public Utilities Commission, Proceeding E999/CI-15-556

The Public Utilities Commission opened a docket in May 2015 to consider the development of policies related to grid modernization.

Rhode Island Public Utilities Commission, Docket No. 4600

In March 2016, the PUC opened a docket to identify and measure the costs and benefits of net metering and DERs. The working group developed a detailed Benefit-Cost Framework that may be used to evaluate DG programs, alternative rate designs, and grid modernization projects.

Vermont Public Service Board, 17-3142-PET

The Public Service Board opened an investigation (in response to an April 10, 2017 Department of Public Service request) to review emerging trends in the utility sector and to examine if changes should be made to how utilities are regulated. The order mentioned trends including: new renewable energy goals, changes to the net metering program, implementation of new enabling technologies (e.g., advanced metering, electric vehicles, energy storage, and heat pumps), increased participation by end-users and third-party aggregators managing load in real time, and the merger of the state's two largest electric utilities.

Rate Case/DER Dockets:

California Energy Commission, California Microgrid Roadmap Proceeding

http://www.energy.ca.gov/research/microgrid/

California Energy Commission staff in collaboration with the California Public Utilities Commission and the California Independent System Operator are developing a Roadmap for the Commercialization of Microgrids in California. This Roadmap will be finalized by the end of 2017.

California Public Utilities Commission, R1408013: Order Instituting Rulemaking Regarding Policies, Procedures and Rules for Development of Distribution Resources Plans Pursuant to Public Utilities Code Section 769

https://apps.cpuc.ca.gov/apex/f?p=401:56:17513033823850::NO:RP,57,RIR:P5_PROCEEDING_SELECT:R1408013

This is the Distribution Resource Plan (DRP) proceeding focused on how the state's' investor-owned utilities – Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E) – can find the value of distributed energy resources (DER) in their distribution systems. The proceeding is also focused on identifying the areas of greatest need for DER - specifically as an alternative to investments in traditional poles, wires, and transformers - and defining the services that may be bought and sold to meet those needs. This proceeding is closely interrelated with the Integrated Distributed Energy Resources (IDER) proceeding (14-10-003) focused on how best to source, value, and integrate these DERs.

https://urldefense.proofpoint.com/v2/url?u=https-3A__powersuite.aee.net_ahoy_messages_HbKZ98n6NAqkBAuaVSP6uBF1uyn65VN5_click-3Fsignature-3Df33385779147887cf23e7407ade60f132c0f2cfb-26url-3Dhttps-253A-252F-252Fpowersuite.aee.net-252Fdockets-252Fca-2Dr1410003-253Futm-5Fcampaign-253Ddeliver-5Fdigest-2526utm-5Fmedium-253Demail-2526utm-5Fsource-253Dmailer&d=DwMFaQ&c=jqQLr8Vjrh9vQZQBMH8t0g&r=CHsvNSMbMS38vN03kr1zHv3tRE1h8d6DUe1d5yk4hns&m=-9sBn3juFg-7ze38qkbi8VYui8N3yL66IpweajpvYkw&s=sGMxVtnKvqOTPAHQvnG9nWphYCPtfbcSkjoLciqySNQ&e=

Colorado Public Utilities Commission, Proceeding 17M-0204E Review of Residential TOU Trial & Demand Rate Pilot

On April 3, 2017, the Commission opened this proceeding to track reporting of the residential demand time-differentiated rates pilot (RD-TDR Pilot) and the residential energy time-of-use trial (RE-TOU Trial) approved in Docket #16AL-0048E.

https://urldefense.proofpoint.com/v2/url?u=https-3A__powersuite.aee.net_ahoy_messages_pzYxDOF7dvZNj03Qh4HDiWJxZTJWnJzK_click-3Fsignature-3D22d2789c59f21782a3d19f31dba9c37a3cbfb4be-26url-3Dhttps-253A-252F-252Fpowersuite.aee.net-252Fdockets-252Fco-2D16al-2D0048e-253Futm-5Fcampaign-253Ddeliver-5Fdigest-2526utm-5Fmedium-253Demail-2526utm-5Fsource-253Dmailer&d=DwMFaQ&c=jqQLr8Vjrh9vQZQBMH8t0g&r=IfbTW3MWhDPBsY_dkjT6m_NoSaxd9URJZkq4FrU87_4&m=6KsAVpWjMXpNlZHUiE5YzBCjAYnMif7sXMmkXdPnWw4&s=7nHpprhWDiefb7WdLsSVoIwXUaH58PmODGhnTHzeDAY&e=

Kansas Corporation Commission, Docket No. 16-GIME-403-GIE In the Matter of the General Investigation to Examine Issues Surrounding Rate Design for Distributed Generation Customers

The Commission opened a general investigation to examine issues surrounding rate design for distributed generation (DG) customers, including: evaluating the costs and benefits, examining alternative rate designs, and determining an appropriate rate structure. This proceeding is only expected to develop policy for DG rate design. Any specific tariff changes will take place in a utility specific filling.

Maryland Public Service Commission, Case No. 9426

Baltimore Gas and Electric Company sought Commission for a pilot project to construct, operate, and recover costs associated with two "public-purpose" microgrids located within the Company's electric distribution service territory.

Massachusetts Department of Public Utilities, Docket #17-05

EverSource has proposed updated base distribution rates as well as a long-term Grid-Wise Performance Plan including deployed of automated devices and technologies, an energy storage pilot program, and an "enhanced electric-grid management system." The plan and rate proposal remains under discussion with the Department of Public Utilities.

New York Public Service Reforming the Energy Vision proceeding, Docket No. 15-20703/15-E-0751 on DER Valuation

This proceeding focuses on developing a methodology for DER valuation that provides a more precise and complete accounting of the values and costs of DERs, including energy storage, than traditional net metering.