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Sizing Tool for a Cost-effective and Resilient Microgrid

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ENERGY STORAGE PROGRAM

U.S. DEPARTMENT OF ENERGY BATTELLE

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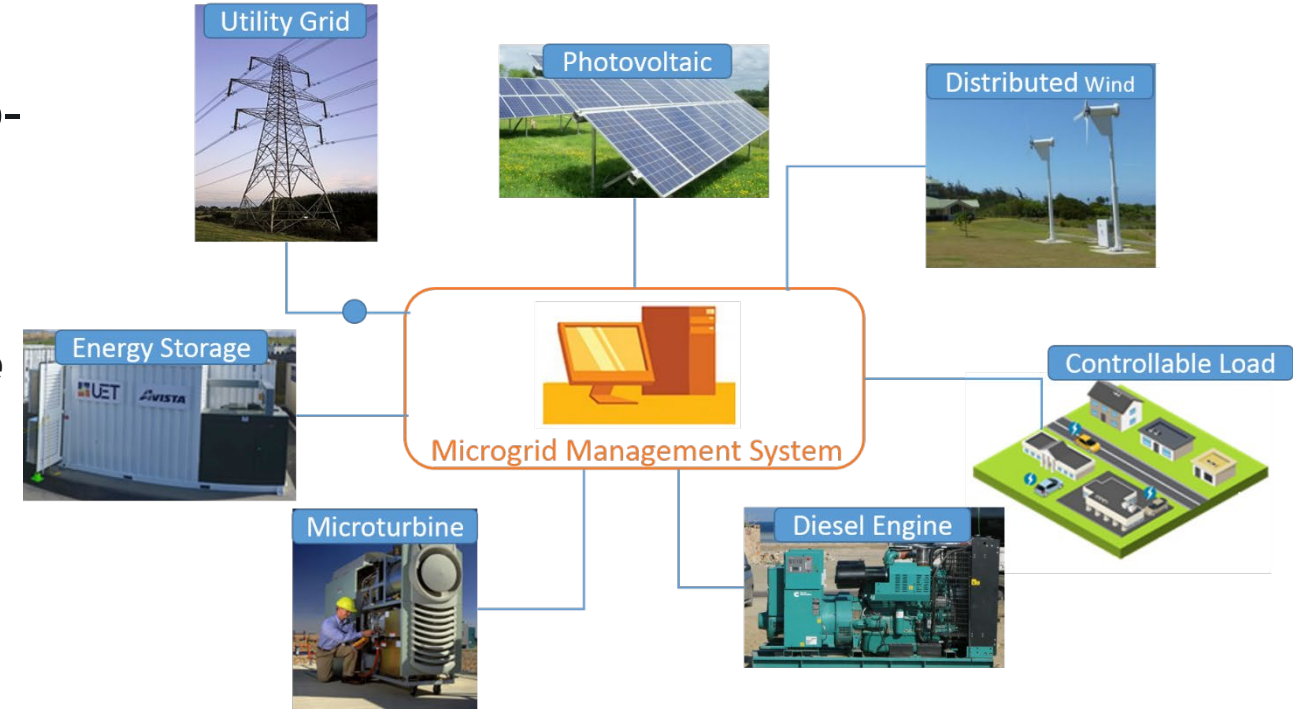
Project Overview

- This project develops a method and tool that allows energy managers for large industrial and institutional customers to select, size, and operate distributed energy resources (DERs) to enhance both the ***resiliency*** and ***economic*** performance of their systems.

- The outcome is an open-source web-based ***modeling and analytics*** tool that directly contributes to
  - ***Electric grid modernization and resiliency of energy infrastructure***
  - ***A resilient, reliable, and flexible electricity system***



Project Team

Pacific Northwest National Laboratory

- Di Wu – Electrical Engineer, *Principal Investigator (PI)*
- Sen Huang – Mechanical Engineer, *Co-PI, tool development lead*
- Xu Ma – Electrical Engineer, *modeling/sizing method*
- Patrick Balducci – Economist, *modeling/sizing method*
- Tao Fu – Data Scientist, *tool development*
- Vanshika Fotedar – Economist, *literature review and testing*
- Avijit Das – Ph.D. Intern, *testing*

Project Objective and Milestones

Objective

Develop a method and tool that allows energy managers for large industrial and institutional customers to select, size, and operate DERs considering both the ***resiliency*** and ***economic*** performance of their systems. The tool is used to achieve resiliency goals while minimizing the net cost (i.e., costs – benefits) of microgrid assets.

Phases

Phase 1: **Literature Review** → ***Phase 2:*** **Methodology Development** → ***Phase 3:*** **Tool Development** → ***Phase 4:*** **Testing** → ***Phase 5:*** **Tool Release**

1) Review existing tools and methods for microgrid DER sizing
2) Develop a co-optimal sizing method
   - Milestone: documented method by 6/30, 2019, completed.
3) Design and implement an open-source web-based application
   - Milestone: DER sizing tool v1 by 8/31, 2019, completed.
4) Test and enhance the tool
5) Develop the manual and release the tool

Project Challenges

Methodology development

- How to incorporate both economic and resiliency performance into the DER selection and sizing process
- How to model various DER technologies with different economic and technical characteristics
- How to simultaneously determine the optimal sizes of different DERs
- How to model and capture diversified system conditions in both grid-connected and islanding modes
- How to capture the interdependency between optimal size and dispatch

Tool development

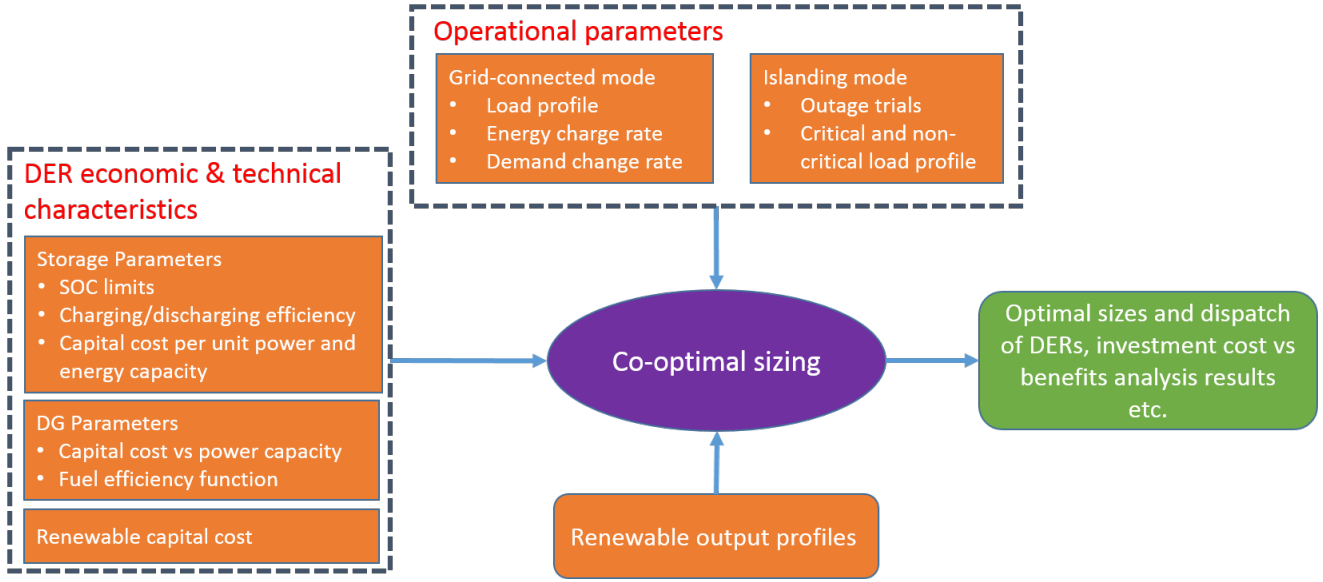
- How to balance between the simplicity of use and the complexity of usefulness
- How to design a flexible and extensible architecture
- How to accommodate users' preferences and ensure users' privacy and data security

Co-optimal Sizing Formulation

- Objective function

min (capital cost + operational cost – operational benefits)

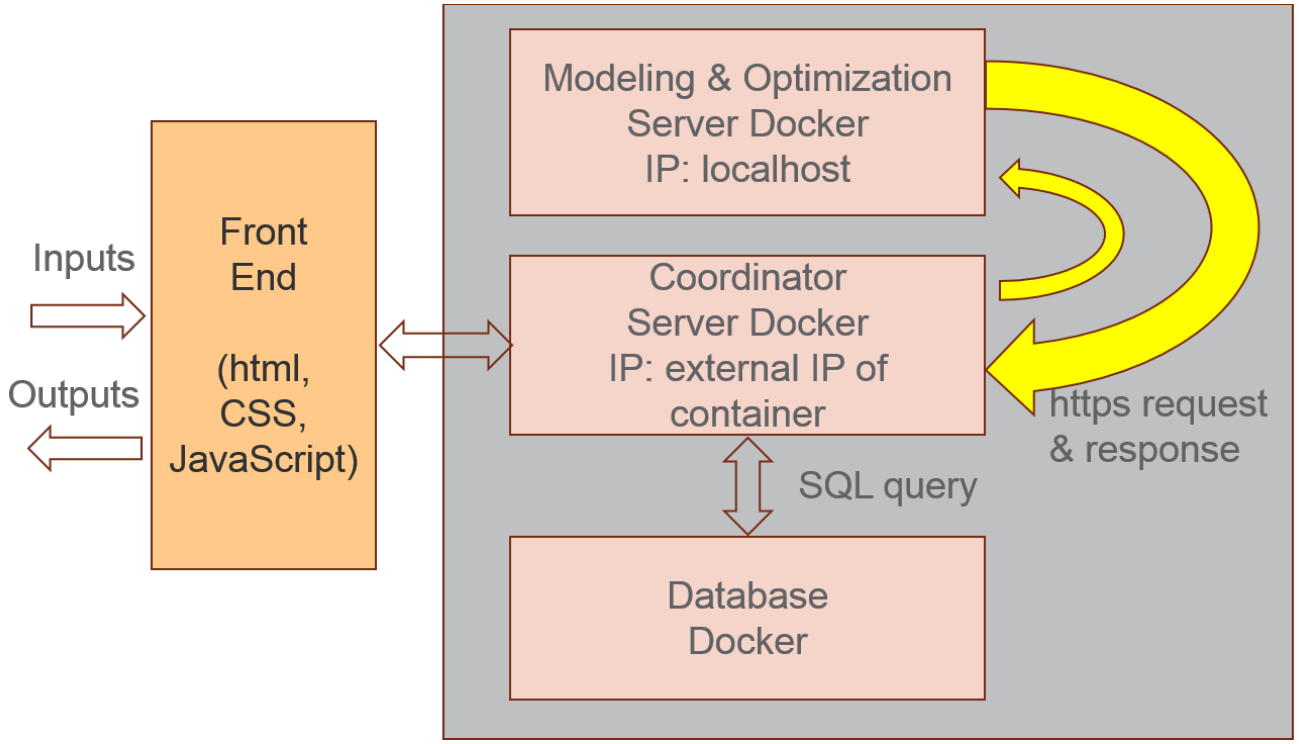
- Models and constraints
  - Resiliency requirement
  - Microgrid power balancing in grid-connected mode
  - Microgrid power balancing in each of the outage scenarios
  - Power output from renewables as a function of their sizes
  - Dispatchable DG power output limits
  - Dispatchable DG fuel consumption and cost
  - Energy storage power and energy limits
  - Energy storage energy state dynamics



Di Wu, Xu Ma, Sen Huang, Tao Fu, and Patrick Balducci, "Co-optimal sizing of distributed energy resources for cost-effective and resilient microgrid," to be submitted.

Sizing Tool Architecture

- The web-based application minimizes dependencies on operating systems
- The modular structure facilitates maintenance and expansion
- The encapsulated environment with Docker eliminates the need for customized settings
- The dedicated Database Docker and SQL query improve data security



Sizing Tool Front-end (Inputs)

Selecting "MG" to create a DER sizing model/analysis

Description displayed on mouse over a field

Selecting types of DERs for sizing

Model Type: MG | Model Name: Demo | User: test

Created: 19-09-16 19:33:02 | Run Time: 0:02:06

Resiliency requirement

Survivability [%]: 90

Probability to survive a random two-week outage

Select devices for sizing

☑ Energy storage system (ESS) ☑ Photovoltaic (PV) ☑ Distributed generation (DG)

Energy/Demand tariff structure

Energy price(.csv file) Choose File default

Demand charge price(.csv file) Choose File default

A representative tariff structure is used as default and users can provide customized inputs

Financial analysis parameters

Financial analysis life cycle: 15

Real discount rate [%]: 6.85

PV

Capital price [$/kW]: 2100

Generation profile per kW (.csv file) Choose File default

ESS

Price (energy) [$/kWh]: 372

Price (power) [$/kW]: 388

Discharging efficiency [%]: 90

Charging efficiency [%]: 90

Representative numbers are used as default. The tool checks customized inputs based on the property of different fields

DG

Generator capital cost (.csv file) Choose File default

Delete | Publish | Duplicate | Run Model

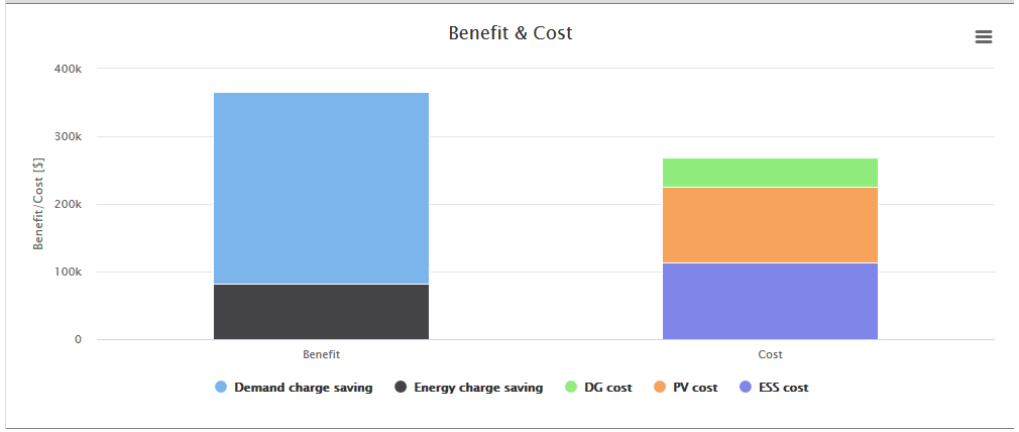
The created model/study can be duplicated or published.

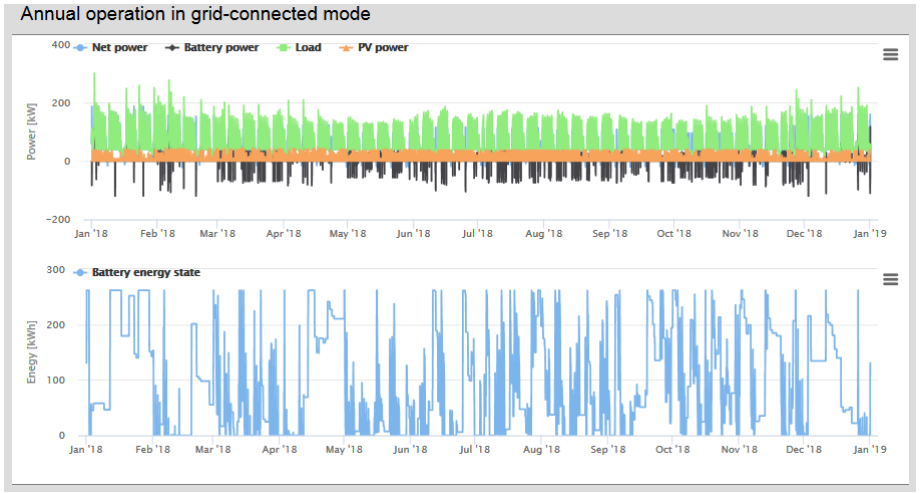
Sizing Tool Front-end (Selected Outputs)

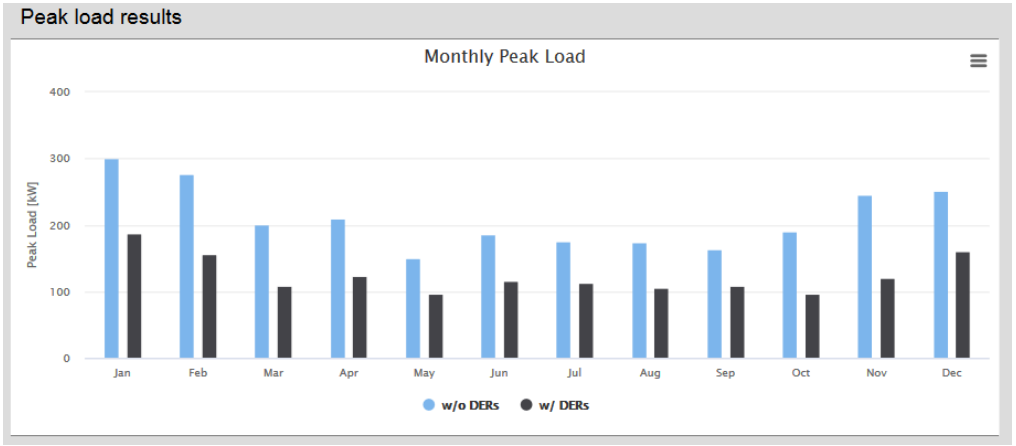
Optimal Sizes and Economic Analysis

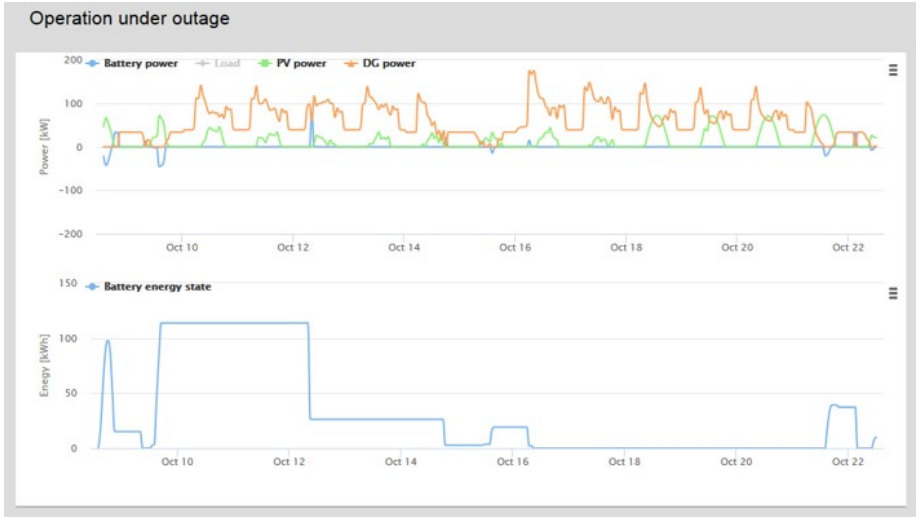
DG power capacity [kW]	PV power capacity [kW]	ESS power capacity [kW]
146	54	120

ESS energy capacity [kWh]
262









Looking Forward

Dissemination Plan

- Set up a public-accessible server using Amazon Elastic Compute Cloud
- Upload the source code and user manual on GitHub

Tool Improvement

- Develop multi-objective optimization and generate the Pareto front to better explore the trade-off between system cost/benefits and resiliency level
- Separate lumped load into critical and non-critical load to improve resiliency analysis
- Model generator failure and capture the impacts on system economics and resiliency
- Incorporate additional practical constraints such as budget limits and on-site fuel storage capacity
- Collaborate with industrial partners to use the tool for planning study, and resiliency and economic analysis of microgrid systems

Acknowledgments

Dr. Imre Gyuk, DOE – Office of Electricity

Mission – to ensure a resilient, reliable, and flexible electricity system through research, partnerships, facilitation, modeling and analytics, and emergency preparedness.

https://www.energy.gov/oe/activities/technology-development/energy-storage

Q/A and Further Information

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