Proceedings of the 2024 Winter Simulation Conference
H. Lam, E. Azar, D. Batur, S. Gao, W. Xie, S. R. Hunter, and M. D. Rossetti, eds.

MICROGRID DESIGN PLANNING FOR THE U.S. DEPARTMENT OF DEFENSE

Daniel Reich[1], Giovanna Oriti[2], Ronald Giachetti[3], Douglas L. Van Bossuyt[3], and Susan M. Sanchez[1]

[1]Dept. of Operations Research, Naval Postgraduate School, Monterey, CA, USA
[2]Dept. of Electrical and Computer Engineering, Naval Postgraduate School, Monterey, CA, USA
[3]Dept. of Systems Engineering, Naval Postgraduate School, Monterey, CA, USA

ABSTRACT

The U.S. Department of Defense operates both permanent and temporary installations throughout the world that have critical needs for secure energy that is reliable, efficient, and resilient. Microgrids are a key infrastructure technology for delivering both primary and backup energy systems. We have developed simulation-based methods for modeling energy requirements, measuring the performance of microgrids composed of distributed energy resources, identifying component capacities required to meet energy demands, and analyzing both robustness and resilience of potential microgrid designs. To deliver these capabilities to installation energy managers for use in infrastructure planning, we have released the Microgrid Planner web application. This design tool has been successfully used for the conceptual design of several pilot microgrids; one is currently under construction.

1 INTRODUCTION

A microgrid is a small, self-sufficient power system with its own controls and distributed energy resources. Organizations operating microgrids generally connect to the main utility grid with the aim of supplementing their power needs or reducing costs (Peterson et al. 2021), but microgrids can also operate independently of the utility grid in an islanded mode (Giachetti et al. 2022). It is this later capability that makes microgrids attractive to military installations for ensuring energy security (Department of Navy 2017). The integration of renewable resources to reduce greenhouse gas emissions is an added benefit, and both the U.S. Navy and U.S. Army recently issued plans for widespread microgrid development (Del Toro 2022; Wormuth 2022).

The U.S. military performs the needs analysis and conceptual design of most systems. The conceptual design is a high-level, architectural design of the system with most technical details absent. The architecture design becomes input to the more detailed design work done by contractors to the U.S. military. Our tool set is aimed at the military personnel who need to determine the high-level power requirements to meet resilience, cost, reliability, cybersecurity, climate resilience (Giachetti and Van Bossuyt 2023), and decarbonization goals. Our focus on the conceptual design phase differentiates our work from many commercial tools. In addition, our work addresses the U.S. Department of Defense (DOD) perspective and emphasis on energy security rather than the cost minimization characteristics of commercial tools.

2 MICROGRID PLANNER

Microgrid Planner (Reich and Frye 2024a; Reich and Frye 2024b) is an open-source software platform designed to assist with early stages of microgrid planning. A brief overview of our analytical methods follows. Some of these features appear in the current release, others have been used offline and are planned for inclusion in future releases.

Our **core computational method** simulates power generation and storage using a facility's power load data with a selected energy management system that defines control logic (Reich and Oriti 2021). Based on the user's selected location, the method performs a weather conditions lookup by date and time in our weather database, which has a default resolution of 30 minutes.

Our **sizing method** presents a decision maker with a range of potential microgrid designs that would satisfy a facility's power requirements, and allows the decision maker to weigh relative advantages and disadvantages of each design (Reich and Oriti 2021; Reich 2024).

Our **sensitivity analysis method** subjects a potential microgrid design to a range of random fluctuations, employing a data farming framework suitable for large-scale simulation experiments (Reich and Sanchez 2023). Future weather conditions and power loads are unknowable. Incorporating stochastic variation provides additional information about how a microgrid may perform in practice.

Our **resilience method** measures two important aspects of resilience: the vulnerability of the microgrid to resist power losses following a disruptive event, and the recoverability of the microgrid to be repaired and return to satisfying full power demand (Giachetti et al. 2022; Giachetti and Van Bossuyt 2023). Multiple executions of the model can be used to explore resilience with respect to different types of disruptions.

3 CASE STUDY

Microgrid Planner was used in designing a microgrid currently under construction at Naval Air Station Sigonella, a U.S. Navy installation co-located on the Italian Air Force installation in Sicily, Italy. A building with critical loads was identified by the Installation Energy Manager (IEM) as a high priority site. The IEM used Microgrid Planner to evaluate different design options and complete the conceptual design of the microgrid, creating a set of specifications used to write the formal request for proposal. The microgrid is expected to be operational by the end of 2024. Two additional microgrids were also designed by the IEM using Microgrid Planner and they are expected to be commissioned in 2025. The application of Microgrid Planner also provided useful verification and validation of the analytical tools described in this paper. Lessons learned feed into the ongoing collaborative development of Microgrid Planner.

ACKNOWLEDGMENTS

This work was supported by the Office of Naval Research as part of the NextSTEP program; the Naval Facilities Engineering Systems Command as part of the Navy Shore Energy Technology Transition and Integration program; and the Director of Operational Energy, Deputy Assistant Secretary of the U.S. Navy.

REFERENCES

Del Toro, C. 2022. "Department of the Navy Climate Action 2030". Technical report, Department of the Navy, Office of the Assistant Secretary of the Navy for Energy, Installations, and Environment, Washington, DC.

Department of Navy 2017. "Three Pillars of Energy Security (Reliability, Resiliency, and Efficiency)". Technical Report P-602, Naval Facilities Engineering Systems Command (NAVFAC), Washington Navy Yard, Washington, DC.

Giachetti, R. E., D. L. V. Bossuyt, W. W. Anderson, and G. Oriti. 2022. "Resilience and Cost Trade Space for Microgrids on Islands". *IEEE Systems Journal* 16(3):3939–3949 https://doi.org/10.1109/JSYST.2021.3103831.

Giachetti, R. E. and D. L. Van Bossuyt. 2023. "Military Energy Resilience Models and Climate: Do Our Models Adequately Consider Climate Risks?". *IEEE Open Journal of Systems Engineering* 1:153–163 https://doi.org/10.1109/OJSE.2023.3324699.

Peterson, C. J., D. L. Van Bossuyt, R. E. Giachetti, and G. Oriti. 2021. "Analyzing Mission Impact of Military Installations Microgrid for Resilience". *Systems* 9(3):69 https://doi.org/10.3390/systems9030069.

Reich, D. 2024. "Microgrid Planner: A Distributed Energy Resource Sizing Method" https://doi.org/10.48550/arXiv.2406.19431.

Reich, D. and L. Frye. 2024a. "Microgrid Planner: An Open-Source Software Platform". *INFORMS Journal on Computing*: Articles in Advance https://doi.org/10.1287/ijoc.2023.0336.

Reich, D. and L. Frye. 2024b. "Microgrid Planner: An Open-Source Software Platform" https://doi.org/10.1287/ijoc.2023.0336.cd. Available for download at https://github.com/INFORMSJoC/2023.0336.

Reich, D. and G. Oriti. 2021. "Rightsizing the Design of a Hybrid Microgrid". *Energies* 14(14):4273 https://doi.org/10.3390/en14144273.

Reich, D. and S. M. Sanchez. 2023. "Sensitivity Analysis of Hybrid Microgrids With Application to Deployed Military Units". *Naval Research Logistics (NRL)* 70(7):753–769 https://doi.org/10.1002/nav.22130.

Wormuth, C. E. 2022. "United States Army Climate Strategy". Technical report, Department of the Army, Office of the Assistant Secretary of the Army for Installations, Energy and Environment, Washington, DC.