Don’t Shed On Me: Optimal Microgrid Control

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# Abstract

Electricity is essential to daily life in the developed world, powering critical systems and services such as hospitals, water supply and wastewater treatment, and other functions. Power outages--such as those driven by increasingly large wildfires and Public Safety Power Shutoffs in California--compromise functionality of these critical services. Microgrids that include storage and distributed generation resources can help alleviate some of these stresses, with the ability to isolate or ‘island’ from the main power grid, and distribute power locally. However, microgrids typically have limited storage and generation available, therefore the ability to prioritize loads and optimize discharge schedules can help to maximize the benefit that these resources can provide, and minimize harm. This study aims to create a model that produces an optimal storage dispatch schedule based on the relative priority of serving different loads, and storage and distributed generation resources available, in order to maximize the benefit of energy storage.

# Introduction

## Motivation & Background

The last few years have seen some of the most dangerous and destructive wildfires in California’s history. The 2018 Camp Fire created immense financial liability for Pacific Gas & Electric (PG&E) ultimately resulting in their bankruptcy. The 2020 California wildfire season has been billed as the most destructive in history, burning almost 5% of all California acreage.[[1]](#footnote-0) The California Public Utilities Commission (CPUC) has given the investor-owned utilities (IOUs) the ability to conduct Public Safety Power Shutoffs (PSPSs) which allows for the de-energization of the electric grid in places deemed to be at risk of causing additional wildfires.[[2]](#footnote-1) The CPUC does recognize, however, the impacts that these shutoff events have: “a PSPS can leave communities and essential facilities without power, which brings its own risks and hardships, particularly for vulnerable communities and individuals”.[[3]](#footnote-2) These risks are especially pronounced for Californians who require access to electricity to power life saving medical equipment.[[4]](#footnote-3)

In the wake of these PSPS events, microgrids have emerged as one possible solution to managing the stress and impacts of prolonged power outages. The United States Department of Energy (DOE) defines microgrids as “a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode”.[[5]](#footnote-4) A variety of challenges exist around the modelling and implementation of microgrids, but their potential benefits over the traditional power grid far outweigh the costs of doing so. In addition to their ability to isolate from broader electrical shutoffs, microgrids’ incorporation of various distributed generation units alleviates concerns regarding the consistent supply of electricity and long-term energy security associated with the existing grid.[[6]](#footnote-5)

## Focus of this Study

This study aims to create a protocol for energy storage control that minimizes priority consumer disturbance and priority load shedding during an islanding event of known time horizon. We will do this by using load and microgeneration forecasting combined with load prioritization and power quality constraints to dispatch distributed resources optimally.

# Relevant Literature

In addition to the references listed throughout this proposal, several other key sources that will guide this study are listed below:

* Basak et al. (2009) - “Microgrid: Control techniques and modeling”
* Gouveia et al. (2017) - “Microgrid energy balance management for emergency operation”
* Maleki et al. (2014) - “Method of evaluating reliability of microgrids in Island mode by using prioritization”
* Moran, Bill (2016) - “Microgrid load management and control strategies”

Complete citations for these references are listed along with the rest of the sources at the end of this document.

# Statement of Work

The table below describes our proposed tasks and team member responsibilities.

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| **Task #** | **Task** | **Task Description** | **Team Member Responsibilities** |
| 1 | Review literature | Review literature related to modeling and optimizing microgrid battery discharge, and write *Introduction: Relevant Literature* report section that summarizes common trends, existing gaps, and sets up the motivation for our study. | Everyone to contribute |
| 2 | Define microgrid characteristics | Based on literature review of typical microgrid battery storage capacity, distributed generation resources (i.e., solar and/or wind), demand/load, and load types, define parameters that characterize hypothetical microgrid. Document in *Technical Description: Methods*. | Allison to lead, everyone to contribute |
| 3 | Define load/customer categories & develop rank ordering | Define load/customer categories that we will include within our model (e.g., hospital, commercial buildings, residential buildings, etc.). Assign a score for each to each load/customer category indicating priority associated with powering it. Potentially assign different priorities at different points in outage. Document schema in *Technical Description: Methods* section of report. | Jake to lead, everyone to contribute |
| 4 | Develop mathematical model | Based on previous tasks, develop system of equations that characterize battery state-of-charge, power demand, power generated by solar and/or wind available to the grid, benefit derived from powering loads, and other relationships as needed. Document approach in *Technical Description: Methods* section of report. | Jack, Allison, & Patrick to lead, everyone to contribute |
| 5 | Implement mathematical model in Python | Implement mathematical model defined in Task 4 in Python, and document output (i.e., optimal hourly schedule of which loads are/aren’t powered) for chosen outage duration. If time allows, vary parameters (e.g., battery capacity or a battery outage, wind/solar available, outage duration, a disturbance to load, etc.) and document changes to optimal hourly schedule, and/or incorporate Monte-Carlo simulation of wind/solar availability (and potentially other parameters) to account for uncertainty. Document findings in *Technical Description: Results* section of report. | Patrick & Maya to lead, everyone to contribute |
| 6 | Contextualize findings | Based on findings, discuss broader implications as a group, and document in *Discussion* and *Summary* sections of report. Update *Abstract* and *Introduction* based on results/discussion. | Jake to lead, everyone to contribute |
| 7 | Develop presentation | Develop slides and rough script for in-class presentation. | Everyone to contribute |

# Summary

This study will optimize the dispatch schedule of microgrid energy storage resources, given known load priorities, operational characteristics, and system resource constraints. Microgrids may be able to provide continuous power service to critical facilities and homes during Public Safety Power Shutoffs, and other disturbances to the broader grid that prevent power delivery from outside the microgrid. However, when operating as an island (i.e., not receiving output from the broader grid), a microgrid must provide power using only local generation and storage. The protocol developed here will instruct load scheduling in such an islanded microgrid where local storage resources are unable to meet total demand. As extreme weather events further compromise transmission resiliency in the coming years, more and more energy providers may seek to supplement or altogether replace risky transmission with microgrids that can remain self-sufficient for extended periods. We hope this optimization model can contribute to the wealth of tools for making these microgrids more safe, efficient, and effective, and even potentially extend their useful operational periods.

# References

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1. https://www.cnn.com/2020/09/05/us/california-mammoth-pool-reservoir-camp-fire/index.html [↑](#footnote-ref-0)
2. https://www.cpuc.ca.gov/deenergization/ [↑](#footnote-ref-1)
3. https://www.cpuc.ca.gov/deenergization/ [↑](#footnote-ref-2)
4. These customers are often referred to as “Medical Baseline” customers and have separate rate tariffs: https://www.cpuc.ca.gov/General.aspx?id=12196 [↑](#footnote-ref-3)
5. Page 84: <https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy%27s%20Microgrid%20Initiative.pdf> [↑](#footnote-ref-4)
6. <https://www.researchgate.net/publication/260113379_Modeling_and_Control_of_Microgrid_An_Overview> [↑](#footnote-ref-5)