MEA Talkeetna Microgrid Project: Distributed Generation in Alaska

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Introduction

Alaska is a diverse state that requires innovative solutions for applied energy and power. Due to the fluctuating climate, diverse terrain, and extensive distances between inhabited areas, the use of microgrids and non-wire alternatives (NWA) throughout the state of Alaska is essential. Alaska continues to prove the favorable characteristics of microgrids, its terrain peppered with individual, localized sources of power to support rural communities. Further endorsing localized power are the natural resources abounding throughout the state. Microgrids are an important step in obtaining reliable energy and environmental conscientiousness. In pursuit of reliability and resiliency, Matanuska Electric Association (MEA) is interested in investing in NWA to support customers who are branching off of long, radial feeders that have proven to provide unreliable power.

Purpose

This project consists of the conceptual design, engineering analysis, and economic feasibility for the implementation of microgrids along an existing long radial feeder in Talkeetna, Alaska. In support of MEA's reliability goals, microgrid and non-wire alternatives with potential broad applications in other low reliability areas are analyzed and applied to a site with a large tourism operator member. The modeling process will give reliable information and specifications required for the establishment of a new microgrid in support of the pre-existing feeder.

Methodology

Homer Modeling

The initial phase of this project involved preliminary analysis with HomerGrid and HomerPro. Both HomerPro and HomerGrid approach the modeling process in the same way. Both simulate a system for one year, optimize the system economically with Net Present Cost (NPC) analysis, and adopt sensitivity analysis to determine what matters and when.

Analysis began with HomerGrid. HomerGrid was ideal for the initial stages of modeling. Through many iterations with this modeling tool, I was able to evaluate estimated loads with the addition of renewable integration incentives, outage simulations, and solar profiles. Starting with insufficient data and constraints, I found the preloaded costs and definitions for technology and renewable resources to be very helpful in allowing me to quickly run simulations without getting bogged down with small details.

Notably, HomerGrid excels in simulating islanded microgrids. In particular, it is often used in looking at grid reliability through infrequent extended outages such as natural disasters ("Which HOMER Model is Right for You?," n.d.). As the Talkeetna Microgrid Project formalized, this feature proved to be uncharacteristic of both the current situation and the objective of the project.

HomerPro, however, proved to be more accessible and multidimensional than HomerGrid for this design. The modeling process continued with this software. Fortunately, the same inputs are required for both softwares, so the research and data accumulation up to this point continued to provide honed results for the modeling. HomerPro proved essential in sizing components to cover the required loads in this microgrid.

"The analysis and design of micropower systems can be challenging, due to the large number of design options and the uncertainty in key parameters, such as load size and future fuel price. Renewable power sources add further complexity because their power output may be intermittent, seasonal, and non dispatchable, and the availability of renewable resources may be uncertain. HOMER was designed to overcome these challenges" (Lambert). For this reason, HomerPro was used in this project to determine which components should be used in the grid and the sizing of this infrastructure.

Data Request

Throughout this modeling process, I formulated a preliminary data request with Microgrid Design Toolkit (MDT) input requirements. Key components from this request such as outage frequency, duration and location, aggregated load data for the substation, and one line diagrams for the substation were received early on. Some of this information, especially the outage and load data, continued to improve the HomerPro models. As more data became available, the models began to converge to similar results. Principally, diesel generators provided the lowest net present cost (NPC), while low cost solar and diesel mingled in similar costs of energy (COE). Because Homer systems optimize based on NPC, diesel generators repeatedly proved to provide the cheapest and most reliable backup source of power through the simulated outages. The data used in obtaining these results is located in this document.

Microgrid Design Toolkit

The Talkeetna Microgrid Project is unique in several ways. One of the most important aspects to keep in mind is that this model accumulates the loads along a long radial feeder that provides unreliable power across this expansive scope. The drastic distances and typical Alaskan environment are not accounted for in HomerPro. The placement of these components and the number of microgrids are pertinent to the modeling process, and HomerPro is unable to simulate these details.

Microgrid Design Toolkit (MDT) is unprecedented in modeling one line diagrams, splitting up assets, component reliability, separated loads, and multi-objective optimization. "The software capabilities include the technology management Optimization (TMP) application for optimal trade-space exploration, the Microgrid Performance and Reliability Model (PRM) for simulation of microgrid operations, and the Microgrid Sizing Capability (MSC) for the preliminary sizing studies of distributed energy resources in a microgrid" (Eddy). Moving forward with MDT ensures that important aspects of this project, such as topology for our components, failure modes, and multi-objective optimization will be integrated into the analysis.

MDT is a highly specialized, recent addition to the microgrid modeling world. Being relatively new, this software is not always user friendly, not easily shared between users, and often difficult to decipher. The majority of my time later on in the internship consisted of many educative runs of the program to determine why it was crashing, analyze non-feasible results, and determine the algorithms behind important aspects of the solutions. Initiating regular meetings with ACEP and MEA, working as a team to determine flaws in both the inputs and outputs, and continuing to integrate new information into the models were all important aspects of this project.

This software's intricate answers often required intricate inputs. Nathan Green was able to provide input for solar profiles and outage curves. Regularly meeting throughout the troubleshooting process, Green and I were able to analyze results, identify bugs in the software and process new data to input in the program. Congruently, we also had the opportunity to meet with John Eddy, one of the original developers of MDT, to discuss the proper use of the program and how to discern important aspects of the model's results. Through this meeting we were able to understand the code behind some results such as MTTR (mean time to repair) and MTBF (mean time between failures), as well as discuss potential areas for improvement.

Data Analysis

In modeling with both MDT and Homer, there were areas where data was not provided or was not usable in its existing form. Data analysis continues to take place in both load and outage data for this project. The scope of this project continued to expand throughout the internship, initially with a specific customer in mind and expanding to multiple microgrid placements over the entire feeder. Adapting and adjusting the data for these jobs was crucial.

For example, while working with the provided load data for three aggregated load sections branching from the Stevens substation, John Eddy discovered that MDT was unable to handle the scattered negative values throughout the document. After further investigation, Nathan Green detected several long outages that were affecting the load values. Specifically, an outage occurring on October 31, 2019 that spanned from approximately 11am to 3pm affected both TS415 (which provides power along the Parks highway) and TS425 (which provides power along the Talkeetna Spur). In order to continue to provide power through this outage, the loads were combined and fulfilled through a normally open circuit. In this circumstance, there is no way to know exactly how much load was from TS415, but since both TS415 and TS425 are usually close in value, we estimated the load as half of the total running through the normally open circuit throughout the duration of the outage.

Another area in which continued adaptation of data was required was in calculating MTTR and MTBF from the outage data given. With the current version of MDT, it is often difficult to find the correct form and placement to indicate outages and failure modes. In order to account for this constraint, separating load sections based on the outages occurring within each section became an important aspect of modeling the entire system. However, with hundreds of lines of outage data available and time-consuming methods to determine the outage location, this became another area to practice estimation and data analysis. In order to get the overall outage data in the correct form, specifically with the time between occurrences modeled as an exponential curve and the duration modeled as a log normal curve, Nathan Green created a python code to obtain a fair estimate of the outages. When reducing the number of data points and separating load sections, this task became highly inaccurate and time consuming. Although my internship is ending before the final stages of this project, this is a continued area of work for the rest of the team.

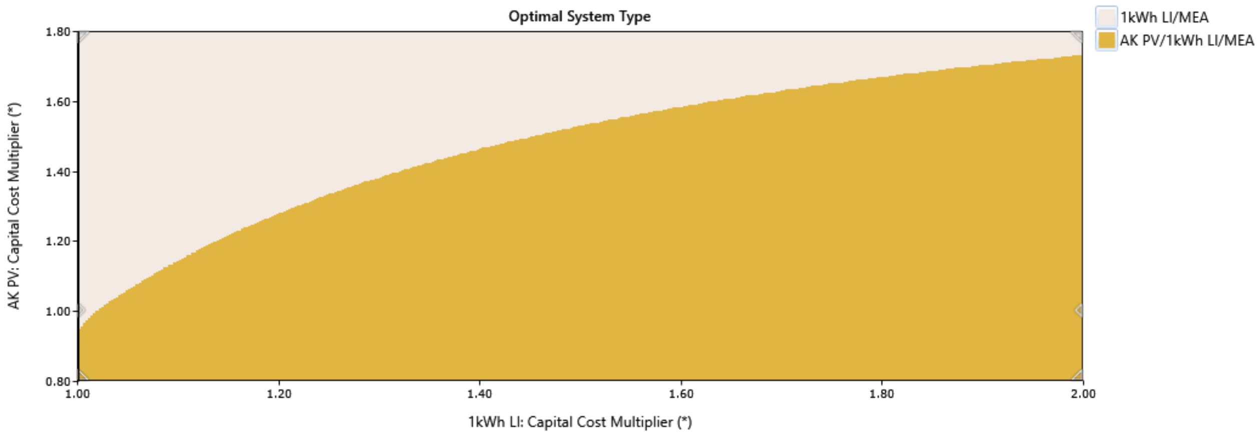
There were other areas of this project where data was not available through MEA. For example, determining the sizing, costs, and maintenance values for potential components was an important result of research, calling vendors for specific prices, and often results given from the modeling software. Due to some of MDT's weaknesses, integrating component sizing from HomerPro proved useful. For example, MDT contains regularly distributed values for generator sizes from 100kW to 3MW. This software does not optimize for unique sizing such as 450kW or 50kW, and is easily overloaded when adding additional options for sizing. For this reason, I continued to utilize HomerPro in accurately sizing diesel generators, PV, and storage to implement in MDT.

Additionally, there were aspects of data given that were used in other areas of study in this project as well as in modeling. One example of this is the transformer data we originally requested for MDT modeling. This data is useful in dividing our larger loads into practical, separated segments that would benefit in determining component placement. As well as offering advantages in MDT modeling, this data was used by Mohammad Kapourchali in his reliability analysis of the project.

MDT inputs are divided into two sections: sizing inputs and islanded inputs. Interestingly, these sections run independently from each other. This project focuses on the islanded inputs, where the given microgrid is run through a series of simulated outages over a period of 1000 years. The major inputs for this section - loads, outages, and solar profiles - were stated earlier. Other data that has been used includes generator, PV, and storage costs, as well as line, transformer, and switch specifications. While much of this data has been provided, many costs, sizes, and lengths have been researched or averaged from the material received. In addition, finding load points along the diagram by aggregating transformer data is still in progress. Since data is continually becoming more accurate, I have created many models to demonstrate these design changes.

Results and Discussion

In the beginning phases of this project, I began with basic models in HomerGrid and HomerPro. Using the original values in Homer, diesel generators repeatedly provided the lowest net present cost system. When implementing sensitivity analysis to reduce the cost of solar and storage, the ideal system involved a combination of primarily diesel generators with small amounts of solar implemented. In order to further obtain Alaska-specific results, I obtained general installation and operations and maintenance costs from Alaska vendors. However, MEA discouraged my research in this area, as they are focusing on solely renewable alternatives unless the divergence in cost was fairly extreme. Supporting MEA's renewable goals, I found the diesel costs to be about $1000 per kW, which is double what Homer estimated. Additionally, although the costs for solar and storage were fairly high in studies conducted a few years ago, these values have continued to decrease significantly. With these more accurate prices for generator, solar, and storage investments in Alaska, my optimizations continued to improve and converge towards more implementation of storage in the system.



This graph, by Michelle Wilber, shows HomerPro optimization results for PV costs between $1.6/W - $3.6/W and storage costs between $550/kWh - $1,100/kWh

Although integrating solar along this feeder was preferable, it was often not an economically feasible option, even at costs as low as $1.77 per watt. However, after applying Alaska specific costs for diesel generators, non-renewable energy was rarely found in the Homer solutions. In this way, the results began to fit the renewable energy goals MEA had set, although maintaining mostly storage solutions versus PV.

MDT continues to be an important part of this project's system analysis. With its important features in multi-objective optimization and splitting up assets and loads, the results produced by this software will be incredibly useful in designating components and their placement on the grid. In addition, it provides an in-depth analysis on microgrid effectiveness and efficiency. "(The MDT's) ability to optimize over discrete, categorical, non-linear, multi-objective spaces make it ideal to solve problems involving topology and asset selection, energy and asset reliability calculations, and a rich set of performance measures" (Eddy). In this way, even with limited constraints or the lack of explicit goals, MDT allows for the analysis of seemingly unlimited possibilities to determine the specific placement and operation of a modeled microgrid.

During this internship, considerable progress was made on the use and understanding of MDT. Although bugs have made many results unusable in previous models, John Eddy provided significant technical and engineering support for both using the program and interpreting results. My current models in MDT are very simple designs containing load sections and separated generation with specification options. There are several investigations still in progress that will continue to contribute to conclusive results from the model. One of these examinations is in aggregating transformer loads to obtain load points along the one line diagram. We are also in the process of analyzing outage data for the feeder, determining placement, duration, and frequency for specific parts of the grid and eventually applying this data to the individual components preexisting on the grid. With these results, the MDT model can become more advanced with sized transformers, additional load additions, switch placement, line length, and component failure modes. These additions will allow for more complicated and interesting results from the model, further converging upon the microgrid solution.

There were many complications in implementing MDT in this project. There were times in running simple models where the system would crash repeatedly and without error messages. Often, error messages were difficult to interpret. Troubleshooting and modifying my models with Nathan Green was invaluable. In addition, John Eddy's support through meetings, modifications, and explanations prompted significant growth in the appropriate use of this new software. Although still in the process of obtaining useful results, MDT continues to prove invaluable to solving the intricate problems introduced in this project.

Conclusions

The current goals of this project are to provide an intricate microgrid model with engineering and economic solutions, as well as allowing the model to be applied to similar long radial feeders on the MEA grid. With these goals in mind, significant progress has been made.

HomerPro and MDT models have been made, with continual adjustments and improvements being applied. To create a more accurate model, specific costs for implemented architecture, more diverse load distributions and specified outage placement and component failure modes can be added as data continues to be evaluated.

In creating a reproducible model to be applied in other areas on the MEA grid, I have formulated a document that contains input information, sources, and links to the original data sources and excel sheets. The document can be located here, and the folder containing all references can be located here.

One of the most important results of my work has been my work on MDT. Since there are very little sources of information regarding the software, the conversation held with John Eddy helped to answer many questions that were not addressed elsewhere. The document with our questions and Eddy's answers is here. In efforts to pass along any knowledge I have regarding the software, I have continued to work in conjunction with Nathan Green. In addition, Nathan Green and I were able to host a demo for Mohammad Kapourchali to further expand project knowledge.

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