High-Level Design of a Distribution Microgrid

DESIGN DOCUMENT

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List of figures/tables/symbols/definitions (This should be the similar to the project plan)

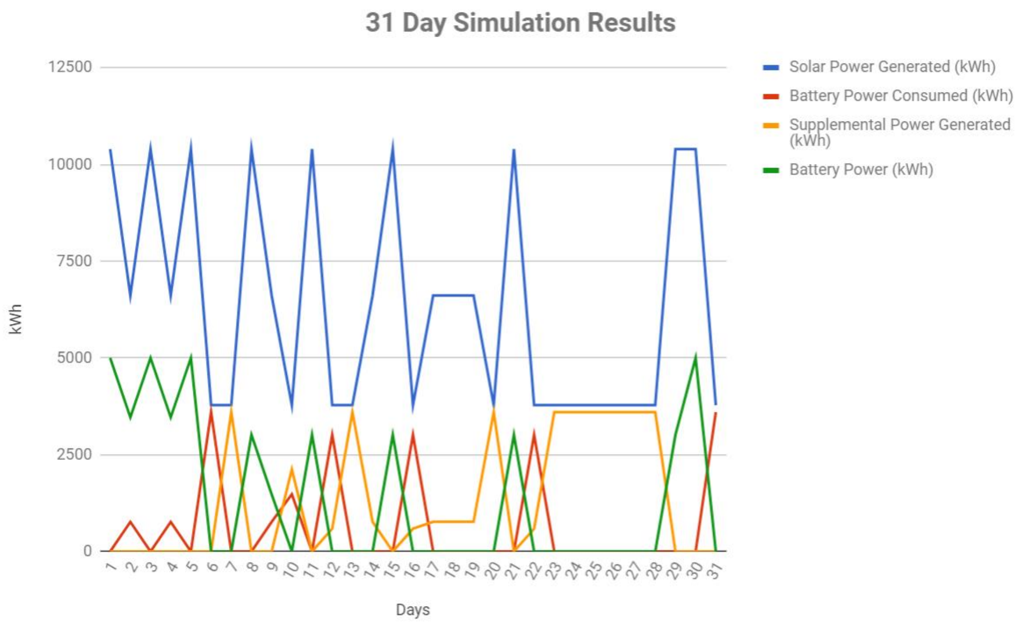

Figure 1: This is a chart that shows where the power is on each given day of the simulation.

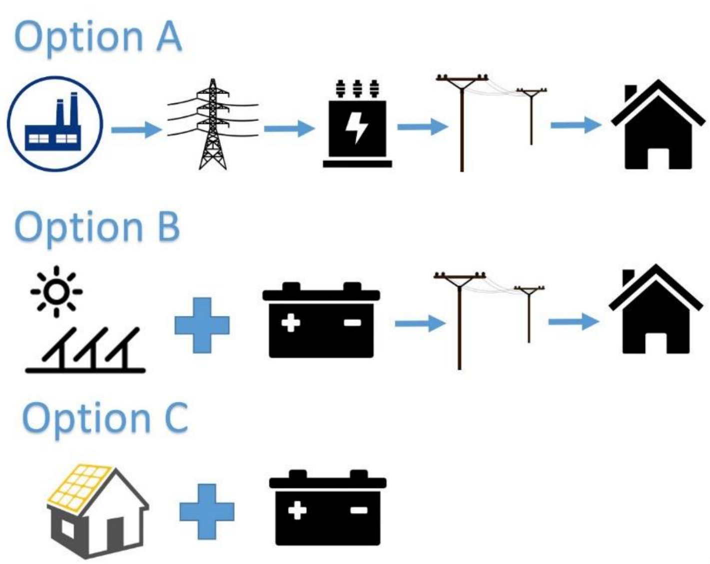

Figure 2: This is a diagram which explains the scenarios of our project; option A is grid connection, option B is large local generation, and option C is small local generation. The main focus of this project will be with option B.

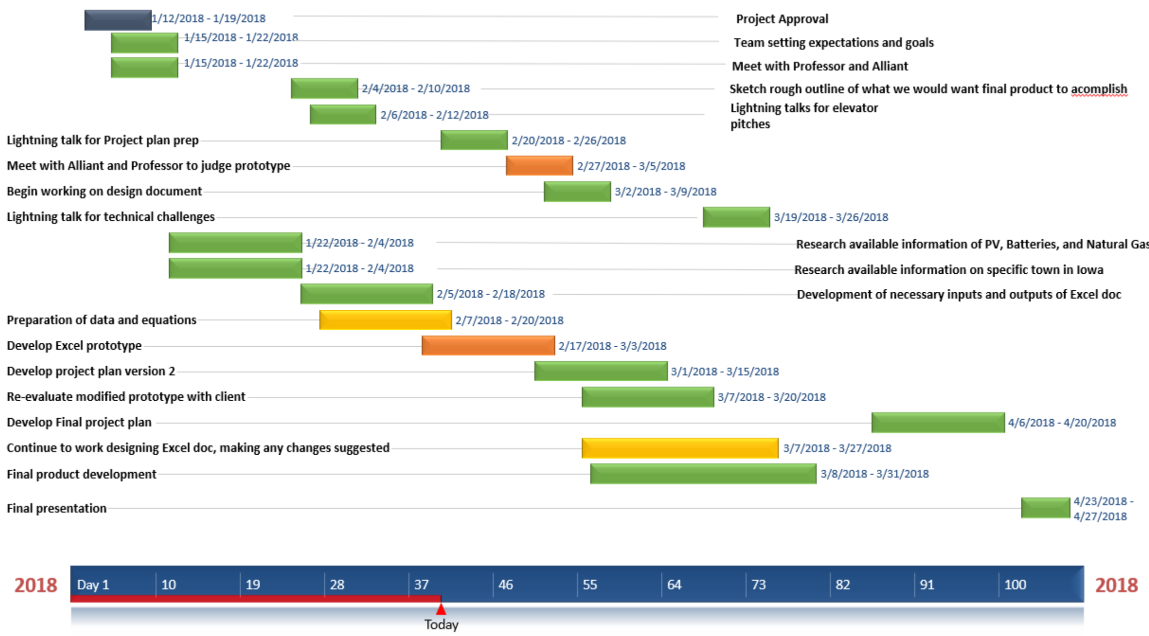

Figure 3: This is a Gantt chart showing our team's project schedule through the first semester.

1 Introduction

1.1 Acknowledgement

Our design team has been in collaboration with Daran Lamos and Logan Heinan of Alliant Energy. Our team advisor, Professor James McCalley, has also been a vital resource in the direction of our design.

1.2 Problem and Project Statement

Alliant Energy has tasked our team with creating a spreadsheet that will calculate the amount of distributed energy needed to meet the kWh demands of a small town in Iowa. This town is miles from the grid and requires long transmission lines to provide power to the town, so it might be more cost effective to turn it into a microgrid.

We will be calculating the initial cost of incorporating a combination of solar panel generation and battery storage to meet various proportions of the town's kWh demand. Once these combinations of solar and battery are generated, we will examine the effects of geographic location, average sunlight, and variable kWh demands on the efficiency of microgrid designs.

1.3 Operational Environment

Our end product will be an excel spreadsheet that will have variable inputs and outputs which model a microgrid environment. This will be used in an office setting by Alliant Energy.

1.4 Intended Users and Uses

The end user of our product is Alliant Energy, specifically for their distribution team. They will be able to use this spreadsheet to estimate the efficiency of a microgrid and create bid sets off of.

1.5 Assumptions and Limitations

Assumptions

- Our microgrid location is Nichols, Iowa
- The microgrid is to be designed with the intent of being completely self-sufficient
- We will be using Seraphim SRP-6MA solar panels
- We will be using Ideal Power SunDial Plus battery/inverters
- The reliability of the system will be tested for a 31 day period
- We will assume worst-case scenarios when making calculations
- Any load not supplied by the solar panels and batteries will be supplied by a natural gas turbine
- Our demand is based off of a peak load demand in Nichols, Iowa on a typical summer and winter day
- We will be using the finished Nichols, Iowa microgrid design to test the effects of varying geological locations, average sunlight, variable kWh demands, and consumer growth.

Limitations

- We will <u>not</u> be factoring in mechanical failure rates of the equipment
- The effects of sunlight on the system is an estimate based off of past sunlight patterns and isn't entirely predictable
- The load growth on the system is estimated based off of past rates of growth in Nichols, Iowa
- Our current system's demand is based off of daily peak demands and isn't a comprehensive demand schedule

1.6 Expected End Product and Deliverables

- The end product will be in the form of an excel spreadsheet
    - Excel spreadsheets are widely used
    - Our end product may be edited for various projects that Alliant Energy may encounter in the future
    - The spreadsheet will include links to any necessary resources such as data sheets, solar radiation maps, calculations, etc.

- Alliant Energy will have two spreadsheets available for their use at the very end of the project in December 2018.
    - A template to enter input information and outputs will be calculated
    - A template that has been filled out to show the Nichols, IA microgrid
        - This will also serve as an example spreadsheet for the template to be filled out for other projects

2. Specifications and Analysis

2.1 Proposed Design

- Our team has created a prototype for our microgrid design. This prototype is capable of simulating a 31 day period of operation with a variable input microgrid.
    - Variable Inputs
        - Solar Radiation/m^2
            - This input is based on the average sunlight at a given period of time in Nichols
            - Solar radiation is divided up into three categories: High, Medium, and Low solar radiation days
        - Peak Power Usage
            - This input is based on the load demand given to us by Alliant Energy
        - Quantity of low solar radiation days where there is no solar panel generation
    - Fixed Outputs
        - Quantity of solar panels used
        - Cost of panels
        - Quantity of batteries used
        - Cost of batteries
        - Total battery capacity
        - Total Solar Generation Power
            - This will be a product of the solar radiation and quantity of panels
        - Natural Gas Turbine Generator Size
            - The size of generator will depend on the proportion of the load being supplied by the solar panels and batteries
        - Cost of Natural Gas Turbine Generator
        - Total cost of the Microgrid system
    - Specifications (fixed)
        - Peak output of solar panels
        - Efficiency of solar panels
        - Cost/kW for solar panels
        - Capacity of each battery
        - Efficiency of batteries
        - Initial cost of solar panels and batteries
        - Cost/kW for Natural Gas turbines

2.2 Design Analysis

We began by defining our project, the scope of our team, and the tasks of each member. We then began collecting information to be compiled in our prototype. We've come to understand that it isn't all that simple to model a microgrid in a spreadsheet because there are so many inputs and outputs that will affect the system.

- Strengths of the design
  - Easily understandable calculations
  - Majority of the desired inputs are able to be implemented
- Weaknesses of the design
  - There are still inputs that need to be researched more in depth
  - Our data and tables are a jumble due to it being a prototype
  - The inputs and outputs don't have descriptions

3 Testing and Implementation

3.1 Interface Specifications

For testing the different systems we design for Nichols, we will be creating a simulation program to test different types of sun radiation and load profiles for many different scenarios. We will be designing the program to simulate winter and summer load profiles, as well as low, medium, and high solar days. This simulation will be put into the final product that outputs design for different microgrids.

3.2 Hardware and software

For testing our system, we will be using Excel to simulate a real-world profile of a day's load, and solar generation. This software will be using summer and winter profiles of load, as well as high, medium, and low solar generation throughout the day. After the load and solar generation is manually put in, the program will track the solar power generated, battery power consumed, and supplemental power generated throughout each hour during the day. Lastly, at the end of each column will be the excess demand not met.

3.3 Functional Testing

In the simulation Excel document, we will be tracking the system to see the amount of solar generation, and then the needed battery and supplemental generation power needed. Because we are given the city's usage in kWh, we will be tracking all variables with kWh. After simulating the system with different profiles, we will be accepting the system based on the excess demand. Accepted designs will have a minimal amount of excess demand, zero excess demand is wanted but not always needed for an efficient design.

3.4 Non-Functional Testing

In addition to testing the performance of the system under normal conditions, we will be testing the system under intense profiles of high load, and low solar generation. We will also be using actual data from Alliant of winter profiles from this current winter, and this summer for testing in the fall semester. In terms of usability, if the system can supply enough power to minimize the excess demand, the system will be compatible with Nichols.

3.5 Process

Refer to Figure 3 for the project timeline and Figure 2 for the general concept of the project.

In our prototype we are currently using a timeline of a day, but we are going to be changing that to hours. When calculating the solar generation, and power supplied we will be first starting with solar power directly supplying the load, and then using extra power to charge the batteries. When solar power is not enough to supply the load, battery power will be consumed until the supply is met. When there is not enough battery, the supplemental generator will be used to power the load. When the solar panels, batteries, and generator are not enough, there will be excess demand. Below in figure 1 is an image from our current prototype with the order of power being used to supply the load from top to bottom.

1		Day 1	Day 2	Day 3	Day 4	Day 5
2	High, Medium, Low Solar Day (1,2,3)	1	2	2	3	3
3	Solar Power Generated (kWh)	10395	6615	6615	3780	3780
4	Battery Power Consumed (kWh)	0	385	385	1855	0
5	Supplemental Power Generated (kWh)	0	0	0	1365	3220
6	Excess Battery Power (kWh)	3395	2625	1855	0	0
7	Excess Demand	0	0	0	0	0

Figure 1 Screenshot from the current simulation prototype.

3.6 Results

We have not tested any designs for Nichols due to the feedback from our client about our first prototype. We will be changing our design from a timeline of days to hours due to the various levels of load and solar generation during a 24 hour period. We will come back to this when we perform testing on the different systems for Nichols.

4 Closing Material

4.1 Conclusion

Thus far in the semester our team has defined the project scope, brainstormed for our design, created and Project Plan and Design Document, and created a version 1 of our prototype.

Our goal for this project is to provide Alliant Energy with a functional spreadsheet which will model and simulate a microgrid system with any given demand and environmental conditions. Our plan of action, or solution, for this design is to approach it with a test-fail approach. Because weather conditions are so unpredictable, we will be designing this system with the worst case scenarios in mind. When a system is connected to the grid, it has backup power readily available. However, an isolated microgrid doesn't have backup grid connection. We must be confident that our design is reliable and efficient. Our simulation will be able to demonstrate the responsiveness of a microgrid to weather and demand conditions.

4.2 References

References

[1]A. Haque Khan and A. Rahman, "A Noble Design Of DC Micro Grid For Rural Area In Bangladesh", 2015. [Online]. Available: https://www.researchgate.net/profile/Alimul_Khan2/publication/271831897_A_Noble_Design_Of_DC_Micro_Grid_For_Rural_Area_In_Bangladesh/links/54d2f8c90cf2b0c6146c7296/A-Noble-Design-Of-DC-Micro-Grid-For-Rural-Area-In-Bangladesh.pdf. [Accessed: 01- Mar- 2018].

This Research paper provided us with information regarding the design of a system with similar requirements to ours. It specifically helped us conceptualize when we should be switching from battery to supplemental generation and how the demand of the location will be met. It also provided us with information related to estimating the growth of the system depending on the locations needs.

[2]"About Microgrids | Building Microgrid", *Building-microgrid.lbl.gov*, 2018. [Online]. Available: https://building-microgrid.lbl.gov/about-microgrids. [Accessed: 01- Mar- 2018].

This website provided us with information regarding how the system will be disconnected from the grid and how we will have to account for the load of the town. It also gave us information distinguishing various types of loads and how important they are to the Microgrid system.

[3]"About Microgrids", *Microgrid Institute*, 2018. [Online]. Available: http://www.microgridinstitute.org/about-microgrids.html. [Accessed: 01- Mar- 2018].

This website allowed us to explore different types of systems for various different uses. It also defined many terms that will be useful in describing our system. It also explained certain economic factors that will give us a strategy for creating the most economically efficient system.

[4]C. Bravo, "Outback Power Inc. - Global Micro-Grid", *Outbackpower.com*, 2018. [Online]. Available: http://www.outbackpower.com/applications/global/micro-grid. [Accessed: 01- Mar- 2018].

This source detailed a basic design of a Microgrid. It allowed us to define the components we will need to create a self-sufficient system that will meet the demands of our location.

[5]"Solar Panels in Nichols, IA: Solar Companies, Cost, and Installation | Decision Data", *Decisiondata.org*, 2018. [Online]. Available: https://decisiondata.org/solar-by-city/nichols-ia/. [Accessed: 01- Mar- 2018].

This website provided us with solar data for Nichols, Iowa that we will use to size our system. This information along with the demand profile of the town will allow us to create the most efficient system.

[6]"Find How Many Solar Panels You'll Need – In 8 Easy Steps", *Coastal Solar*, 2018. [Online]. Available: https://coastalsolar.com/many-solar-panels-will-need/. [Accessed: 01- Mar- 2018].

This website detailed some of the calculations necessary to size the system according to demand and solar data. It also briefly explained the cost analysis in determining if the system is economically viable for our location.

[7]"Solar Maps | Geospatial Data Science | NREL", *Nrel.gov*, 2018. [Online]. Available: https://www.nrel.gov/gis/solar.html. [Accessed: 01- Mar- 2018].

This source provided us with solar irradiance data for the United States. This will be used later in our design when we expand it to various locations instead of just Nichols, Iowa.

[8]B. Capehart, "Microturbines | WBDG Whole Building Design Guide", *Wbdg.org*, 2018. [Online]. Available: https://www.wbdg.org/resources/microturbines. [Accessed: 01- Mar- 2018].

This website explained the purpose and uses of microturbines. This allowed us to understand how we can use microturbines as supplemental generation for our system. If we don't produce enough solar power, and we don't have any stored in our batteries, then we can activate the microturbines to meet the necessary demand until we can begin producing solar energy again.