High-Level Design of a Distribution Microgrid

PROJECT PLAN

Team Number: 11
Client: Alliant Energy
Adviser: James D. McCalley
Communications Engineer: Nicholas Stitzell
Power Engineer: Joseph Thurin
Power Engineer: Taylor Murphy
Research Engineer: Minoru Fernando
Data Engineer: Remo Panella
Team Email: sddec18-11@iastate.edu
Team Website: https://sddec18-11.sd.ece.iastate.edu

Revised: Version 2, 3/29/18

Table of Contents

List of Figures

List of Tables

List of Symbols

List of Definitions

Please include any definitions and/or acronyms the readers would like to know.

Microgrid: A small network of electrical consumers using a local supply that is usually attached to a larger grid, but with the ability to operate autonomously from the grid.

Distributed Generation: The generation of energy at or very near the location it is consumed.

kWh: kilo-watt hour, a unit of power.

1 Introductory Material

1.1 Acknowledgement

If a client, an organization, or an individual has contributed or will contribute significant assistance in the form of technical advice, equipment, financial aid, etc, an acknowledgement of this contribution shall be included in a separate section of the project plan.

1.2 Problem 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 effectiveness of incorporating a combination of solar panel generation and battery storage into this town. Once this optimal combination of solar and battery is found, we will examine the effects of externalities such as latitude and longitude, average sunlight, and variable kWh demands on the efficiency of the microgrid.

1.3 Operating 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 and shared with their clients.

1.4 Intended Users and Intended 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. This will be shared with clients to demonstrate the economic value of a microgrid.

1.5 Assumptions and Limitations

Assumptions

- We will not need to factor in the economics of the system
- We will not need to factor in the reliability of the system
- We will be using a combination of solar and battery
- kWh and peak demand info is not exact

Limitations

- The effects of longitude/latitude can only be estimated
- Daylight is only an estimate based on past daylight

1.6 Expected End Product and Other Deliverables

At the cumulative end of the project Alliant Energy will have a spreadsheet tool in excel that will allow them to manipulate inputs and outputs relating to their desired microgrid. This excel document will also be programmed to simulate a microgrid environment based on the inputs and outputs entered. We have an external simulation tool, MATLAB, that we will be using to build our simulation within excel. Alliant Energy will not be using this as a project deliverable since they don't desire a MATLAB license and the excel simulation is easy to understand for their clients. Alliant Energy will also be receiving an instruction manual for operating the excel file as an additional deliverable.

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

The objective of the task is to have a spreadsheet which calculates an estimate of the quantity of solar panels and batteries needed to meet the requirements of a given system and simulates the environment of any microgrid.

2.2 Functional Requirements

Understand power system analysis when using equations to calculate system requirements.

Compare different specifications of solar and battery models to find the most efficient applications for this project.

Upload project related materials to course website to organize project and meet course requirements.

2.3 Constraints Considerations

Constraints and Non-Functional Requirements

- Weekly meeting with client and advisor Tuesdays at 4pm
- Upload all project materials to a google folder, and all relevant material to the project website.

As for standard protocols within our team, we will consult one another, our advisor, and client when making decisions. We will also only use credible online sources and information given to us from the client.

2.4 Previous Work And Literature

http://www.outbackpower.com/applications/global/micro-grid

A basic design we might want to implement if we decide that a residential instead of utility system is preferred.

http://www.microgridinstitute.org/about-microgrids.html

Has good defintions of different types of systems under the microgrid image to determine what type of system we want.

https://en.wikipedia.org/wiki/Microgrid

Info under the Microgrid control section I think is most important, help us determine what sort of control systems we want in place for our system.

https://building-microgrid.lbl.gov/examples-microgrids

The examples on the left are very helpful. I haven't read thorugh them all yet but I will check them out tomorrow to see which fits our needs the closest.

https://building-microgrid.lbl.gov/about-microgrids

Images on the right just have a very basic idea of what we are trying to accomplish, good to visualize the components we need to address.

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

I believe the flow chart on page 7 will help us address the various components.

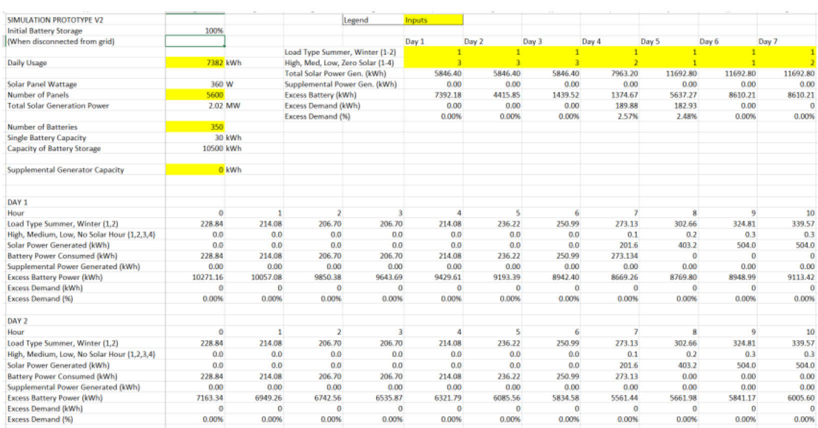
2.5 Proposed Design

A combination system of solar panel generation and battery storage. We will have solar generation providing most of the power and having backup battery storage along with supplemental generators when needed. The quantities of photovoltaic panels, batteries, and generators are determined based off of the simulation environment. The user is able to control the variables being input to create the simulation, and the simulation is used to calculate quantities and costs of the microgrid system which will be visualized in a table and diagrams.

We are utilizing MATLAB as a means to build this simulation in excel. The end-product design will only require the user to input a few things to run the simulation, but we are piecing the extensive calculations and information for the simulation together manually. This is a very long process and not at all feasible for an end product. Therefore we will be simulating large numbers of data points automatically in MATLAB as opposed to constructing the whole simulation in excel off of manually generated variables. This will also give us a greater accuracy in the simulation design since we will be able to run the simulation hundreds of times more in MATLAB than excel.

The diagrams are still in progress, so what is currently available are screenshots of the inputs tab and the 31 day simulation diagram.

Figure 3:



SIMULATION PROTOTYPE V2		
Initial Battery Storage	100%	
(When disconnected from grid)		
Daily Usage	7382	kWh
Solar Panel Wattage	360	W
Number of Panels	5600	
Total Solar Generation Power	2.02	MW
Number of Batteries	350	
Single Battery Capacity	30	kWh
Capacity of Battery Storage	10500	kWh
Supplemental Generator Capacity	0	kWh

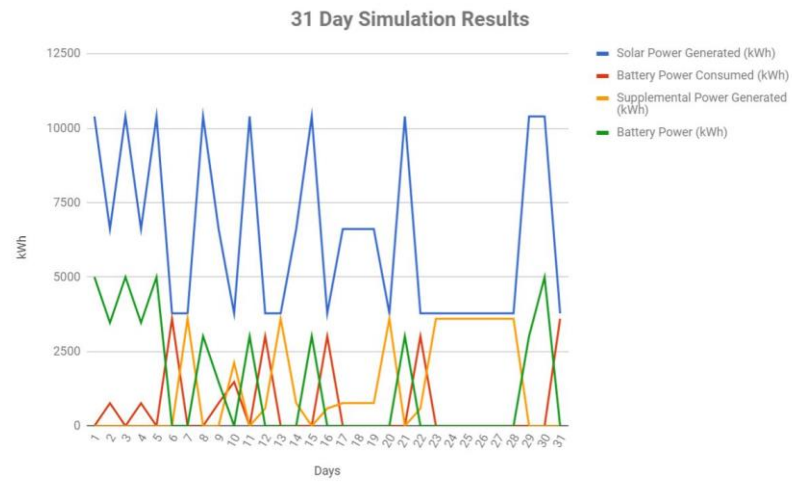
Legend: Inputs

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Load Type Summer, Winter (1-2)	1	1	1	1	1	1	1
High, Med, Low, Zero Solar (1-4)	3	3	3	2	1	1	2
Total Solar Power Gen. (kWh)	5846.40	5846.40	5846.40	7963.20	11692.80	11692.80	11692.80
Supplemental Power Gen. (kWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Excess Battery (kWh)	7392.18	4415.85	1439.52	1374.67	5637.27	8610.21	8610.21
Excess Demand (kWh)	0.00	0.00	0.00	189.88	182.93	0.00	0
Excess Demand (%)	0.00%	0.00%	0.00%	2.57%	2.48%	0.00%	0.00%

DAY 1											
Hour	0	1	2	3	4	5	6	7	8	9	10
Load Type Summer, Winter (1,2)	228.84	214.08	206.70	206.70	214.08	236.22	250.99	273.13	302.66	324.81	339.57
High, Medium, Low, No Solar Hour (1,2,3,4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3
Solar Power Generated (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	201.6	403.2	504.0	504.0
Battery Power Consumed (kWh)	228.84	214.08	206.70	206.70	214.08	236.22	250.99	273.134	0	0	0
Supplemental Power Generated (kWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Excess Battery Power (kWh)	10271.16	10057.08	9850.38	9643.69	9429.61	9193.39	8942.40	8669.26	8769.80	8948.99	9113.42
Excess Demand (kWh)	0	0	0	0	0	0	0	0	0	0	0
Excess Demand (%)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

DAY 2											
Hour	0	1	2	3	4	5	6	7	8	9	10
Load Type Summer, Winter (1,2)	228.84	214.08	206.70	206.70	214.08	236.22	250.99	273.13	302.66	324.81	339.57
High, Medium, Low, No Solar Hour (1,2,3,4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3
Solar Power Generated (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	201.6	403.2	504.0	504.0
Battery Power Consumed (kWh)	228.84	214.08	206.70	206.70	214.08	236.22	250.99	273.13	0.00	0.00	0.00
Supplemental Power Generated (kWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Excess Battery Power (kWh)	7163.34	6949.26	6742.56	6535.87	6321.79	6085.56	5834.58	5561.44	5661.98	5841.17	6005.60
Excess Demand (kWh)	0	0	0	0	0	0	0	0	0	0	0
Excess Demand (%)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Figure 4:



2.6 Technology Considerations

The strengths of the current technology are that local solar generation and battery storage already exists on small and large scales. We will be able to use current examples of local generation and storage for our own design.

The downside is that the technology for solar generation is evolving rapidly and there are no perfect ways to store energy.

One major technology consideration to take into account is our use of excel. Excel is a great tool for laying out information in a user friendly way, which is why our team and Alliant chose this as our deliverable. However, our team needs to be able to run extensive simulations to create the microgrid and we have our limitations in excel, the biggest being that our team isn't able to code in the language that excel runs on. This is why we will be using MATLAB to build the simulation in excel. MATLAB is a tool designed for large quantities of data points and we are well acquainted with this tool.

2.7 Safety Considerations

No safety concerns to consider.

2.8 Task Approach

Describe any possible methods and/or solutions for approaching the project at hand. You may want to include diagrams such as flowcharts to, block diagrams, or other types to visualize these concepts.

2.9 Possible Risks And Risk Management

Possible risks include,

- Using less efficient solar and battery systems than are available
- Confusion with representing information in an intuitive spreadsheet

2.10 Project Proposed Milestones and Evaluation Criteria

Milestones

- Initial combination of solar and battery capable of supplying enough power
- Implementing supplemental generation and 100%, 90%, and 80% power supply calculations
- Duration of distributed generation
- Future changes to system to keep up with increasing kWh demand
- Use Nichols, IA as a basis for design of other similar microsystems
- Model all Milestones in excel

2.11 Project Tracking Procedures

We will be using this project plan and our internal google folder to track the overall progress of our project.

2.12 Expected Results and Validation

The desired outcome of our project is a satisfied customer and project advisor.

We will consume the effectiveness of our project on a high level by testing our spreadsheet with many different scenarios for microgrids.

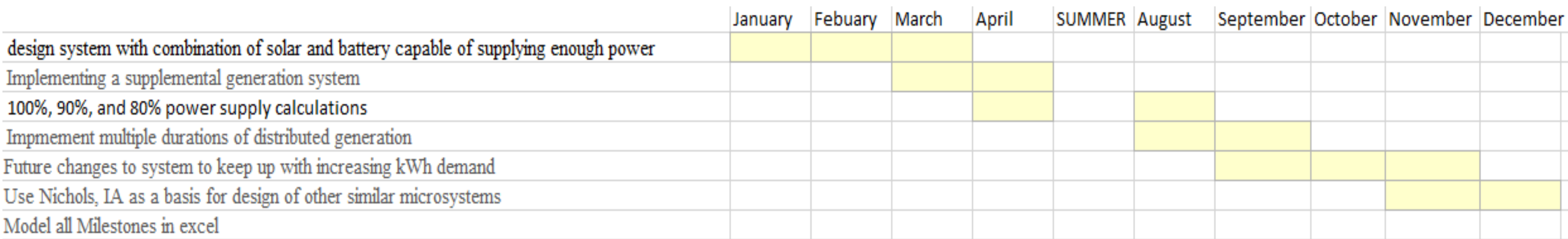
2.13 Test Plan

Input variable load demands to account for all possible scenarios.

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline

The below Gantt chart is an early estimate of our project timeline based on the objectives our client gave us. We've listed the primary objectives below and gave them each a designated window that we expect to have them finished by. This is an early estimate and is subject to change as the client's needs and the project scope change.



3.2 Feasibility Assessment

A realistic end-project will be an excel spreadsheet that estimates the efficiency of a solar and battery microgrid. It will be challenging to make an all-encompassing spreadsheet, so we will base our calculations off of our microgrid design for Nichols, Iowa and extrapolate this information to other potential locations. We only have load data from Nichols, Iowa for half of a year, so we will be simulating the second half of the year. This will be feasible as we will be using similar load profiles from other towns to estimate the hourly load at any given time of year. This will not be 100% accurate, as it is a future projection. It will not be feasible to use this design as an exact estimate for costs seeing that accurate cost projections aren't available without a full-year load profile from Nichols, Iowa. The initial cost of photovoltaic and battery technology also changes frequently enough to make a long term cost projection likely obsolete.

3.3 Personnel Effort Requirements

Milestone	Nick	Joe	Taylor	Remo	Minoru
System combination	Understand and communicate	Use the specs from the client and	Use the specs from the client and	Model the equations used and the	Research to fill any information

of solar and battery	the process/outcome with client and advisor through weekly status reports and other course material	Minoru to design an efficient generation and storage system for Nichols, IA	Minoru to design an efficient generation and storage system for Nichols, IA	inputs/outputs in an excel spreadsheet to send to the client	gaps and to find efficient solutions
Implementing a supplemental generation system	Understand and communicate the process/outcome with client and advisor through weekly status reports and other course material	Use the specs from the client and Minoru to design an efficient supplemental generation system	Use the specs from the client and Minoru to design an efficient supplemental generation system	Model the supplemental generations effect on the microgrid through excel	Identify possible supplemental generation solutions. (ex: diesel vs natural gas)
Power Supply Calculations	Understand and communicate the process/outcome with client and advisor through weekly status reports and other course material	Use a combination of solar, battery, and supplemental generation to meet the different levels of power supply	Use a combination of solar, battery, and supplemental generation to meet the different levels of power supply	Model the power supply as a variable input based on the amount of power supply being delivered by the microgrid	Find economical differences between different levels of power supply
Durations of distributed generation	Understand and communicate the process/outcome with client			Find out how long the system will be operable under normal and extreme	Find out how long the system will be operable under normal and extreme

	and advisor through weekly status reports and other course material			conditions in the system location	conditions in the system location
Future changes with increasing demand	Understand and communicate the process/outcome with client and advisor through weekly status reports and other course material	Come up with solutions to combat the increasing demand on the microgrid system	Come up with solutions to combat the increasing demand on the microgrid system	Model future estimates for inputs/output in excel	Look at the possible constraints to growth with our current design
Use Nichols, IA as a basis for design	Understand and communicate the process/outcome with client and advisor through weekly status reports and other course material	Design the microgrid system to meet the kWh requirements sent from client	Design the microgrid system to meet the kWh requirements sent from client	Distinguish in the excel chart the microgrid design for Nichols vs any other systems	Find any externalities on the system coming from Nichols, IA and its surrounding environment
Model all milestones in excel	Understand and communicate the process/outcome with client and advisor through weekly status			Work with Nick to ensure that the excel spreadsheet accurately represents our microgrid design in an intuitive way	

	reports and other course material			for the client to handle.	

3.4 Other Resource Requirements

No other resources will be required.

3.5 Financial Requirements

There are no financial requirements for our project.

4 Closure Materials

4.1 Conclusion

Ultimately, we will be providing a spreadsheet that allows Alliant Energy to see the costs/benefits of creating a microsystem in Nichols, IA. The spreadsheet may also be used for other similar systems, but Alliant is addressing Nichols because it is a far distance from interconnection and has promise of being a candidate for a microgrid.

4.2 References

"About Microgrids." *Microgrid Institute*, www.microgridinstitute.org/about-microgrids.html.

Bravo, Cristian. "Micro-Grid." *Outback Power Inc. - Global Micro-Grid*, www.outbackpower.com/applications/global/micro-grid.

building-microgrid.lbl.gov/about-microgrids.

building-microgrid.lbl.gov/examples-microgrids.

Khan, Alimul. *A Noble Design Of DC Micro-Grid For Rural Area In Bangladesh*. 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++.

"Microgrid." *Wikipedia*, Wikimedia Foundation, 5 Feb. 2018, en.wikipedia.org/wiki/Microgrid.

4.3 Appendices

No appendices at this time.