High-Level Design of a Distribution Microgrid

Senior Design Team 11
Website: https://sddec18-11.sd.ece.iastate.edu/

Client: Alliant Energy
Darin Lamos and Logan Heinen of the Distribution Engineering Department
Faculty Advisor: Professor James McCalley

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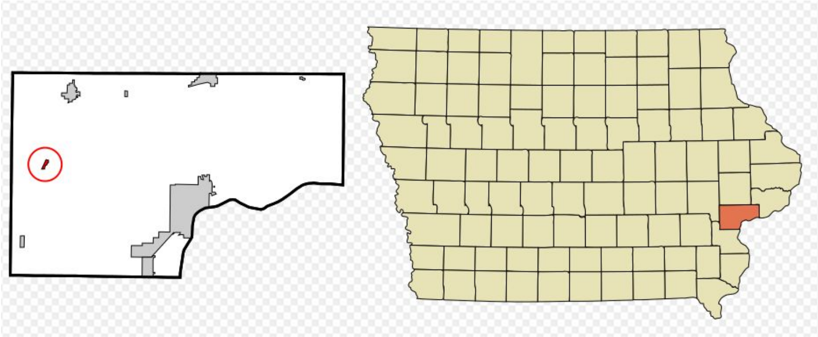
Problem Statement

Alliant Energy has tasked our team with creating an Excel tool that will calculate the ideal combination of solar panels, batteries, and supplemental generation needed to meet the kWh demands of Nichols, 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 create a microgrid in Nichols.

Population: 361
Peak Demand: 630 kVA for 3 hours
Total Annual Load: 2,231 MVA
Fed via grid interconnection



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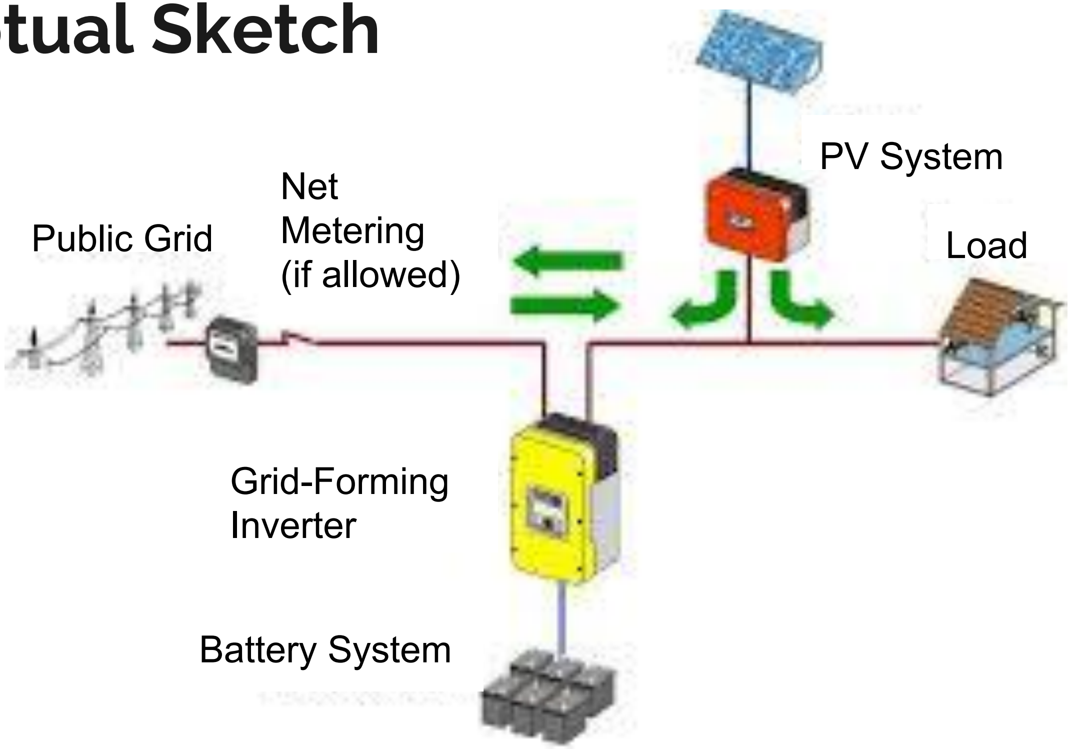
Conceptual Sketch



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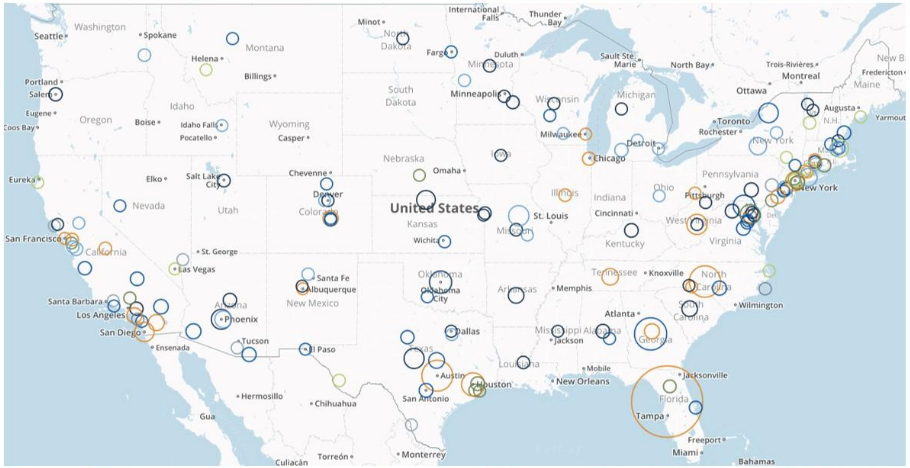
Market Survey

- Few island microgrids
- Evolving Photovoltaic technology
- Remote towns require long transmission lines
- Philippines Microgrid 2018
  (2MW Solar, 1.5MWh Battery, Diesel Gen 1,260 kW)

Map of Operational Microgrid Deployments by End-User Type Across the Continental U.S.*



■ Commercial ■ Military Installation ■ University/Research Facility ■ City/Community ■ Public Institution ■ Island ■ Remote Community ■ Multiple End User Types**

Source: GTM Research, U.S. Microgrid Tracker Q3 2017

* The size of the bubbles correspond with the total capacity (MW) installed in that location.
** Microgrids are mapped based on city location; when multiple microgrids are in the same city they may get the multiple end user designation. In some cases for data privacy, data is given at a state or national level. In these cases, the microgrids are mapped at the center of the state.

Figure 1

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Functional Requirements

- The simulation environment shall include solar radiation, generation, and load.
- The design will consist of solar panels, batteries, and supplemental generation from diesel fuel generators.
- The design will identify the quantity of solar panels and batteries required to meet the desired load.
- The design will quantify the relationship between Net Present Value ($/kWh) of the system and demand not met.

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Non-Functional Requirements

- Visual representations of cost vs efficiency (demand not met)
- Simulation to test for a year of data
- Show other possible combinations in separate tabs
    - 100% Solar Combinations
    - Combinations With More Excess Demand
- Condense all important information into one user interface

Technical Constraints/Considerations

- The final deliverable shall be in the form of an Excel spreadsheet
- The only sources of power for the microgrid shall be solar panels and batteries
  - Supplemental generation is added for demand not met

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Potential Risks & Mitigation

- Accuracy of future load growth and PV and battery quantities to supply the load
    - The growth of a town can only be estimated based on past trends and would affect the growth of the microgrid
    - The ratio between the quantity of PV and batteries is dependant on the weather of the microgrid location.
        - For example, a location with less solar radiation will require more solar panels to charge the batteries and supply the load, rather than a location with more solar radiation.

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Resource/Cost Estimate

- Our project does not require any funds
- All necessary resources on data, costs and technology specifications for the Nichols system is provided by Alliant

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Project Milestones

First Semester:

- Initial combination of solar and battery capable of supplying enough power
- Simulating the microgrid for one week, one month, one year
- Implementing supplemental generation and 100%, 90%, and 80% solar supply

Second Semester:

- Outputting the optimal combination of panels, batteries, and supplemental generation
- Recommending 3 different combinations for user inputted costs and excess demand
- Using the simulation to model the cost and reliability of panel and battery combinations

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Detailed Design - Semester 1

SIMULATION PROTOTYPE V3			Legend
Initial Battery Storage	50%		
Month	2	February	
Average Daily Usage	7,308	kWh	
Solar Panel Wattage	360	W	
Number of Panels	5,555		
Total Solar Generation Power	2.00	MW	
Number of Batteries	200		
Single Battery Capacity	30	kWh	
Capacity of Battery Storage	6,000	kWh	
Total Initial Battery Charge	3,000	kWh	
Supplemental Generator Capacity	-	kWh	

Generate Random Usage
(90% to 110% of Average Daily Usage)

Generate Random Solar Days
(1, 2, or 3)

Print Daily Totals

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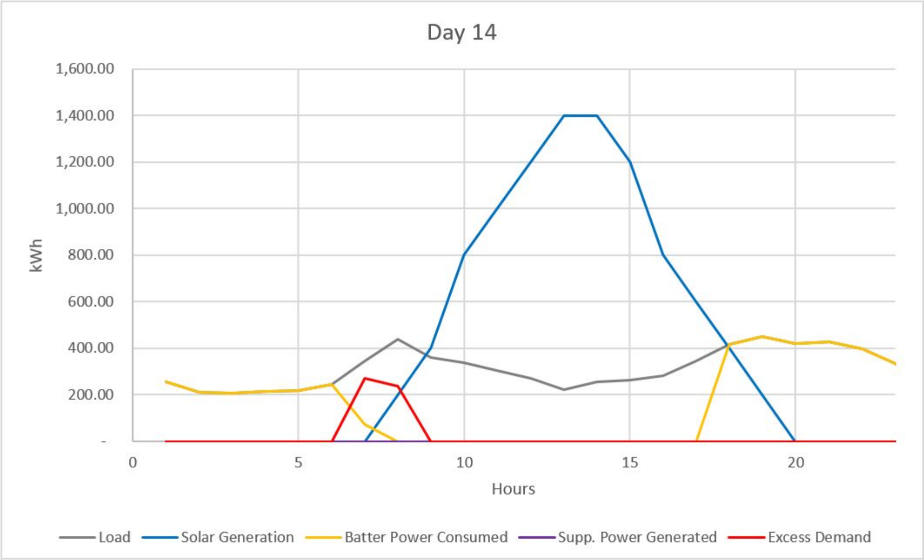
Detailed Design - Daily



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Detailed Design - Yearly

Fall Schedule

- August - October: Start economic based calculations and include inverters
- Sep - Nov: Reverse the initial simulation tool to output the acceptable combinations
- Oct - Dec: Design VBA code to run numerous simulations and output combinations to Excel that meet user defined parameters
- Nov - Dec: Output recommended combinations and a graph comparing cost and reliability
- Dec: Finalize Senior Design Project and prepare to deliver to Alliant

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Functional Decomposition - Semester 2

1. Enter input information for the simulation
    a. Average daily usage per month
    b. Maximum size supplemental generator
    c. Yearly excess demand allowed
    d. Miscellaneous startup costs.
2. Specifications Tab
    a. Equipment specifications, install, fuel, and maintenance costs, etc.
3. Load and Solar Profile Tabs

Final Simulation Tool		
Average Daily Usage		
January	6,943.23	kWh
February	6,636.36	kWh
March	4,947.97	kWh
April	6,056.23	kWh
May	4,225.81	kWh
June	5,204.23	kWh
July	6,509.29	kWh
August	7,382.06	kWh
September	6,169.67	kWh
October	5,465.48	kWh
November	6,533.20	kWh
December	7,308.35	kWh
Max Size Supp Gen:	100	kW
Yearly Excess Demand Allowed (%)	0.500%	
Misc Startup Costs (Land, additional distribution, etc)	$ 500,000	
Total Average Yearly Demand:	2,230,966	kWh
Yearly Excess Demand Allowed:	11,154.83	kWh

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Technology

- Excel VBA (Visual Basic for Applications)
  - Randomizes one year of load and solar data
  - 9,350 Combinations of solar panels and batteries
    - 100 - 11,000 Solar Panels (360W)
    - 100 kWh - 8,500 kWh Battery
  - Each combinations is simulated through the same year of solar/load data
  - Supplemental Generation is added to combinations with excess demand

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Technology - Cont.

- Excel VBA (Visual Basic for Applications)
  - Acceptable combinations printed to result tabs
    - Based on total yearly excess demand
  - Recommended combinations printed to “Inputs” tab
    - Recommended combination
    - 0% excess demand with supplemental generation
    - 100% Solar combination (no supplemental generation)
  - Program can be used for other locations

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Final Simulation Tool

Instructions: Enter Values for highlighted cells, hit run, view results below and in results tabs

Average Daily Usage		
January	6,943.23	kWh
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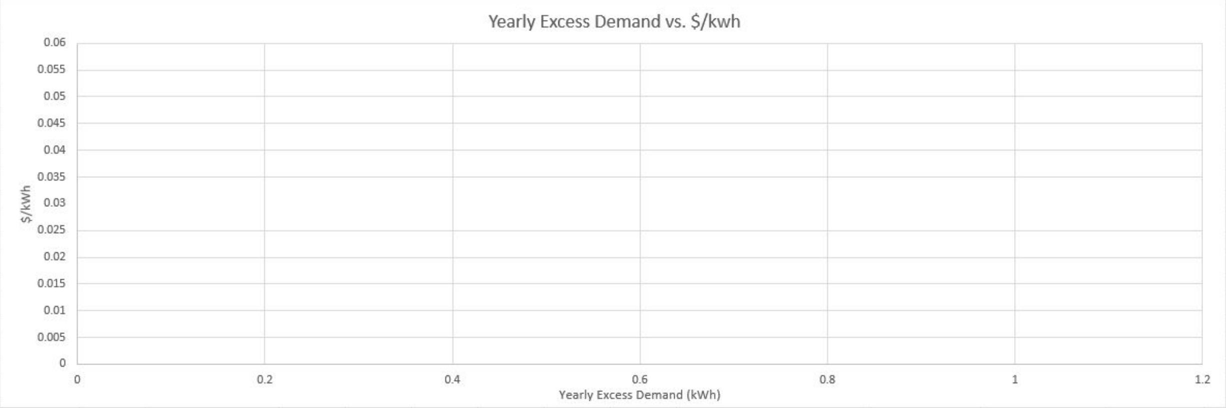
Run

Clear Results

Recommended:	0% Excess w/Supp	100% Solar:
Solar Capacity (MW)		
# of Inverters		
Battery Capacity (kWh)		
Supp. Generation Size (kW)		
Yearly Excess Demand (kWh)		
Maximum % Excess Demand		
Install and Base Cost		
Yearly Operation Cost		
30 Year Total Cost		
30 Year PV Total Cost		
$/kWh		



Inputs | Results With Excess Demand | Results 0% Excess Demand | Specifications | Solar Profiles | Load Profiles | All Results

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Final Simulation Tool

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Average Daily Usage		
January	6,943.23	kWh
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Run

Clear Results

	Recommended:	0% Excess w/Supp	100% Solar:
Solar Capacity (MW)	1.98	2.41	2.45
# of Inverters	66	81	82
Battery Capacity (kWh)	3,700.00	4,100.00	4,100.00
Supp. Generation Size (kW)	100	25.76	0
Yearly Excess Demand (kWh)	10,769.06	0	0
Maximum % Excess Demand	69.70%	0.00%	0.00%
Install and Base Cost	$2,684,000.00	$2,897,339.00	$2,878,000.00
Yearly Operation Cost	$38,311.57	$44,380.00	$44,920.00
30 Year Total Cost	$3,845,393.00	$4,233,495.00	$4,230,356.00
30 Year PV Total Cost	$3,302,390.00	$3,613,680.00	$3,603,057.00
$/kWh	0.0579	0.0634	0.0633

Inputs | Results With Excess Demand | Results 0% Excess Demand | Specifications | Solar Profiles | Load Profiles | All Results

Our Recommended Combination - Nichols, IA

	Recommended:	0% Excess w/Supp	100% Solar:
Solar Capacity (MW)	1.44	2.23	2.38
# of Inverters	48	75	80
Battery Capacity (kWh)	2,500.00	3,600.00	4,200.00
Supp. Generation Size (kW)	300	293.11	0
Yearly Excess Demand (kWh)	2,097.67	0	0
Maximum % Excess Demand	28.79%	0.00%	0.00%
Install and Base Cost	$2,262,000.00	$2,937,423.00	$2,900,000.00
Yearly Operation Cost	$43,766.68	$41,945.72	$44,040.00
30 Year Total Cost	$3,687,767.00	$4,208,072.00	$4,226,072.00
30 Year PV Total Cost	$2,968,441.00	$3,614,472.00	$3,610,853.00
$/kWh	0.0553	0.063	0.0633

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Implementing Tool

- Alliant
  - Their newly formed micro-grid team will use this in-addition to other software (Homer)
  - Other locations in Iowa with the potential to implement a microgrid
- Iowa State
  - Possible use by an Iowa State graduate student to assist in microgrid research

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Conclusion – Questions?

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Sources

Figure 1: Metelitsa, Colleen. “U.S. Microgrids 2017: Market Drivers, Analysis and Forecast.” *U.S. Microgrids 2017: Market Drivers, Analysis and Forecast* | *Greentech Media*, Nov. 2017

Kenning, Tom. “'Solar for the Country': Inside Southeast Asia's Largest Micro-Grid.” *PV Tech*, PV-Tech, 23 Nov. 2018, www.pv-tech.org/editors-blog/solar-for-the-country-inside-southeast-asias-largest-micro-grid.