Designing Scalable, Affordable, and Efficient Microgrids

The Sustainable and Equitable Allocation of Resources Lab

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Executive Summary

Microgrids are typically small-scale power grids that are controlled at a local level.

The SEAR Lab's research goal was to design a new microgrid system that was:

1. Scalable
2. Affordable
3. Efficient

Microgrids can either be connected to the power grid and work alongside the main grid, or they can be completely off-grid. For the scope of our project, we opted for an off-grid design.

Through the design and implementation of our methods, we also wanted to ensure to maximize energy reliability, and energy sustainability.

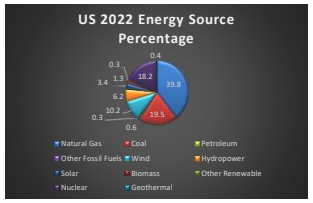
Background

Electricity production currently faces two main issues: energy sustainability and energy reliability.

1. Our current energy production is a result of the burning of limited fossil fuels.

2. Modern Society cannot function off the grid, or at least without an electricity source.

Table 1. US 2023 Energy Sources



Microgrids present a strong potential solution to both these issues as they derive energy from clean renewable sources such as solar power and wind energy. Because of this, they emit little to no green house gases. Furthermore, while access to these renewable sources may be intermittent, microgrids can be connected to the power grid, and run alongside it, picking up the slack when needed, increasing energy reliability.

Design Methods

There are four main components to a microgrid that we need to take into careful consideration when designing our model:

- The renewable energy source
- The charge controller, which is responsible for managing the current in the system
- The inverter, which converts the DC current from the batteries and solar panels to a usable AC current
- And finally, the batteries, responsible for storing the excess energy

Figure 1. Current Type Flow

- Within the battery storage system themselves, we needed to connect the batteries in series form to maximize the voltage the system can provide.
- A frame was also necessary here to hold the multiple parts of the system, we decided to go with a generic heavy duty kitchen cart to ensure affordability and availability.

Design Implementation

We were able to design two models:

- One with regular lithium-Ion batteries that can be purchased online.
- One with repurposed battery packs.

The battery packs used in the second build were created in lab from the battery cells of a Nissan Leaf Electric Vehicle. We wanted to integrate these recycled batteries into our model to increase sustainability. Instead of ending up in a land field, these battery cell's life were elongated through their incorporation in our build.

Through out the designing and testing of our microgrid, we were able to acquire real-time current, and voltage data through the use of a Bluetooth charge controller.

Figure 2. First Fully Functioning Model

Figure 3. Battery Packs

Table 2. Real Time Microgrid Data

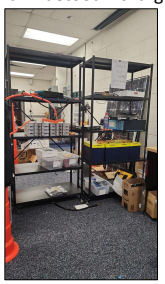
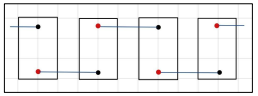


Figure 4. Test Models

Method Results

- Scalability: While the models we build are small scale, their design can be generalized for bigger projects by increasing the inverter watt capacity, number of batteries, and the number of solar panels or wind turbines that are integrated into the system.
- Affordability: Apart from the repurposed battery packs, all the equipment used in our models is available online and can be recreated. The costs of the designs were approximately 2200 USD for the microgrid running with purchased batteries, and approximately 910 USD for the one running with the repurposed battery packs.
- Efficiency: Through series battery connections, we were able to maximize the voltage the microgrids can produce when the batteries are at full charge. For the repurposed battery pack model this value sits at 15 volts with 260amp Ah, and for the purchased battery model this would be 48 volts with 100 Ah. Lastly, the design contains an inverter watt capacity of 3500, meaning these models can run appliances up to that wattage, such as televisions, heaters, and a washing machine.

Figure 5. Series Battery Diagram



Conclusions

- Overall, the three desired parameters were met. The microgrid design proved to be scalable, affordable, and efficient.
- However, there is always room for progress, connecting our design models to the power gird could give us stronger insights to the capabilities and limitations that come from working with the grid.
- Through our microgrid research, we were also addressing two societal concerns: Energy Sustainability and Energy Reliability.
- Our microgrid design maximized sustainability through the use of solar panels, a clean renewable source, and recycled and repurposed battery packs that came from an old electric vehicle. Lastly, in terms of reliability, our model's battery system is responsible for storing excess energy that is available for use when needed.

References

1. US Energy Information Association https://www.eia.gov/tools/faqs/faq.php?id=427&t=3
2. Center for Climate and Energy Solutions on Microgrids https://www.c2es.org/content/microgrids/
3. DC/AC Energy https://www.cleanenergyreviews.info/blog/ac-coupling-vs-dc-coupling-solar-battery-storage
4. Inverters https://www.pnnl.gov/news-media/simulating-role-grid-forming-inverters-future-electric-grid
5. Microgrid Controls https://www.nrel.gov/grid/microgrid-controls.html
6. Inverter Installation https://www.asobolife.com/how-to-install-an-inverter-in-a-camper/
7. Battery Lifetime Analysis Simulation Tool https://www.nrel.gov/transportation/blast.html
8. Battery Second Use Information https://www.nrel.gov/transportation/battery-second-use.html
9. Are EV Batteries Recyclable from https://blog.ucsusa.org/jessica-dunn/are-ev-batteries-recyclable/
10. Inside the Battery of a Nissan Leaf https://www.qnovo.com/blogs/inside-the-battery-of-a-nissan-leaf