OGZEB Hybrid Thermal Electrical Energy Storage System

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ABSTRACT / INTRODUCTION

- Solar-powered off-grid houses have excess energy during the day, but run out at night or after multiple rainy days
- Air conditioning represents a major portion of a house's electricity usage
- Our team designed two systems to work simultaneously
  - Battery array for general electricity needs (outlets, lights, appliances)
  - Innovative thermal energy or cold storage system to ease AC usage
- Most effective and economical method of storage is grid-tie connection
  - Sell excess energy to the grid, buy energy when needed

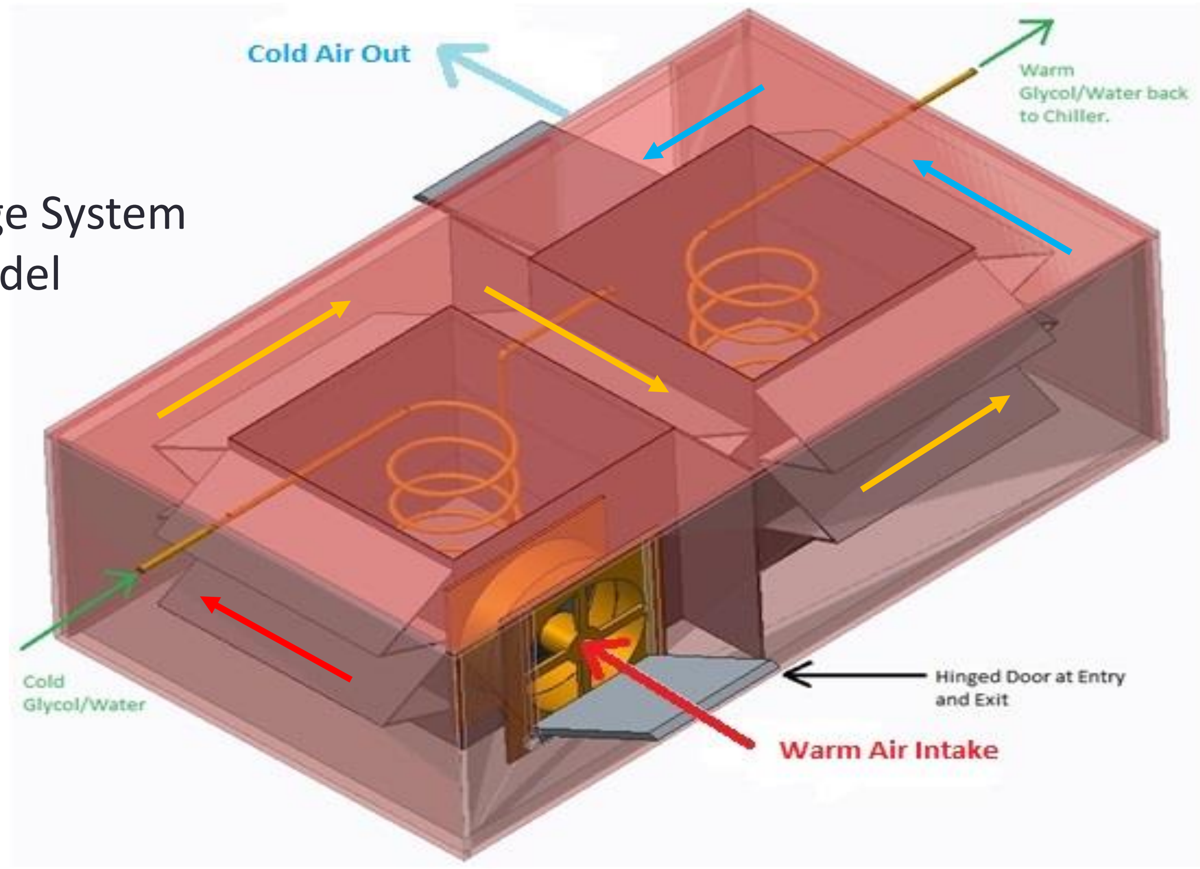
OBJECTIVES

- Build a hybrid thermal and electrochemical energy management system for FSU's Off-Grid Zero Emission Building (OGZEB)
- Minimize power losses from multiple energy conversions
- Use recyclable materials for sustainability purposes (LEED certification)
- Create a system that can be easily constructed, tested, and maintained for future research
- Evaluate and conduct preliminary research on grid-tie connection
  - Analysis and cost components
  - Possible profit from selling unused energy to the grid
- Stay within budget
- Ideate and design potential system improvements

ICE STORAGE SYSTEM PROTOTYPE

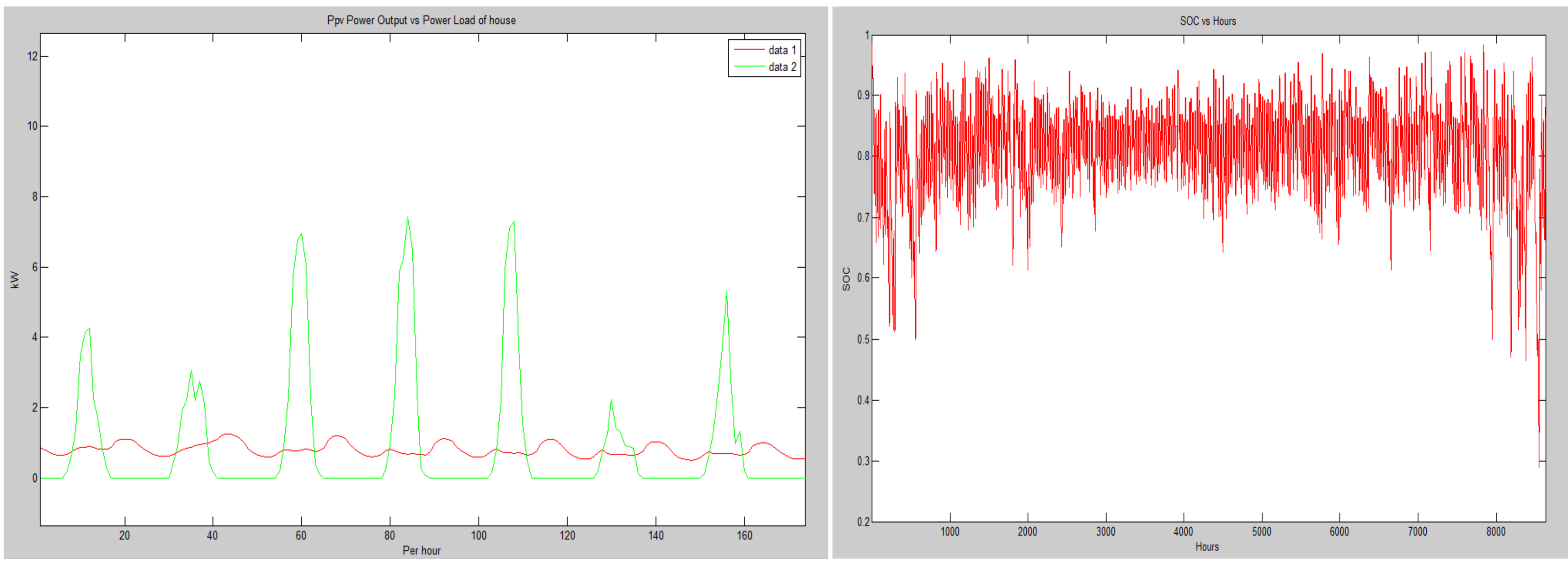
- Recirculating Glycol/Water Chiller chills water storing energy through temperature change
- Prototype scaled down and operated manually due to budget constraints

Ice Storage System Model



BATTERY ARRAY SELECTION

- Battery array downsized for cost efficiency and new Full River Deep Cycle 400-6 batteries (415 Amp hours, 6 Volts) purchased to replace aging batteries

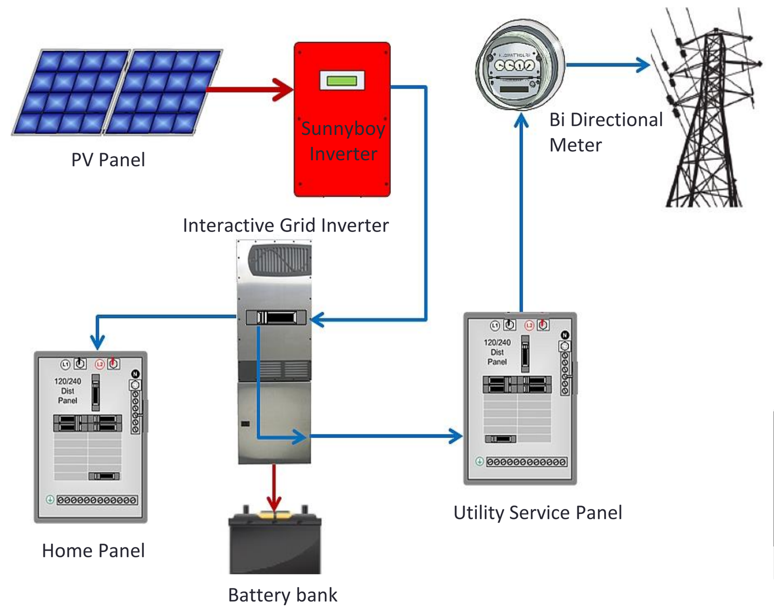


GRID-TIE SYSTEM RESEARCH

Grid-tied systems route solar electricity to a utility grid that allows the customer to:

- ***Consume*** solar power when it is available and the utility grid is working.
- ***Purchase*** electricity from the grid when sun does not shine
- ***Sell*** excess of solar power to the grid and receive a credit for exporting power (net metering)

- Financially viable, environmentally friendly power
- Producing power where it is consumed
- Protection against fluctuating power prices
- Simple maintenance

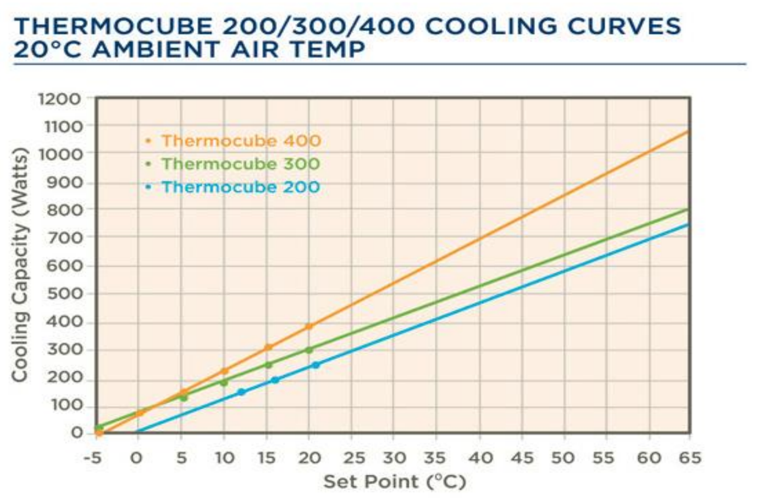


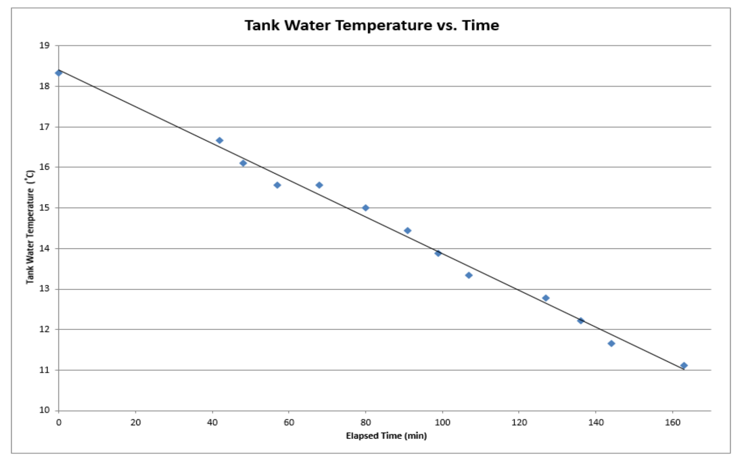
RESULTS-EXPERIMENTAL VS. THEORETICAL

Prototype vs Full Size System

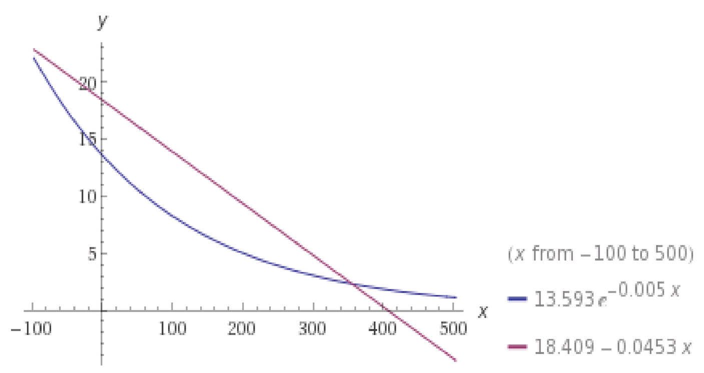
Variable	Scale Down Prototype	Full Size System
Water Tank Capacity	30.8 liters	758 liters
Chiller Cooling Capacity	100W	7000W
Theoretical Freezing/22°F-0°F times	28 hours/7.87 hours	12 hours/2.77 hours
Air-Flow	365 CFM	1200 CFM
Theoretical System Cooling Rate	930W	7400W

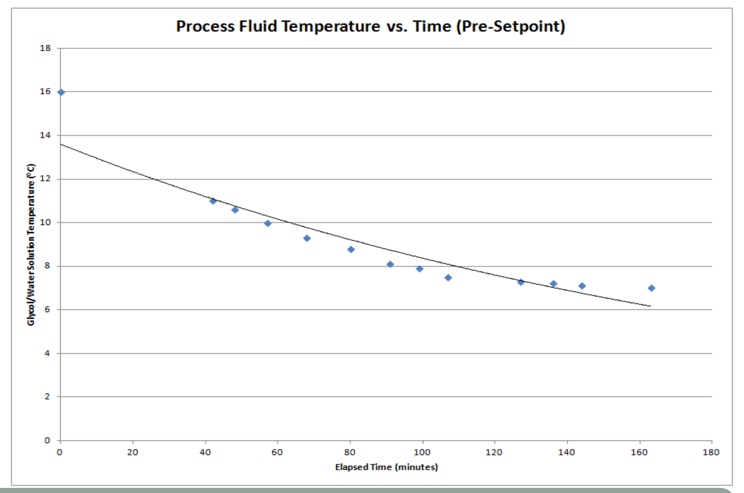
- Data points from the cooling process were taken and the following curves were generated to show the tank water temperature & chiller process fluid temperature vs. time. Based on the trendlines shown in the graphs, data was extrapolated until both the chiller process fluid and the tank water reached 1°C (close to 0°C). It is assumed that after the temperatures of the process fluid and water tanks equalize at the 6 hour mark, the tank water follows the same trend-line as the process fluid. According to the extrapolated data, it was predicted that it would take a total of 8.67 hours for both fluids to go from 22°F to 0°F which is very close to the original prediction of 7.87 hours.





Trend-line Data Extrapolation





CONCLUSIONS

Our team selected a battery system and completed design of the ice storage prototype. Because of the cost requirement of a full size system using this concept, a scaled down prototype nicknamed the Thermal Battery was built and will be used as a proof of concept and be simulated using outside air rather than the house air. The Thermal Battery was predicted to cool at a rate of 930W but when the water was brought down to 0°C, only 683W of cooling was achieved. Possible losses in system performance include:

- The mounting of the fins
- Airflow Pressure Loss
- Imperfect exposure to cold surface area
- Thermometer calibration error
- Error in Nusselt Number correlation used in 930 W prediction

Most of these flaws can be corrected with more readily available resources. The cost and energy summary if a full size version of the Thermal Battery were to be implemented into the OGZEB is displayed below in Figure 16. These calculations were done assuming a levelized cost of $0.12/kWh and that in both cases the system would run for 11 hours a day and 9/12 months of the year. Because 12 hours of chilling is required to fully charge the system, the daily and annual savings were based upon the comparison of both systems after every 24 hours of running. With these assumptions $234.85 and 1957.1 kWh can be saved per year which gives a payback period of around 34 years for a full size system construction and installation cost of $8000. These calculations allowed for the overall conclusion that the system would not be very cost effective for the OGZEB or a house of similar size. However, the concept itself could be used very effectively on a larger scale and remains an improvement on current Ice Storage technologies. These improvements most notably include a decrease in the number of heat transfer processes and the extra power consumption of a water pump during the discharge period.

Cost & Energy Prediction-Full Size System Implementation

	Hours of Charging	Hours of Discharge	Charging Hours-Power Consumed	Cooling Hours Power Consumed	Full Period in Hours	Annual Hours of Cooling	Annual Energy Consumption	Annual Cost
No Storage	N/A	N/A	N/A	3.5 kW	24	3011	10538.5 kWh	$1,264.62
With Storage	12	12	5.5 kW	0.2 kW	24	3011	8581.4 kWh	$1,029.77
						Savings:	1957.1 kWh	$ 234.85