DOE Collegiate Wind Turbine: Electrical Design

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NAU NORTHERN ARIZONA UNIVERSITY
Office of Undergraduate Research and Creative Activity

COLLEGIATE WIND COMPETITION
U.S. DEPARTMENT OF ENERGY

1. Project Motivation

The 2019 Collegiate Wind Competition (CWC) team representing Northern Arizona University will be the fifth team representing the university at the annual event. CWC is an annual showcase of wind energy education and advancement organized by the United States Department of Energy (DOE) and National Renewable Energy Laboratory (NREL). The challenge is to design and manufacture a tunnel scale wind turbine. The electrical aspects of the wind turbine include the design, manufacturing and assembly of the power electronics needed to provide efficient power output. The power electronics must be designed to work together and must fit within the constraints of the competition.

2. Problem Definition

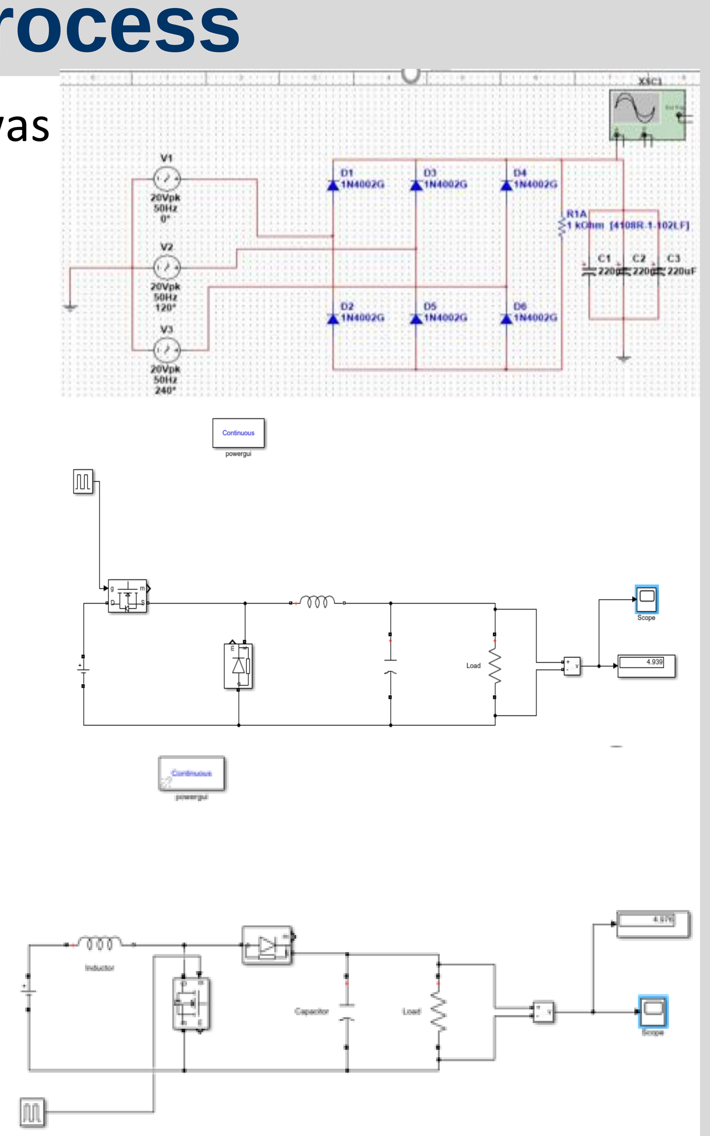
To compete, teams follow a strict set of rules to ensure an even competition level for all teams competing. The turbine must be capable of withstanding windspeeds up to 20 m/s and produce an output of 5V. The electronics must be within a safe enclosure and capable of running without human interaction. Teams will then compete in a series of tests designed to strain all components of the turbine.

3. Design Process

The design process was straight forward and followed these steps highlighted below.

a. Simulations
b. Component Research
c. Purchasing Parts
d. Prototyping
e. Testing
f. PCB

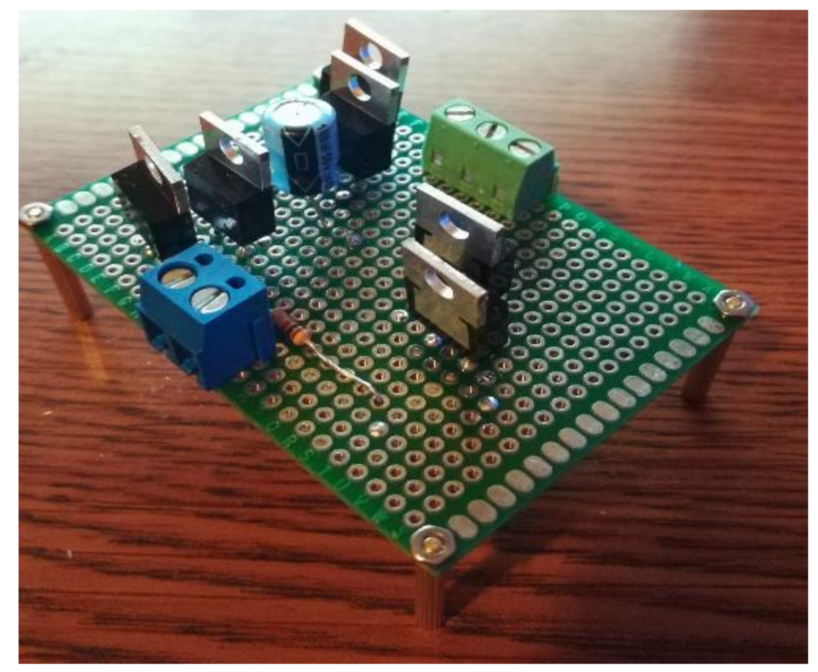
The simulations are seen to the right.



6. Final Design

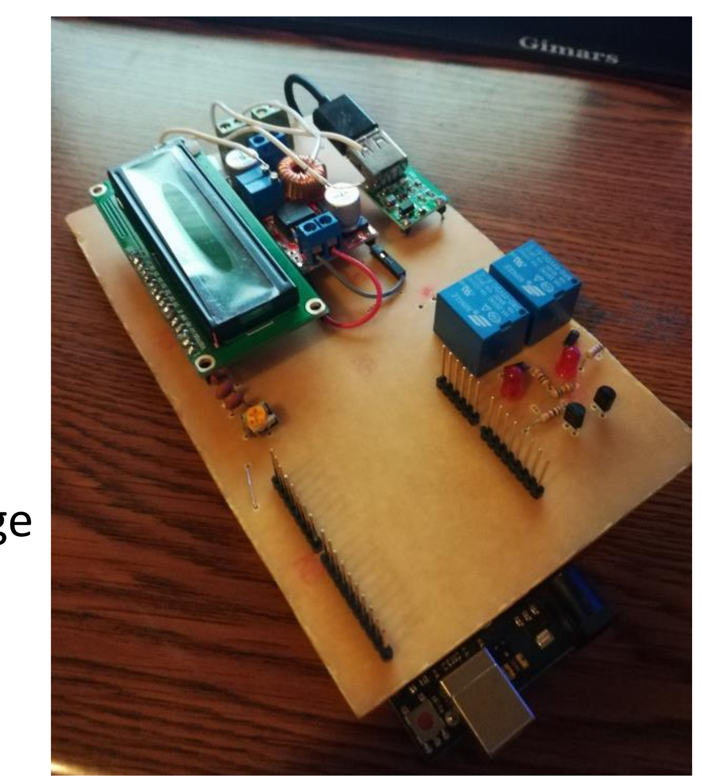
The NAU's Turbine Electric final design is an AC-DC three-phase rectifier that is a passive converter. This connects to the and starts activating the DC-DC Buck and Boost converters. The final product has both a buck and a boost converter and uses relays to switch between them as needed.

The rectifier can be seen to the right as Figure 2. This passive converter works accepting a wild AC voltage from the generator and passing it through a precisely configured set of Schottky rectifiers. The capacitor is used to steady the output DC voltage and help maintain a constant value. The resistor is used to deplete the capacitor when the input voltage is disconnected.

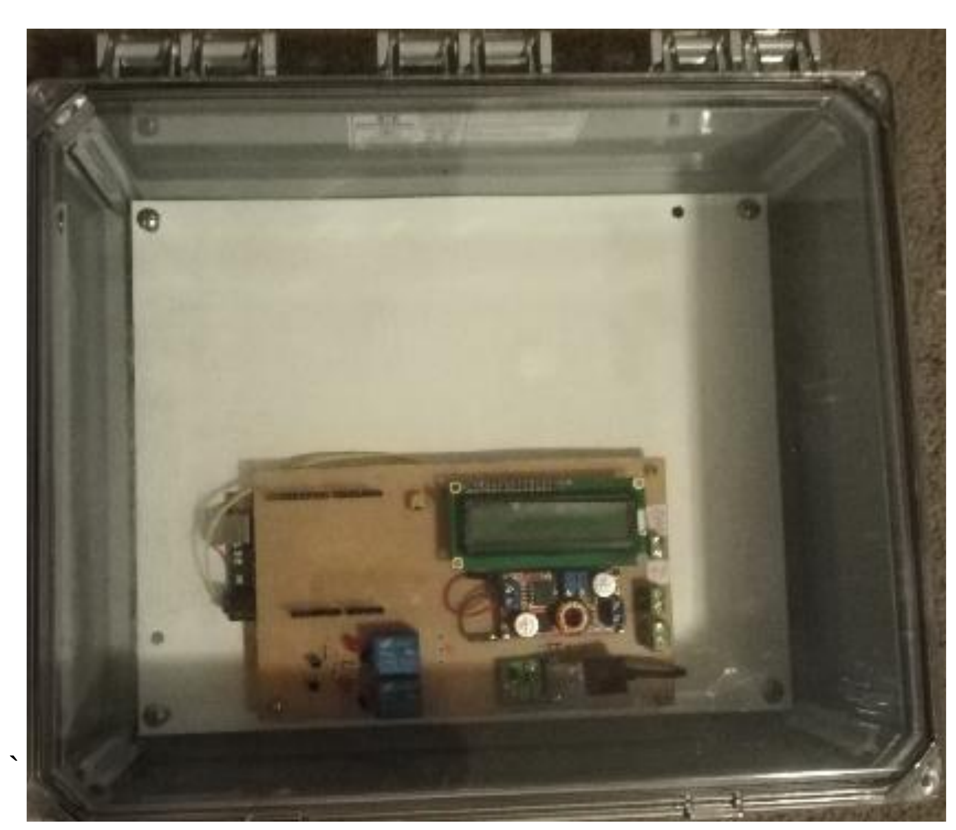


The DC-DC Boost converter increases the voltage above 5V. The DC-DC Buck converter then decreases the voltage to 5V. The buck converter was designed to accept up to 25V. These two converters are both placed on a customized PCB and activated by the AC-DC rectifier.

- Key Features
  - Compact Design
  - Passive Cooling
  - Easy Wire Connections
  - Modular Design
  - Passive Converter Switching
  - Converter Indicator Lights
  - LED Display for Input/Output Voltage
  - Printed Circuit Board
  - Passive Conversion
  - Replicable Results



The final product will be enclosed within a NEMA 3 case with a removable sub-panel for easy access when changing components. The case while house the buck and boost converters while also providing a good space for wire management.



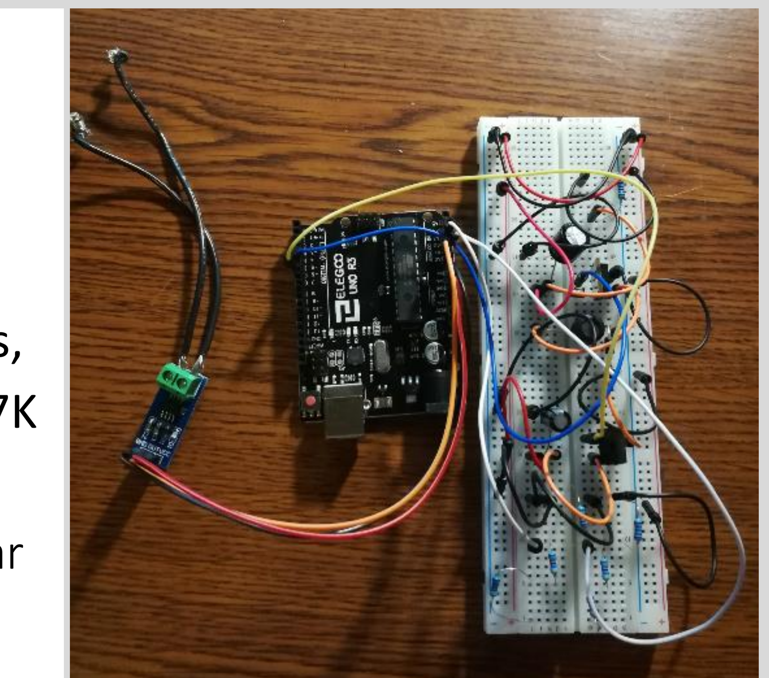
The competition takes place from May 6th to May 9th and will feature a wide variety of tests designed to stress the wind turbine and the electronics controlling the output. During competition, there will be little time for creating new parts so it is important that backups were made and tested in case components break and need to be switched during the competition.

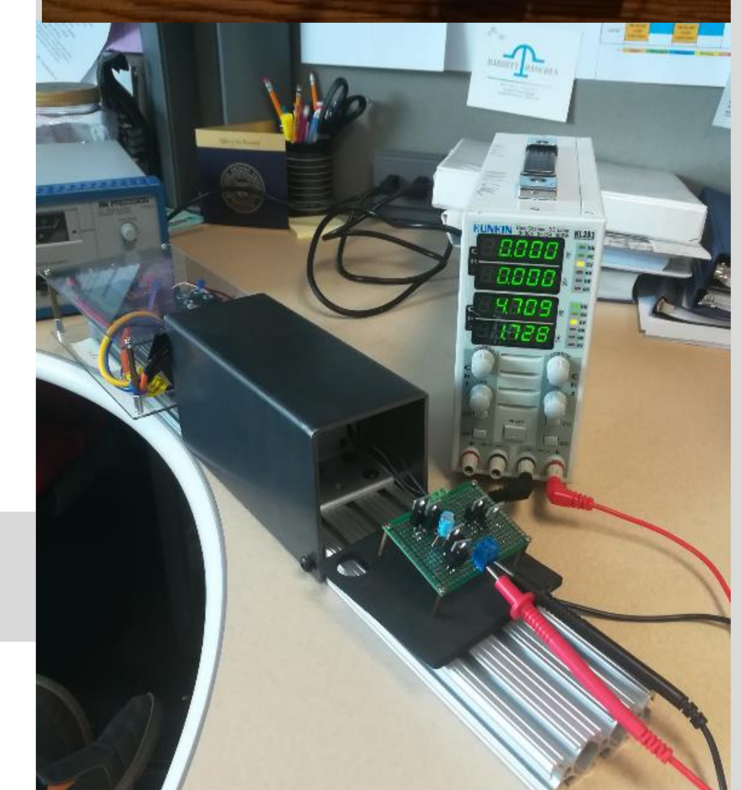
4. Construction Process

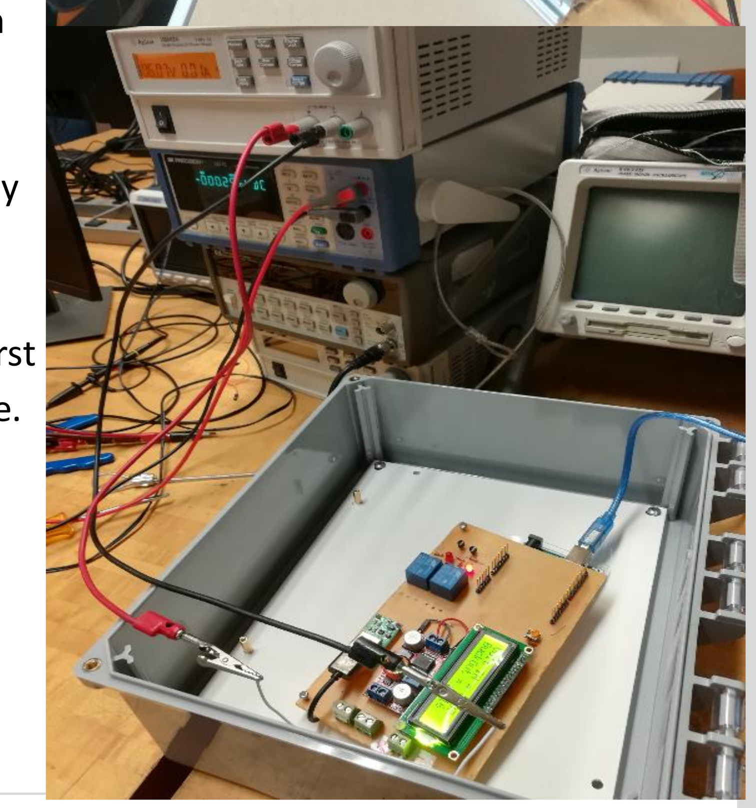
- AC-DC rectifier
  - Components: 100uF Capacitor, 6 Schottky diodes
- Buck and Boost converter
  - Components: P/N MOSFET Channel's, 100uH Inductor, 220uF Capacitor, 4.7K ohm resistors, Schottky diodes

The construction of each converter was very similar and follows the steps below.

- Breadboard building
- Breadboard testing
- Perf board building
- Perf board testing
- PCB Designing
- PCB Printing
- Soldering

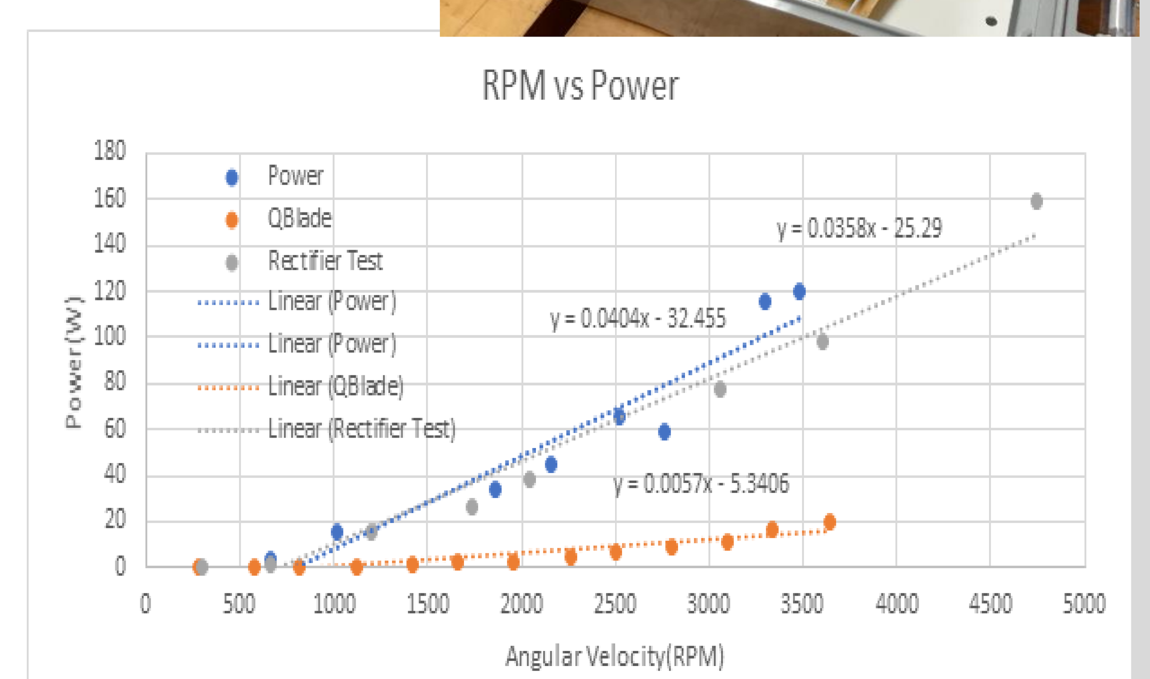






5. Testing Procedures

- Rectifier
  - The rectifier was tested on both an open and closed circuit by using a dynamometer. The open circuit test determined the maximum voltage expected while the closed circuit helped verify that the components could maintain functionality with increased amperage.
- Boost Converter
  - The components for the boost converter were first tested using a breadboard with low input voltage. The Arduino was used to measure the output voltage and adjust the duty cycle depending on the input voltage. The components were then soldered onto a perf board for higher voltage testing.
- Buck Converter
  - The buck converter components were tested on a breadboard with low voltage and current to verify the output voltage was less than the input voltage. The components were then soldered onto a PCB for full scale testing.



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Acknowledgements

Special thanks to David Willy and Venkata Yaramasu for sponsoring the project and helping guide the team through the design process. Thank you to NAU for providing funding for the project and to the DOE for providing the opportunity to compete with our project.