NORTHERN ARIZONA UNIVERSITY
College of Engineering, Forestry & Natural Sciences

COLLEGIATE WIND COMPETITION
U.S. DEPARTMENT OF ENERGY

2016 Collegiate Wind Competition: Tunnel Electrical Team

Meet the Team

- Brayden Worrell
  - Team Lead
- Zachary Sabol
  - Budget Liaison
- Michael Evans
  - Software Expert
- Jess Robinson
  - Controls Expert
- Korey Holaas
  - Power Electronics Expert
- Scott Muente
  - Load Expert

Outline

- What is the CWC?
- Project Description
- Electrical Layout
- Competition Requirements
- Power Electronics
- Controls & Software
- Load
- Manufacturing
- Testing Results

What is the CWC?

Collegiate Wind Competition (CWC): Undergraduate student competition sponsored by the U.S. Department of Energy. Consists of 2 challenges:

1. Marketable Turbine
   - Identify viable market
   - Design turbine for market
   - Prepare a business plan to enter market

2. Tunnel Turbine
   - Design turbine for wind tunnel testing
     - Compete against 12 other Universities in these tests
     - Have a design link between tunnel and market turbines

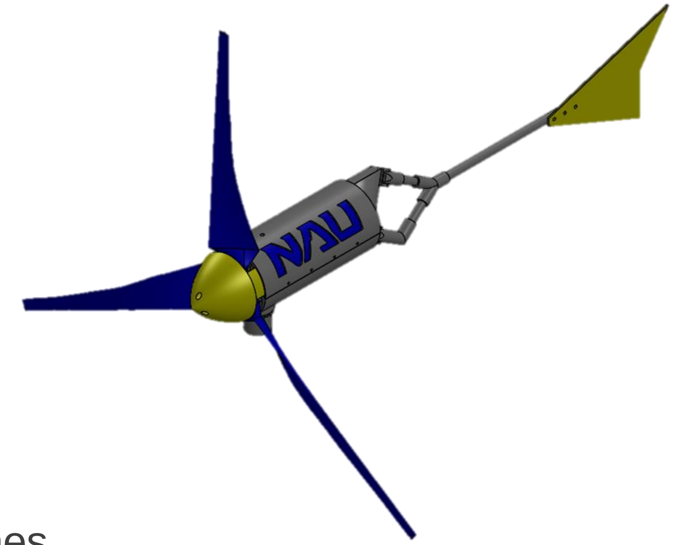

Figure 1: Marketable Turbine

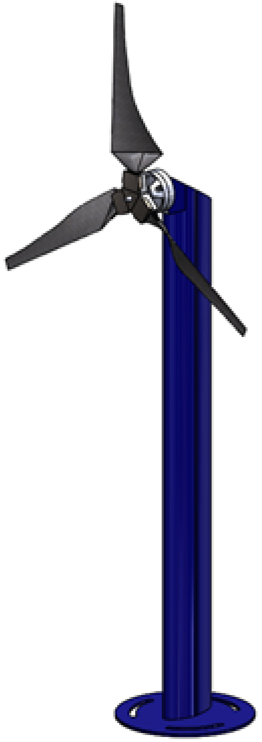
Figure 2: Tunnel Turbine

Project Description

1. Design turbine for wind tunnel testing
   - Electrical:
     - Power Electronics
     - Software
     - Controls
     - Load

Sponsors

U.S. DEPARTMENT OF ENERGY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

NORTHERN ARIZONA UNIVERSITY

NOVAKINETICS AEROSYSTEMS

Advisors

- David Willy
- Karin Wadsack
- Dr. Venkata Yaramasu
- Dr. Tom Acker
- Dr. Marc Chopin
- Ross Taylor
- John Sharber

Layout of Turbine Electrical Components

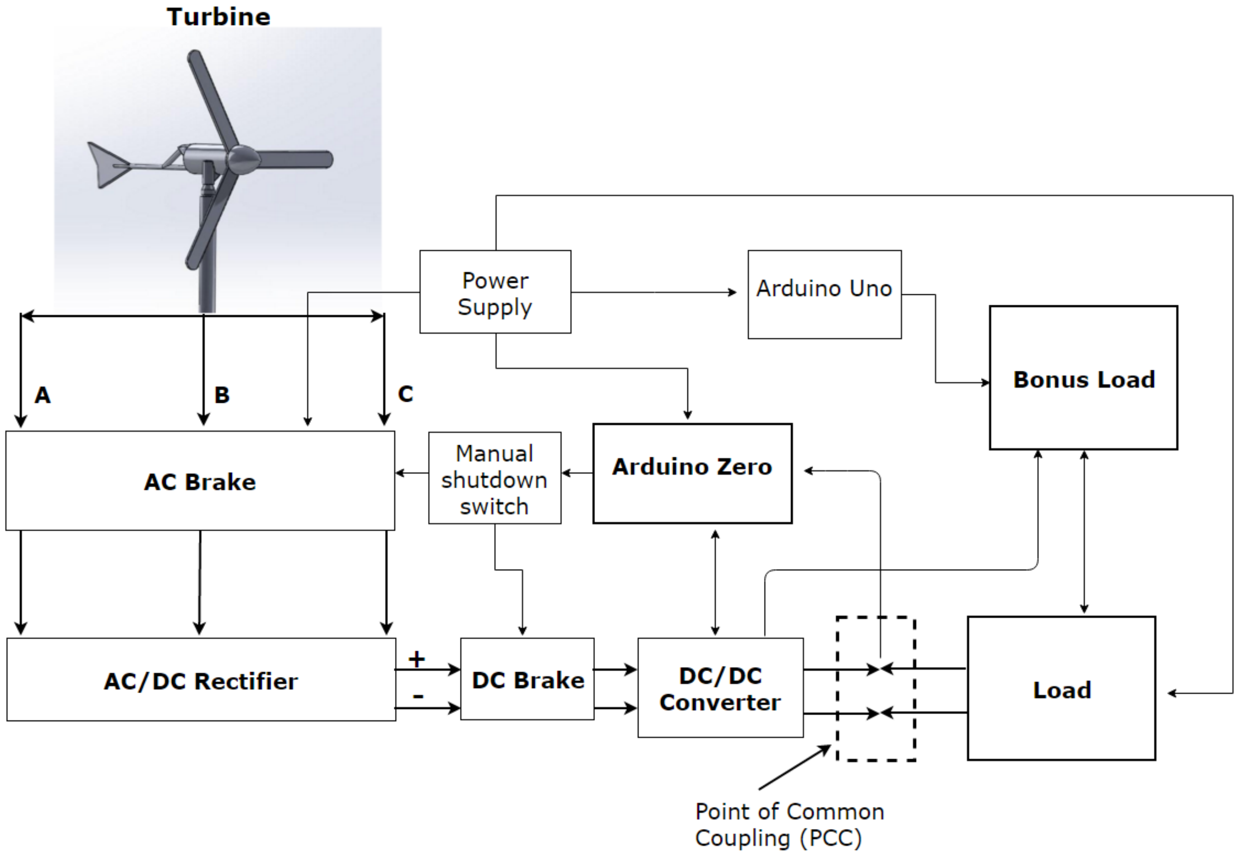

Figure 3: Electrical block diagram

Competition Requirements

1. Power Curve Performance Test
   - Measure power versus wind speed

2. Control of Rated Power and Rotor Speed Test
   - Measure power output and RPM versus wind speed

3. Safety Test
   - Aim for 90% reduction in RPM when brakes are turned on

Figure 4: Component testing in Flagstaff

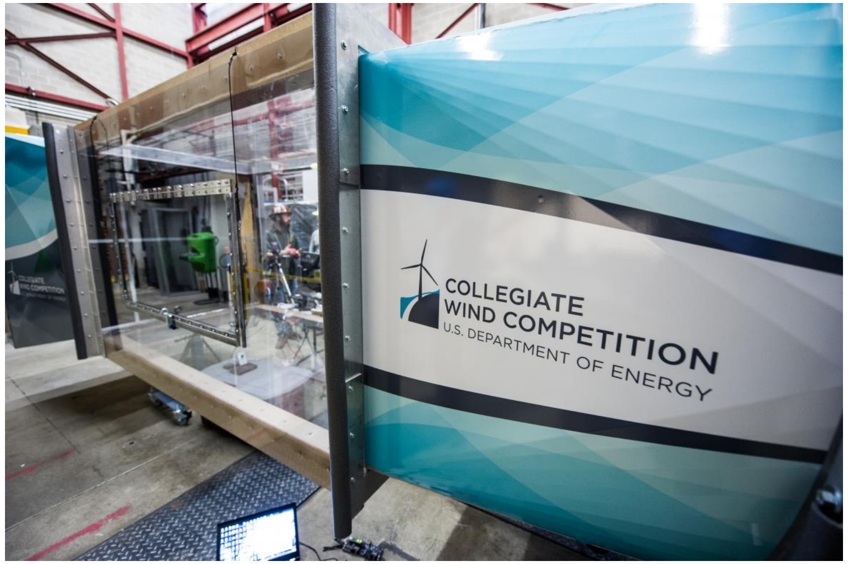

Figure 5: A previous year's competition tunnel [1]

Power Electronics

- Rectifier
  - Converts AC power to DC power
  - Passive model
    - Operates without a control signal

- DC/DC Converter
  - Buck-Boost topology
    - Step-up or Step-down input voltage through control of transistor
  - PSpice simulations to confirm calculations

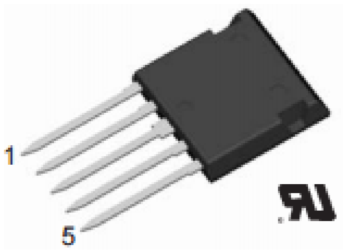

Figure 6: The Passive Rectifier Model [2]

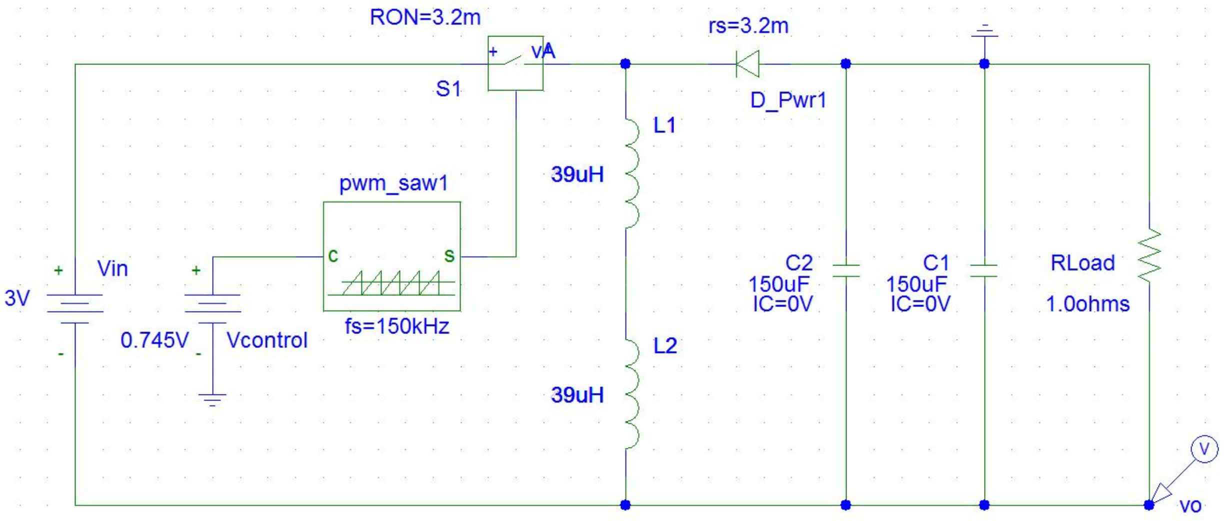

Figure 7: A DC/DC Converter Simulation

Controls - Software

- Power Curve
  - States 1 – 4

- States 1 through 3
  - Arduino ZERO
  - Using DC/DC converter
  - Closed loop PWM control

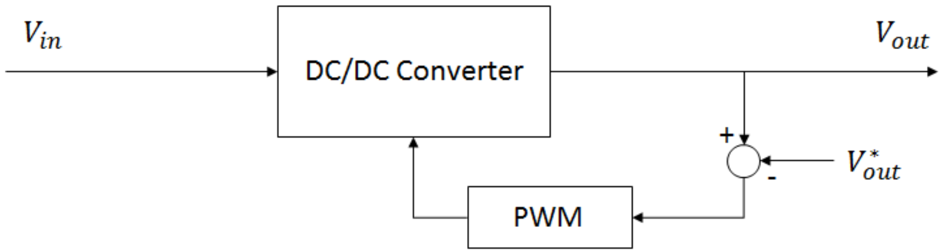

Figure 9: State 2 and 3 Block Diagram

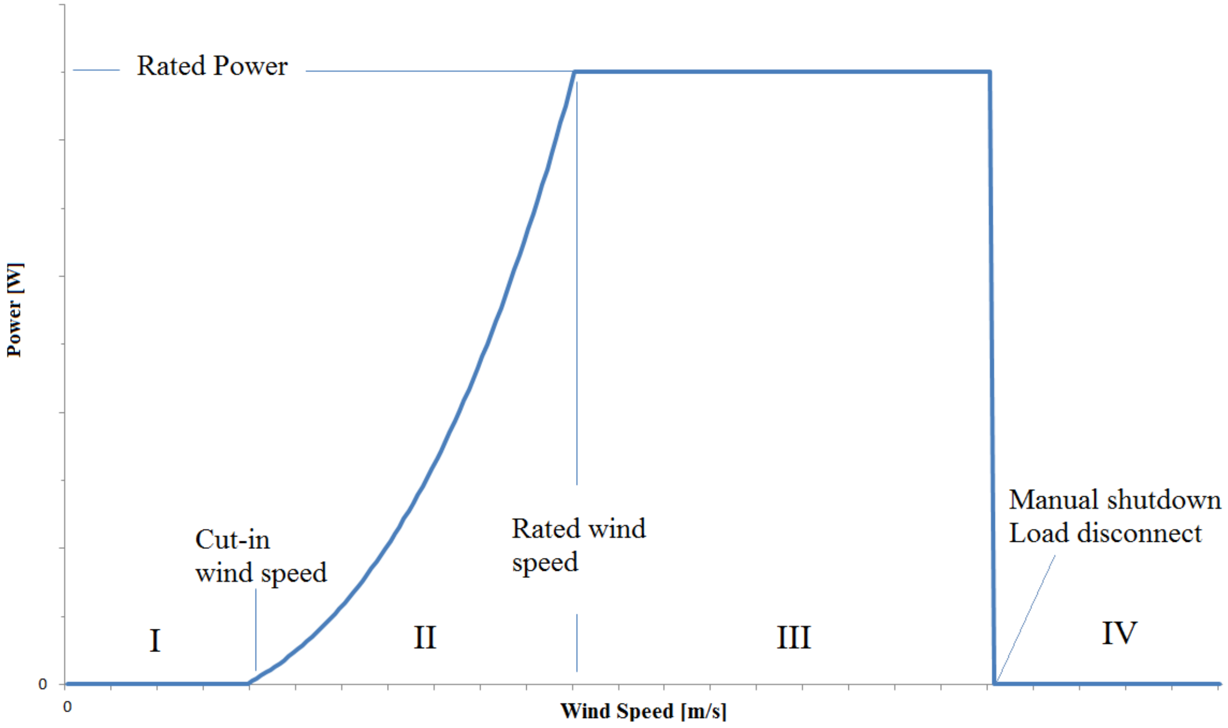

Figure 8: Example of wind turbine power curve

Controls - Hardware

- Brakes
  - AC and DC brakes
  - Turbine shutdown
  - Manual shutdown switch
  - Load disconnect

- Arduino ZERO Microcontroller
  - Activation of brakes
  - Sensing voltage

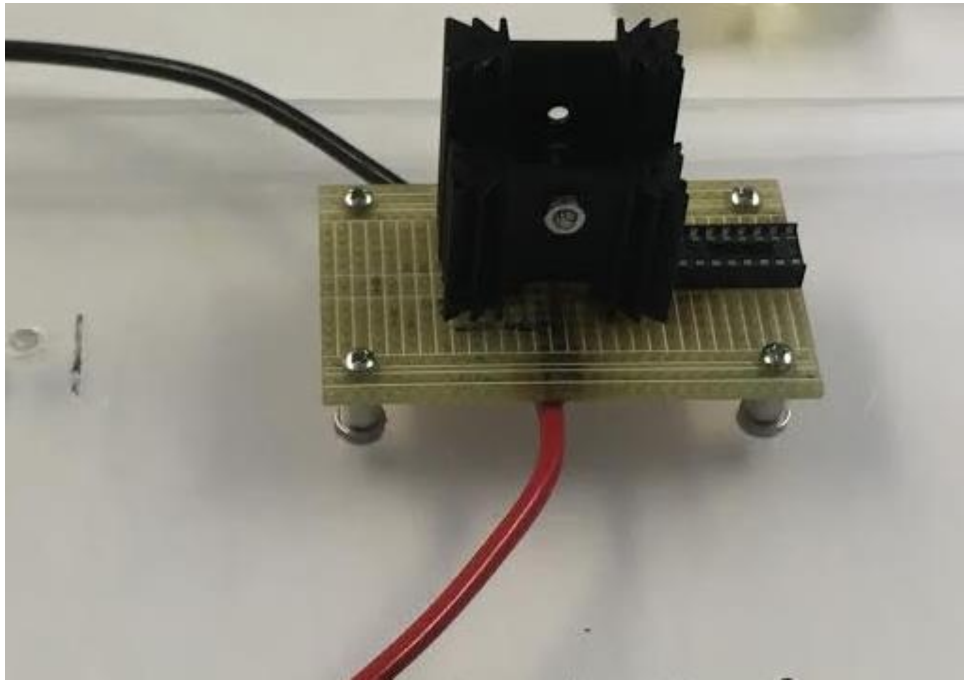

Figure 10: DC Brake Board

Figure 11: Arduino ZERO Microcontroller

Load

- Load
  - The basic load for dissipating power from the generator
  - Uses an adjustable power resistor that can dissipate up to 300 watts

- Bonus Challenge Load
  - Relates to deployment design
  - As more power is produced, more lights turn on

Figure 12: Variable Resistor

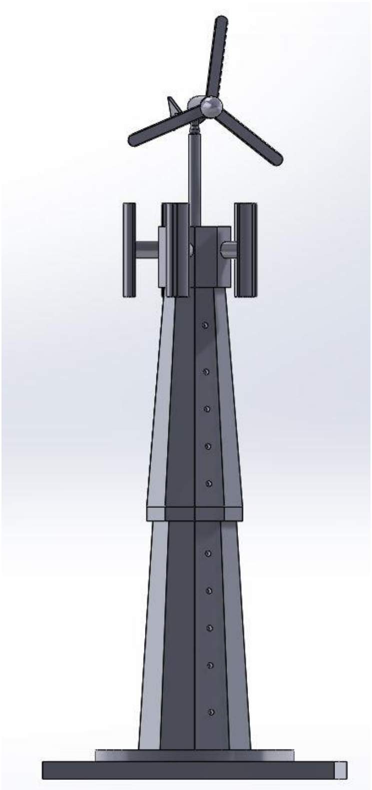

Figure 13: Bonus Load CAD Model

Manufacturing

- Prototyping
  - Moved from small sections to full circuit
- Manufacturing
  - Tested one part at a time as team mounted and connected components
  - Revisited designs as the team tested their components

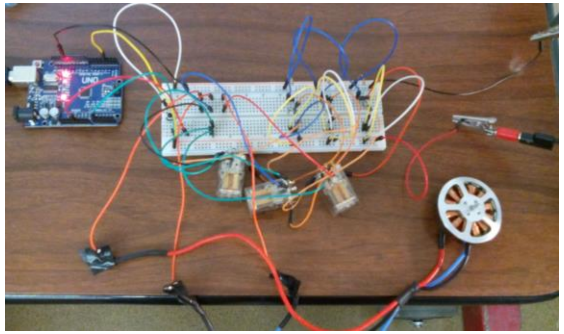

Figure 13: AC Brake Prototype

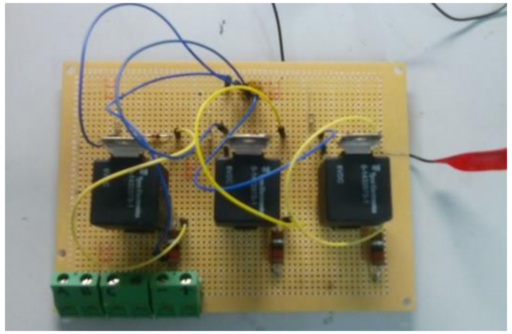

Figure 14: AC Brake Manufacturing

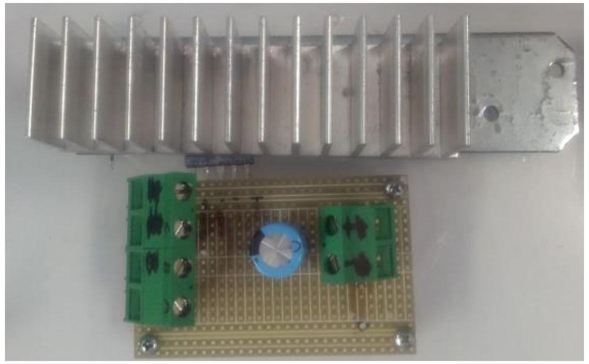

Figure 15: Rectifier Board

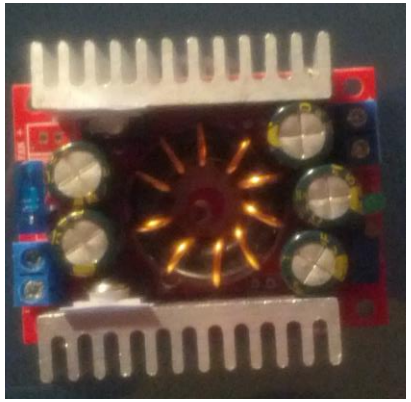

Figure 16: DC/DC Converter

Testing Results

- Connected components to turbine output, measured values and recorded for later analysis.
  - Brakes worked effectively up to 12 m/s wind speed
  - Rectifier has a voltage loss of 1.25 V and is ~85% efficient
  - DC/DC Converter bugs led to redesigns
  - Bonus Load operational
  - Software code redesigned to match new changes

Figure 17: A still from a recorded tunnel test

References

[1] – Schroeder, Dennis. (2015, May 1). *Collegiate Wind Competition Photographs* [Online]. Available: energy.gov/eere/collegiatewindcompetition/

[2] – IXYS. *Shottky Three Phase Rectifier Bridge* [Online]. Available: ixdev.ixys.com

Questions?