Wind Turbine

Tamara Roberson
Candidate for Associate Software Engineer

Who Am I?

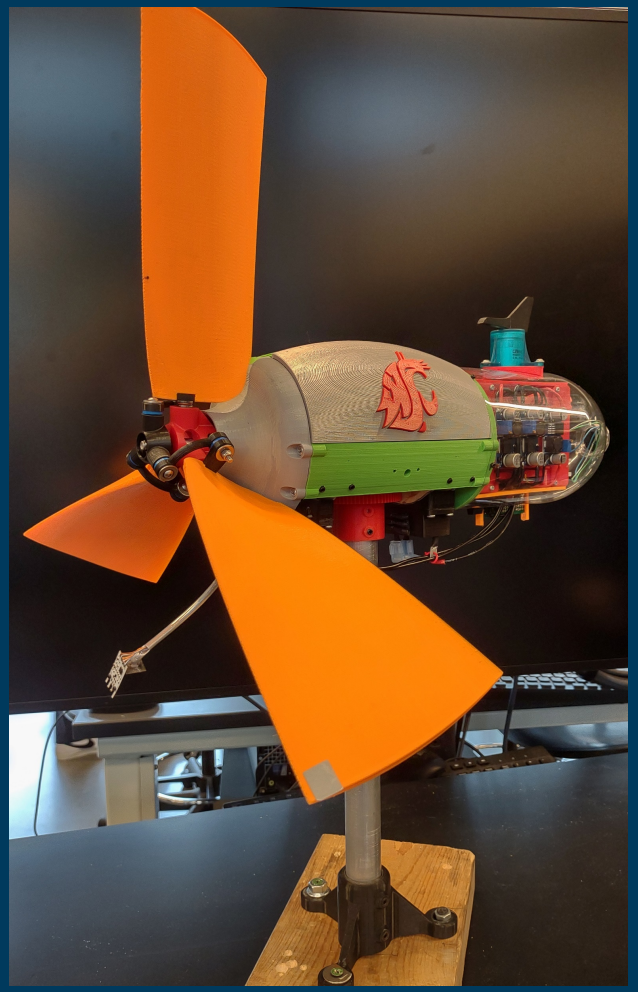
- Tamara Roberson
- Graduating from WSU Everett with a BSEE and CS minor this week
- Starting a career in embedded software
- Hobby: Board Games

Who Are You?

- Name
- Specialization
  - Not your job title
  - What are you the “go to” person for?
  - React? Analog ICs? LaTeX? Regulations?
- Hobbies
  - Open-Source Software? Video Games? Hiking? Museums?

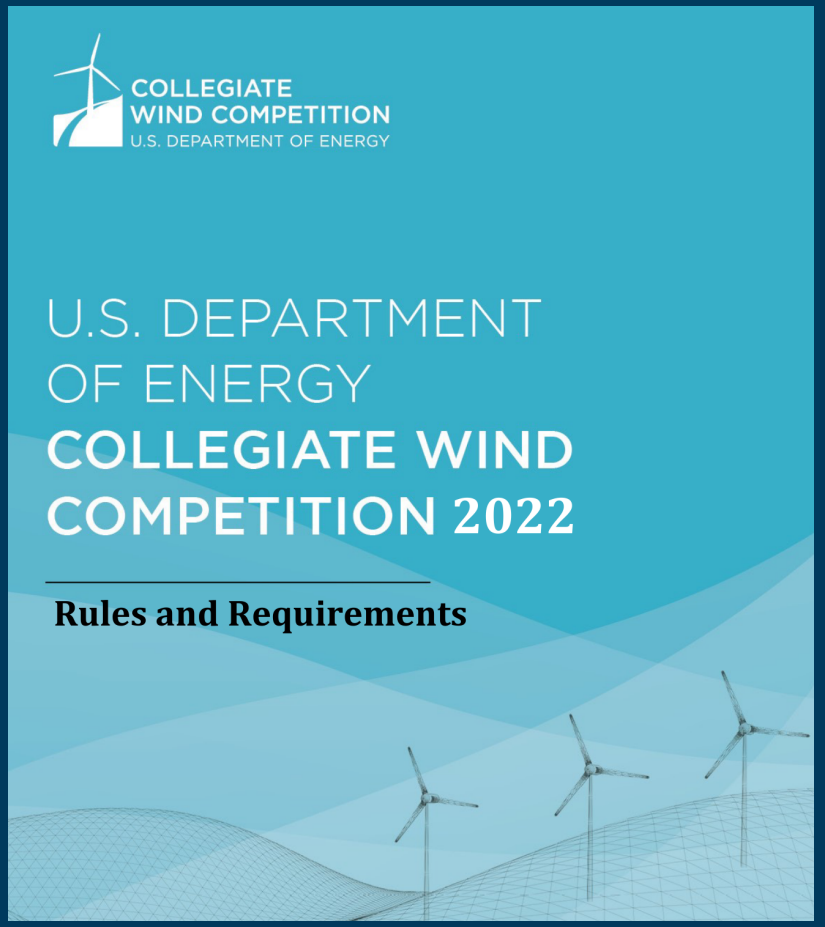
The Team

- Senior Design Project and Engineering Club Team
- US Department of Energy Collegiate Wind Competition
- Team of 3 EEs, 1 ME
  - Club also includes several Business and Communications students for outreach and wind farm business analysis



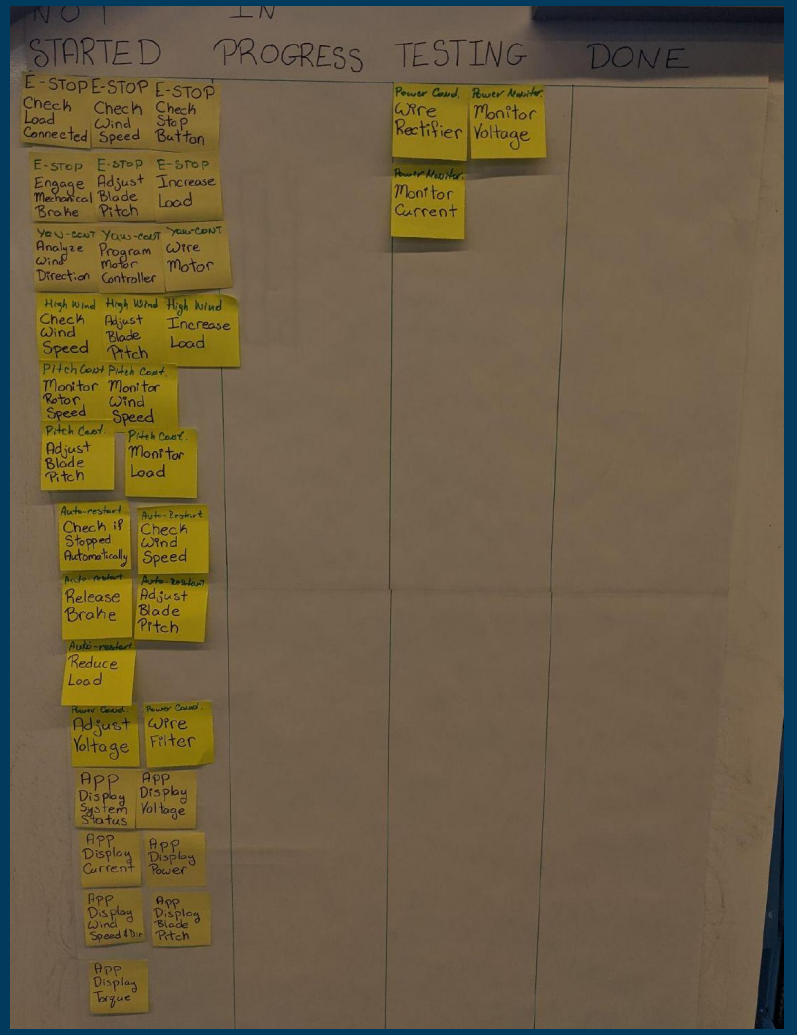
Design Considerations

- Collegiate Wind Competition rules
- Offshore wind turbine designed to be installed in the Gulf of Mexico
- Primary goal: stable, clean 48V dc power
- Secondary goals:
  - Emergency stop and restart
  - Power Arduino controller
  - Yaw control to realign turbine into the wind



Project Management

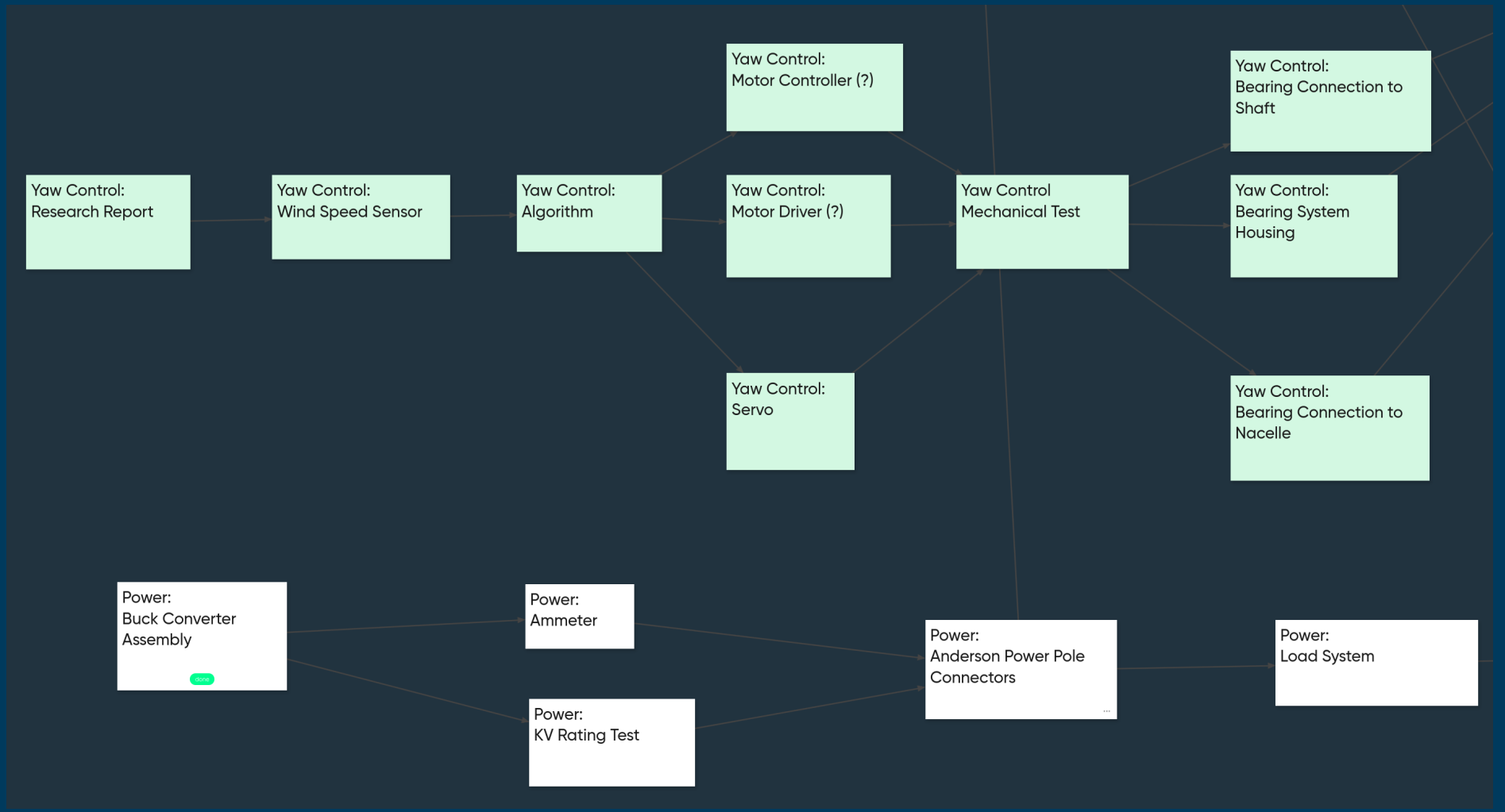
- Wrote user stories
  - “As a,” “I want to,” “So that”
  - Analyzed requirements
  - Created tasks
- Post-It note Kanban first
  - Moved to Trello



Project Management

- Initial work was based on a broad breakdown of subsystems
  - This made it difficult to understand what needed to be done
- For the second semester, I named myself as project manager
  - Studied Project Management on Udemy

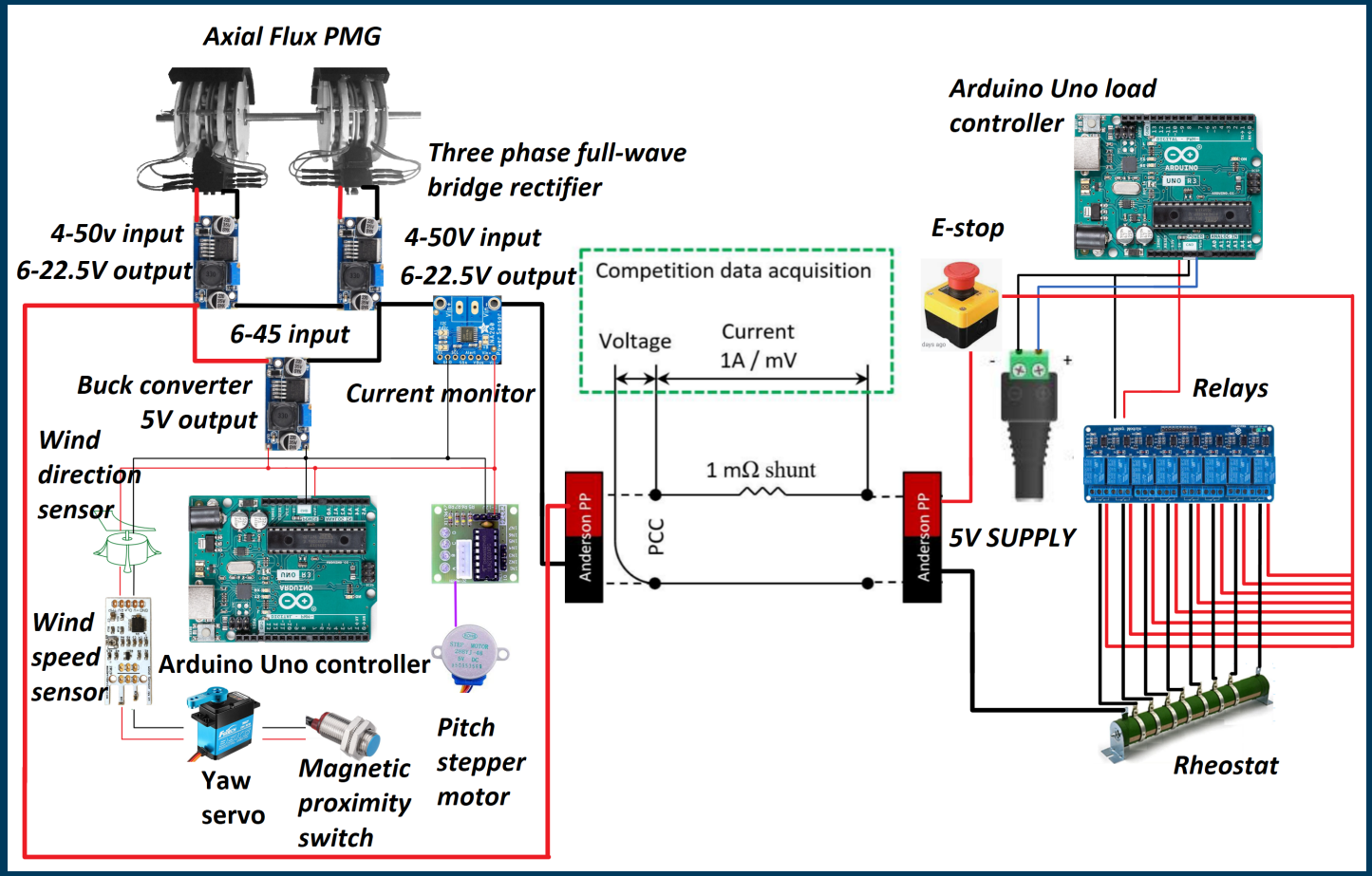
Project Management



Subsystems

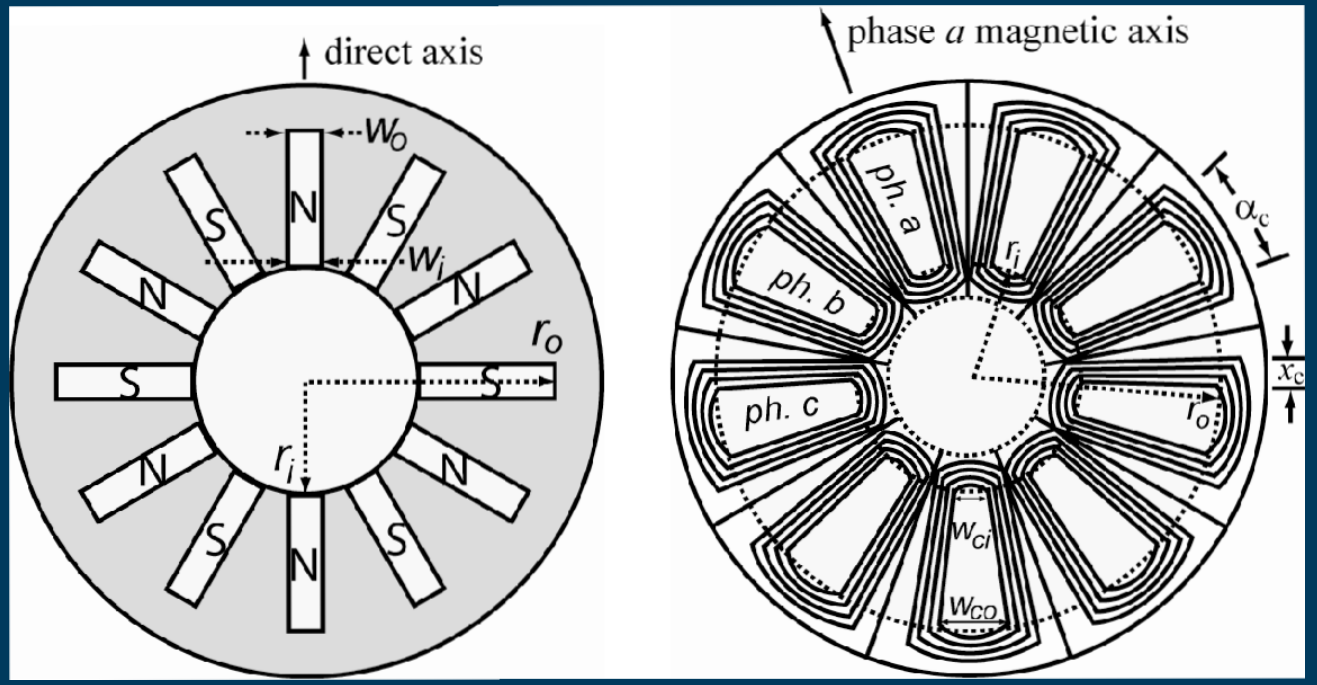
- Power Generation
- Load Control
- Blade Pitch Control
- Yaw Control
- Wind Speed Sensor
- Software and Communication

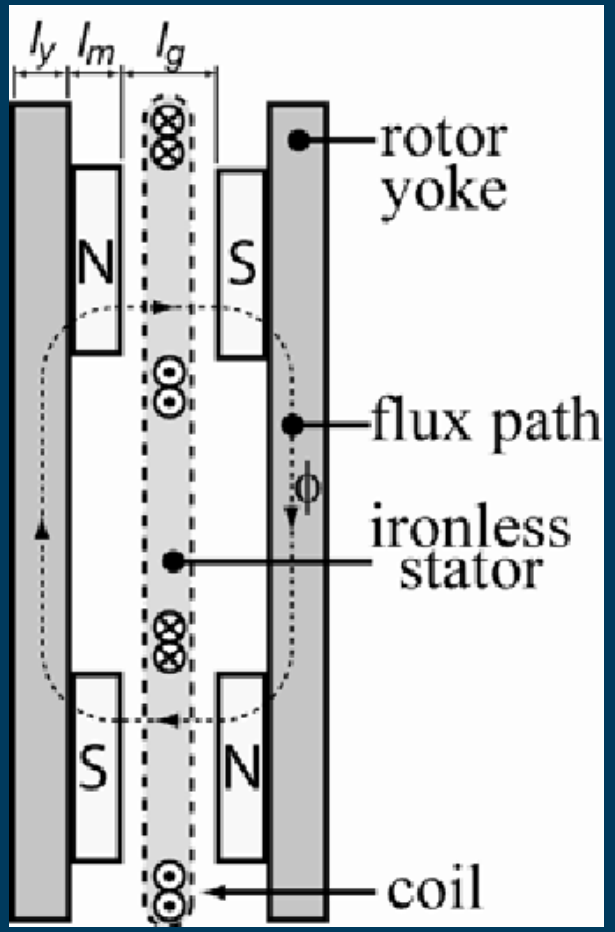
- Integration Testing



Power Generation

Axial-Flux Permanent Magnet Generator (AFPMG)

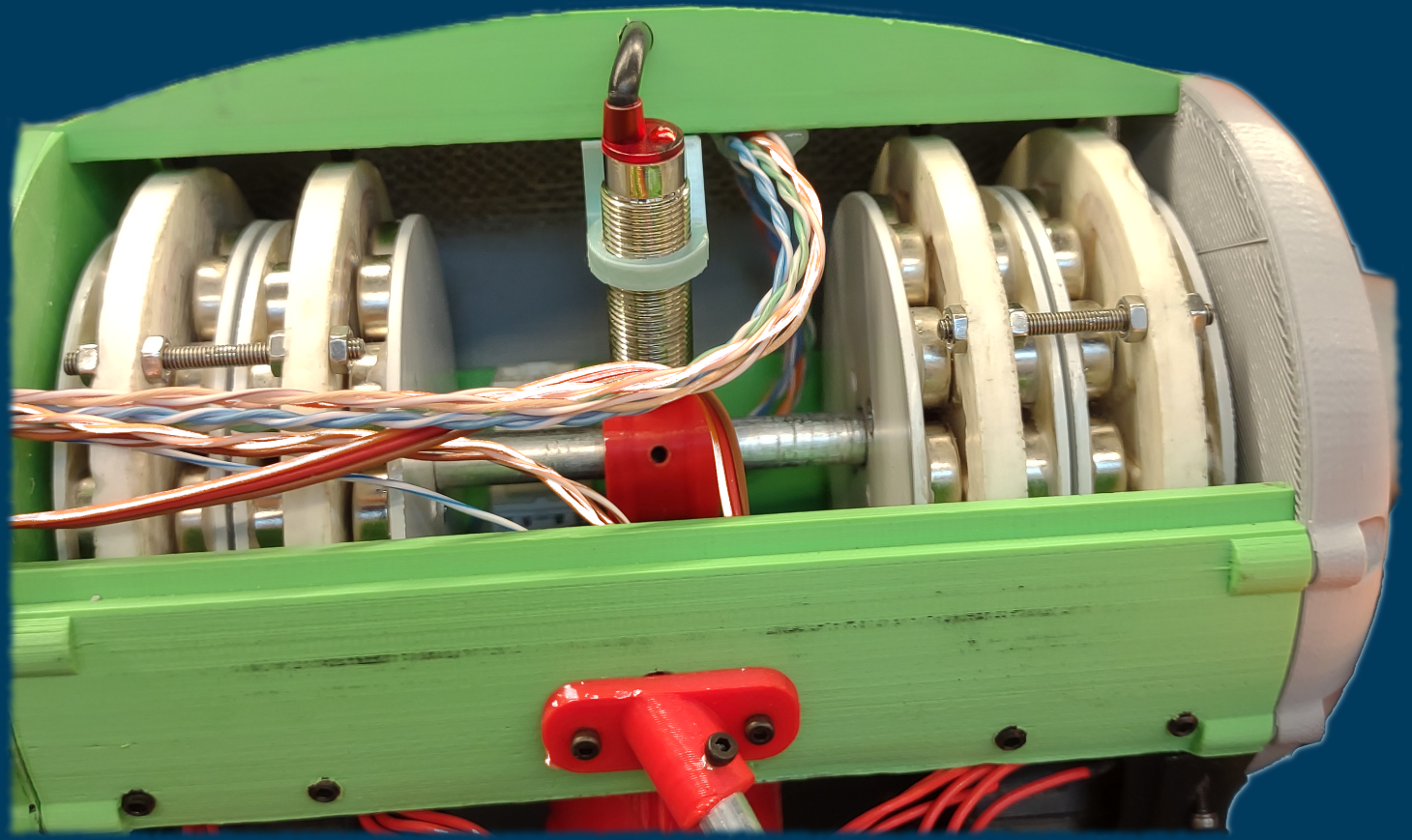




Price, G., Batzel, T.D., Comanescu, M., & Muller, B.A. (2008). Design and Testing of a Permanent Magnet Axial Flux Wind Power Generator.

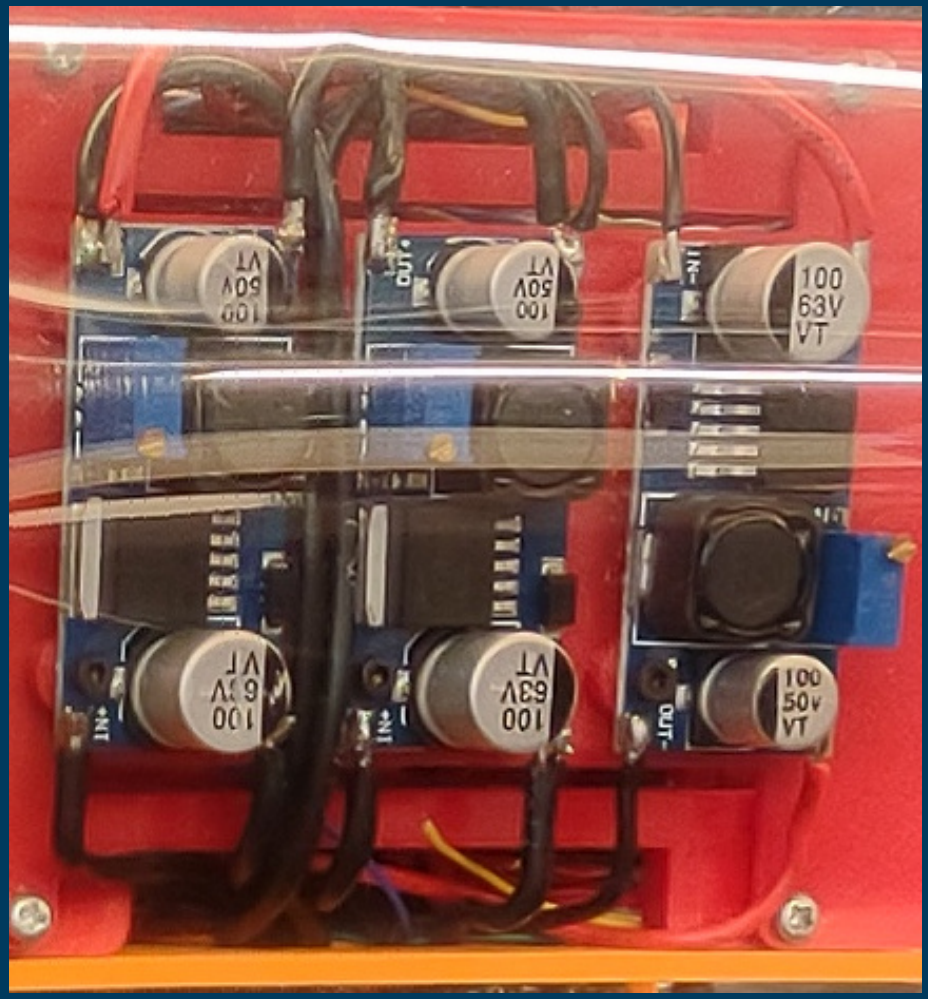
Power Generation

- Needed low cogging torque
- 4 generators in series
- Weight balanced over column
- Produces high torque, even at low speed



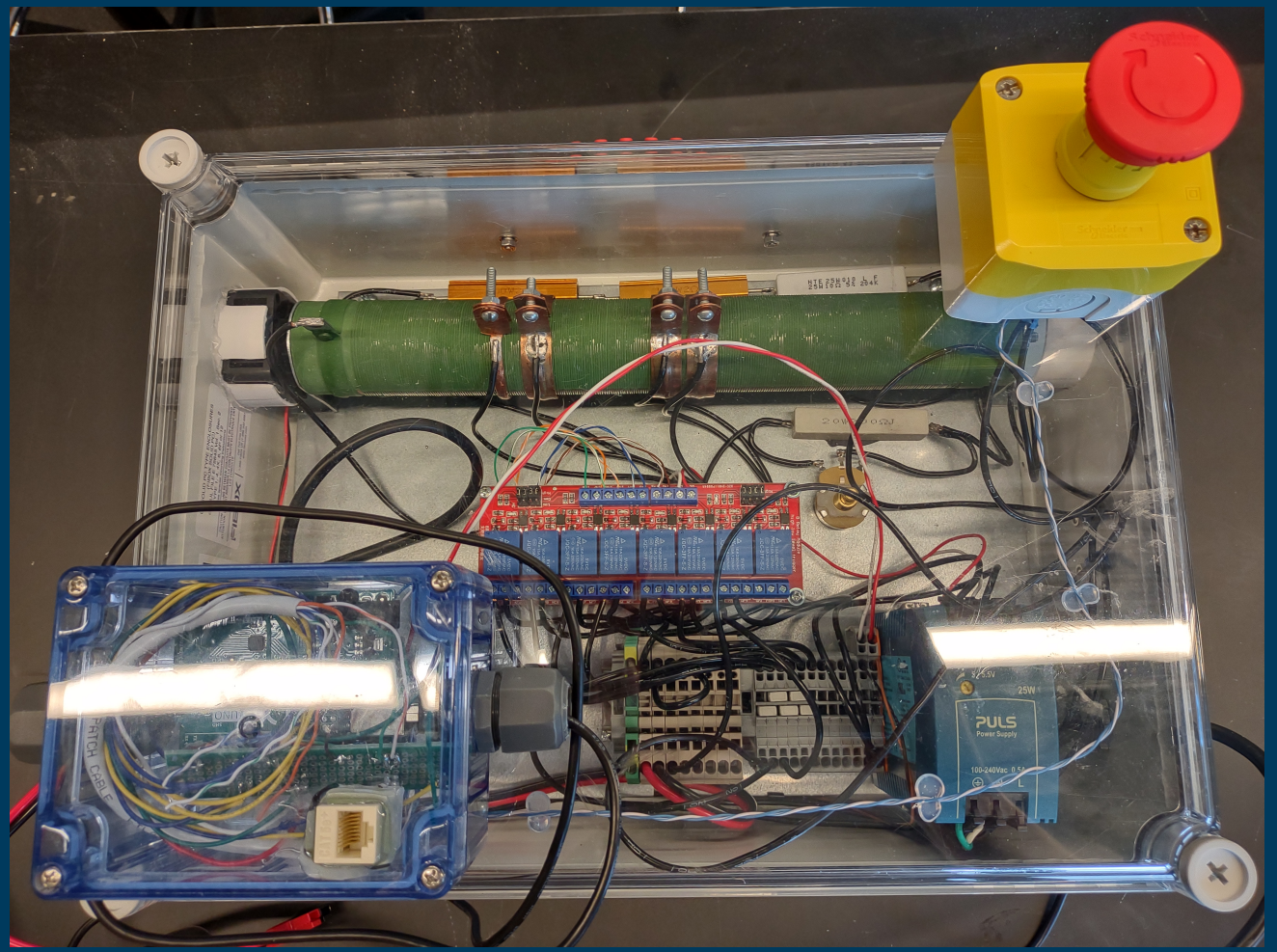
Power Generation

- Two buck converters ensure the produced power remains just under 48V
  - 48V maximum allowed for safety
- One buck converter at 5V for Arduino
- Problem: Two buck converters that are in series require 4.5V each
  - 9V but Ardiuno is 5V



Load Control

- Linear rheostat
  - 400W, 200Ω
- 8 bank optically-isolated relay
- Emergency stop button
- Arduino controller
  - Ethernet port

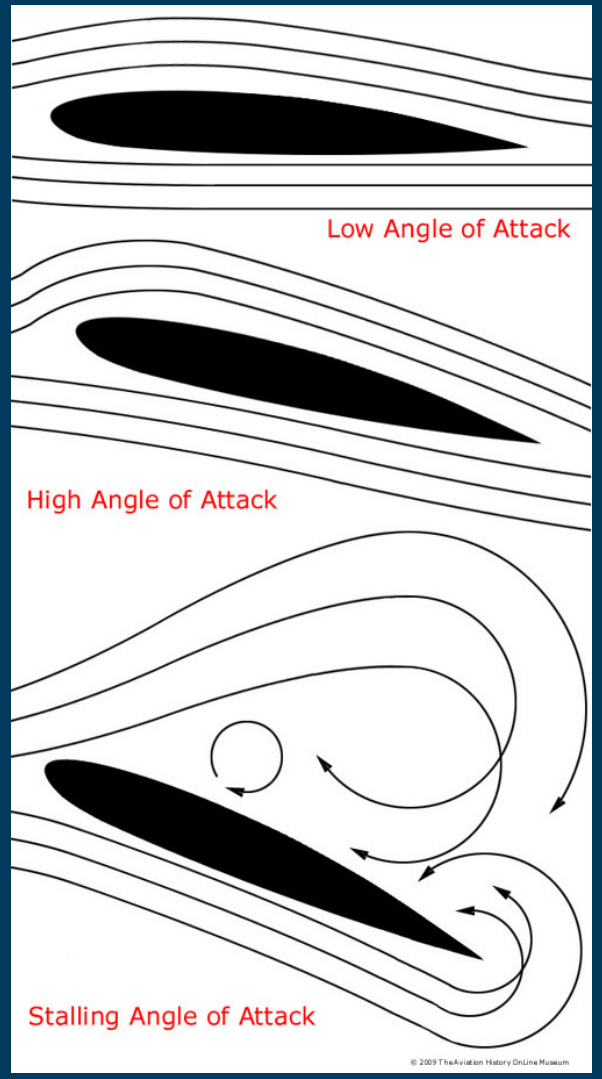


Blade Pitch Control

- Servo motor was imprecise
- Stepper motor could be configured
- Control system monitors the rate of change in speed

Blade Pitch Control

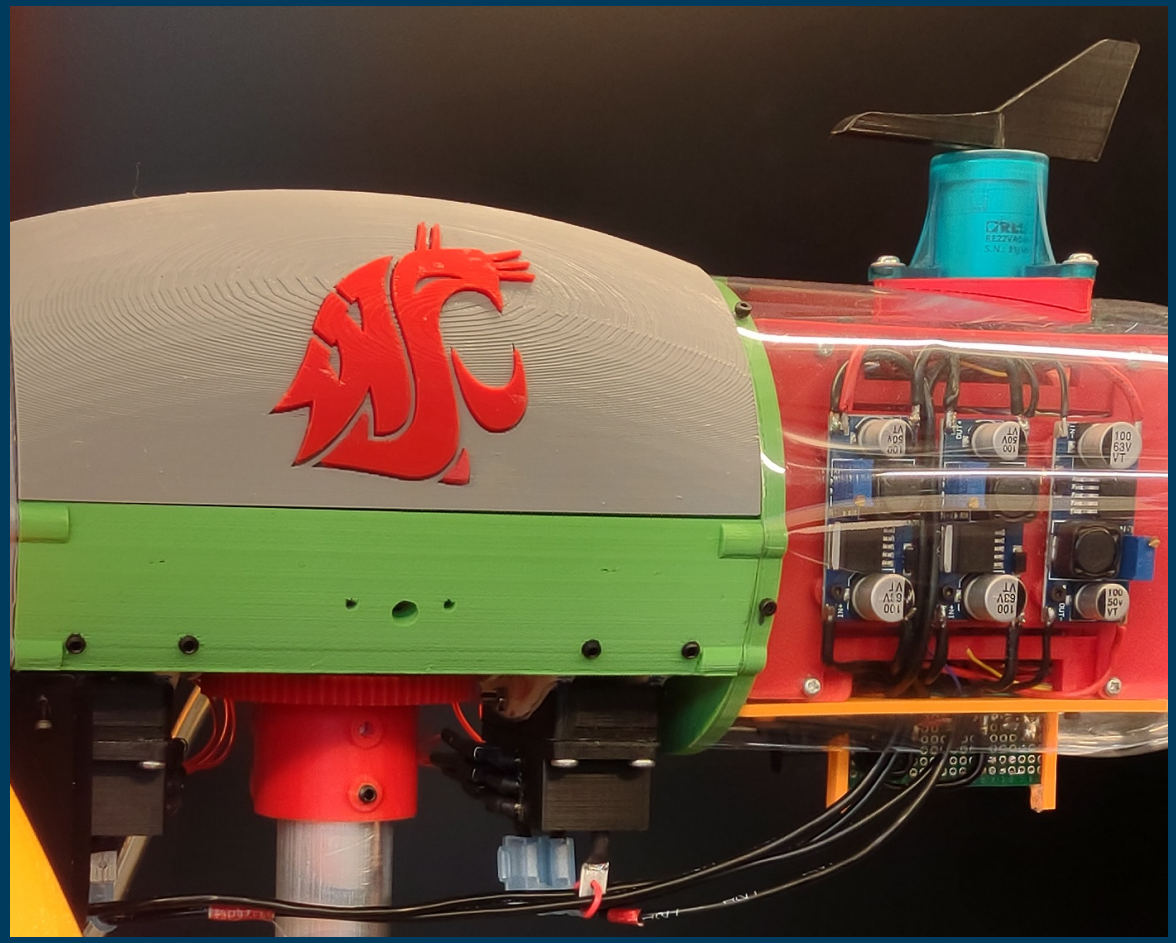
- Turbine blades rely on the same Bernoulli's principle as airplane wings
- Increasing the angle of attack improves lift, creating torque
- But too high and the laminar flow is broken, causing the turbine to stall



"Angle of attack," The Aviation Online History Museum, Jun. 1, 2015. [Online]. Available: http://www.aviation-history.com/theory/angle_of_attack.htm.

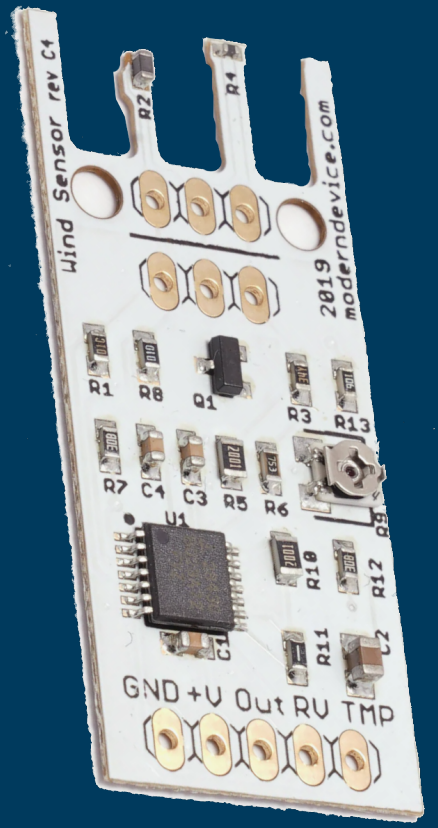
Yaw Control

- Turbine must rotate to face the wind
- Active yaw system provides more control
- Wind direction sensor triggers continuous servo motor
  - 7:1 gear reduction



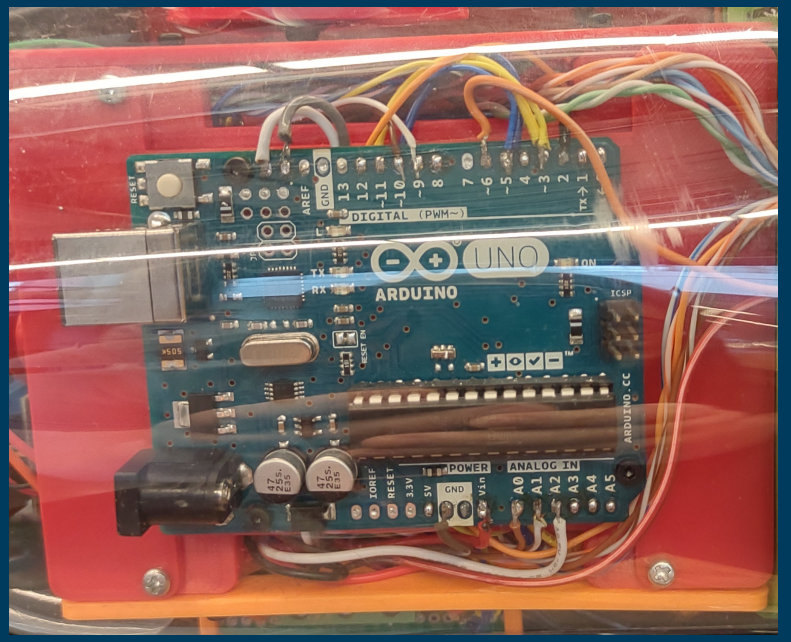
Wind Speed Sensor

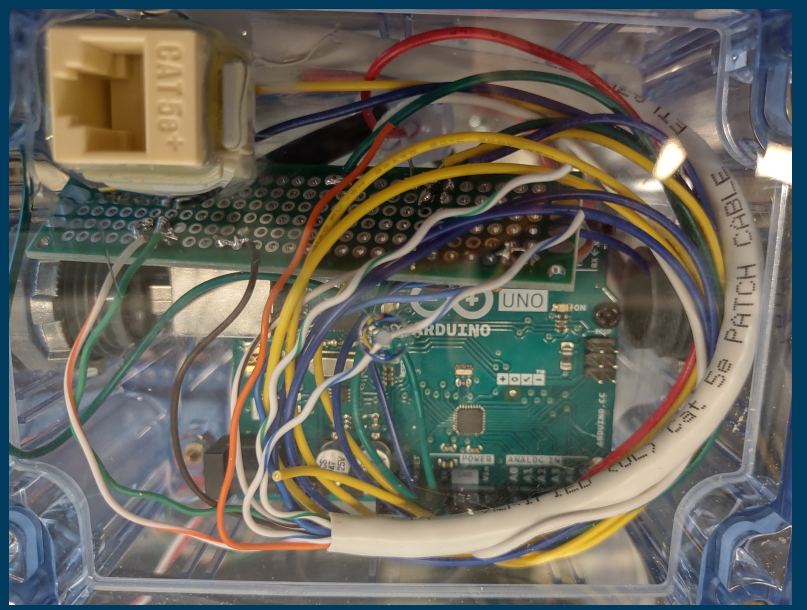
- Hot wire anemometers measure the temperature of a fine wire
- Tried 12V hot wire
  - Too high
- Tried cup anemometer
  - Where to mount?
- Selected 5V hot wire



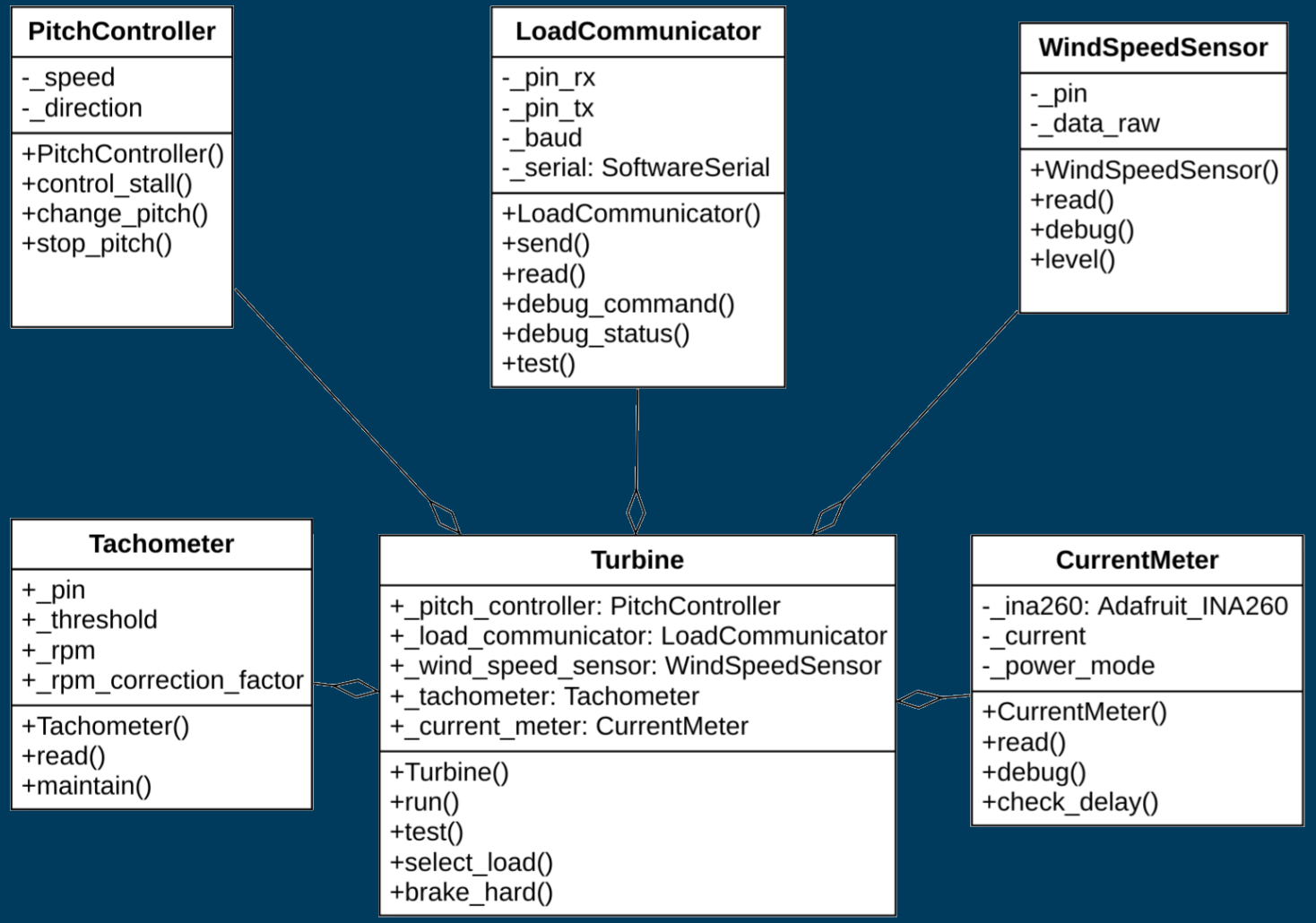
Software

- Turbine Arduino
- Load Control Arduino
- Communicate over UART using a modified Ethernet cable
- Turbine sends the load controller a command
  - Increase, Decrease, Disable, Maximize
- Load controller returns status

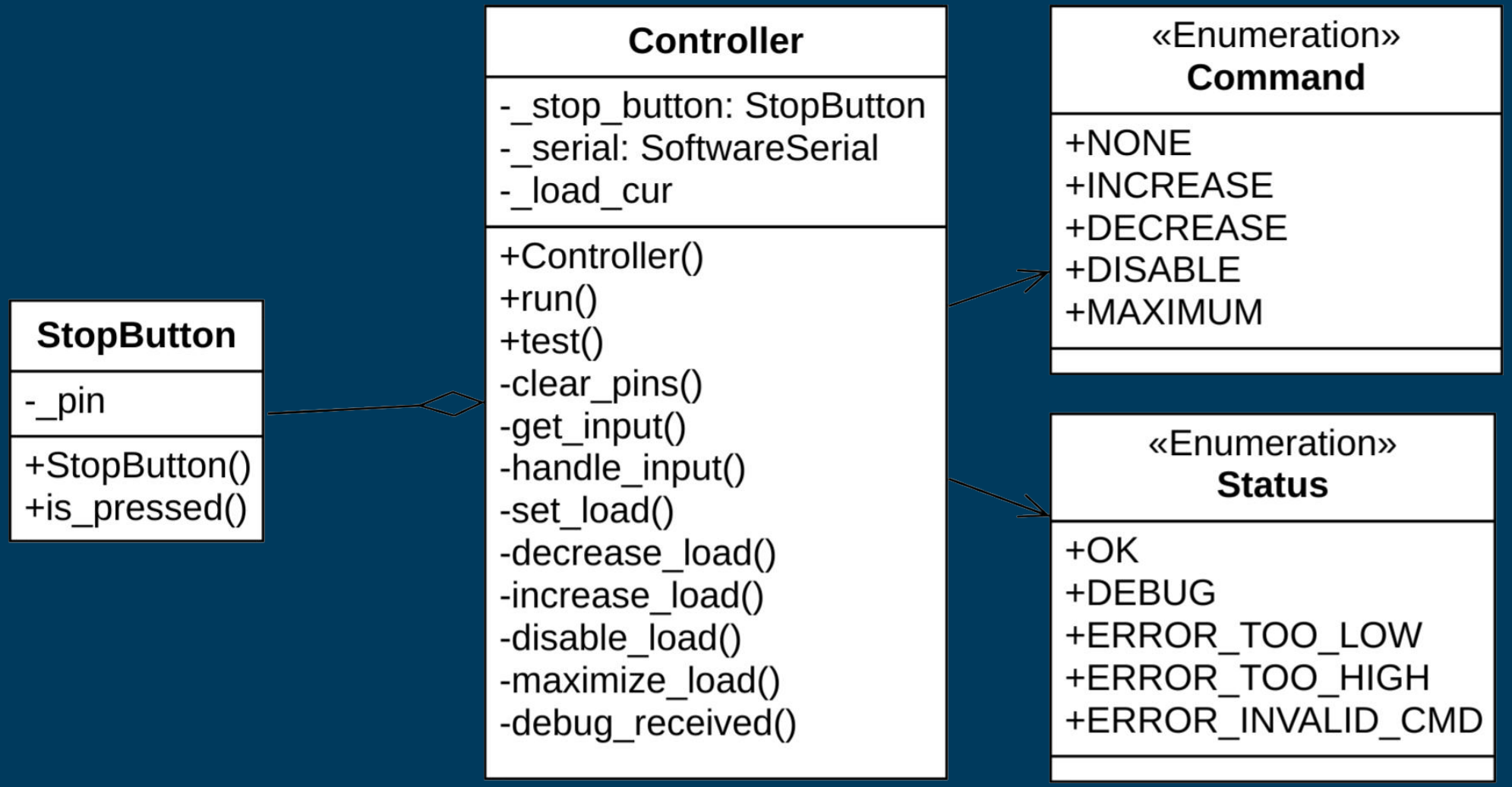




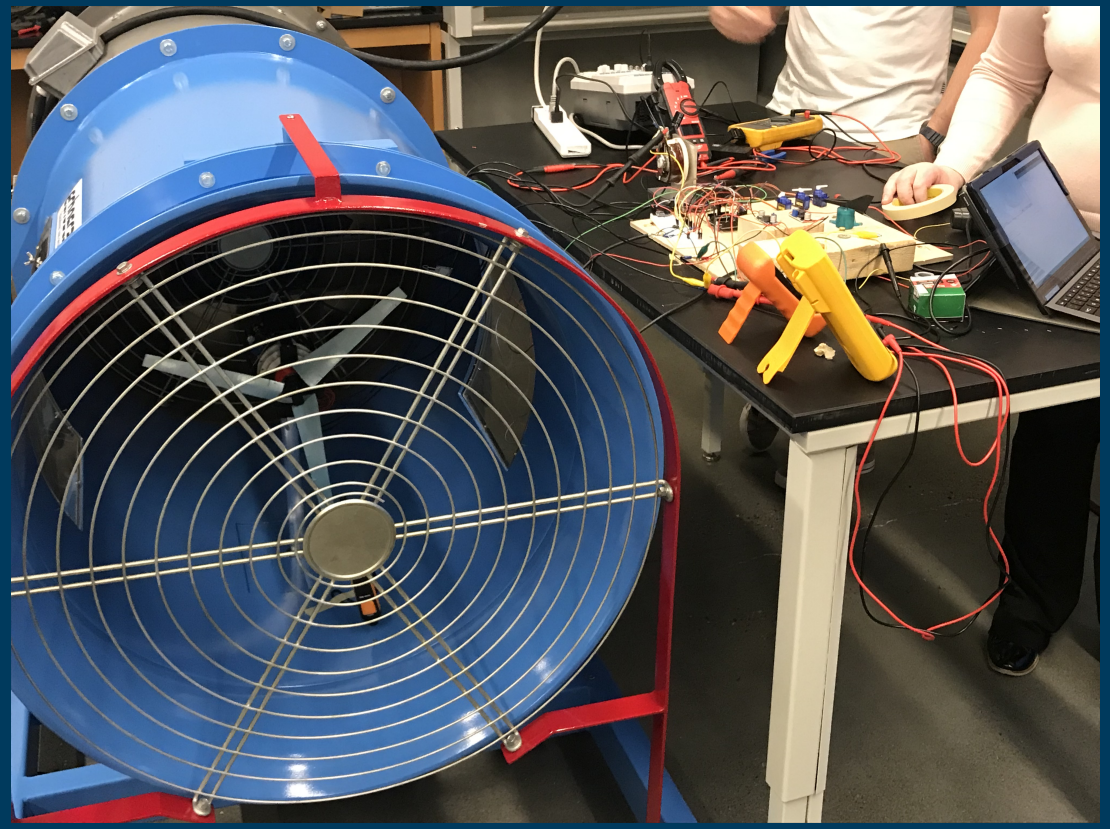
Software: Turbine

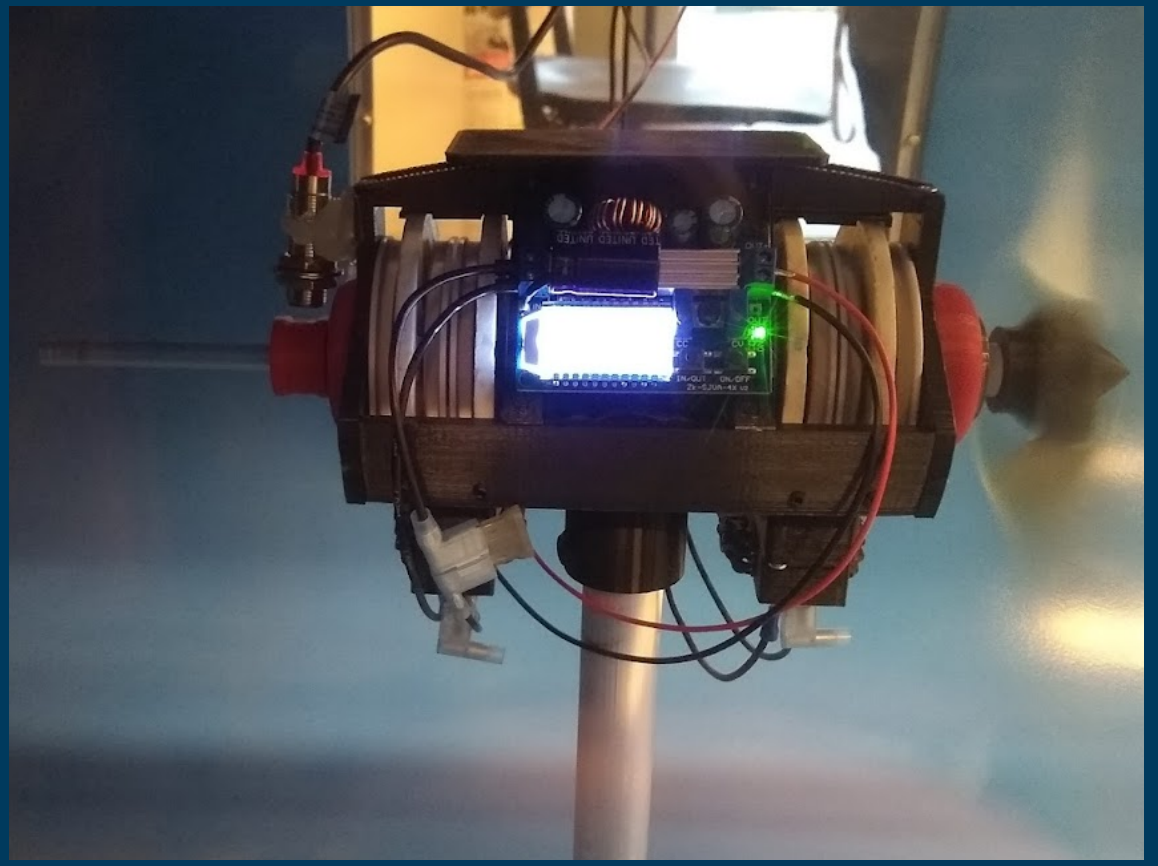


Software: Load Controller

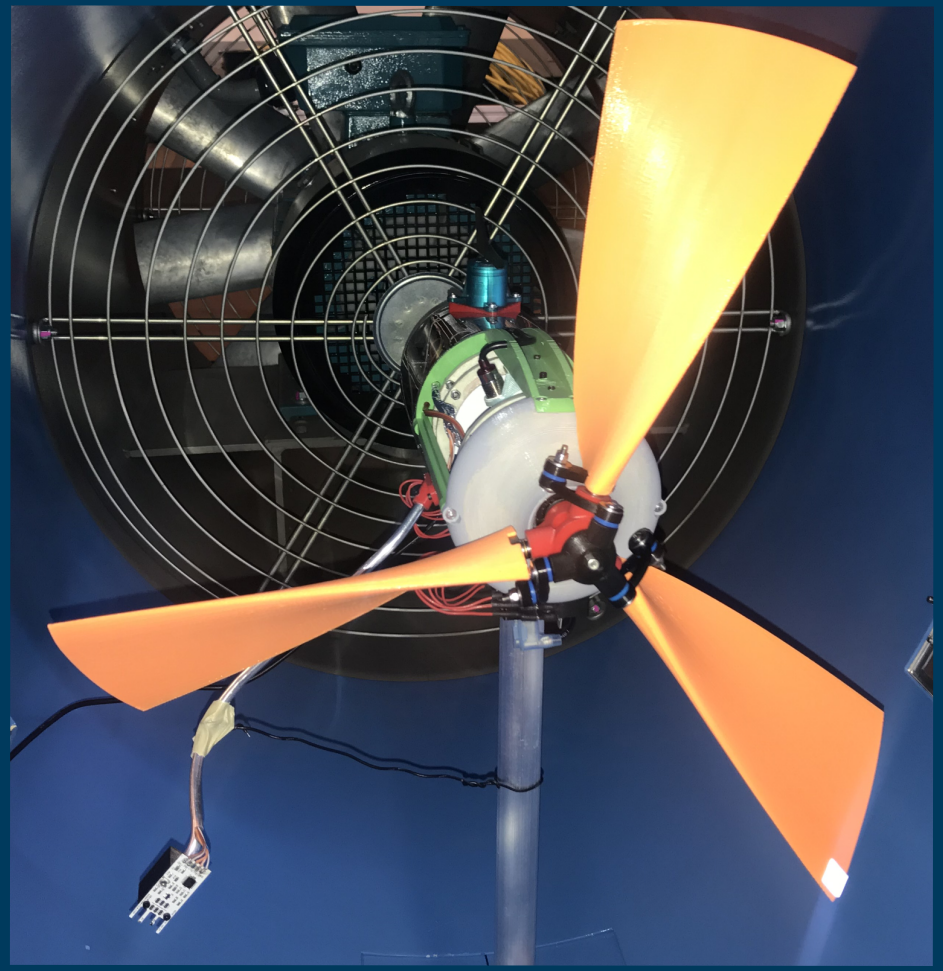


Testing





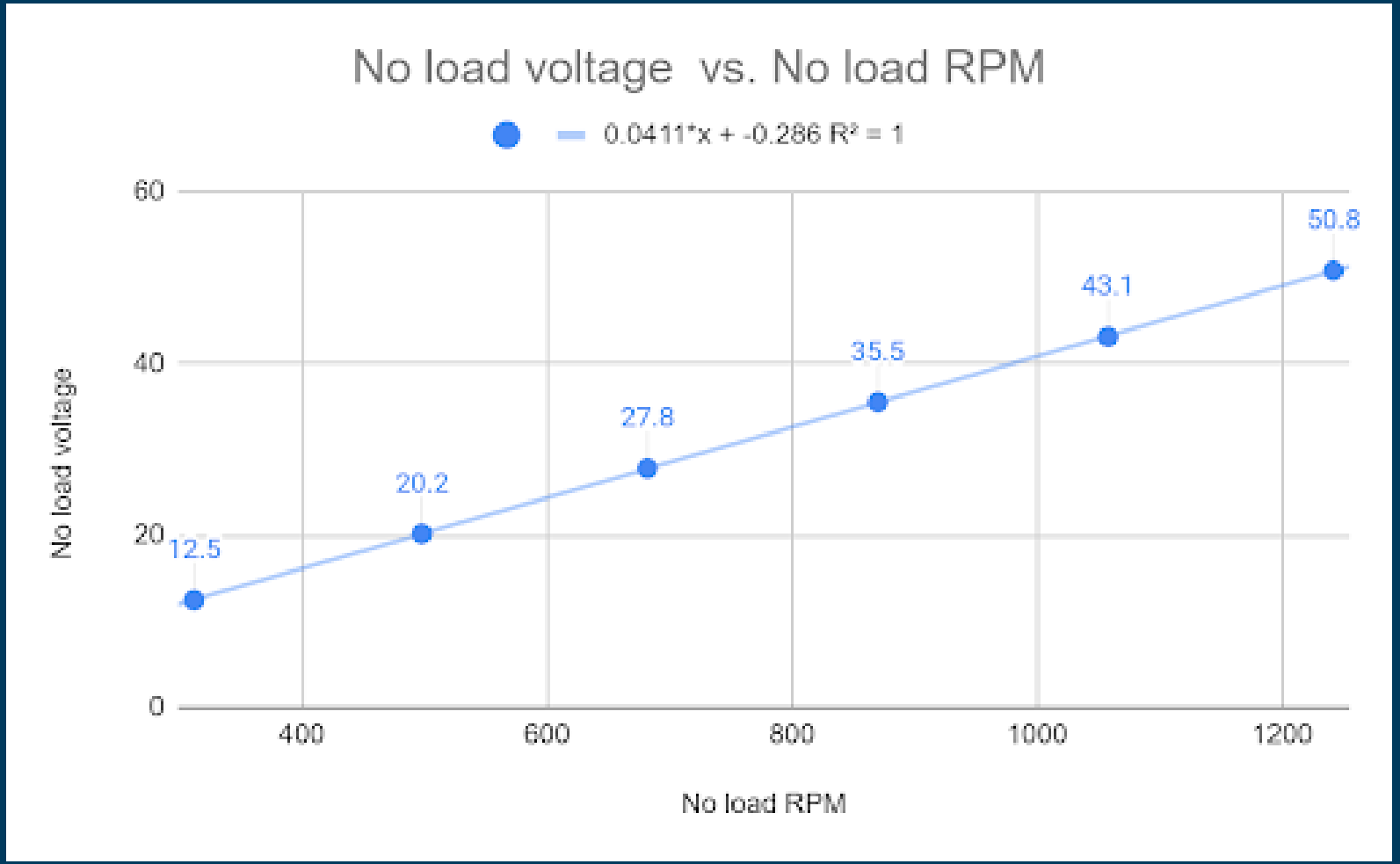
Testing



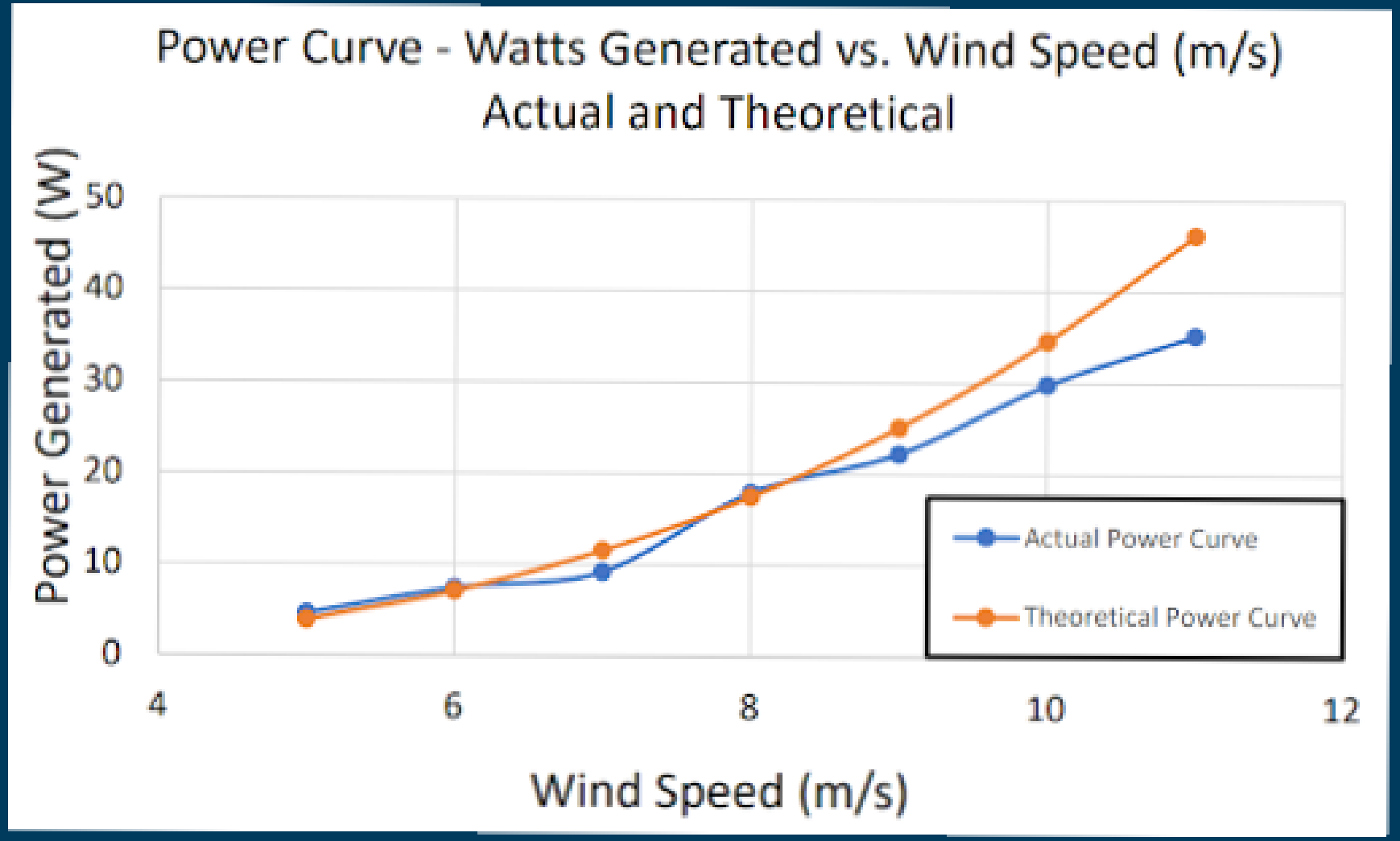
Tension Test: Need 25 lbf (2000 RPM),
Breaking Point: 870 lbf

Results

Kv Rating:
24 RPM / V



Results


Power Curve - Watts Generated vs. Wind Speed (m/s)
Actual and Theoretical
Power Generated (W)
50
40
30
20
10
0
4
6
8
10
12
Wind Speed (m/s)
Actual Power Curve
Theoretical Power Curve

Acknowledgments

Electrical
- Boris Gindlin
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