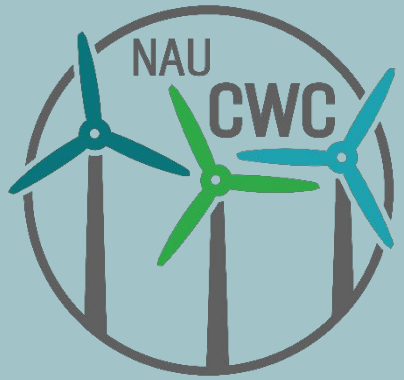


Team 5: NAU CWC ‘20-21 EE Team

Final Project Presentation

Aidan Nash, Noah Bell, Benjamin Allen, Nolan McNeil, Evan Kramer

Project Introduction

About our Client:

- Professor Venkata Yaramasu, PhD
  - School of Informatics, Computing, and Cyber Systems (SICCS)
  - Research Interests: Renewable Energy, High Power Converters, variable-speed drives, electric vehicles, energy storage, smart grid, and model predictive control
  - Author of “Model Predictive Control of Wind Energy Conversion Systems” published by Wiley-IEEE Press in 2016

Evan Kramer

Project Introduction

Problem Statement: The Department of Energy (DOE) supported an annual Collegiate Wind Energy Competition (CWC) at the American Wind Energy Association (AWEA) CLEANPOWER conference. The problem is as more wind energy was incorporated into the U.S. power generation mix, qualified workers are needed to fill related jobs at all levels

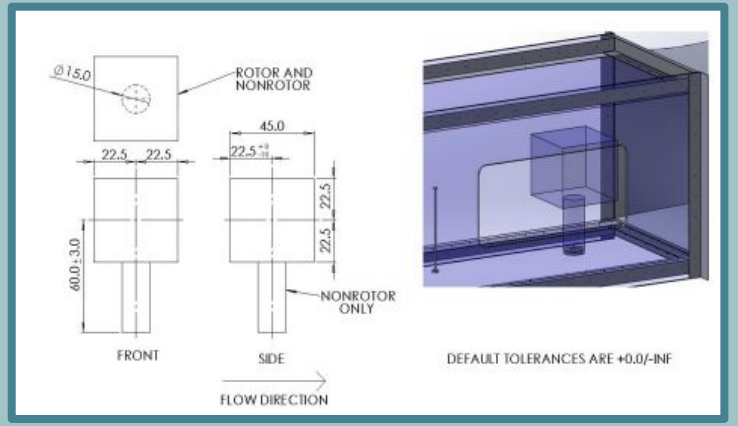
Goals: The goal of the CWC was to prepare students from multiple disciplines to enter the wind energy workforce by providing real-world technology experience. The NAU team consisted of one electrical, and two mechanical engineering subteams.

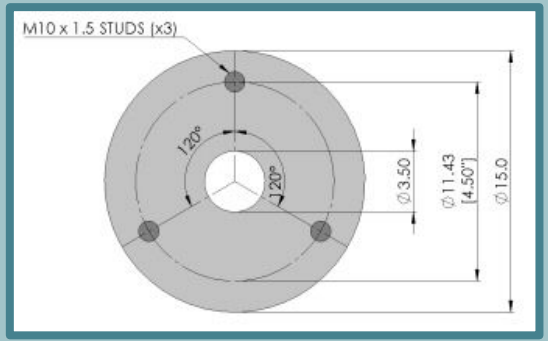
Project Description: The team was responsible for all electrical components and enclosures from the turbine to the load. This included a three-phase generator, an AC/DC converter, a DC/DC boost converter to raise the voltage, a microcontroller (MCU) circuit to regulate the output voltage, and a resistive load.

Evan Kramer

Important Requirements

- Entire turbine must fit within volume specified:
  - Turbine bust withstand 22 m/s wind speed
  - Up to 25 m/s when parked
  - Rotor and Non-rotor parts contained in 45 cm^3 box
  - Turbine height and width < 61x122 cm
- Wind Turbine must be mountable on test stand:
  - Base plate material no thicker than 16.1 mm
- Electrical Requirements
  - DC current must be at or below 48 volts
  - Base plate must hold 100 kOhm or less resistance
  - The turbine must be in separate enclosures from the load





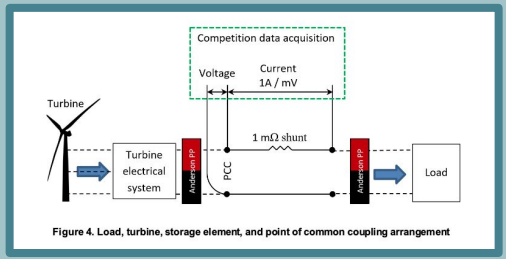
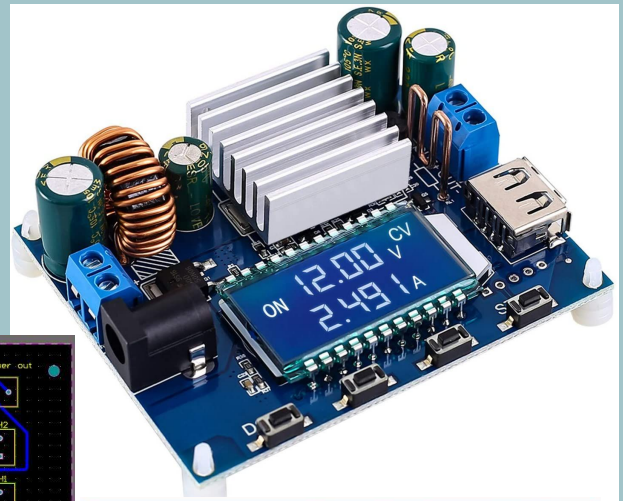


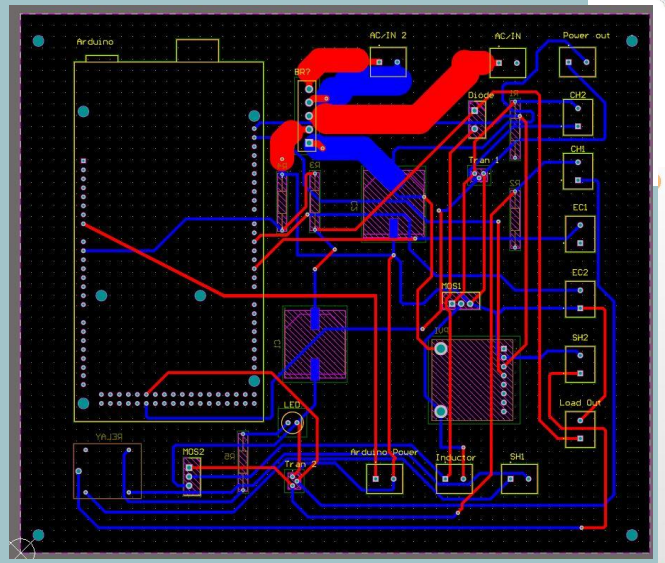
Figure 4. Load, turbine, storage element, and point of common coupling arrangement

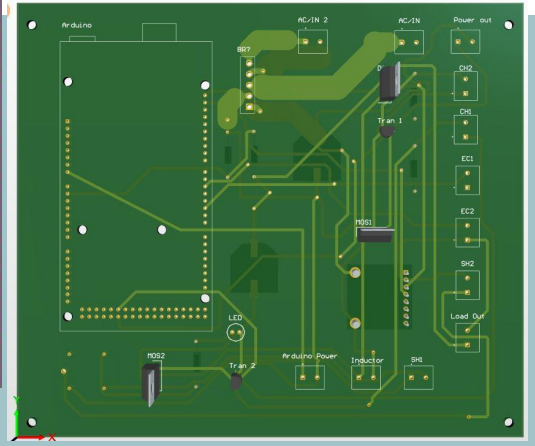
Evan Kramer

Prototypes: Overview

- DC/DC Converter
- Rectifier Circuit
- PCB







Nolan McNeil

Prototypes DC/DC Converter

Timeline: January 2021-February 2021

Goal:

- Successful completion of perf board by end of February.

Status:

- Successful completion with working model,
- Did not complete on time due to component back orders.

Nolan McNeil

Prototypes: Bridge Rectifier

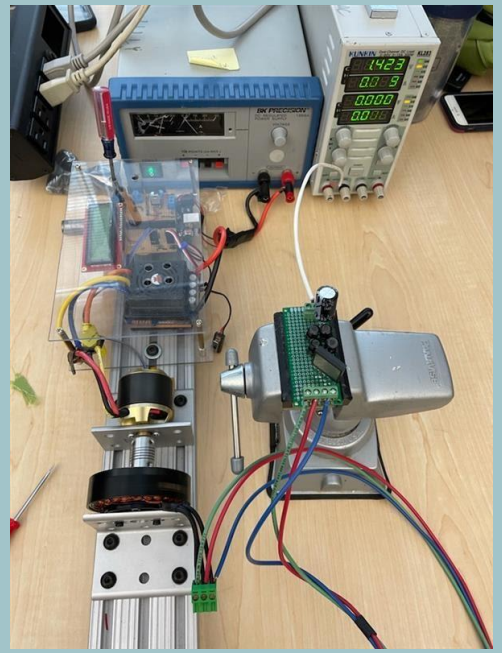
Timeline: December 2020- February 2021

Goal: Obtain power curve and test the rectifier.

Status: Complete

Notes:

- Inductors were blown due to high amperage.
- More inductors added in parallel.
- Successfully generated power curves for multiple motors.



Nolan McNeil

Prototypes: PCB

Timeline: January 2021-April 2021

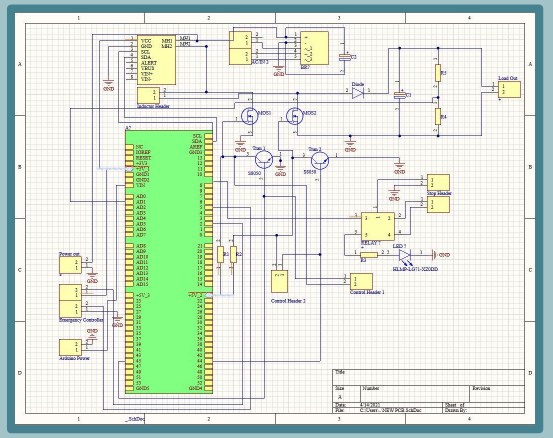
Goals:

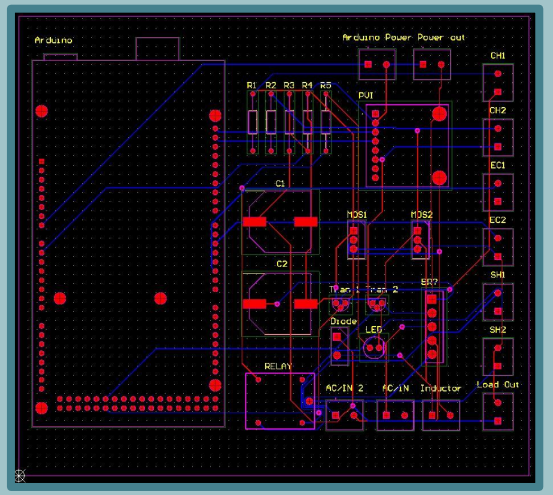
- Bridge rectifier PCB prototype by March 15th.
- Complete PCB by April 15th.

Errors:

- Trace width
- Schematic redesign/modifications
- Footprint creation
- Layering

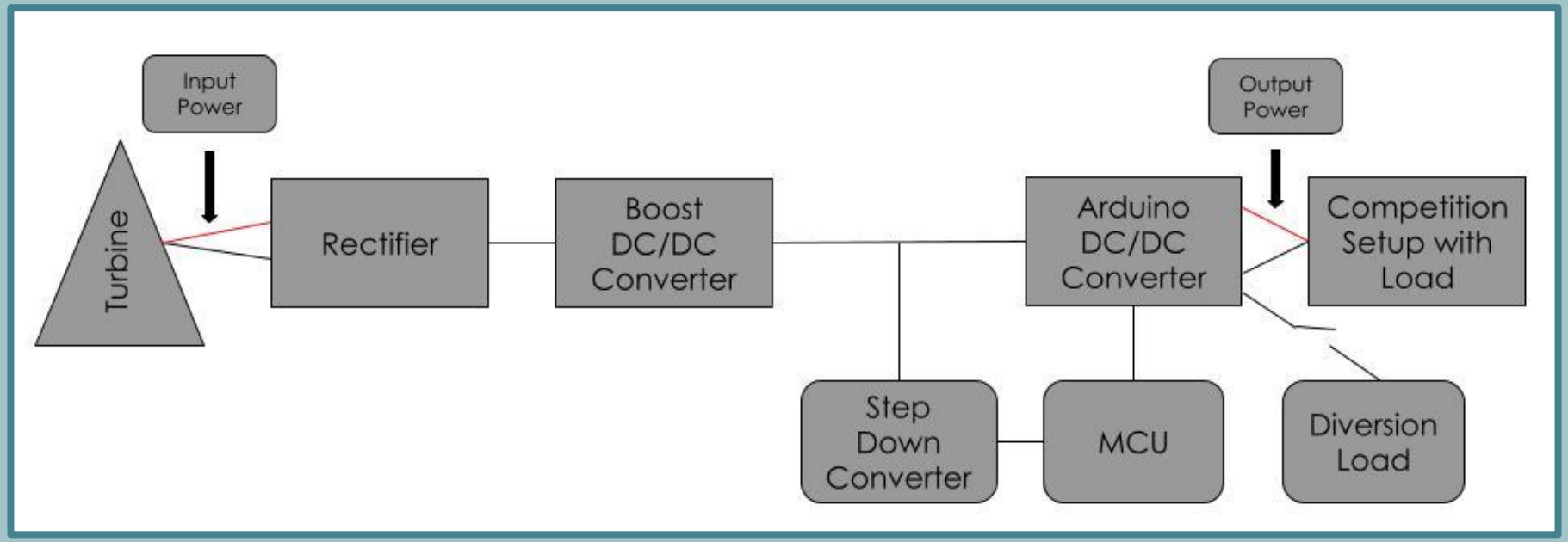
Status: Final Prototype complete. Final design coming.





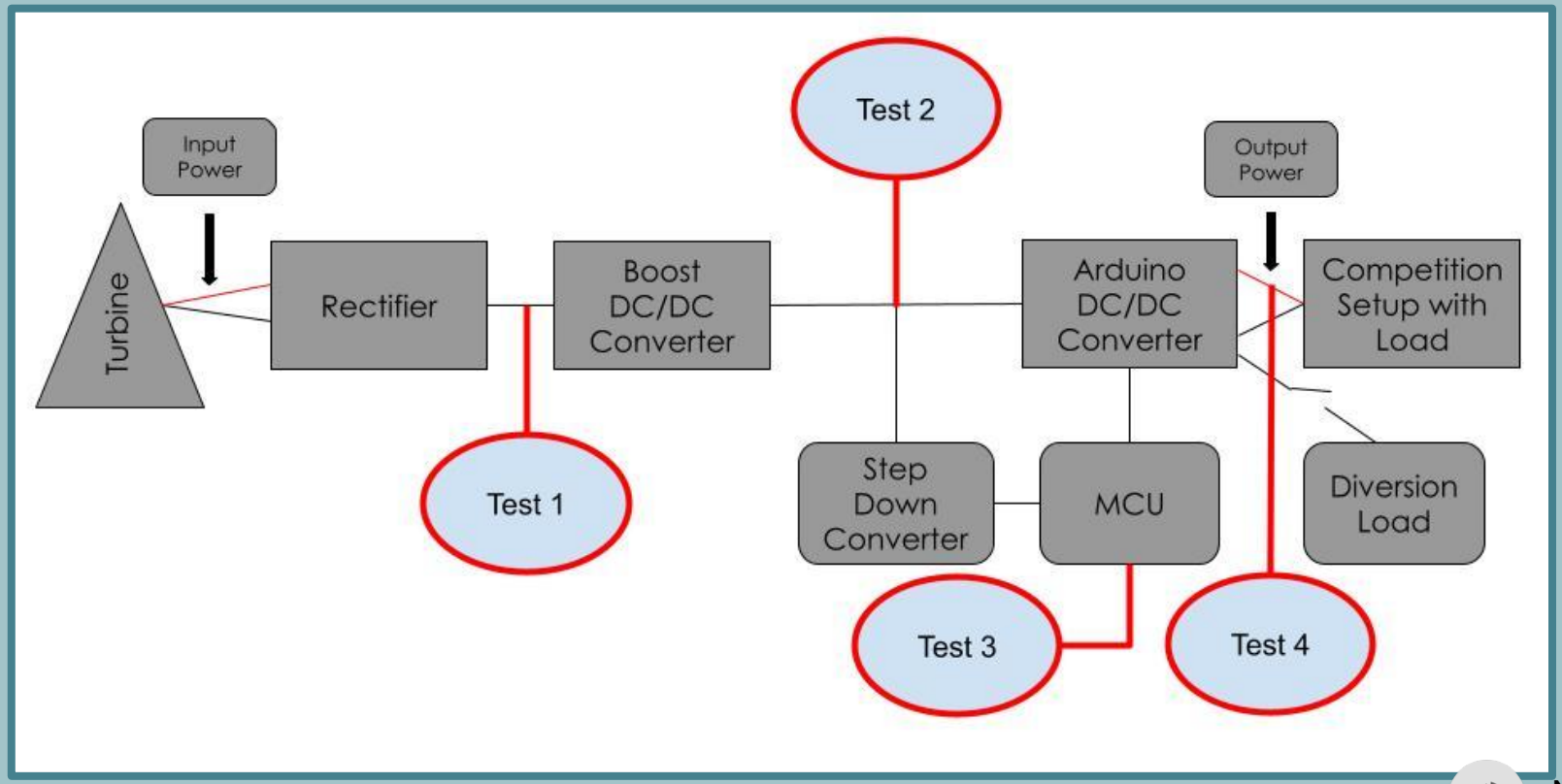
Nolan McNeil

Level 1 System Architecture



Noah Bell

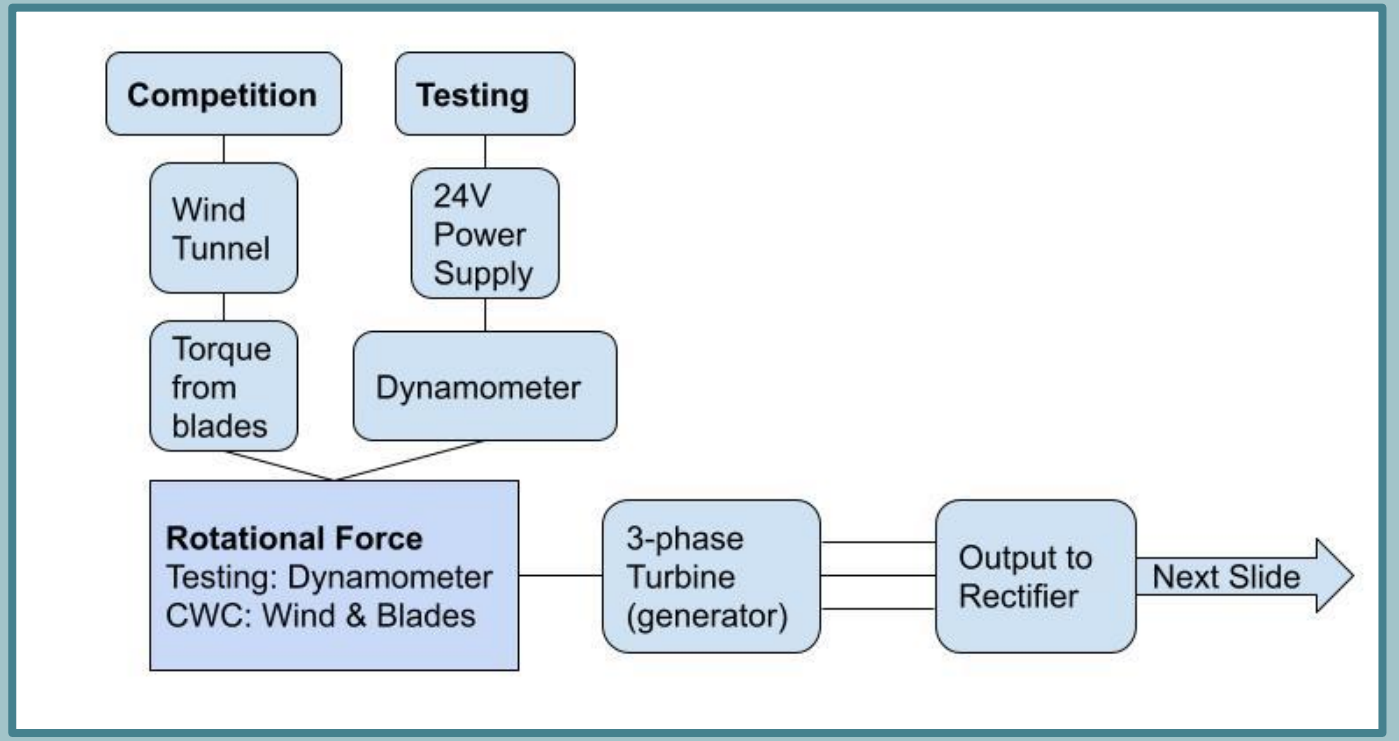
Testing System Architecture



Noah Bell

Level 2 System Architecture - Generator

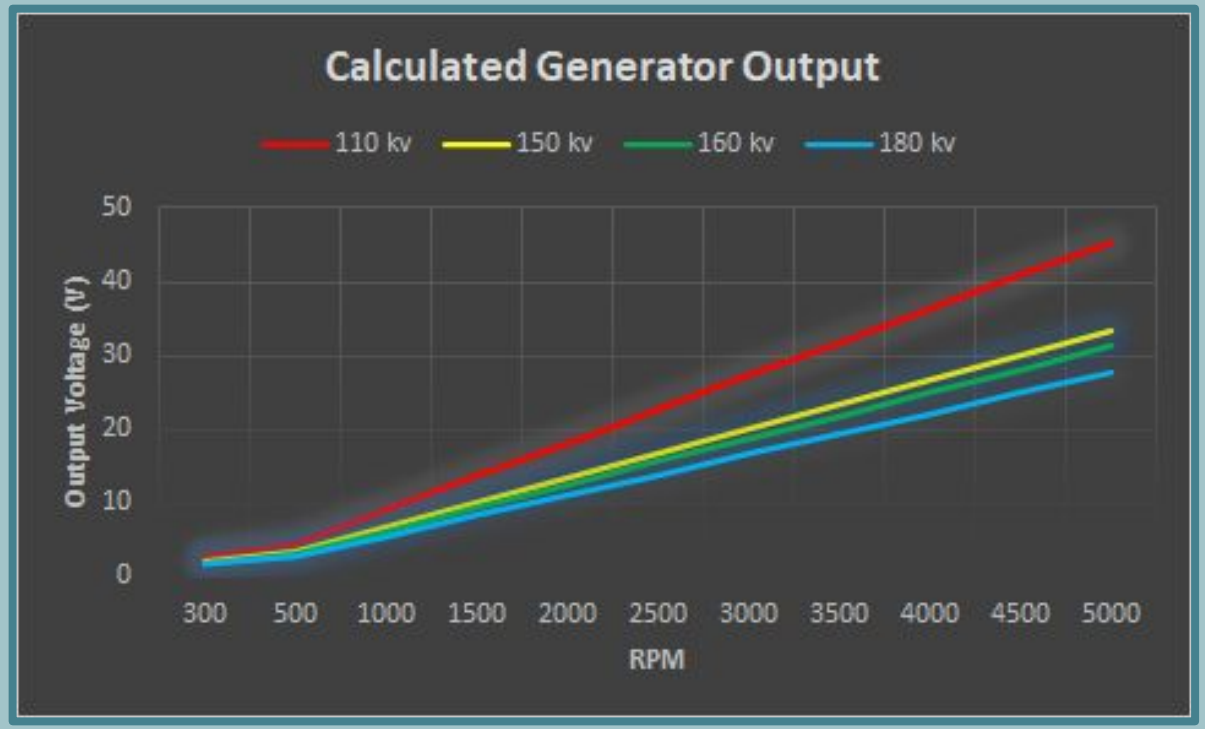
- Competition will implement wind tunnel for testing
- Lab testing used dynamometer with adjustable speed control
- 3-phase output goes to rectifier



Noah Bell

Testing Results - Generator Selection

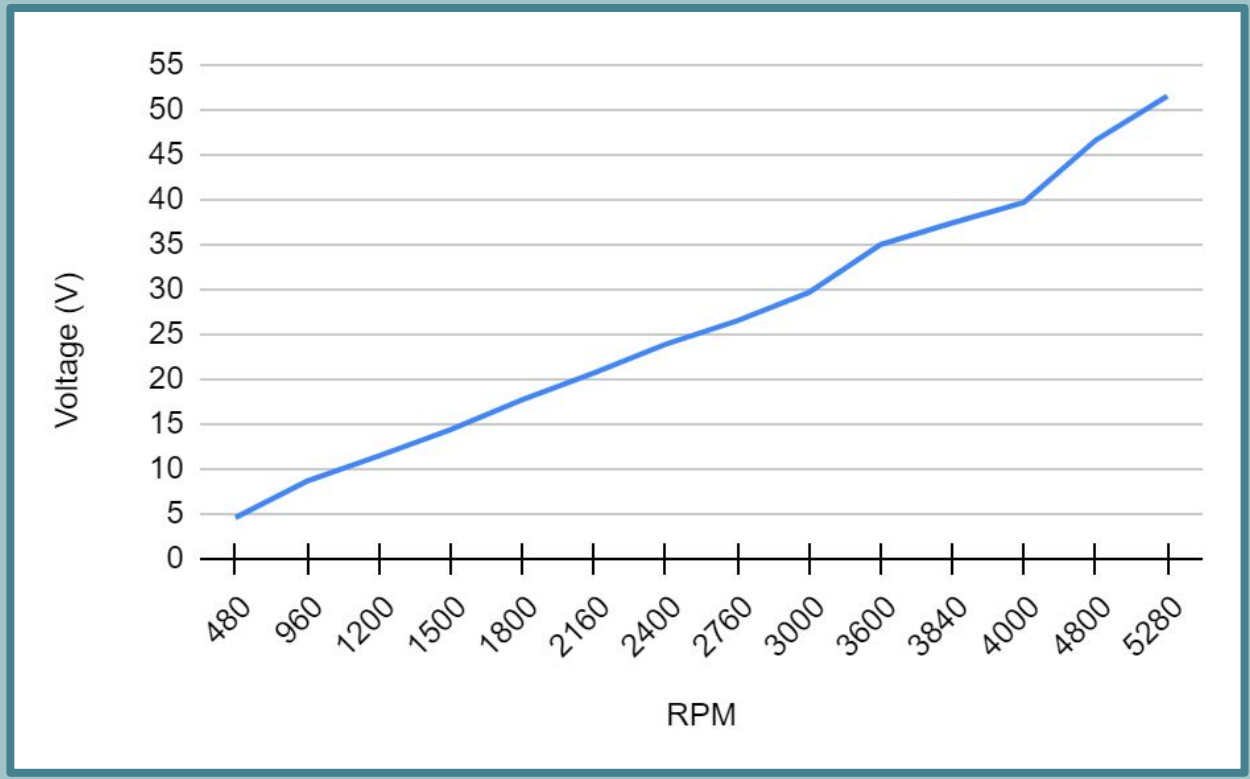
- Figure shows the expected voltage output of various generators
- Kv = rpm / volt
- Motor selected: MAD 5010 110 kv (red line)



Noah Bell

Testing Results - Generator

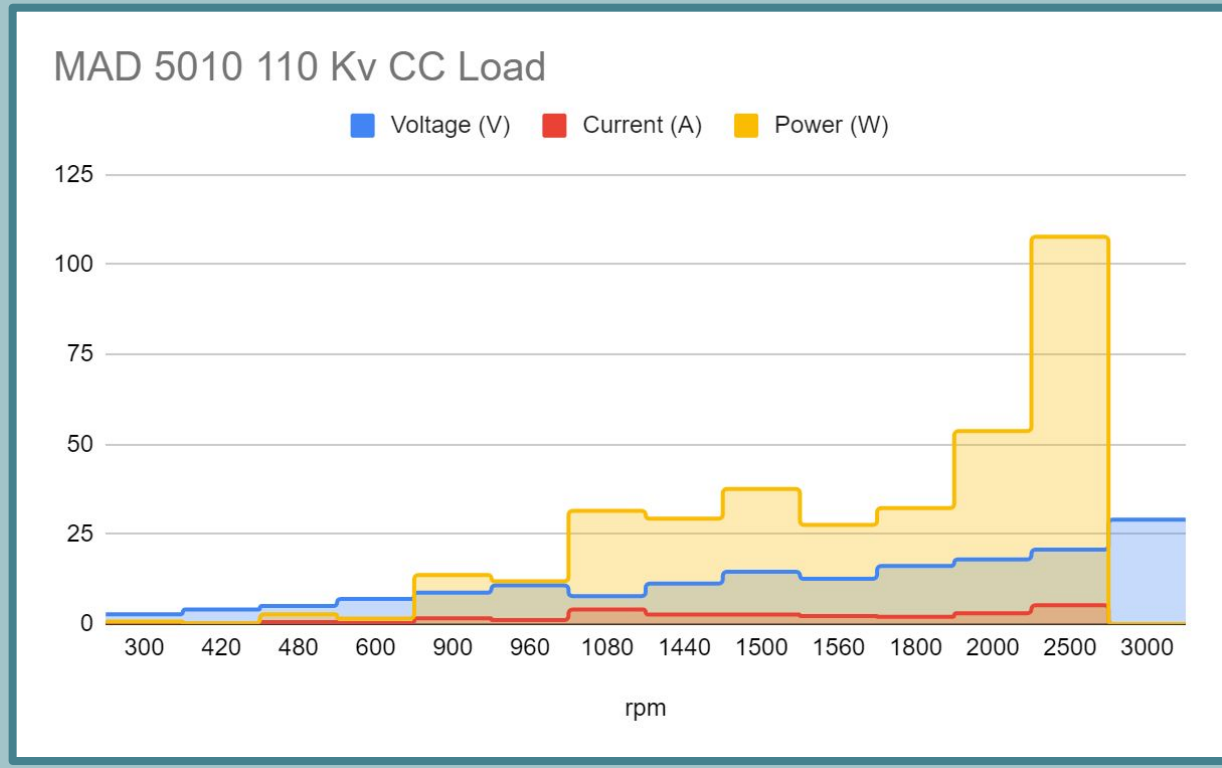
- MAD 5010 110 kv
- Kv = rpm/volt
- Open Circuit Testing
- Min voltage: 4.67 at 480 rpm
- Max voltage: 51.5 V at 5280 rpm



Noah Bell

Testing Results - Generator

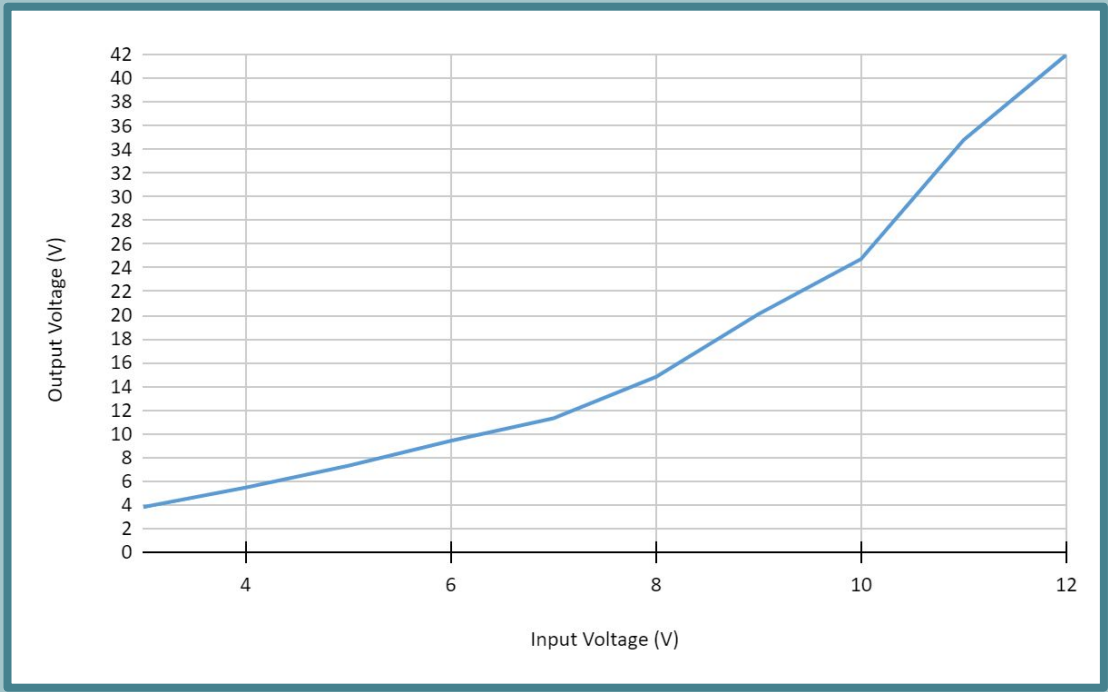
- Power output
- Max speed tested: 3000 rpm
- Min speed startup: 300 rpm
- Peak power output: 108.4 W at 2500 rpm



Noah Bell

Testing Results - DC/DC Converter

- Using a variable DC load at .03A of CC, we were able to boost
  - Once we increase the current past .05A, the voltage no longer boosts
  - On a fully resistive load, it doesn't boost at all
- Attempted switching to a different MOSFET, with the same results
- Could potentially work in an integrated system assuming we could limit current



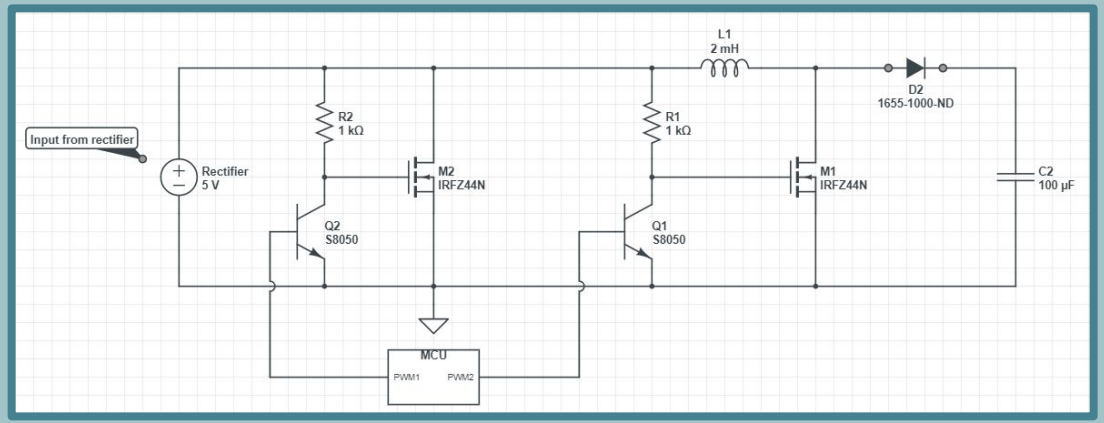
Voltage curve based on .03A CC, 10kHz, 50% Duty cycle

Aidan Nash

Testing Results - DC/DC Converter cont.

- Verified the MOSFET gate voltage to be in proper operating region
- Transistor is properly switching based on o-scope reading
- Capacitor is discharging
- MCU is properly outputting

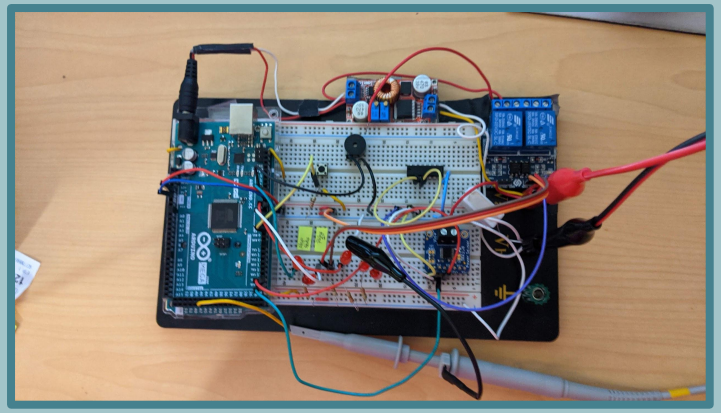
- The team reached out to the client, and are currently in the process of troubleshooting
    - For the time being, we integrated with a prefab boost

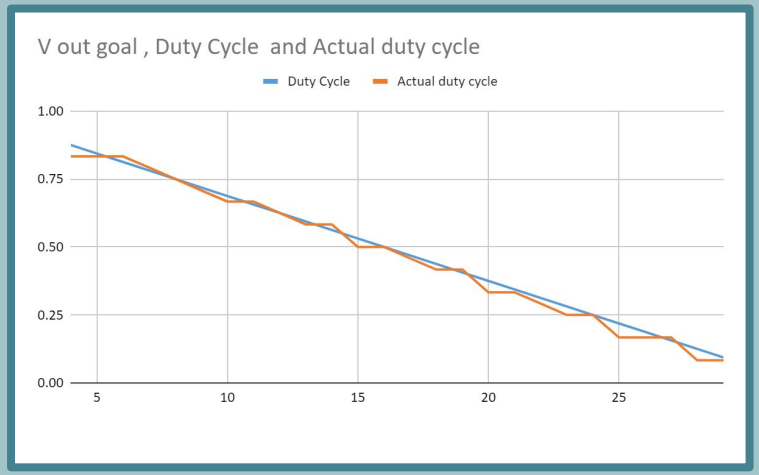


Aidan Nash

Testing Results - MCU

- Power supply and Oscilloscope were used to test the Arduino system
- Emergency Stop mode
  - Loss of load or emergency button pressed
  - PWM signal is zero and brakes activated
- Normal operation mode:
  - PWM changes based on the voltage
- Both tests were a success





Benjamin Allen

Analysis of Results

- MAD 5010 110 kv generator motor was selected based on testing
- Three phase rectifier testing was a success
- MCU test was a success
- Boost Converter needs more work to become operational

- Next step:
  - Integrate components onto PCB board
  - Test PCB using generator mounted to dynamometer
- Integrate Boost system with Mechanical team systems
  - Adapt code to work with Mechanical team systems
  - Test PCB using generator mounted to turbine shaft with blades.

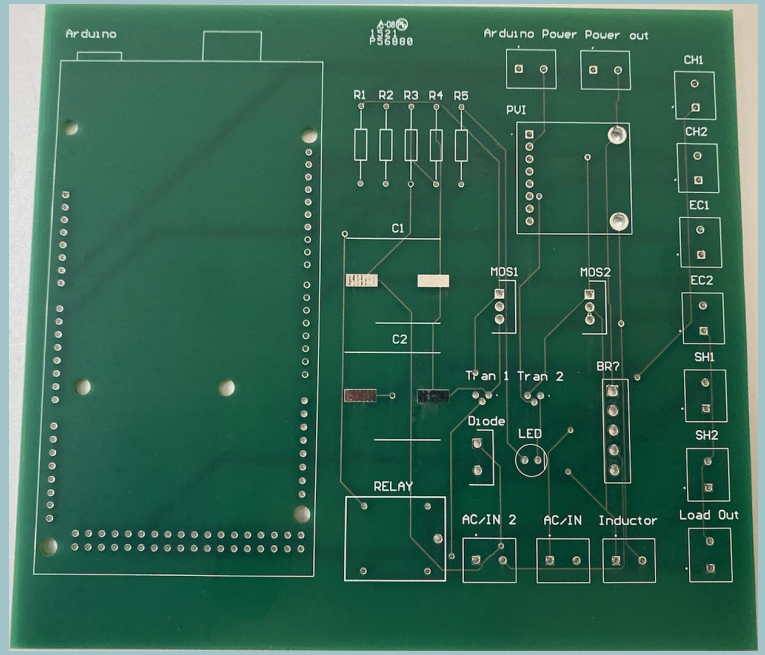
Benjamin Allen

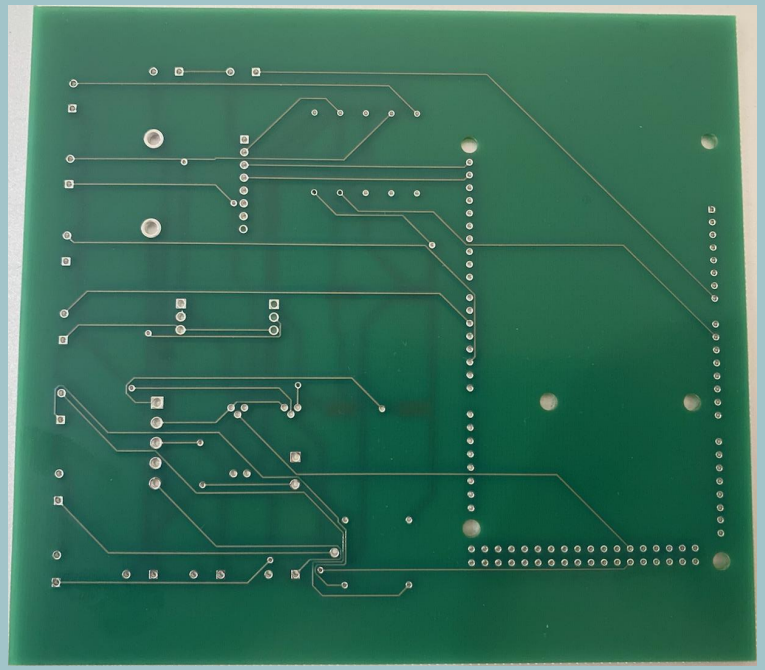
Technical Challenges

- Boost Converter
  - Our biggest struggles were with the boost converter
  - Being able to handle a max of 10A is a necessity, so figuring out why it will not is paramount
  - Without the boost converter, everything else in the system will not work properly, as most of it relies on the boost outputting properly
- Parts buying
  - Getting parts quickly through NAU is practically impossible
  - Assuming a lead time of 2 weeks on top of distributors lead time is a real bottleneck
- Inter-Team Struggles
  - ME team's lack of understanding of EE components, and vice versa
  - Have had to reorder and redesign several components

Aidan Nash

Conclusion: Final PCB





Aidan Nash

Conclusion

- The user manual will make the next team’s project far more simple
  - They will be able to understand the basics faster, and see the troubles we had to try to avoid them
- The teams should all have weekly design meetings to discuss requirements
  - This year’s team did this, and it helped tremendously
- We of course have not yet integrated or competed, but we are hopeful about finishing and fully integrating to a working system
- Overall, the team had many successes, and a few failures, but all in all, we learned an incredible amount from both

Aidan Nash