cyclone
CWC23

Ian Luff, Danielle Dockins

April 28, 2023

Collegiate Wind Competition

- Goal of 100% clean energy by 2035 [1]
- Founded in 2014 by DoE and NREL
- Offer students real-world technology experience
- Networking and enhance school curriculums

ENERGY.GOV

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

[1] “About the Collegiate Wind Competition,” *Energy.gov*. [Online]. Available: https://www.energy.gov/eere/collegiatewindcompetition/about-collegiate-wind-competition. [Accessed: 20-Apr-2023].

CWC 2023 Challenge

"Competition participants will need to create an effective mechanical, electrical, and aerodynamic wind turbine and load design with a fixed-bottom sea foundation that is safe and reliable for testing in an on-site wind tunnel with a sea simulation tank" [2].

[2] US Department of Energy, "Collegiate Wind Competition 2023 - Rules and Requirements," 2022, pp. 1- 26

CWC 2023 Tasks

- Power Curve Performance Task
  - Stability of the power curve over various wind speeds
- Control of Rated Power and Rotor Speed Task
  - Ability to control the speed and power output at high wind speeds
- Safety Task
  - Ability to turn off the system under emergency conditions
- Durability and Foundation Success Tasks
  - Ability to withstand and draw power from varying wind speeds

Problem Statement

Create an electrical system

- Output power
    - Stable
    - Efficient
    - Safe
- Versatile
- Durable

Requirements and Constraints

- Requirements [2]
  - Emergency shutoff capabilities
  - Restart for any wind speed above 5 m/s
  - Turbine shut down within 10s
- Constraints
  - Voltage at the PCC must be less than 48 V
  - No bulk energy storage over 10 Joules
  - Anderson connectors

Architecture

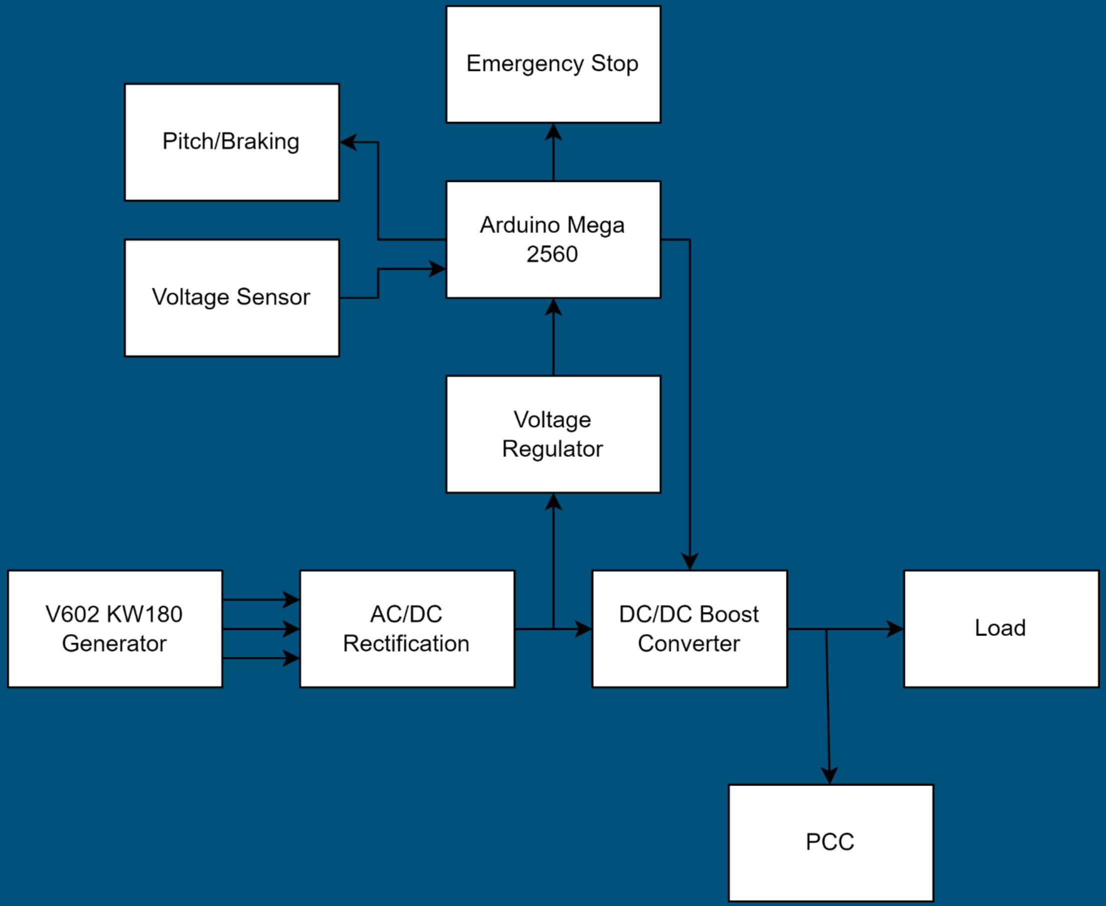

Figure 1: Architecture of Electrical System

AC/DC Rectifier

- Generator outputs 3-Phase AC
- PCC and Load require DC
- Rectifier prevents negative voltage values
- Capacitor prevents signal from dropping

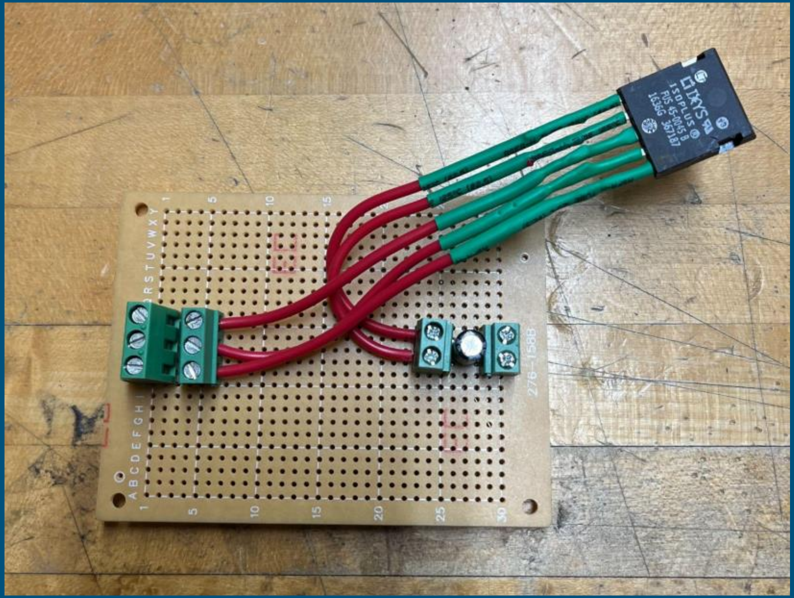

Figure 2: Rectifier w/ Smoothing Capacitor

DC/DC Boost Converter

- Input voltages: 1-20V
- Output: 20-40V
- Normally single input and single output
- Used to obtain a relatively constant voltage
- The most challenging subsystem
    - Required a lot of versatility

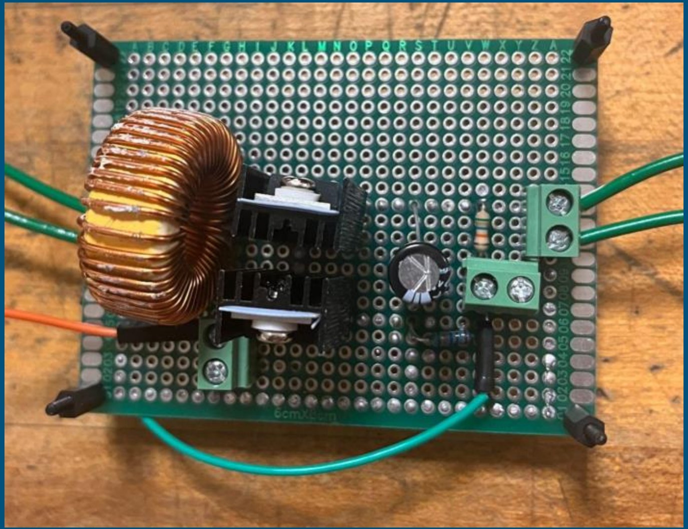

Figure 3: Boost converter

Microcontroller: Arduino Mega 2560

- Boost converter
  - Duty cycle of the MOSFET
- Pitching/braking
  - Angle of the blades
  - Amount of braking force
- Emergency stop
  - Detects emergency conditions
  - Pitches and brakes accordingly

Figure 4: Arduino Mega

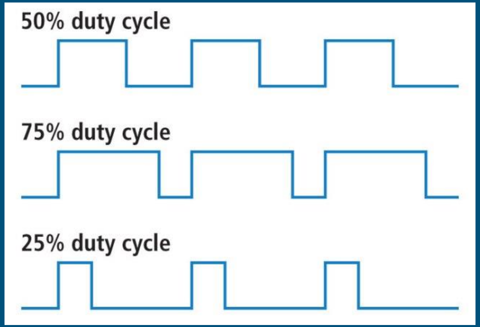

Figure 5: PWM Signals [3]

[3] "Pulse width modulation," *Pulse Width Modulation - SparkFun Learn*. [Online]. Available: https://learn.sparkfun.com/tutorials/pulse-width-modulation/duty-cycle. [Accessed: 21-Apr-2023].

Voltage Sensor

- Used to gather information for boost converter
- Had to design for our project
- Inside the actuators for position sensing

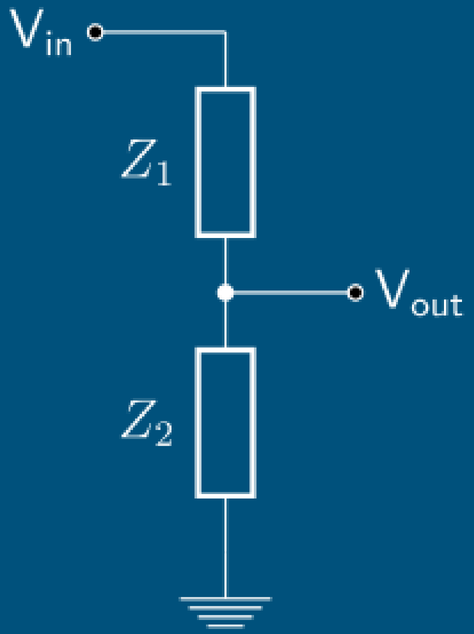

Figure 6: Circuit of a Voltage divider [4]

[4] “Voltage divider,” *Wikipedia*, 31-Mar-2023. [Online]. Available: https://en.wikipedia.org/wiki/Voltage_divider.[Accessed: 21-Apr-2023].

Voltage Regulator

- Outputs: 5V at 1.2A
- Used to power Arduino
- Two situations
  - Load connected
  - Load disconnected

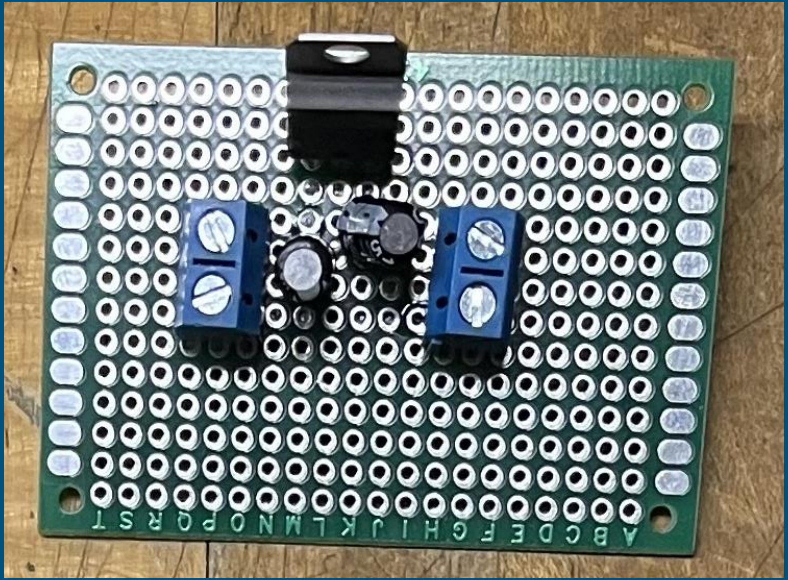

Figure 7: Voltage Regulator

Pitch and Braking

- Two linear actuators
- Pitch
  - Used for start up operations
  - Also for slowing down/emergency operations
- Braking
  - Keeps the RPM at safe levels
  - Pivotal in emergency situations

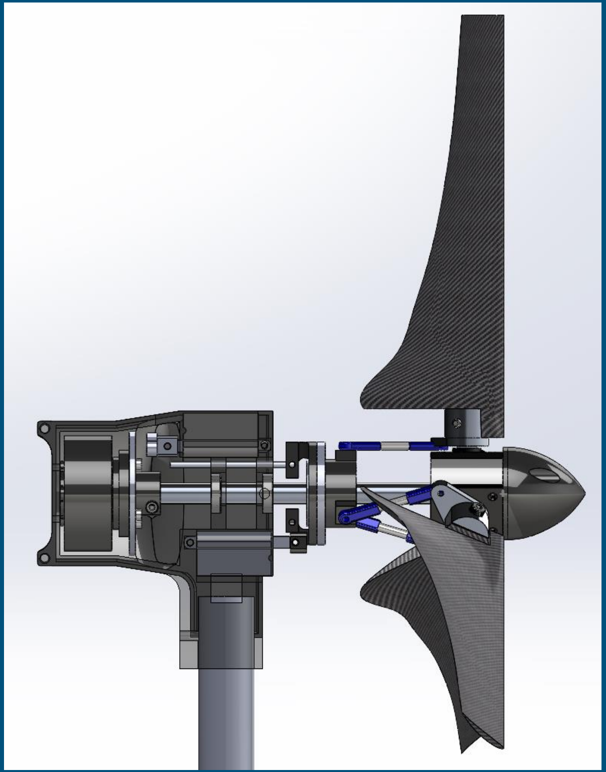

Figure 8: Solidworks model of the turbine built by ME

Testing

- Three key tests
  - Rectifier
  - Boost Converter
  - Voltage Regulator
- Instrumentation
  - Function generator
  - DC Power Supply
  - Digital Multimeter
  - Oscilloscope

Figure 9: Function Generator

Figure 10: Digital Multimeter

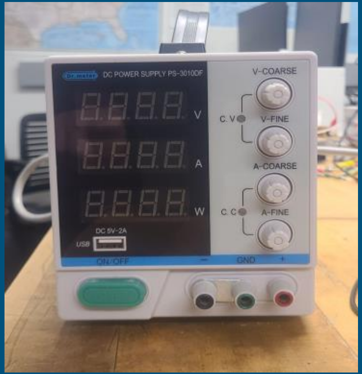

Figure 11: DC Power Supply

Rectifier Testing

Table 1: Rectifier Input, Output, and Ripple Voltages

RPM	Input Voltage (V)	Output Voltage (V)	Ripple (mV)
300	1.7	1.4	4.08
608	3.3	2.96	40
900	5	4.51	48
1200	6.7	6.24	49
1500	8.3	7.78	56
1800	10	9.43	32

Boost Converter Testing

Table 2: Boost Converter Input and Output Values

Input DC Voltage	Duty Cycle	Input Current	Input Power	Output Voltage	Output Current	Output Power	Efficiency
5	78%	0.51	2.555	21.825	0.1	2.19	85.71%
6	78%	0.53	3.179	26.431	0.099	2.62	82.42%
7	78%	0.54	3.78	31.095	0.099	3.08	81.48%
8	78%	0.55	4.394	35.683	0.099	3.53	80.34%
9	77%	0.54	4.865	39.387	0.099	3.9	80.16%
10	71%	0.48	4.8	39.136	0.099	3.87	80.63%
11	63%	0.43	4.725	39.128	0.099	3.87	81.90%
12	56%	0.39	4.676	39.147	0.099	3.87	82.76%
13	51%	0.36	4.68	39.107	0.099	3.87	82.69%
14	46%	0.33	4.616	39.175	0.099	3.88	84.06%
15	42%	0.3	4.5	39.174	0.099	3.88	86.22%
16	39%	0.28	4.48	39.195	0.099	3.88	86.61%
17	36%	0.26	4.42	39.166	0.099	3.88	87.78%
18	32%	0.24	4.32	39.189	0.099	3.88	89.81%
19	29%	0.23	4.37	39.247	0.098	3.85	88.10%
20	27%	0.22	4.4	39.193	0.099	3.88	88.18%

Boost Converter Testing Cont.

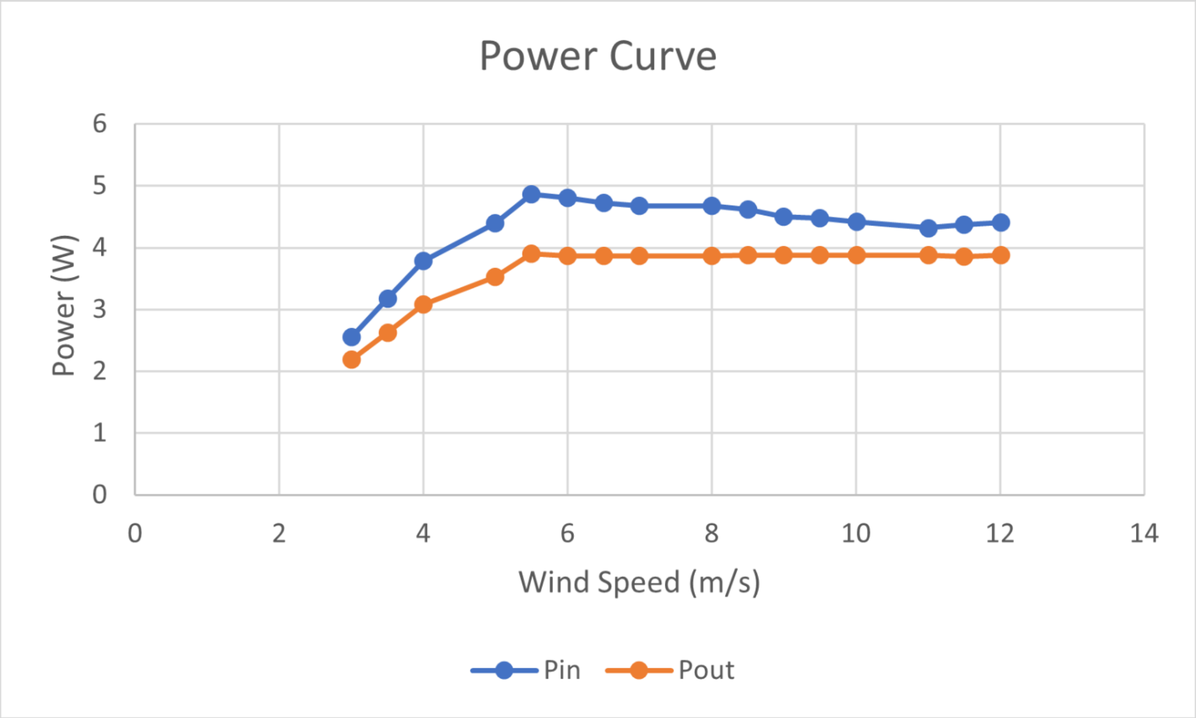

Figure 12: Power Curve of the Boost Converter

Voltage Regulator Testing

Table 3: Input and Output Voltage of the Voltage Regulator

Input Voltage	Expected Output Voltage	Output Voltage
4	5	3.06
5	5	3.91
6	5	4.84
7	5	5.02
9	5	5.01
11	5	5.02
13	5	5.03
15	5	5.02
17	5	5.02
19	5	5.02

Conclusions

- System Stability
  - Power Curve showed better stability than input
- Efficiency
  - Never below 80% efficient
- Safety
  - Braking, pitching, and contingency plans ensure a safe system
- Versatility
  - Components operate as expected for all inputs
- Durability
  - Components are rated for worst case scenario

Key Takeaways

- Renewable energy sources require flexible system architectures.
- Innovation is required to meet sustainability goals.
- Provides an opportunity to understand the underlying process behind the creation of wind turbines

Thank you