Collegiate Wind Competition 2017-2018

Electrical Team

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COLLEGIATE WIND COMPETITION
U.S. DEPARTMENT OF ENERGY

Project Description

- **Event Sponsors:**
  - United States Department of Energy (DOE)
  - National Renewable Energy Laboratory (NREL)
- **Event Objective:**
  - Increase college students' knowledge of wind turbines to satisfy the growing demand
- **Electrical Team Objective:**
  - Work with Mechanical Team to design, build, and test a wind turbine for Collegiate Wind Competition 2018 (CWC18).

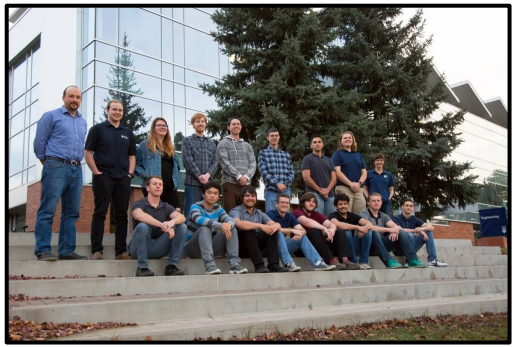

Figure 1: CWC Engineering Team

Project Description

- **Components of Competition:**
  - Power Curve Task
  - Control of Rated Power and Rotor Speed Task
  - Cut-in Wind Speed Task
  - Durability Task
  - Safety Task

- **Design Requirements:**
  - DOE provided rules and regulations for the CWC18 outlining the competition
  - Engineering Requirements were established using this document

Table 1: Engineering Requirements and Targets[1]

Engineering Requirements	Target
NEMA Electrical Rating	Type 1
Required Voltage at PCC	5V-48V
Energy Storage Input Rating	<16V
Rated Power	30 ± 2W.

Project Description

Electrical Subsystems:

- Generator
- Rectifier & Dump Load
- Boost Converter
- Buck/Boost Converter
- Controls

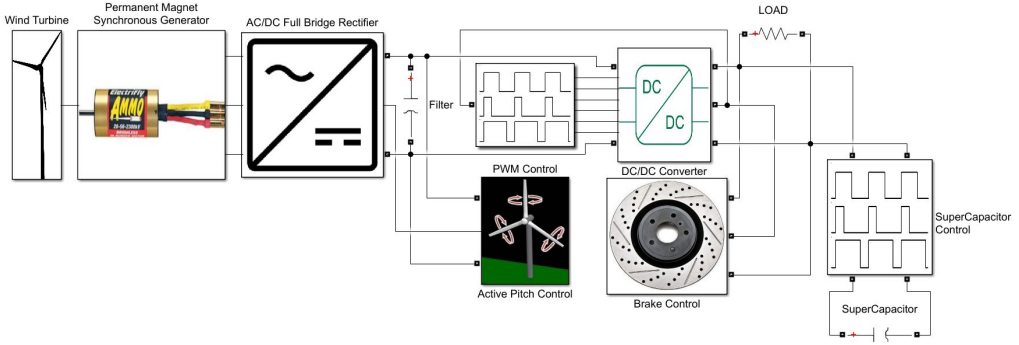

Figure 2: Overview of Electrical System

Generator

- Ammo 1530KV inrunner generator
- Optimal for low torque, high RPM applications
- Low voltage output of 0-3V suited for durability test

Figure 3: Ammo Generator

Rectifier & Dump Load

- Diode:
  - Forward Voltage: 0.28 V
- Capacitor:
  - 100 uF
- Dump Load:
  - 0.27 ohm

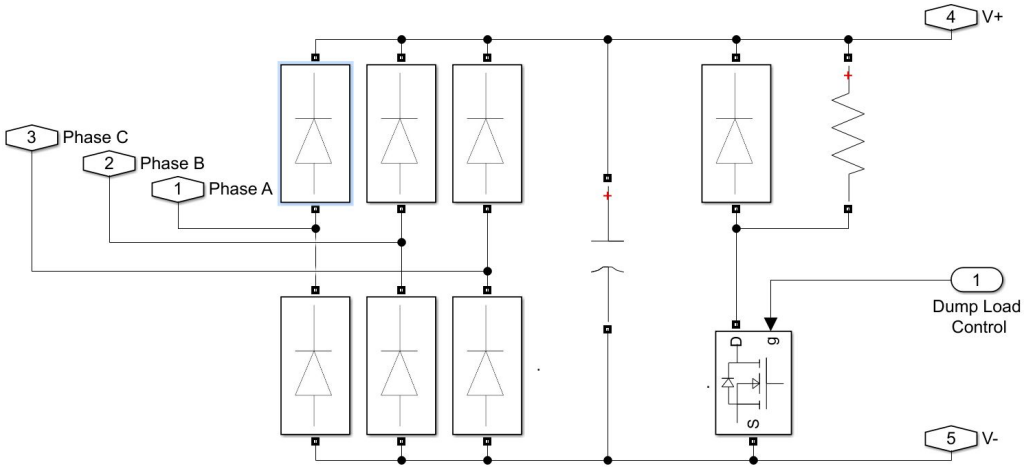

Figure 4: Rectifier and Dump Load

Boost Converter

- Three Channel Interleaved Synchronous Boost Converter
  - Each channel rated for 5A input current.
  - Three channels to make converter 15A rated input current.
  - Each MOSFET turns on & off with Pulse Width Modulated signals.
  - Each channel has a pair of power MOSFETs that have opposite PWM signals.
  - Each pair of MOSFETs PWM signals are 120° out of phase from each other.

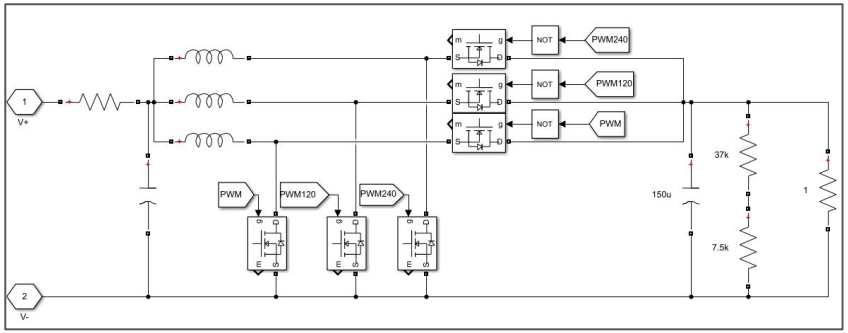

Figure 5: Three Channel Boost Converter

Buck/Boost Converter

- Synchronous Bi-Directional Buck-Boost Converter
  - Boost the voltage to 12V to charge ultracapacitor faster
  - Bucks the voltage back down to a regulated 5V
- Two State Operation
  - Charge (S1 High and S2 Low)
  - Discharge (S1 Low and S2 High)

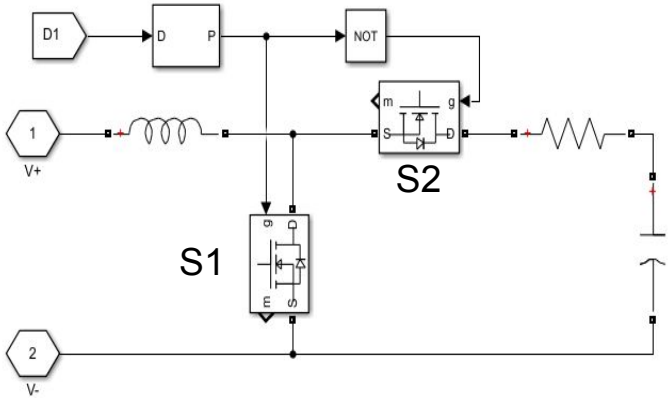

Figure 6: Bi-Directional Buck-Boost Converter

Controls

- Brake system:
  - Current sensor is used to read the Amps.
  - 4-channel relay is connected to the Solenoid
  - Button to control the brake.
  - Arduino used to read values and controlling.
- Active hub:
  - Linear actuators.
  - Voltage divider to sense voltage.

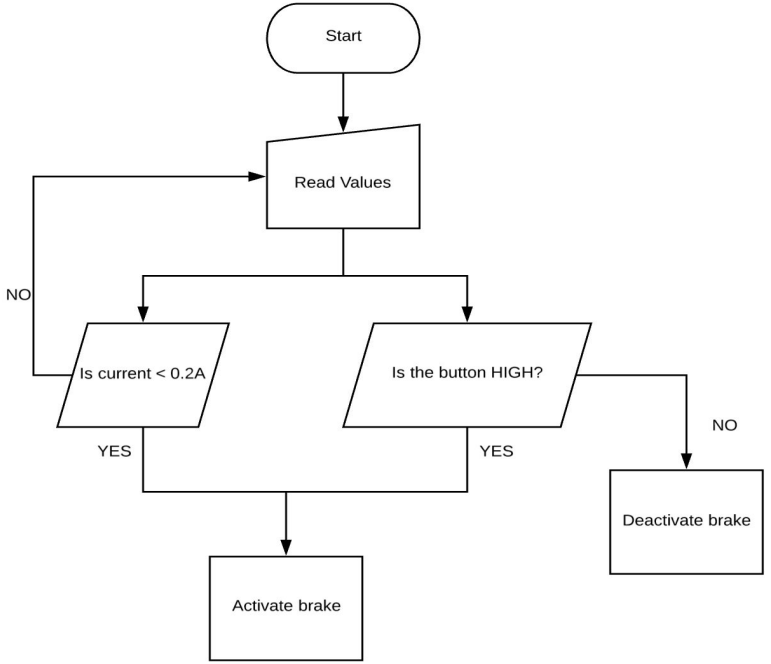

Figure 7: Code Flowchart

Design Process

- Simulink Modeling

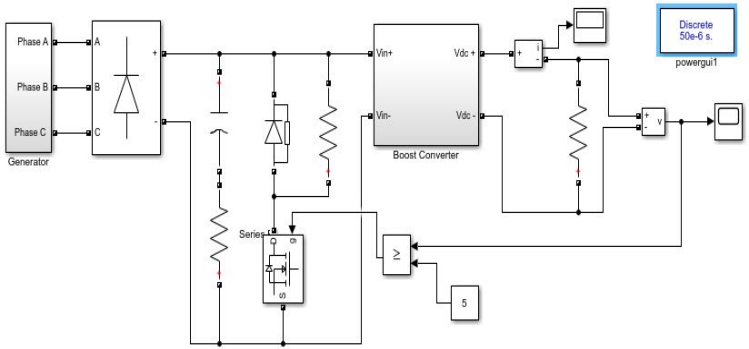

Figure 8: Overall Simulink Prototype

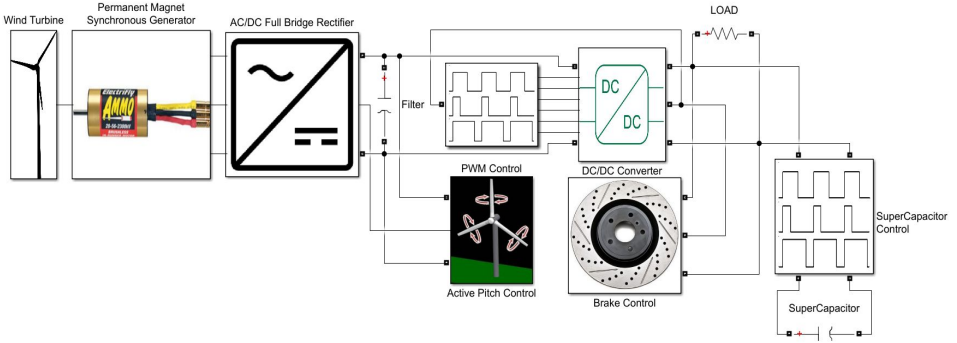

Figure 9: Final Design System

Design Process

- Prototyping

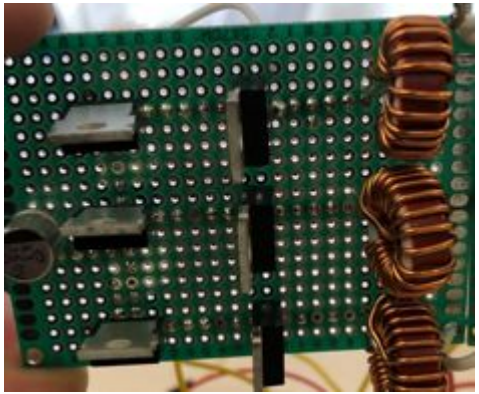

Figure 10: Boost Converter Rev.1

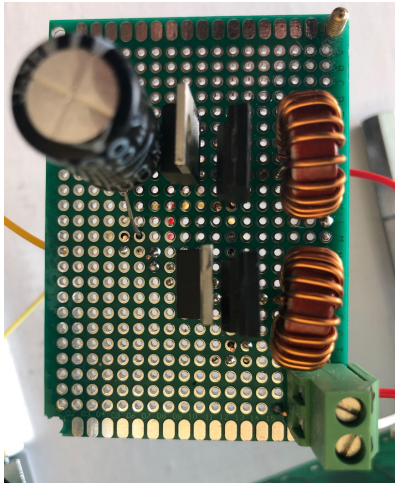

Figure 11: Boost Converter Rev.2

Manufacturing Process

- PCB Manufacturing
  - Outsourced to Advanced Circuits [2]
- Soldering components
  - Through Hole
  - Surface Mount

Figure 12: Through Hole soldering

Figure 13: Surface Mount soldering

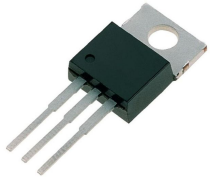

Figure 14: Through Hole MOSFET

Figure 15: Surface Mount MOSFET

Final Design

- Components on PCB Rev. 2
  - Rectifier
  - Dump Load
  - Gate Drivers
  - Boost Converter
  - Buck/Boost Converter
  - Arduino Due
  - Peripherals
- Off Board Components
  - Relays
  - Ultra Capacitor
  - Resistive Load

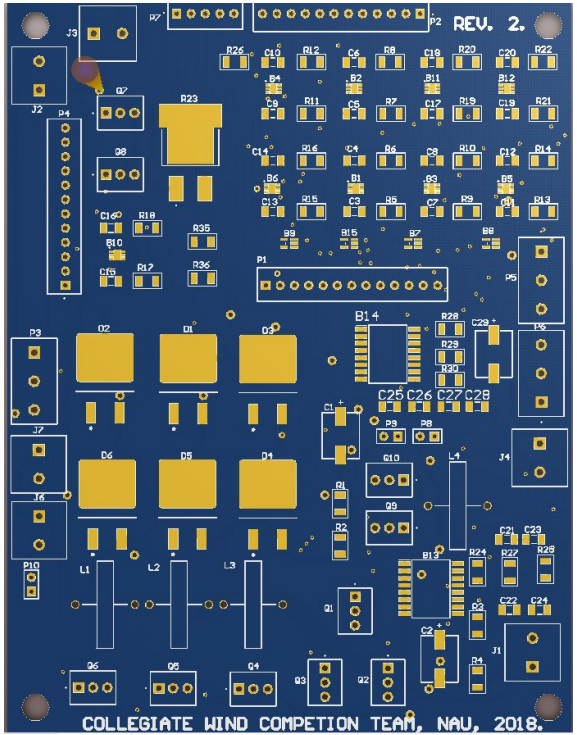

Figure 16: PCB Rev. 2

Testing Procedures

- Bench testing
  - Consisted of simulating cut-in speed and steady-state wind speed with dynamometer and power source
- Testing single subsystems before testing the system as a whole
  - Generator
  - Converters
  - Actuators
  - Solenoid
- Testing at an off campus wind tunnel
  - Power curve
  - Braking
  - Durability

Data Collected

- Bench Testing

	Cut-in	Steady-State
Vin	0.50V	2.5V
Vout	2.0V	5.0V
Iin	1.0A	5.0A
Iout	0.50A	2.5A
Pout	1.0W	12.5W

- Wind Tunnel Testing

	Cut-in	Steady-State
Vin	0.11V	1.75V
Vout	1.0V	5.0V
Iin	1.81A	2.85A
Iout	0.20A	1.0A
Pout	0.20W	5.0W

Experience Gained

- Power Electronics Design
- Simulink Modeling
- Surface Mount Soldering
- Component Selection
- PCB Design
- Knowledge of Wind Turbines

References

[1] Energy.gov. (2018). 2018 Collegiate Wind Competition Rules and Requirements | Department of Energy. [online] Available at: https://www.energy.gov/eere/collegiatewindcompetition/downloads/2018-collegiate-wind-competition-rules-and-requirements [Accessed 15 Sept. 2017].
[2] 4pcb.com. (2018). Printed Circuit Board Manufacturer & PCB Assembly | Advanced Circuits. [online] Available at: http://www.4pcb.com/ [Accessed 27 Apr. 2018].

Questions?