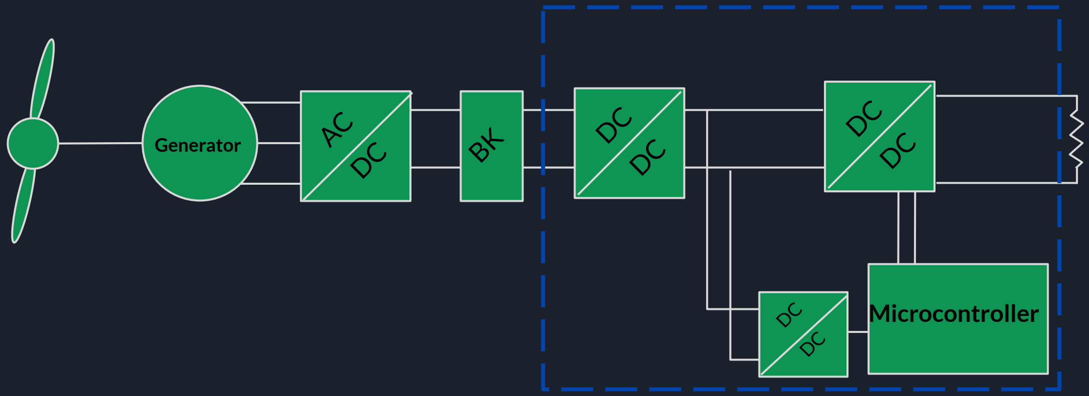
Collegiate Wind Competition (CWC) 2020: DC-DC Converter

Booster Pack:
Humoud Abdulmalek
Mohammed Almutairi
Nigel Grey

Presenter: Mohammed

Introduction

- Clients
  - Dr. Venkata Yaramasu
  - Mr. David Willy
- Mentor
  - Jason Foster
- Project
  - CWC 2020
  - DC-DC Boost converter

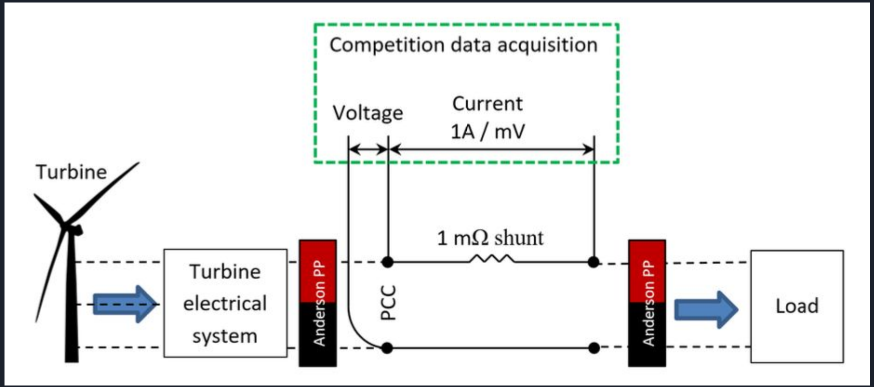


Presenter: Humoud

Project Motivation

CWC Capstone: DC-DC Team

- Task: ***Research, design, and build a turbine for deployment in the high wind environment of eastern Colorado.*** [1]
- Role: Design and implement a DC-DC converter system within the ***turbine electrical system*** that is effective, safe, and reliable.



Presenter: Mohammed

Constraints & Requirements

Initial CWC Rules

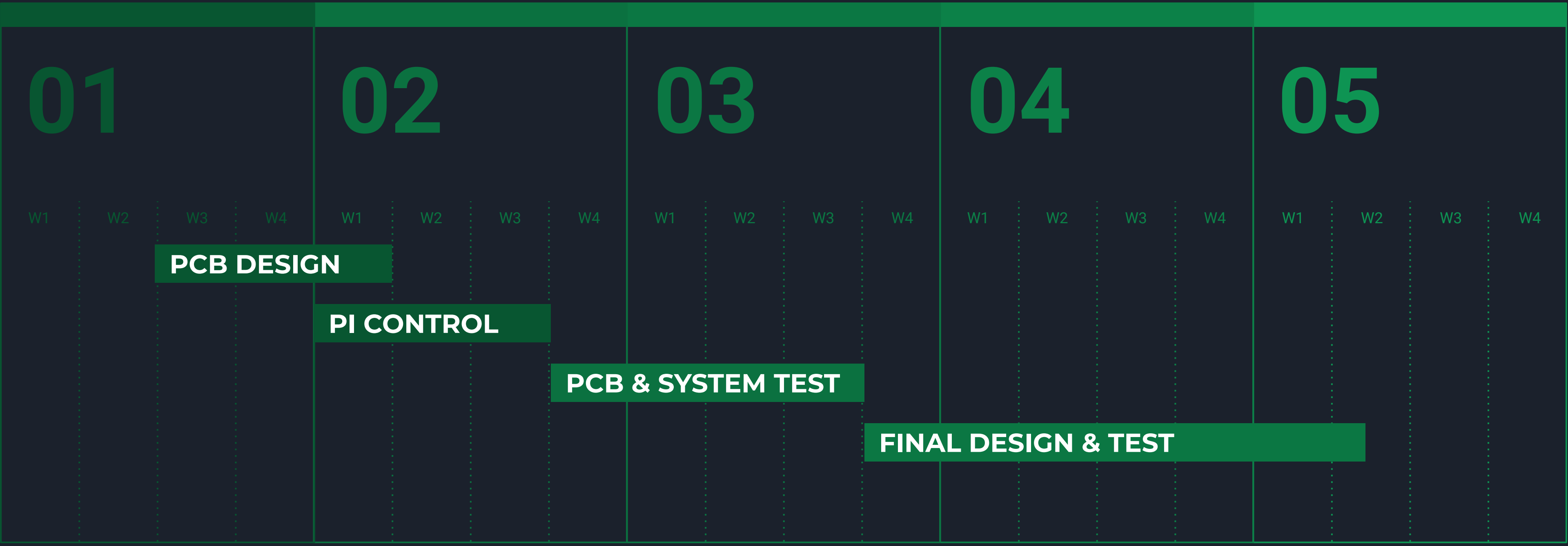
- Voltage must be direct current (DC)<48V
- The turbine base plate must be tied to ground with a ≤100 kΩ resistor
- Capacitors and inductors may not be used as bulk energy storage on turbine side of PCC
- No capacitors rated >10J of energy storage
- Turbine components must start from a zero charge state
- All external wired connections must be optically isolated
- Turbine electronics separately enclosed
- PCC interfacing wires terminated with Anderson Powerpole connectors

COLLEGIATE WIND COMPETITION
U.S. DEPARTMENT OF ENERGY

Presenter: Mohammed

Original Approach

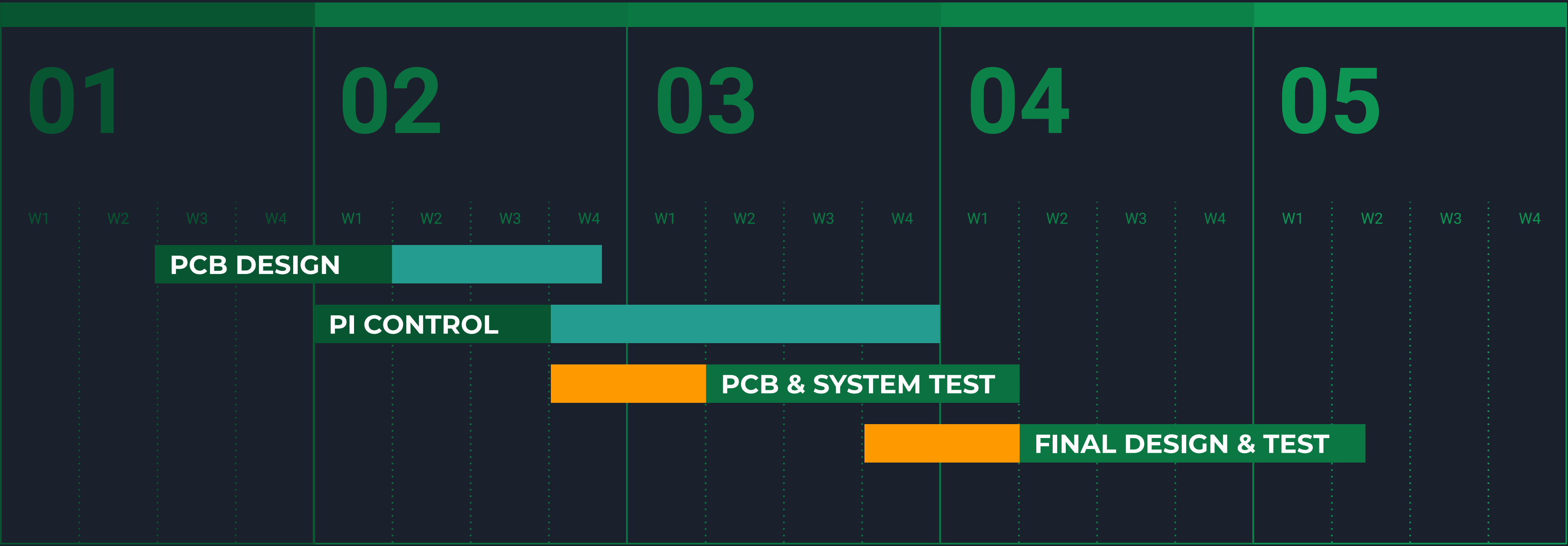
January 13th - May 8th



Presenter: Nigel

Modified Approach

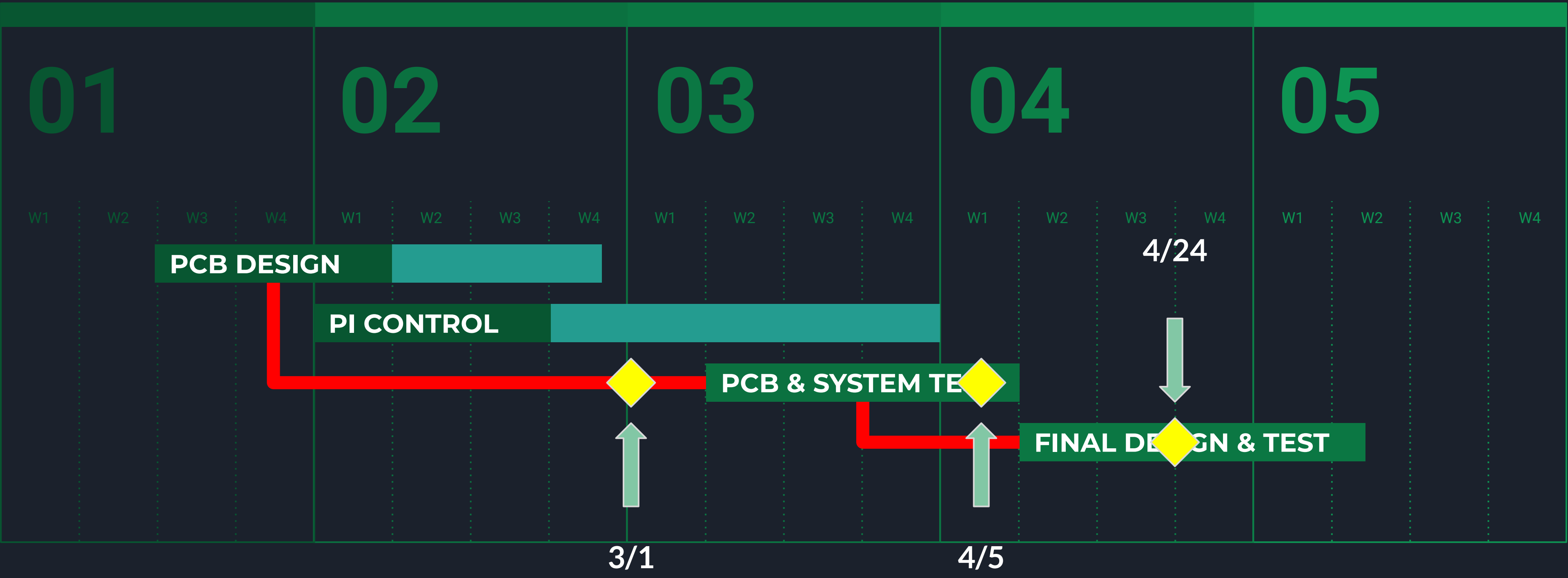
January 13th - May 8th



Presenter: Nigel

Modified Approach: Milestones

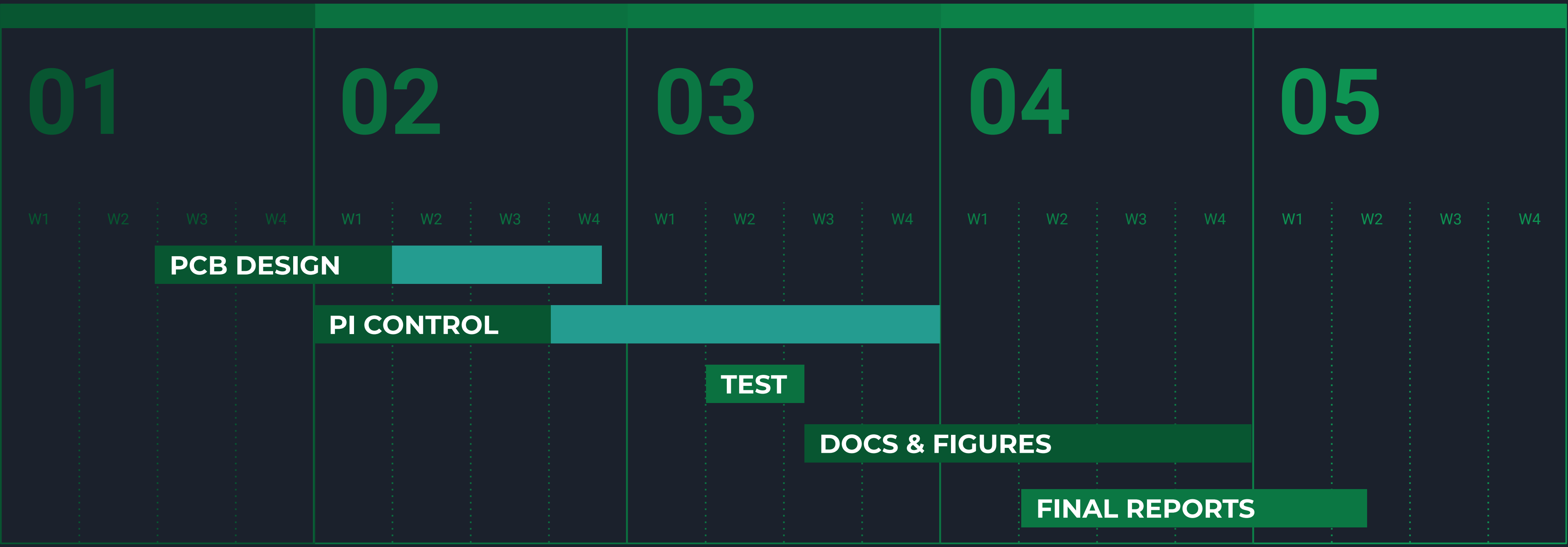
January 13th - May 8th



Presenter: Nigel

Final Approach

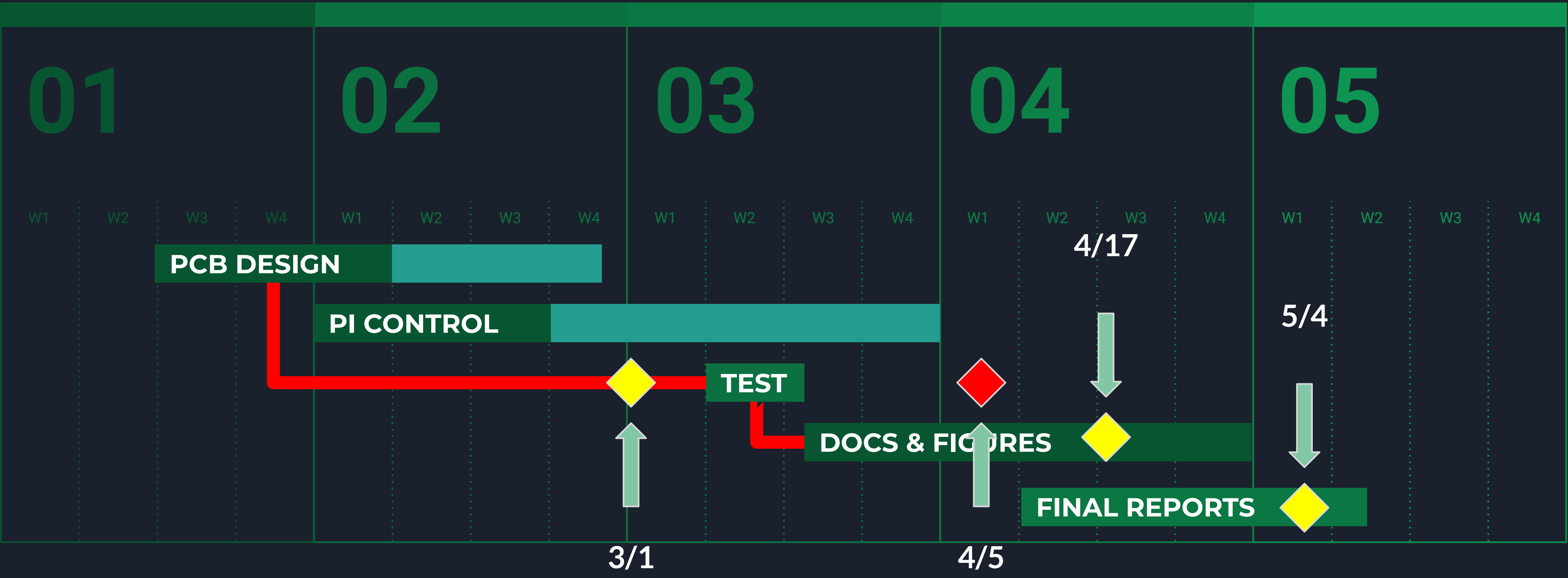
January 13th - May 8th



Presenter: Nigel

Final Approach

January 13th - May 8th



Presenter: Nigel

Metrics for Success

DC-DC Team Original WBS

DC-DC converter system

- Research converter topology
  - Study CWC rules
  - Research wind energy systems
- Prototype converter and controller
  - Prototype converter and controller
  - LM555 boost converter
  - PI-Controlle r
  - PI boost converter
- Integrate DC-DC system with Aux team circuits
  - Layout and print PCB
  - Assemble PCB
  - Test PCB
  - Power signal deliverable
- Integrate PCB with turbine
  - Final test
  - Technical design report
  - Demo

Presenter: Nigel

Metrics for Success

DC-DC Team Revised WBS

DC-DC converter system

- Research converter topology
- Study CWC rules
- Research wind energy systems

- **Prototype converter and controller**
  - Prototype converter and controller
  - LM555 boost converter
  - PI-Controller
  - PI boost converter

- **Integrate DC-DC system with Aux team circuits**
  - Layout and print PCB
  - ~~Assemble PCB~~
  - ~~Test PCB~~
  - ~~Power signal deliverable~~

- ~~Integrate PCB with turbine~~
  - ~~Final test~~
  - Technical design report
  - ~~Demo~~

Presenter: Nigel

Metrics for Success

DC-DC Team Revised WBS

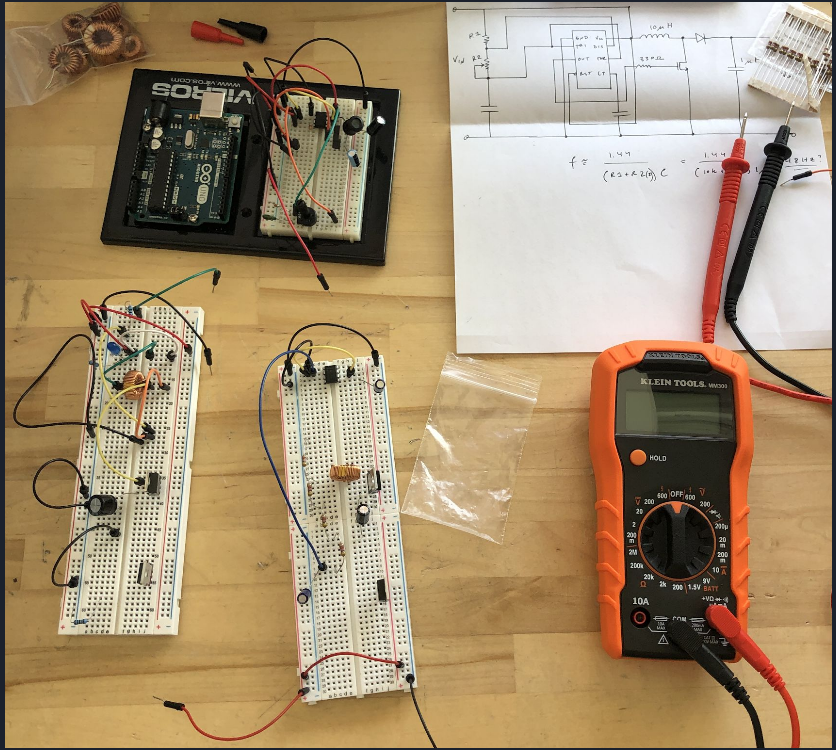
DC-DC converter system

- Research converter topology
  - Study CWC rules
  - Research wind energy systems
- Prototype converter and controller
  - Prototype converter and controller
  - LM555 boost converter
  - PI-Controlle r
  - PI boost converter
- Integrate DC-DC system with Aux team circuits
  - Layout and print PCB
  - ~~Assemble PCB~~
  - ~~Test PCB~~
  - Figures for Dr. Yaramasu
- ~~Integrate PCB with turbine~~
  - Virtual Q&A
  - Technical design report
  - Virtual demo

Presenter: Nigel

DC-DC System Design
Prototypes

- Boost converters
  - LM555-Controlled



Presenter: Nigel

DC-DC System Design

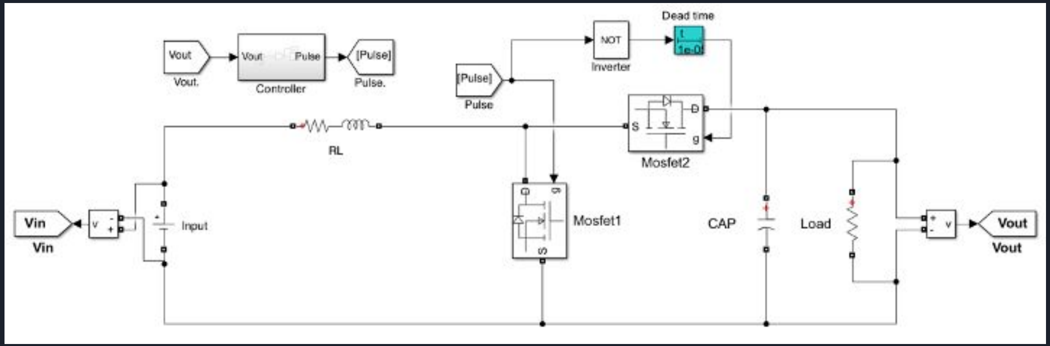
Fixed Duty-Cycle Boost Converter

Presenter: Nigel

DC-DC System Design

Prototypes

- Boost converters
    - LM555-Controlled
    - PI-Controlled
        - Simulation



Presenter: Nigel

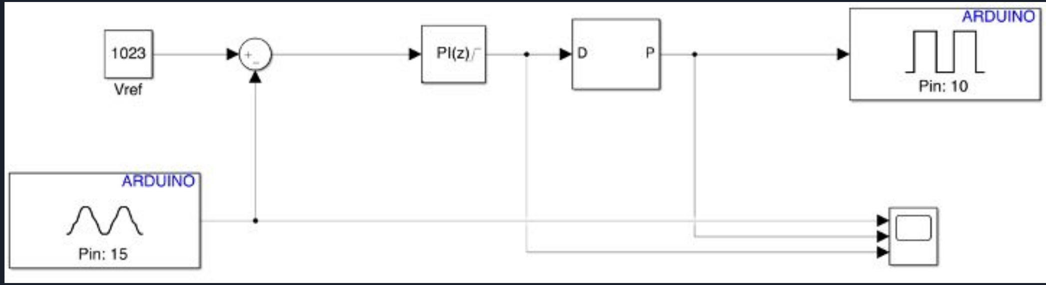
DC-DC System Design

Synchronous Boost with PI

Presenter: Humoud

DC-DC System Design
Prototypes

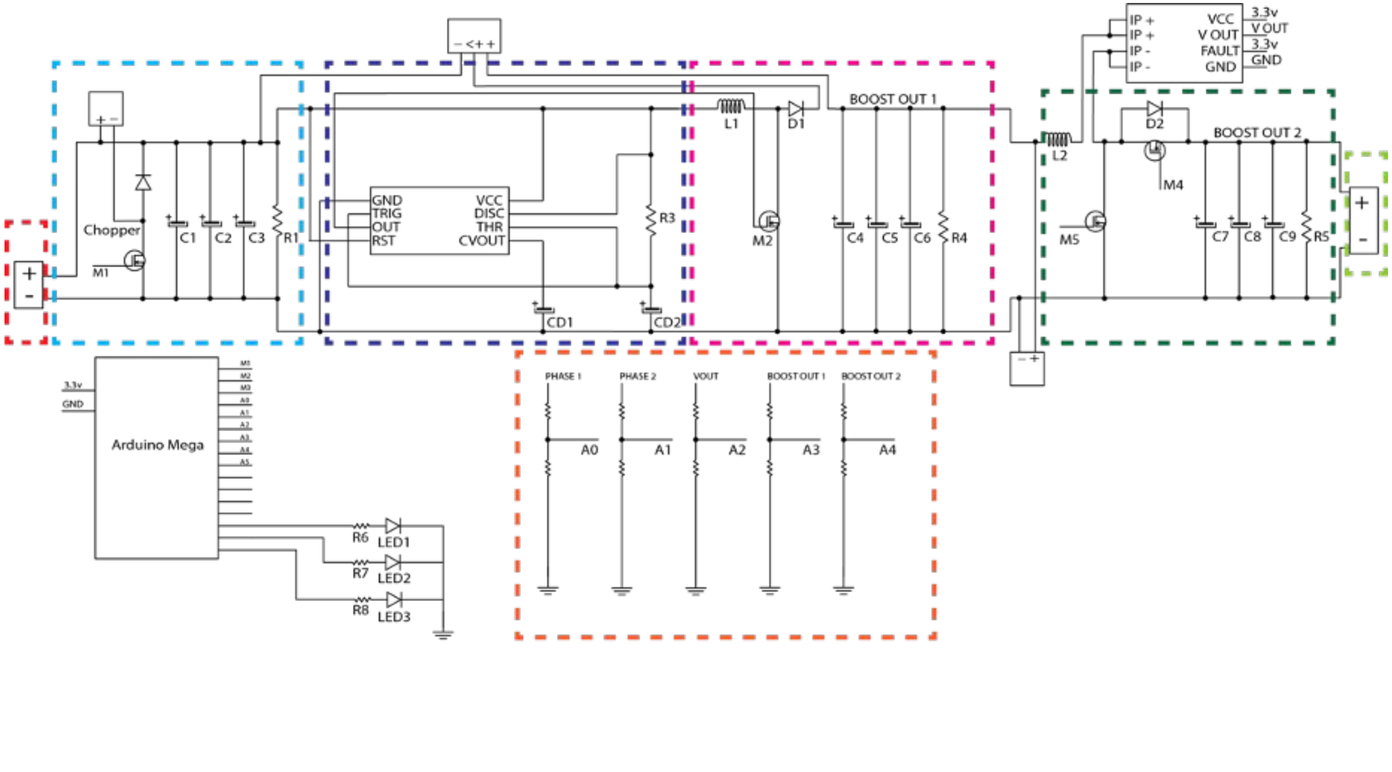
- Boost converters
  - LM555-Controlled
  - PI-Controlled
    - Simulation
    - Physical circuit



Presenter: Humoud

Converter System: Overview

DC-DC and Aux Circuitry

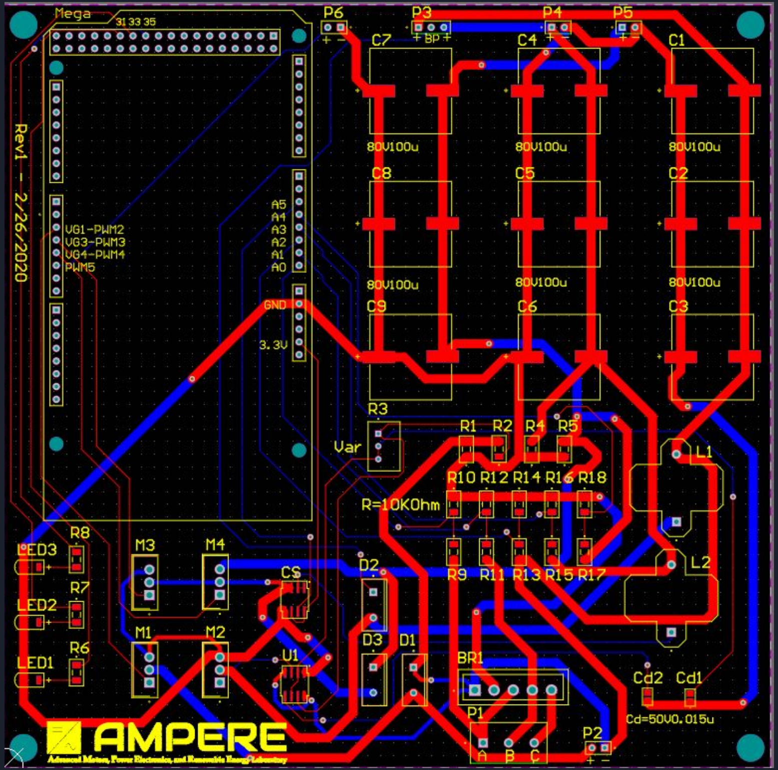


Presenter: Nigel

Converter System: PCB Integration

January 13th - March 1st

- Highly collaborative effort between our team and the Aux team
- Built custom footprints
- Labeled all components and connections
- Separated communication components from power components
- Developed net classes to define widths of power lines and communication lines

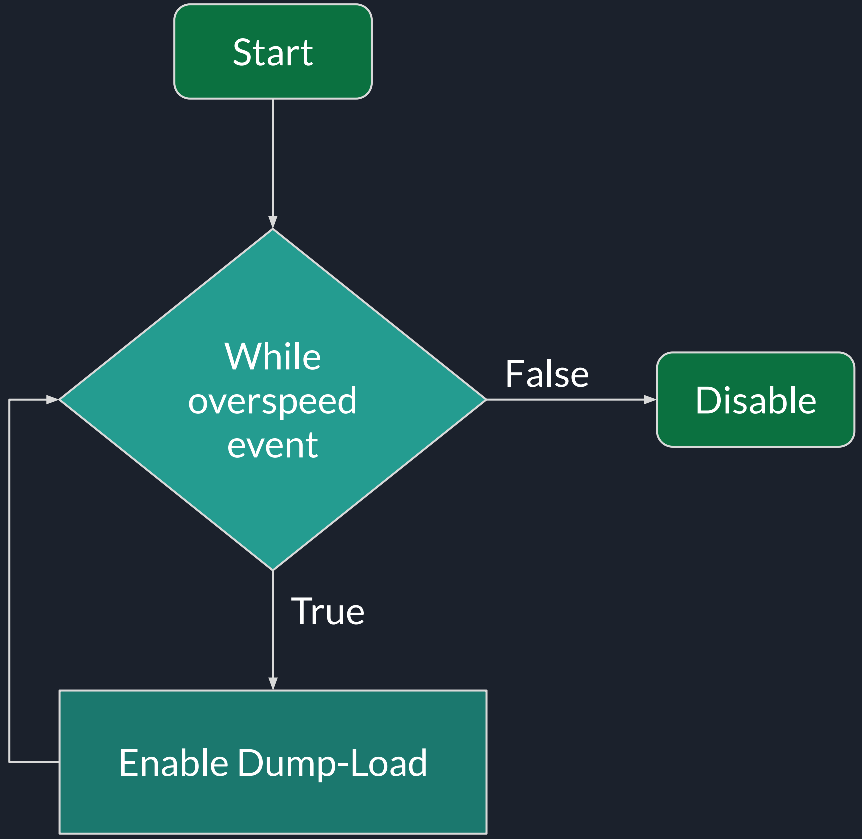


Presenter: Nigel

Control System: Overview

February 1st - April 1st

1. Dump-Load Circuit
2. Phase 1-2 Voltage Measurement
3. PI Controller
4. Current Sensor Measurement
5. Stage 2, 3, & 4 Voltage Measurements
6. Actuator Signal

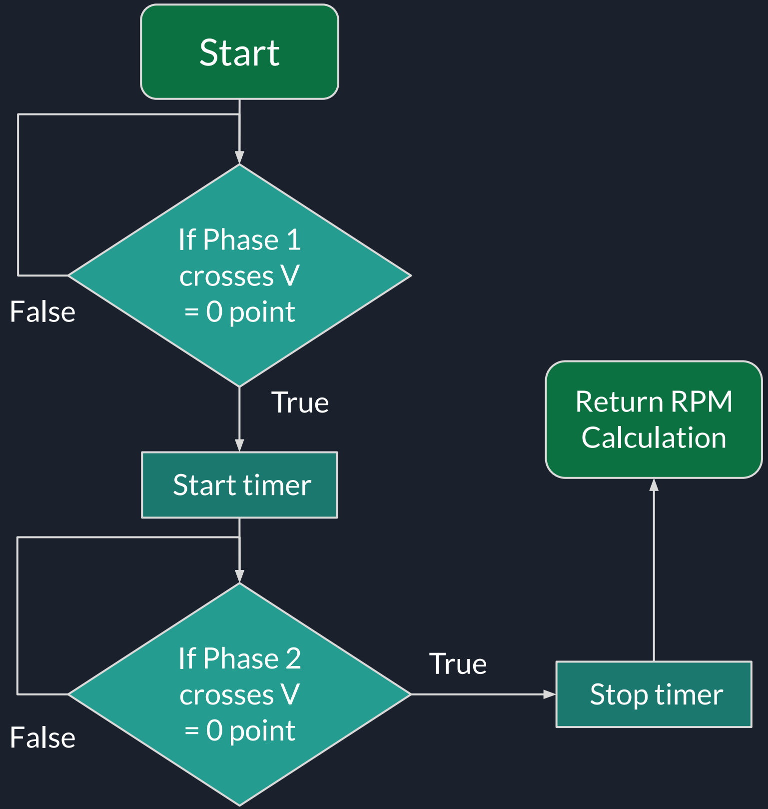


Presenter: Nigel

Control System: Overview

February 1st - April 1st

1. Dump-Load Circuit
2. Phase 1-2 Voltage Measurement
3. PI Controller
4. Current Sensor Measurement
5. Stage 2, 3, & 4 Voltage Measurements
6. Actuator Signal

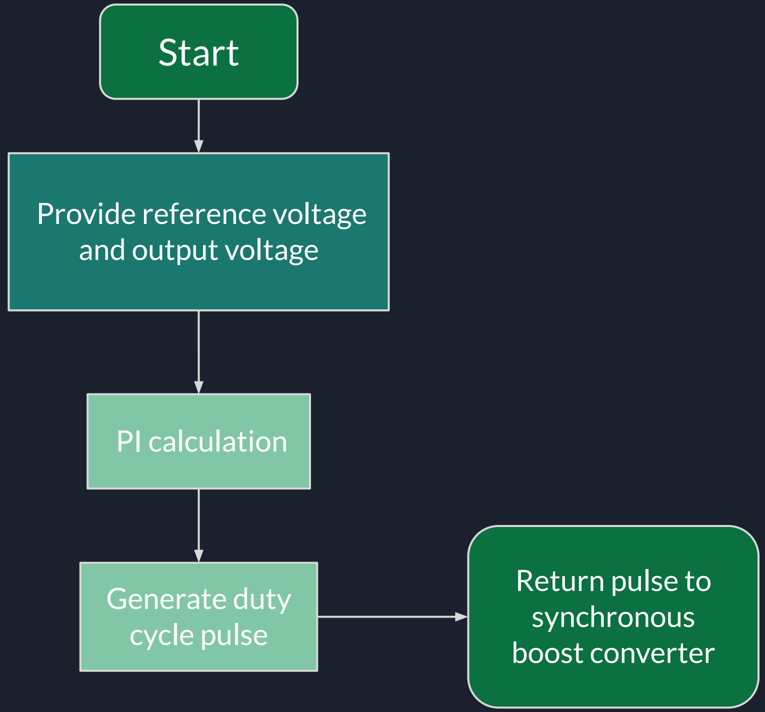


Presenter: Nigel

Control System: Overview

February 1st - April 1st

1. Dump-Load Circuit
2. Phase 1-2 Voltage Measurement
3. PI Controller
4. Current Sensor Measurement
5. Stage 2, 3, & 4 Voltage Measurements
6. Actuator Signal

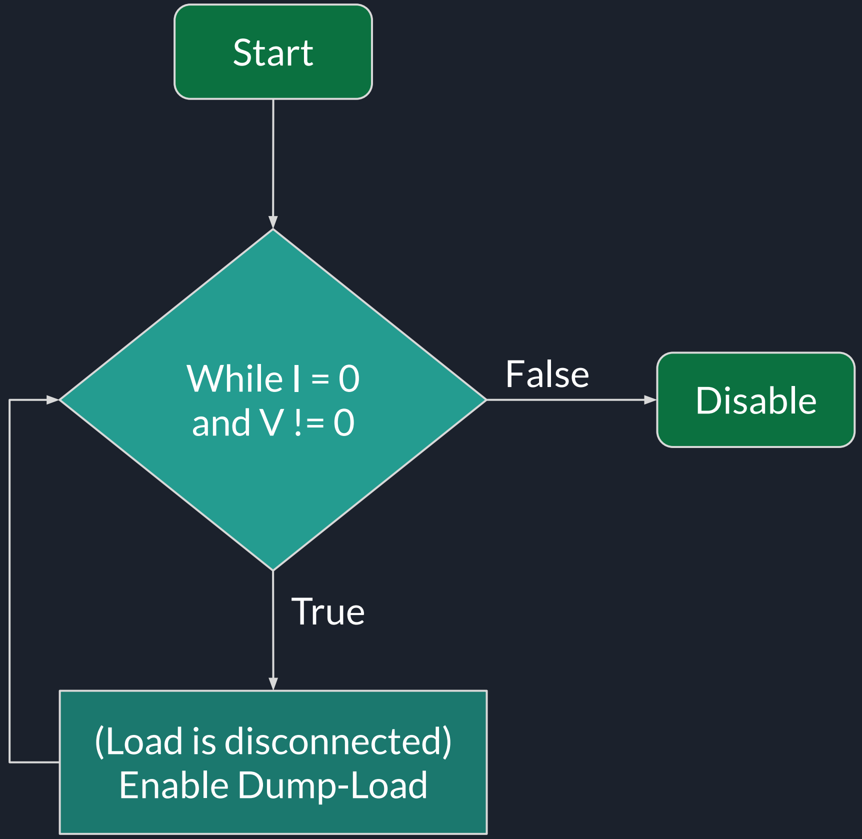


Presenter: Nigel

Control System: Overview

February 1st - April 1st

1. Dump-Load Circuit
2. Phase 1-2 Voltage Measurement
3. PI Controller
4. Current Sensor Measurement
5. Stage 2, 3, & 4 Voltage Measurements
6. Actuator Signal

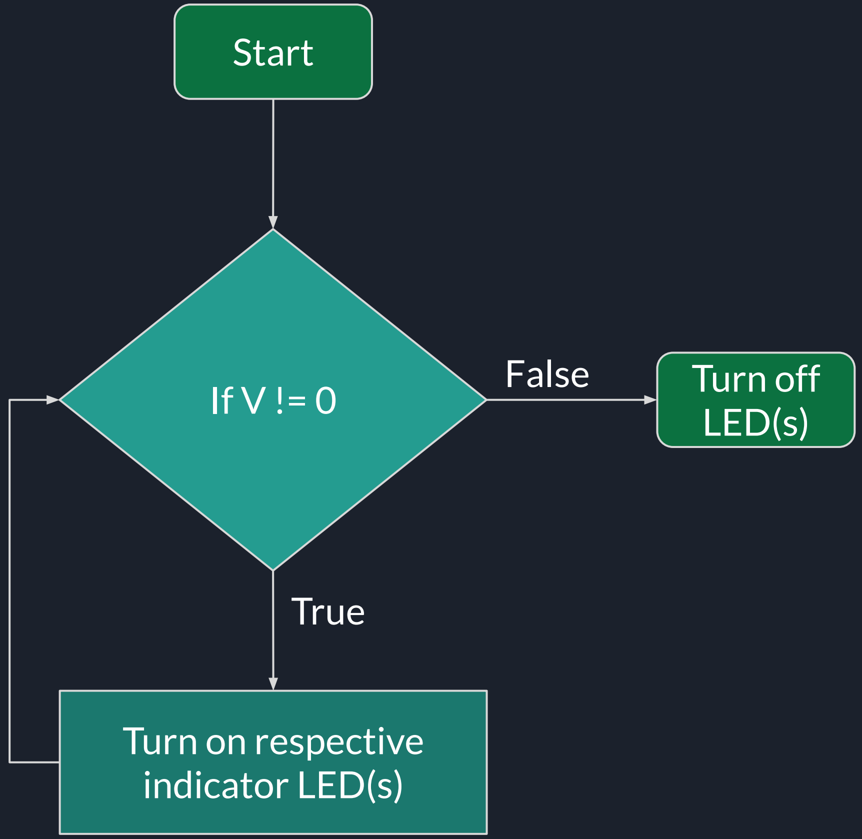


Presenter: Nigel

Control System: Overview

February 1st - April 1st

1. Dump-Load Circuit
2. Phase 1-2 Voltage Measurement
3. PI Controller
4. Current Sensor Measurement
5. Stage 2, 3, & 4 Voltage Measurements
6. Actuator Signal

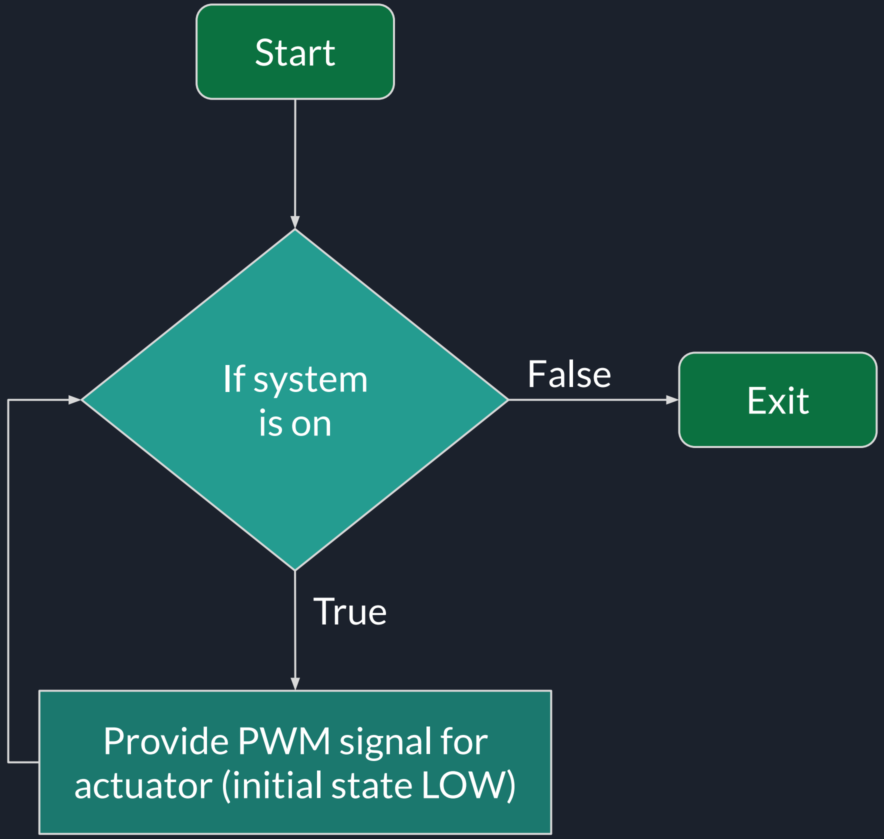


Presenter: Nigel

Control System: Overview

February 1st - April 1st

1. Dump-Load Circuit
2. Phase 1-2 Voltage Measurement
3. PI Controller
4. Current Sensor Measurement
5. Stage 2, 3, & 4 Voltage Measurements
6. Actuator Signal



Presenter: Nigel

Proportional Integral (PI) Control

February 4th - April 1st

Tune PI	Simulink export	Test circuit

Tune PI

- Test PI in Simulink
- Fine tune the controller
- Develop optimum Duty Cycle

Simulink export

Export Simulink module to Arduino using:

- Hardware support package
- Simulink Embedded C Code

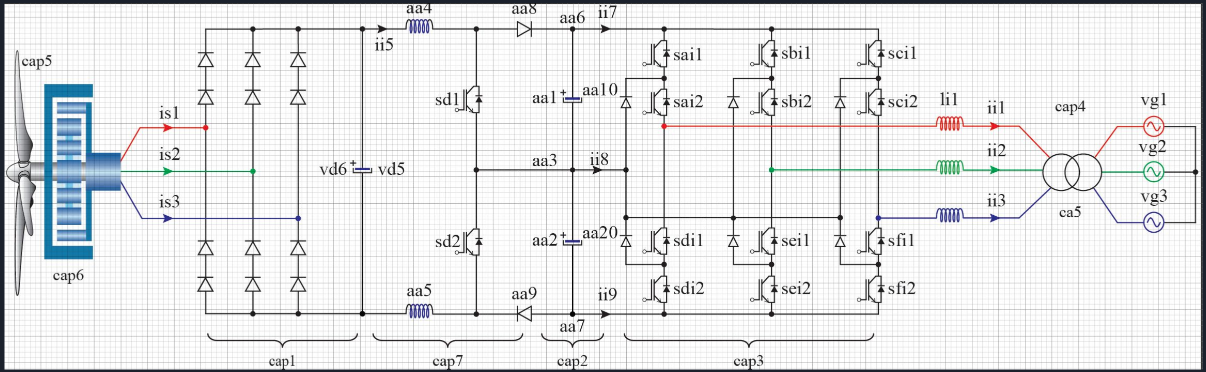
Test circuit

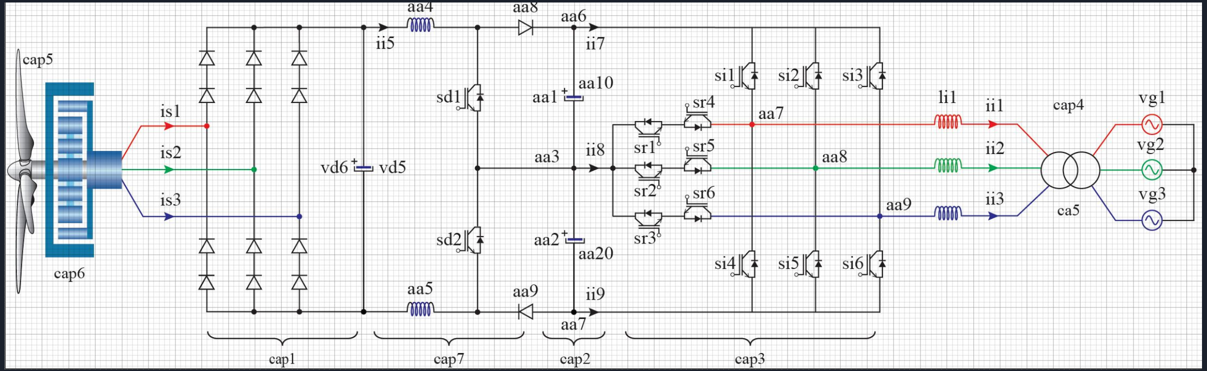
- Test simultaneous boost converter circuit with fixed input voltage and load
- Test with variable input and load
- **Due to rule revisions for competition, all testing after March 13th was completed at the simulation level**

Presenter: Humoud

Adobe Illustrator Figures

April 7th - May 7th



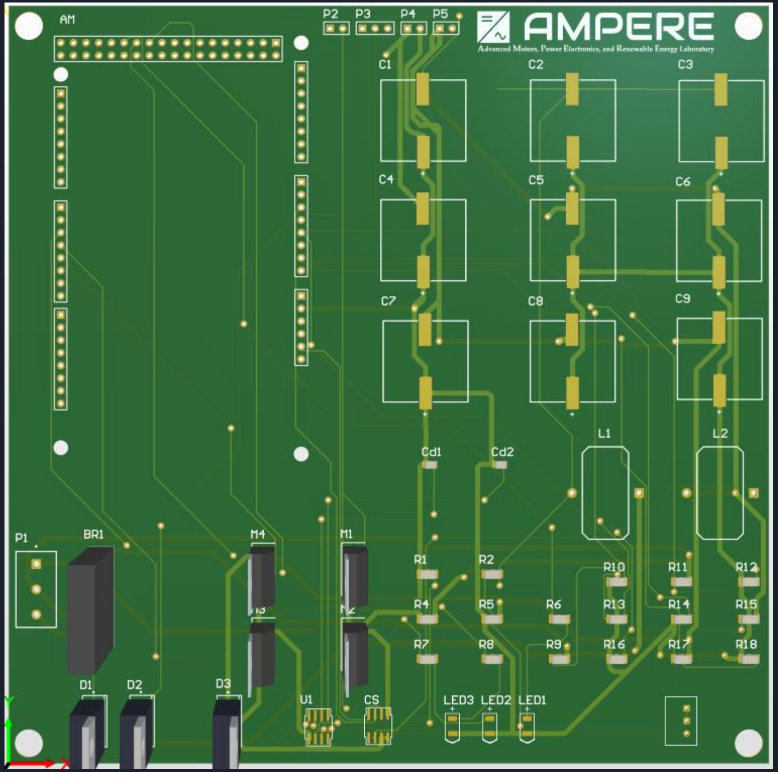


Presenter: Humoud

Documentation

March 9th - May 7th

- In addition to Capstone deliverables, we have collaborated on a ***User Manual*** for future NAU CWC teams
- The comprehensive ***Final Report*** developed by all CWC teams is the basis for scoring this year's competition
- The recorded ***Virtual Demo*** constitutes the remaining points, since all deliverables after February 23rd were cancelled [1]

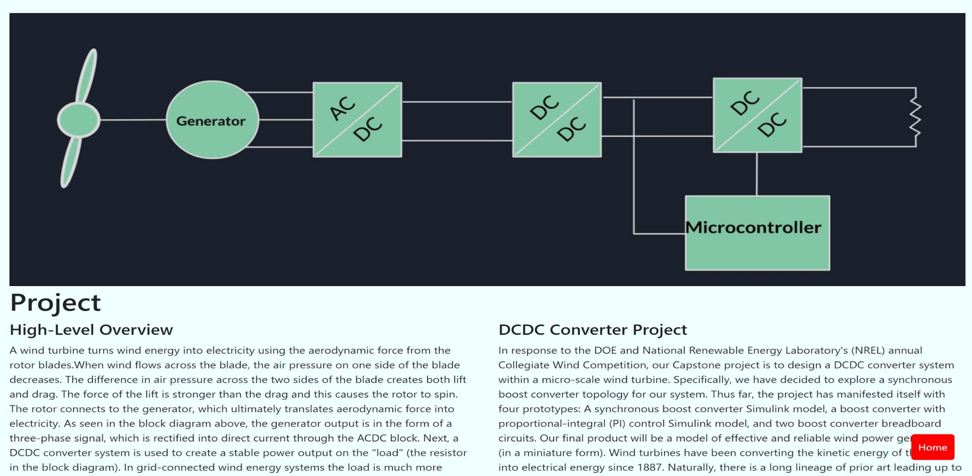


Presenter: Mohammed

Website

January 31st - May 8th

- Created a website from scratch using HTML
- Styled using CSS & Bootstrap
- Used JavaScript to perform specific functions
- Completed all pages

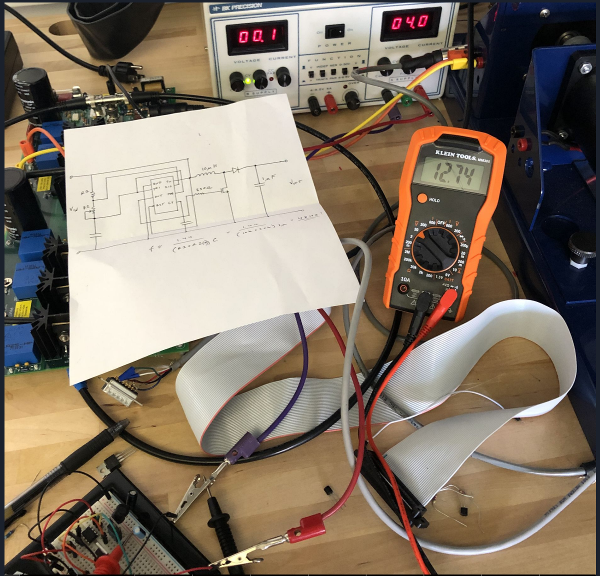


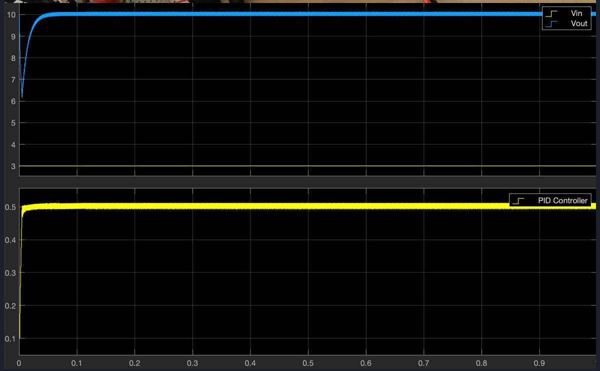
Presenter: Mohammed

Technical Challenges

Simulation vs. Real World

- The primary challenge was during any transition from simulation to physical circuit
- Once the PI controller was successfully running our boost converter circuit, the output signal became much closer to ideal
- Consistent power supply and amount of current drawn by the Arduino(s) would likely be the most difficult challenge





Presenter: Mohammed

Technical Challenges

Simulink Export

- The design relies on an export of a Simulink module to the Arduino to avoid writing a C program from scratch
- Simulink provides an embedded coder feature that can generate and flash a C program directly from the module
- The challenge was figuring out how to export the program to the Arduino using the Arduino support package; this was overcome by gaining familiarity with the control theory and coding environment

Presenter: Humoud

Future CWC

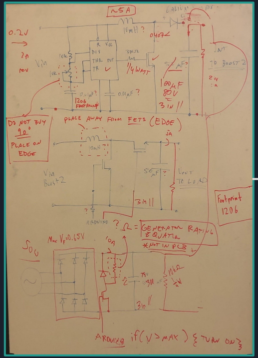
DC-DC Team Recommendations for Success

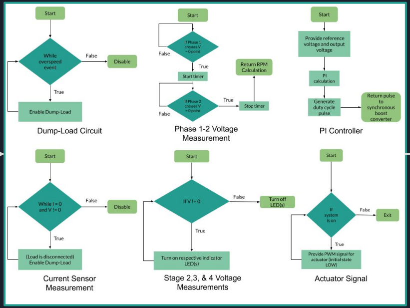
- ***Read the rules*** early on, and often
- ***Communicate*** frequently and effectively with ME and EE teams
- ***Build circuits***; do not exclusively rely on ideal simulations
- ***Simplify*** as much as possible; minimize the number of parallel control operations

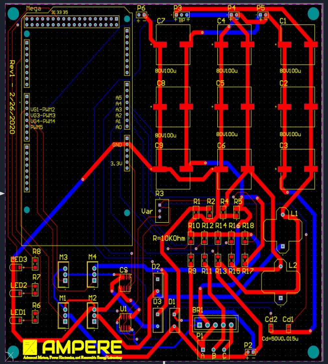
Presenter: Mohammed

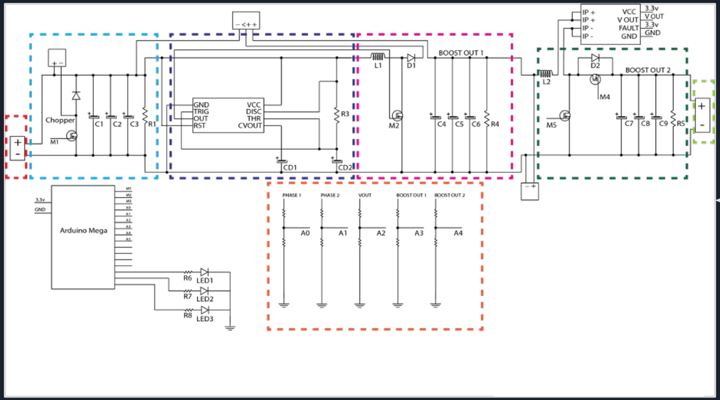
Conclusion
Finished Project

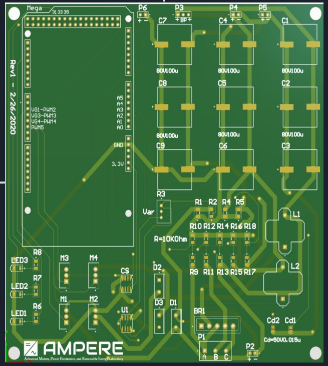
- **We successfully researched, designed, and simulated, an efficient and modern wind turbine electrical system**
- The design, documentation, and demonstration will be competitive on this year's virtual stage
- Our challenges will provide future teams with key insight for years to come







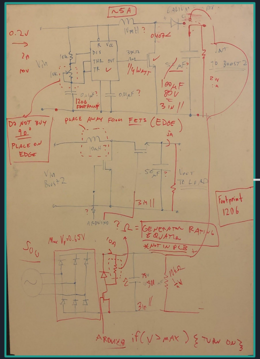


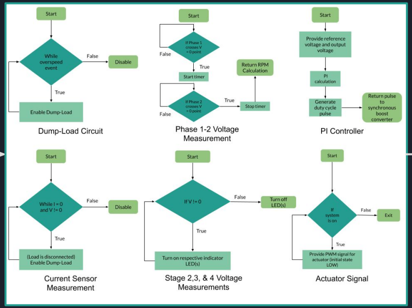


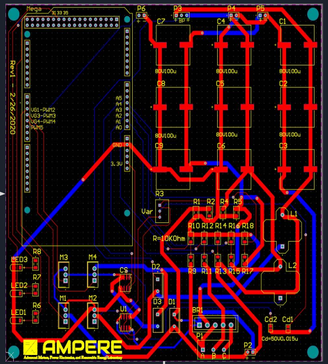
Presenter: Nigel

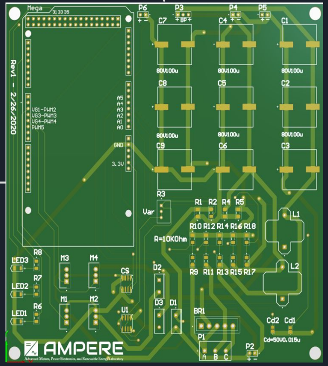
Conclusion
Finished Project

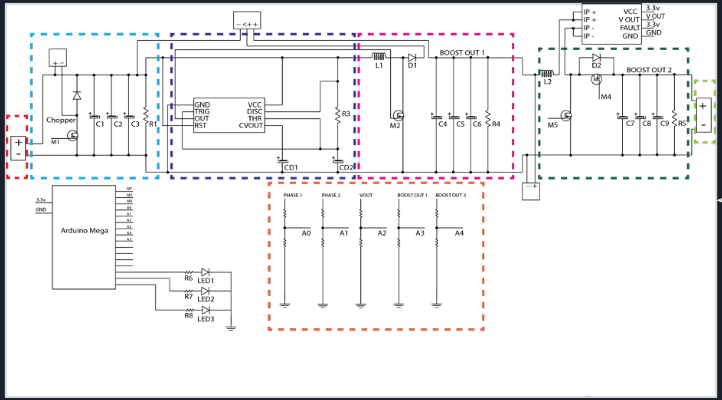
- Thank you!











Presenter: Nigel

References

[1] U.D. of Energy, *Collegiate wind competition 2020*, [Online; accessed April 10, 2020], 2020. [Online]. Available: https://www.energy.gov/sites/prod/files/2020/04/f73/cwc-2020-rules-requirements-1.pdf.