Turbine Electric

DOE Wind Competition EE Team

Design Review 4

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1. Introduction

We are Team Turbine Electric of the DOE Collegiate Wind Competition. Our capstone project consists of designing and building the electrical components involved in the operation of a wind turbine. Our project is multi-disciplinary. The mechanical engineering team will be designing the actual wind turbine while our team will focus on the electronics. There are three main converters that we will have to build. The first converter is an AC/DC rectifier which will take in the three-phase AC voltage produced from the turbine motor and convert that to DC voltage. The competition asks that our wind turbine outputs five volts during consistent operation. This means that after we have converted the AC voltage to DC, we will need to either buck or boost the voltage depending on the input voltage received from the generator. The competition also asks that we thoroughly document all our procedures. This means that even after we finish building our converters, we will still have a lot of writing to do to satisfy the competition requirements.

We created a very broad WBS chart that covers all aspects of our project. We have highlighted five main “tree’s” that need to be completed for us to succeed on this project. The first main task is planning. This means having meetings with our client and figuring out what is needed for the competition. During this time, we will read through all the competition rules and regulations and start formulating a plan that will fit within the constraints of the competition. We will assess our budget and determine if we will have enough money to complete the project. During the planning phase we will also agree on meeting times with our client and with the team. After our planning for the project is complete, we will move onto the design of the systems. The systems listed above in the first and second paragraphs will need to be designed and mathematical calculations will need to be conducted to ensure we order parts that will work for the project. Once we have designs laid out on paper, we will begin translating them to software simulations to verify the functionality. Once we know our circuits work on the simulation, we will have to physically start building them and then test them again. We will start by building them using a breadboard for low voltage simulations. Once that works, we will solder everything to a prototype board and test the circuit with higher voltages. Once all these tests pass, we will need to design the PCB. When our PCB design is complete, we will combine our project with the mechanical engineering team’s turbine and verify that it works with their design. There will be many tests conducted with the mechanical engineering team once we have both completed our builds. It is during this time that both teams will be working on the grueling amount of documentation needed for the competition. All these primary tasks have been laid out below in the WBS Chart.

We have completed all of the converters and only have testing and documentation left to complete. The AC/DC rectifiers we built have all been tested and will work great for competition. The two DC/DC converters are giving us trouble. We have completely built both of them but during testing they are not performing how we intended them to. The DC/DC buck converter worked well at first when we initially built it but since we have been testing it more it is starting to not work as well. The DC/DC boost converter is built but just not really working at all right now. When we put in an input voltage it seems like it is not reading the voltage at all. It also does not display any output voltage. We are not sure what is going on with the converter right now so we will need to do more testing to figure out how to fix the converter. The competition is in three weeks, so we do not have a lot of time to figure out what is going wrong and complete testing with the mechanical engineering team. We need to start looking into our contingency plan and think about purchasing other converters that will work for competition.

2. Problem Description (Juntong)

The U.S Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) created the Collegiate Wind Competition in 2014 to help facilitate wind energy incorporate into the United States power generation mix. Wind Vision report: By 2035 wind energy could supply the nation's electricity needs by 35%. Competition objective: Preparing students to enter the wind energy workforce by providing real-world technological experience. In order to take in this competition and gain a good place in the competition, we Electric Turbine team cooperate with Mechanical engineering team to build a complete wind turbine.

As an EE team our tasks is to cover the designing, building and testing of a wind turbine. First, we will have to rectify the AC signal that is produced from the 3-phase AC motor attached to the wind turbine. We will then need to use a DC-DC converter to get the voltage within the desired range for the competition. The wind turbine will produce a variable DC signal once it has been converted from AC. Our design will need to be able to accept a wide range of DC input ranges and boost it to a consistent voltage. We have also learned that we will need to power our arduino and the circuit we build using the wind turbine.

a. AC/DC Rectifier

An electrical device that changes alternating current flow (AC), which occasionally turns around bearing, to direct current flow (DC), which flows in just a single direction. The procedure is known as correction, since it "fixes" the bearing of current. These converters can be passive or active. The

b. DC/DC Buck Converter

A kind of DC to DC converter that has a reduced output voltage. The output voltage is stepped down from the input current. In order to conserve power, the output current is stepped up.

c. DC/DC Boost Converter

Produces an output voltage which is greater than the source voltage. Boost converter is also called a step-up converter since it "steps up" the source voltage. Since power must be preserved, the output current is lower than the source current.

3. Design Process (Chris)

a. AC/DC Rectifier

The AC/DC rectifier is the easiest converter we needed to build because it is a passive converter. This means that it does not need to have any help from an Arduino and is capable of converting the voltage by using only diodes and a capacitor. We started this design by drawing a simple diagram of what our converter should look like. This can be seen below as Figure 1.

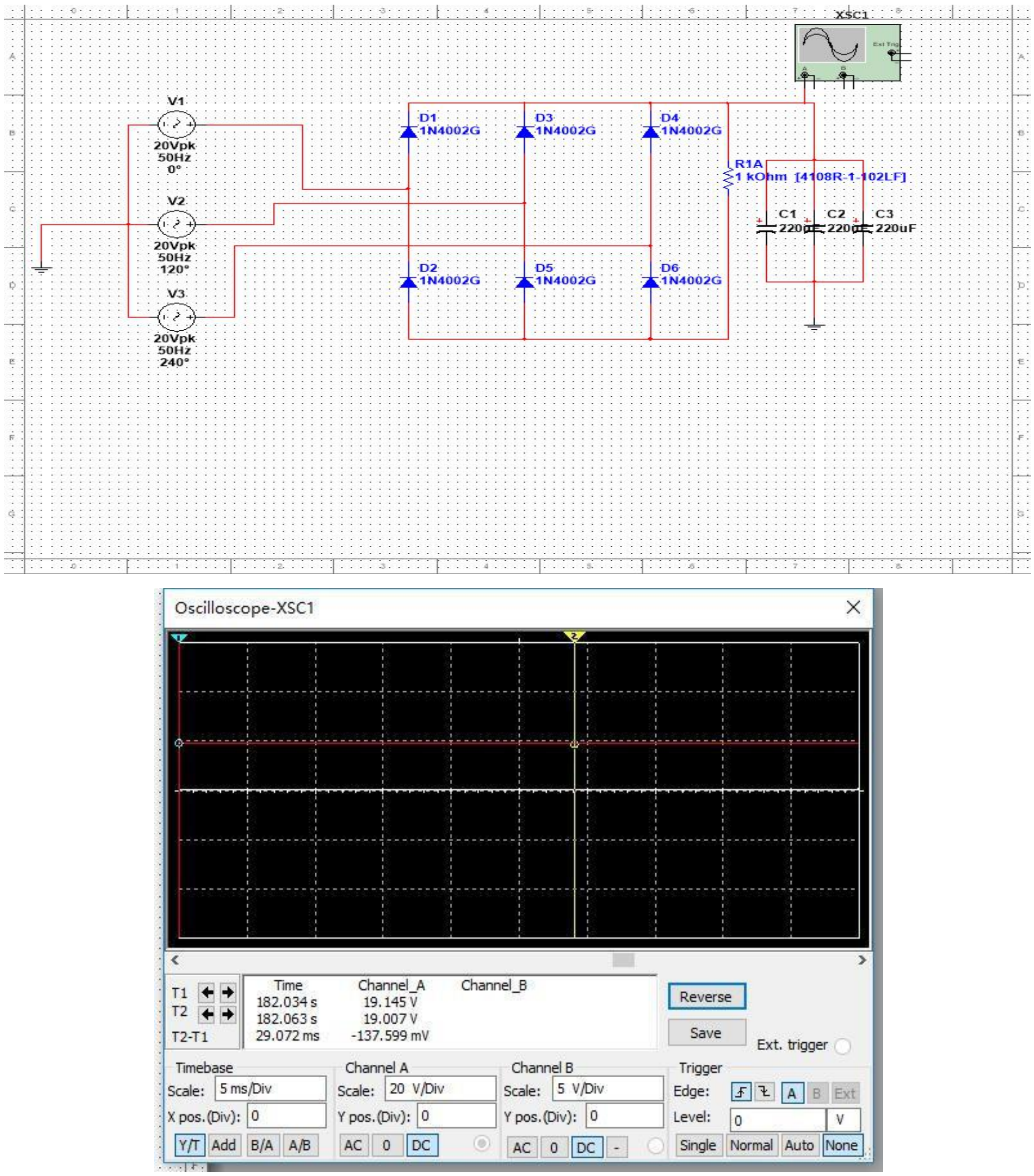


Figure 1

Once we had our basic diagram designed, we started looking for the Schottky Diodes that would be able to withstand the correct amount of voltage and current that would be put into them. We decided to go with the TO-220AC Schottky Diodes. These diodes can withstand up to 200V and 20A. This is perfect for the competition because we do not want to run the risk of burning the converter during the competition. We then determined that a 220uF capacitor would be perfect for smoothing the DC voltage after it has been converted. Lastly, we determined that a way to deplete the capacitor quickly upon disconnect would be ideal. A few simple calculations resulted that a 1000 Ohm resistor would deplete the capacitor in under 1 second. We then ordered enough parts to make multiple of these converters. Once the parts arrived, we started soldering the components to a perfboard. A finished image of our rectifier can be seen below as figure 2.

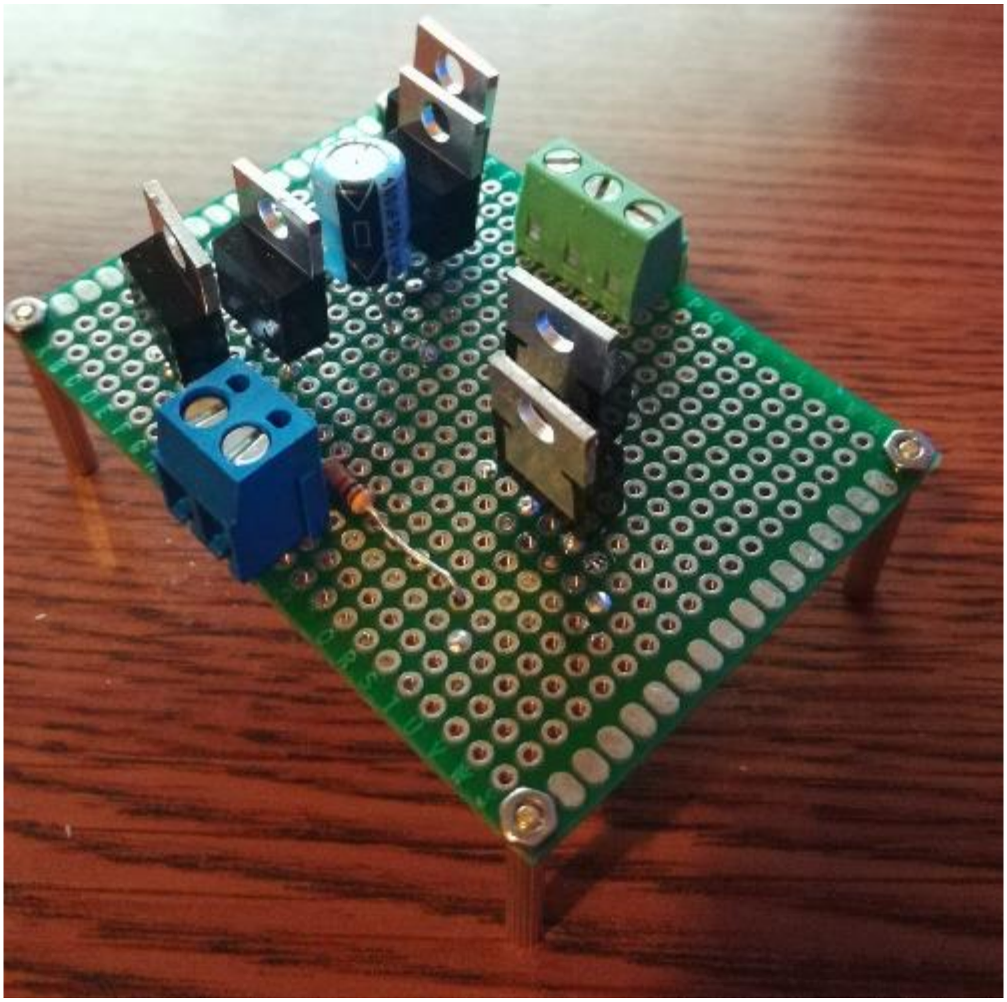


Figure 2

We then needed a way to test our rectifier. Since there are no three-phase AC power supplies in the engineering labs we had to use a dynamometer to verify our rectifier worked.

b. DC/DC Buck Converter

The buck converter was a little bit more challenging than the rectifier to design and build. We started by looking at our design constraints and figuring out what our buck converter would need to do. We knew that the output voltage would always have to be 5V and the input would have to be something greater than that. The buck converter would need to connect to the rectifier and boost converter and use those voltages to produce the output. We started by creating a simple simulation of a buck converter to get a general idea of what components we would need to use to build the buck converter. An image of the simulation can be found below as figure 3.

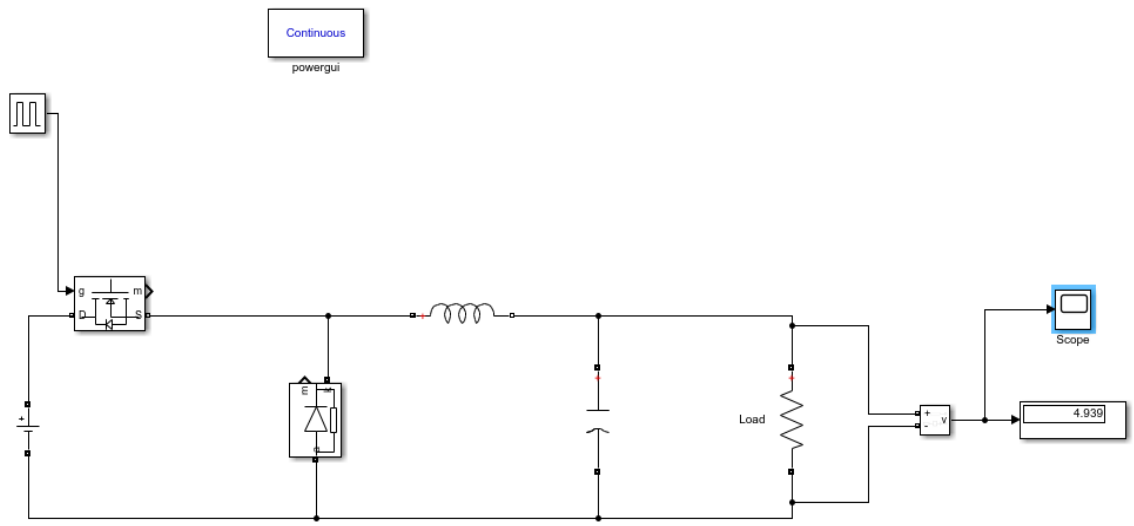


Figure 3

Once the simulation was working and we knew what parts we would need, we started looking into components to purchase. We determined that these components would work best for our design. These can be found below as figure 4.

Component	Description
XL4015	DC/ DC 180-KHz Buck Converter, 5 A/36 V
M7	SMD version of 1N4148 Diode
HSN3631A S	Numeric Three-Digit LED Display,
LM317	Adjustable Voltage Regulator
SS54	Schottky Diode 40 V/5 A
47 uH/5 A	Power Inductor
50K MT	Multi-Turn Preset Potentiometer 50K
LED	Indicator light
Capacitor 220uF/35 v	Capacitor used for smoothing the signal
Capacitor 100uF/50 v	Capacitor used for smoothing the signal

Figure 4

When all of the components arrived, we hooked them up to a breadboard to begin testing if they would work for the competition. The components we purchased allowed the input voltage to go up to 25V with 15A of current. We hooked up the multimeter to our output wires and set an input voltage of 12V. We found that our initial output voltage was around about 8V. We used the potentiometer to adjust the duty ratio of the circuit until we arrived at a constant 5V output. We modified some code from the previous year's buck converter in order to make ours work with any input voltage. The final design for our buck converter can be found below as figure 5.

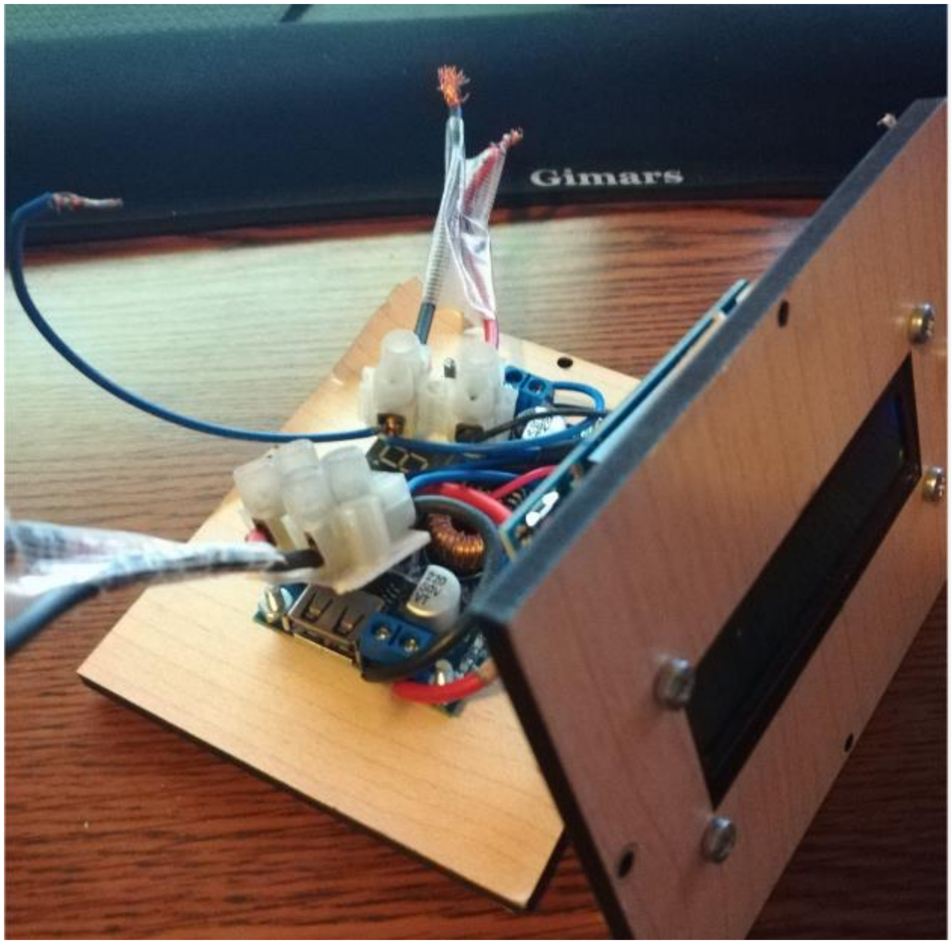


Figure 5

c. DC/DC Boost Converter

The boost converter was even harder than the buck converter to design and build. This converter has to take the rectified DC voltage that is under 5V and either boost it to a consistent 5V or boost it above 5V so the buck converter can take it down to 5V. This was very challenging because it was hard to find components that would accept the low input voltage that we would need for competition. We followed the same process of simulating the design first to figure out what components we would need. The results of our simulation can be found below as Figure 6.

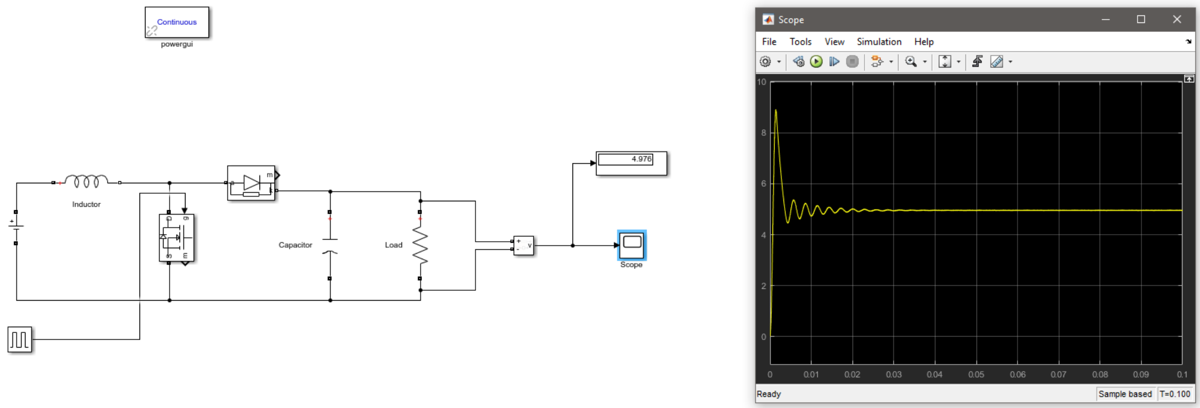


Figure 6

Once we had a better idea of what we would need for the boost converter we started looking for components. We ordered the components that would work best for our build and when they arrived, we hooked them up to a breadboard for low voltage and current testing. We were confident our boost converter was going to work so after we finished the breadboard testing, we started the perfboard testing and eventually created a PCB for the boost converter. The results of the final design can be found below as figure 7.

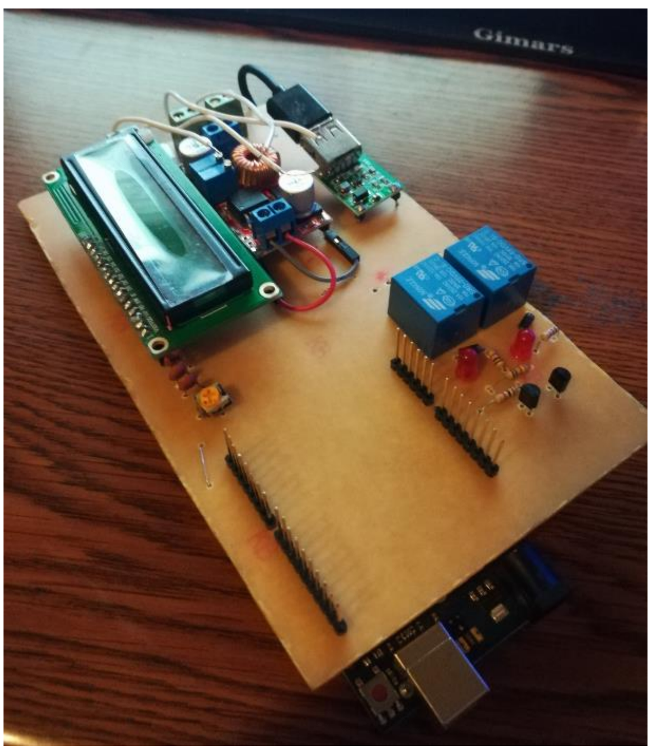


Figure 7

4. Design Constraints (Abdallah)

a. AC/DC Rectifier

The AC/DC Rectifier converts AC to DC while the current flow being passive. The schematic of the design should be soldered to a PCB as well as having standoffs to help in the reducing the temperature where the rectifier will be placed up tower behind the fan for cooling. In addition, the design needs to withstand high voltage and current.

b. DC/DC Buck Converter

The DC/DC buck converter steps down the voltage from a max of twenty-seven volts to the required five volts needed and has to withstand high current. The schematic of the buck converter design should be printed on the board and then have the components attached the to the Perf board.

c. DC/DC Boost Converter

The DC/DC boost converter steps up voltage from a least one volt to the required five volts with the help of a saver relay to help it boost such a low voltage also needs to withstand high current. The schematic should be etched on board connecting the boost converter components on the PCB.

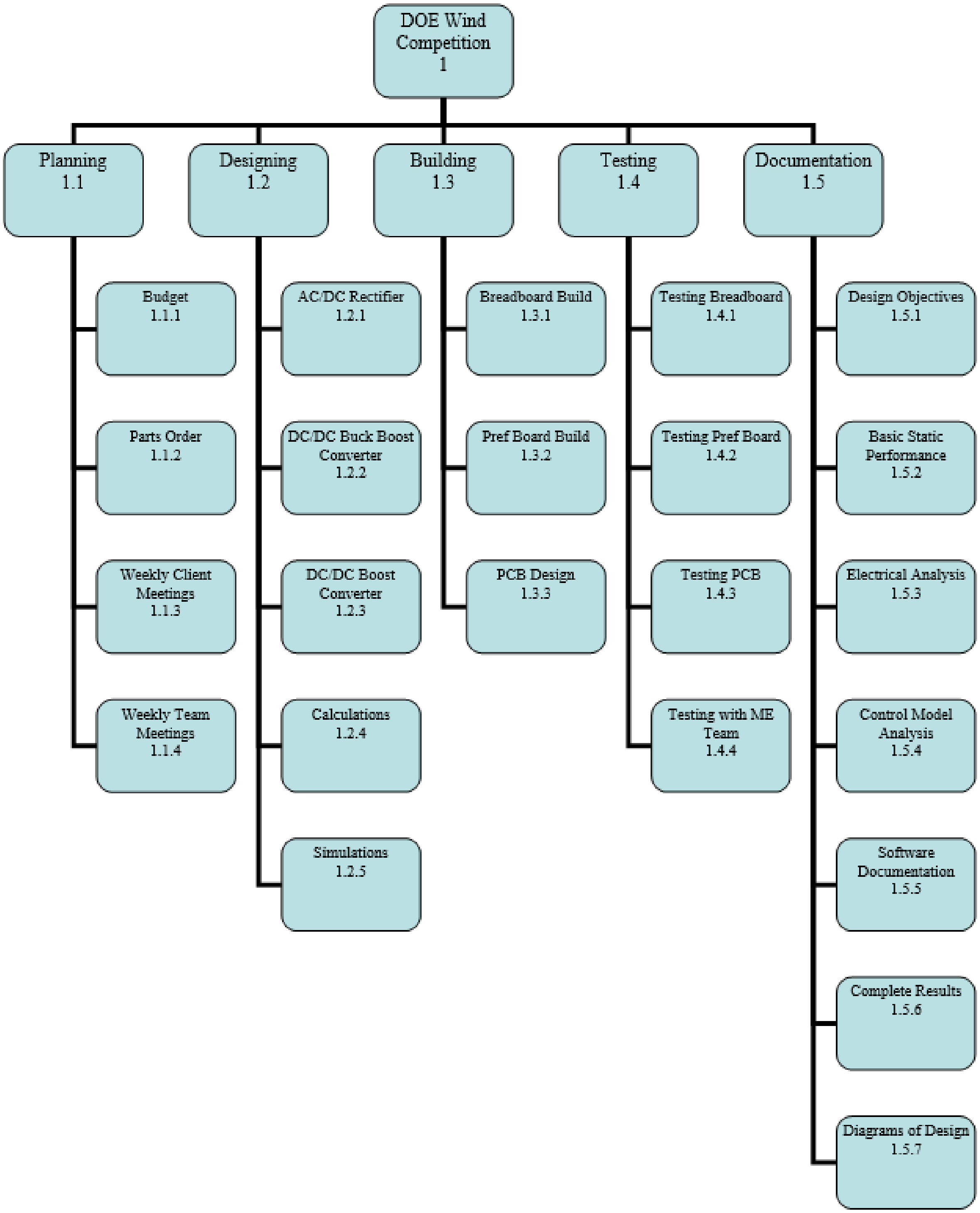
5. WBS Guidelines/Wrap-Up (Chris)

We are on track to complete every aspect of the design we laid out in our WBS chart. We knew from the start that we would need to have 3 working converters and we have completed all three of those designs. We are still working on the paperwork, but we don’t have an option of not completing that; so that will be finished within the upcoming days. We did not need to change any aspects of our WBS chart over time because from the start we had a good idea of what the client was asking and what was needed from our group. We found that the Gantt chart didn’t really help us very much and we never really used it. We meet for 6 hours each week and steadily worked on the design until it was complete. We knew this would be enough time to finish everything and we knew that we would need to have everything completed by the time the mechanical engineering team we finished with their design. Since we never used a Gantt chart and just worked on each component as needed, we did not include our previous Gantt chart here. We have attached our detailed WBS chart below.

TABULAR VIEW

Level 1	Level 2	Level 3
DOE Wind Competition	1.1 Planning	1.1.1 Budget 1.1.2 Parts Order 1.1.3 Weekly Client Meetings 1.1.4 Weekly Team Meetings
	1.2 Design	1.2.1 AC/DC Rectifier 1.2.2 DC/DC Buck Boost Converter 1.2.3 DC/DC Boost Converter 1.2.4 Calculations 1.2.5 Simulations
	1.3 Building	1.3.1 Breadboard Build 1.3.2 Pref Board Build 1.3.3 PCB Design
	1.4 Testing	1.4.1 Testing Breadboard 1.4.2 Testing Pref Board 1.4.3 Testing PCB 1.4.4 Testing with Mechanical Engineering Team
	1.5 Documenting	1.5.1 Design Objectives 1.5.2 Basic Static Performance 1.5.3 Electrical Analysis 1.5.4 Control Model Analysis 1.5.5 Software Documentation 1.5.6 Complete Results 1.5.7 Diagrams of Design

TREE STRUCTURE VIEW



WBS Dictionary

Level	WBS Code	Element Name	Definition
1	1	DOE Wind Competition	All work to complete the task outlined by our client and compete in the competition.
2	1.1	Planning	The work to initiate the project.
3	1.1.1	Budget	Determining how much money we have and get a general idea of how much everything will cost.
3	1.1.2	Parts Order	Based on our budget, order parts for the prototyping phase of the project. Determine our remaining budget and order more parts as necessary.
3	1.1.3	Weekly Client Meetings	Meeting with Professor Willy and the mechanical engineering team every Friday afternoon.
3	1.1.4	Weekly Team Meetings	Electrical engineering team meetings every Tuesday and Thursday for a total of six hours a week.
2	1.2	Design	Initiating our plan and formulating ideas of how to solve the problem.
3	1.2.1	AC/DC Rectifier	Hand drawn diagrams of this type of converter, taking notes of what parts we will need to build it.
3	1.2.2	DC/DC Buck Boost Converter	Hand drawn diagrams of this type of converter, taking notes of what parts we will need to build it.
3	1.2.3	DC/DC Boost Converter	Hand drawn diagrams of this type of converter, taking notes of what parts we will need to build it.
3	1.2.4	Calculations	Based on our diagrams we will do calculations to determine what specific parts will work for our design.
3	1.2.5	Simulations	Taking those parts and diagrams and putting them into Simulink simulation software to ensure the design works as intended.
2	1.3	Building	Work involved to execute the project.
3	1.3.1	Breadboard Build	Take all our simulations and physically build them with the correct components on the breadboard. Basic, low voltage tests to ensure functionality.
3	1.3.2	Pref Board Build	If the breadboard test works, implement the design on a prototype board and test with higher voltages to verify functionality.
3	1.3.3	PCB Design	Once we are sure our design can meet the competition needs we will design the PCB to work for the competition.
2	1.4	Testing	Quality control of our designs.
3	1.4.1	Testing Breadboard	Low voltage tests to ensure the circuit is built correctly and the output values are correct.
3	1.4.2	Testing Pref Board	Higher voltage testing to ensure the circuit is built correctly and the outputs are what we expect. This test more closely resembles the final design of the project.

3	1.4.3	Testing PCB	The final build of our project. Test to ensure that the circuit still works correctly and gives the desired output.
3	1.4.4	Testing with Mechanical Engineering Team	Combine our PCB with the mechanical engineering team's turbine and ensure that it works for the needs of the competition.
2	1.5	Documentation	The work to close-out the project.
3	1.5.1	Design Objectives	Report explaining what we were going for with the design of our converters. Explaining our thought process.
3	1.5.2	Basic Static Performance	Report showing all our testing procedures and documenting the results of our converters.
3	1.5.3	Electrical Analysis	Analysis of all the electrical components we used to complete the build of our converters.
3	1.5.4	Control Model Analysis	Not too sure what this is right now. More research needed before writing this portion of the documentation.
3	1.5.5	Software Documentation	Highlighting the software used to complete the project.
3	1.5.6	Complete Results	Final paperwork showing our results and how the electrical and mechanical engineering team's designs came together for the final design.
3	1.5.7	Diagrams of Design	Hand drawn diagrams and simulations showing our initial designs for the project.

We created a WBS chart to reflect all of the aspects of our project that we would need to complete during the full design process. With this WBS chart we color coordinated our tasks and made it easier to see what was already completed and what we still need to work on. We have attached the most recent version of our WBS chart below as Figure __. As seen in the figure, everything that is purple is already completed and ready to go for competition. There is nothing we haven't started yet and everything is at least above 50% complete. We recently started all the documentation for competition which is the main thing we will be working on now that most of our design is complete. In total we are now 81% of the way through completing our project. The only things left to complete are the testing with the mechanical engineering team and the documentation. In our previous documentation we stated that failure was not an option because we needed to have something ready for competition. We knew going in that there was no aspect of our WBS chart that we could leave unfinished and luckily, we were able to complete each design. The WBS chart showing our work completed can be seen below as Figure 8.


100%
80%
90%
77.5%
88.9%
66.7%
81.28%
50%
DOE Wind Competition 1
Planning 1.1
Designing 1.2
Building 1.3
Testing 1.4
Documentation 1.5
Budget 1.1.1
Parts Order 1.1.2
Weekly Client Meetings 1.1.3
Weekly Team Meeting 1.1.4
AC/DC Rectifier 1.2.1
DC/DC Buck Boost Converter 1.2.2
DC/DC Boost Converter 1.2.3
Calculations 1.2.4
Simulations 1.2.5
Breadboard Testing 1.3.1
Pref Board Testing 1.3.2
PCB Design 1.3.3
Testing Breadboard 1.4.1
Testing Pref Board 1.4.2
Testing PCB 1.4.3
Testing with ME Team 1.4.4
Design Objectives 1.5.1
Basic Static Performance 1.5.2
Electrical Analysis 1.5.3
Control Model Analysis 1.5.4
Software Documentation 1.5.5
Complete Results 1.5.6
Diagrams of Design 1.5.7

Figure 8

6. Conclusion

As seen from this document, we are very far along on our project. It started a little rough and we were unsure of where to go, but with each week's meetings we learned more and prototyped more designs until we had working converters. Some aspects of the project were easier than others, but there was nothing that we couldn't complete. Some upcoming challenges we face are that the wind tunnel here in Flagstaff is currently non-operational. This means that we will need to create a device that will allow us to mount the wind turbine to a car so that we can drive around at an appropriate speed to test whether all the components are working correctly for both the mechanical and electrical engineers. We still need to get our converters condensed into a carrying compartment that is within regulation for competition. We have already ordered our enclosure and are just waiting for that to arrive before we can put the components inside. The documentation for competition isn't too bad since we have already written a lot about the project for our class. Lastly, competition itself will be a challenge because if anything breaks, we will need to fix it on the spot. There will be a lot of speaking with judges and explaining our design. We are glad that we could work on such an interesting capstone project and feel proud that we were able to complete all three converters on time for testing with the mechanical engineers. We are looking forward to competition and hope to finish favorably.