Design Review 4

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Project: Photovoltaic Inverter

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Introduction :

In recent years, clean energy became to a important resource because of the global warming. Solar power as one of the clean energy is easy to take from nature is also sustainable energy. So there is a strong need for central inverter of utility-scale photovoltaic energy system, but people found that the efficient of the photovoltaic system was not very well, it may due to many reason and one of them is the partial shading. The team objectives and goals of the project are to develop the next generation large-scale PV system interfaces with integrated energy storage for improved energy efficiency, reduced manufacturing cost, enhanced system reliability, and grid code compliance with proper control. Also, help calibrate the time expectation for the project.

Our team members are Khaled Albannai, Mohamad Elsaleh, Xuanyu Bai, Jiaxin Zheng and we are working with our client Dr. Yaramasu. This is the Design Review 4 documentations we discussed more in detail about the project, Client's Problem, Design process, Project Constraints, Metrics of success, WBS status Update.

Client's Problem:[Khaled Albannai]

It is predicted that sometime in the next 100 years the fossil fuel will be depleted, and it is important for us to start approaching and improving a different path and a transition from fossil fuel to photovoltaic energy, because over the years between 2010 and 2016, utility-scale solar installations have grown at an average of 72% each year, which our client to develop and research the next large generation large-scale PV system interfaces with integrated energy storage for improved energy efficiency, reduced manufacturing cost, enhanced system reliability, and grid code compliance with proper control. Our client prof. Yaramasu asked us to build an MMC(Modular Multilevel converter), This converter will be used for grid-connected large-scale PV systems, and we are also going to study how can we store energy and used it night time,

Project charter:

We want to provide central PV inverters with the flexibility to search for global MPPs by means of energy storage to compensate for output power. Central PV inverters based on modular multilevel converters (MMC) are available with input voltages from 3.5 MW and 1500 V DC. These ratings mean that the PV system is a low voltage and high current system. Therefore, low-cost SiC-MOSFETs are ideal for implementing low-voltage sub-modules in MMC. By connecting a larger number of submodules, the voltage of each submodule becomes lower. The large number of sub-modules results in a lower dv / dt, eliminating the grid side filter. For the details, we need to work on the utility-scale(MW) PV+MMC+Predictive control in the lab.

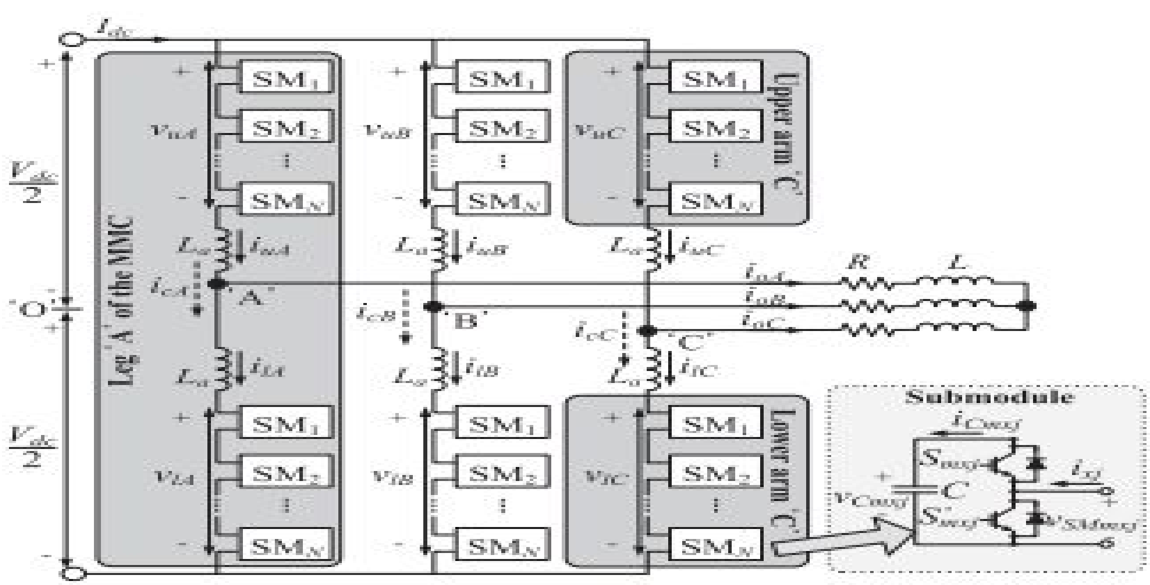
Project objectives and goals:

The objectives and goals of the project are to develop the next generation large-scale PV system interfaces with integrated energy storage for improved energy efficiency, reduced manufacturing cost, enhanced system reliability, and grid code compliance with proper control. We need to solve the problem of the large-scale photovoltaic grid-connected energy storage system by using MMC technology. The system's interface converter will help to improve the stability of the grid system. For the proposed large-scale photovoltaic system, we will come up with effective control and design method to achieve line voltage distortion operation. We will learn techniques to compensate for the voltage drop in the grid system and study the overall closed-loop stability.

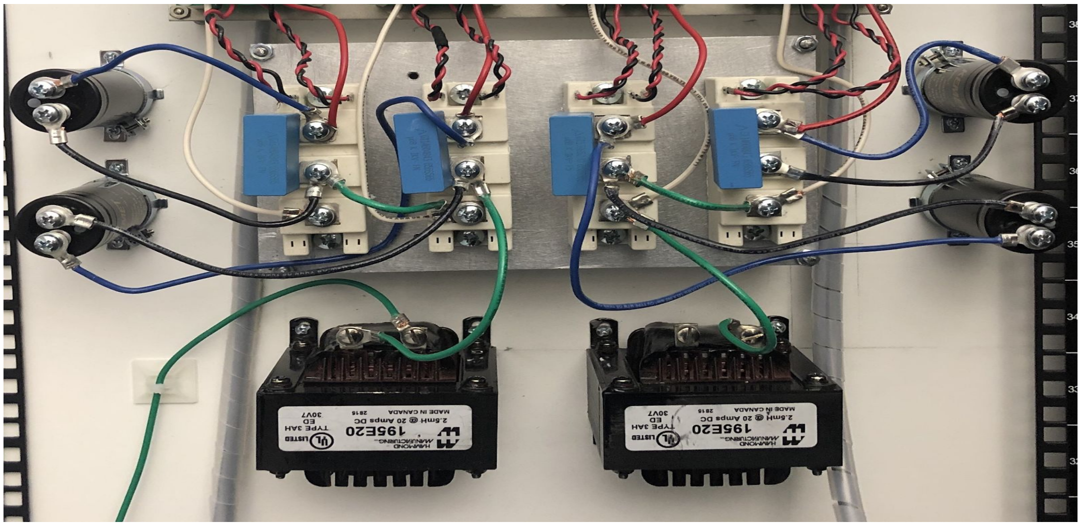
Project complement:

The proposed research project will be conducted at the NAU Ampere Laboratory. Due to the MW rating, the prototype cannot be used for laboratory testing, considering the small power converter with a rated power of 5 kW. The entire system will use the same unit value as the actual power to achieve the same operational characteristics of the conversion system for proper verification. The MMC prototype and mesh simulator will be built in the lab. The photovoltaic energy system will be tested by testing the equipment on the experimental platform.

Design process: [Mohamad Elsaleh]



Structure of three phase MMC Fig. 1



Leg of the MMC Fig.2

MMC Converter Built Fig.3

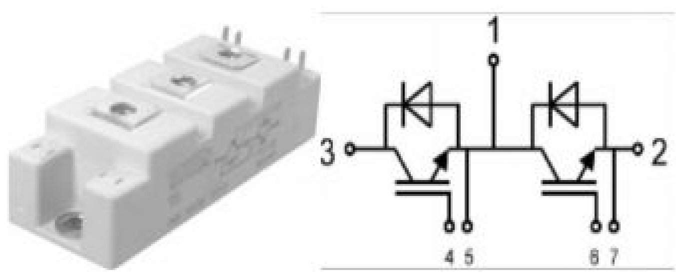
Our Modular Multilevel Converter is made of 3 phases, control unit in the middle with a primary purpose of sending the signals, with a sensing unit to measure the current and voltage throughout the circuit, and at the bottom, we have the switching unit, input from the solar panel and the output to the grid.

Project Subsystems: [Mohamad Elsaleh]

Subsystem 1: (3 phases)

In figure 2 is close up look into on of the phases in the MMC converter we built and each phase will have these components.

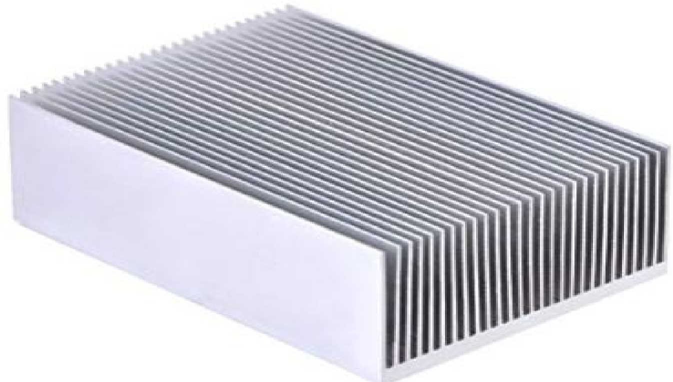
Insulated-Gate Bipolar Transistor (IGBT):(4 per phase)



IGBT Fig.4

The device is a three terminal power semiconductor device primarily used as an electronic switch, which will provide high efficiency and fast switching.

Heat sink:(1 per phase)



Heat Sink Fig.5

Heat sink is used to disperse the heat in a electronic circuit, which will cool down all the components in the circuit, and this will help to increase the performance of the components output.

Capacitors:(4 per phase)

The capacitors we are using have a value of 1000 µF , and the function of these capacitors is to store electrical energy and give this energy back to the circuit when it's necessary.

Snubber Capacitor:(4 per phase)

We have 4 snubber capacitor connected over each IGBT, the main task for a snubber capacitor is to suppress the voltage spikes caused by the circuits inductance when a switch opens.

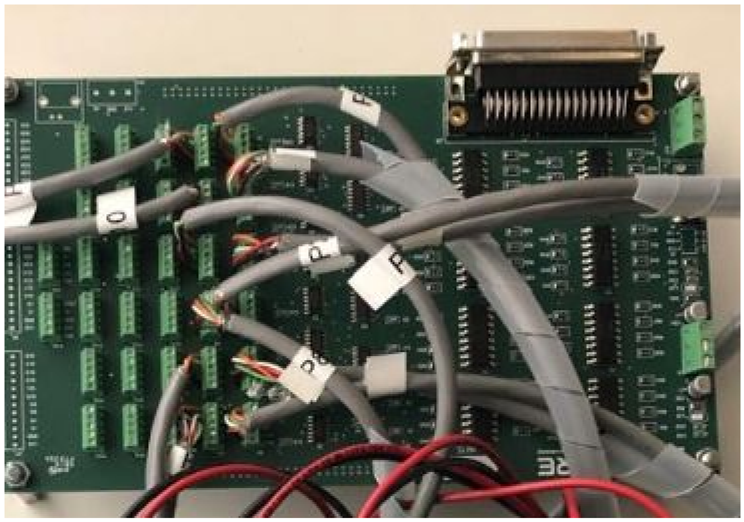
Inductor:(2 per phase)

In each phase we have two inductor connected with value of 2.5 mH, is used to store energy in a magnetic field when electric current flows through the circuit.

Subsystem 2:

This subsystem is used to control the input of the converter, after we connect the converter to the power source we will send signals from the dSpace which will be received by the gate drivers to operate the converter, also this subsystem is used for sensing the voltage and current to ensure everything is working properly.

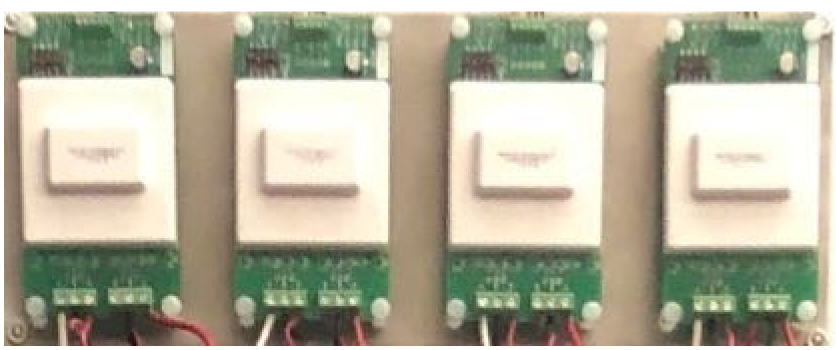
Interface Board:



Interface Board Fig.6

The interface board is used to connect to the dSpace, which will receive and convert Transistor-transistor logic (TTL) into CMOS logic.

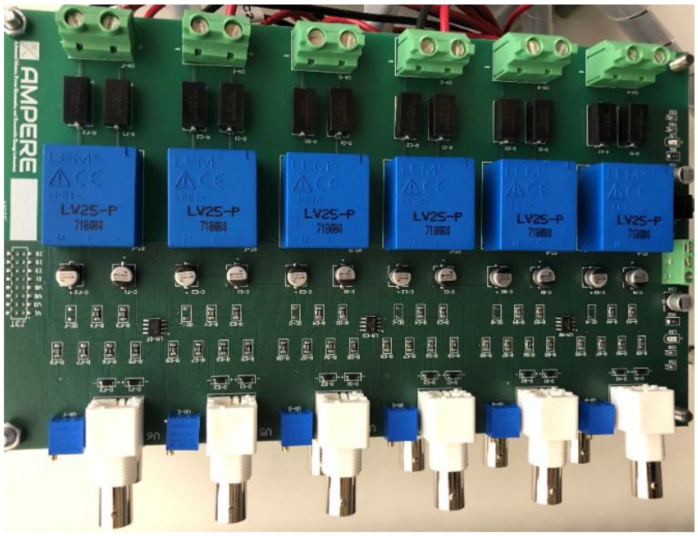
Gate Drivers:(4 per phase)



Gate Drivers Fig.7

Gate drivers are used for high application, these devices are used as control unit to send and receive signals from Simulink/DSpace to the IGBT's, the gate driver will take the low voltage input from dSpace and then it will turn on/off the IGBT’s, also the gate driver will allow us to control each phase separately to ensure each phase is working properly.

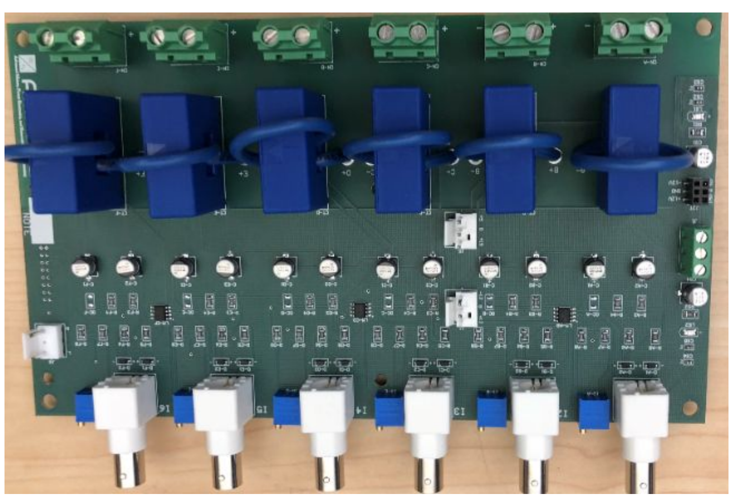
Voltage Sensors:



Voltage sensor Fig.8

Voltage sensor is used to measure the voltage signal, by converting the power parameters into DC current, DC voltage and isolated output digital or analog signal, and it will be connected to a oscilloscope to get all those output waveform.

Current sensors:



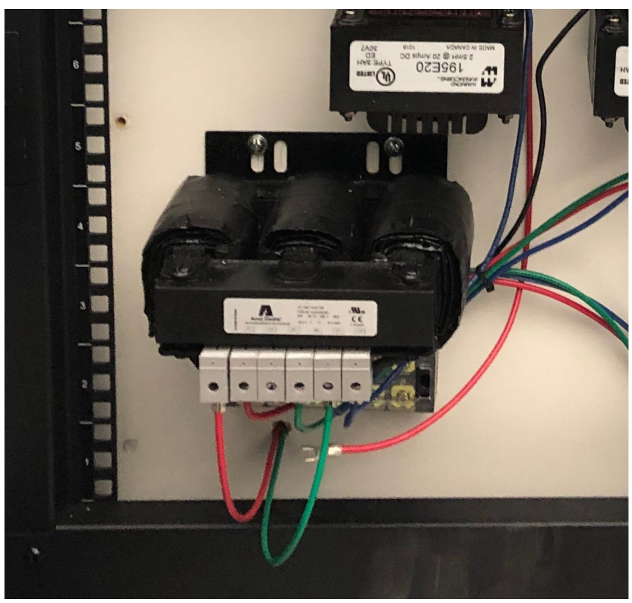
Current sensor fig.9

The current sensor is used to sense the current flowing through each phase, and give a feedback and information if the system is meeting the desired output, all this information can be obtained by connecting the current sensor into a oscilloscope.

Subsystem 3:

In the subsystem 3, we are using the 3-phase inductor due to the small space and also as the client requested. Also, the relay board for safety purposes. Last the power supply we are using the

3-phase Inductor:



3-phase Inductor fig.10

The three phase inductor is used in many different applications such as renewable energy power conversion and high-power battery charging etc. First we had three big individual but they were taking a lot of space and then out client decided to change it to the 3-phase single inductor it is more convenient.

Relay board:

Relay Board Fig.11

The relay board work as a safety switch for our Inverter. It controls the input current and the output circuit electromechanical it can turn it on and Off.

Power supply:

Power Supply Fig.12

We will be using the photovoltaic power profile emulation (PPPE), this device will be used to define different level of profiles to be tested on the inverter, such as controlling voltage input and temperature, so is device will basically act like a 100 solar panel and this would saving space and money for the rechearch.

Project Constraints:[Xuanyu Bai]

- Team Constraints:

  At the beginning of the project, our team has to do some decision on our job separation. We didn’t know each other so we made some divergence but after we start to know each other and talk about the differences, everything just got better.

- Client Constraints:

  In last semester, we started building the PV inverter on a wooden show stand board and when we finished almost 50% of the hardware, our client came to the lab and checked our devices. And, we were told that he changed his mind and he got a new idea of the show strand board which he think it’s better. We were given a metal holder support by the client which would makes it look more professional and he wanted the equipment to be in industrial standards, so the problem is that we had to reinstall the inverters base on his new idea which made us to change the plan to spend more time on installation.

- Equipment Constraints:

  There were some of materials and devices not given, we had to order the parts to continue building the Inverter, such as 12 of 1000 μF Capacitor, 1 big Inductor 3 Phase Inductor, some Gate drivers parts, 4 IGBT and wooden boards. So the problem is that a lot of parts we had to order from out of the country, that means it will takes about 10-15 days or longer to deliver which make a delay on our schedule

  Also at the beginning of the project, we figured out that the wooden stand board we had could not hold all of the components. We discussed with our client saying that we need to increase the size of the wooden structure to fit our equipment and make project easy to work with. After get the client’s permission, we increased the size of wooden board so we got more space for wire connections and in case of failure we can easily locate the problem.

- Economy Constraints:

  As the professional equipment, there were some of kind expensive devices we used in this project. Even though we were given a budget, it still can not reach our estimate for the parts. So the problem is the team has to spend a lot more money on their own which is different from what we realized before.

Metrics of success(WBS): [Jiaxin Zheng]

-Outline：

Our team is required to deliver the best product which is the converter to the client. Based on his needs and converter requirements, such as being high stander as buying it for a third-party manufacturer. In addition, our team will make sure to follow and satisfy the client with the final product. Here, we have outline some very specific success metrics listed below for each task and activity in the PV Inverter.

1.Hardware

- A moveable stand
- The correct size of components

2.Cutting/Drilling

- Attaching a total of 12 gate drivers on a metal sheet
- A show stand board

3.Assemble units

- All the components set up on the board
- Complete three phases in the correct position

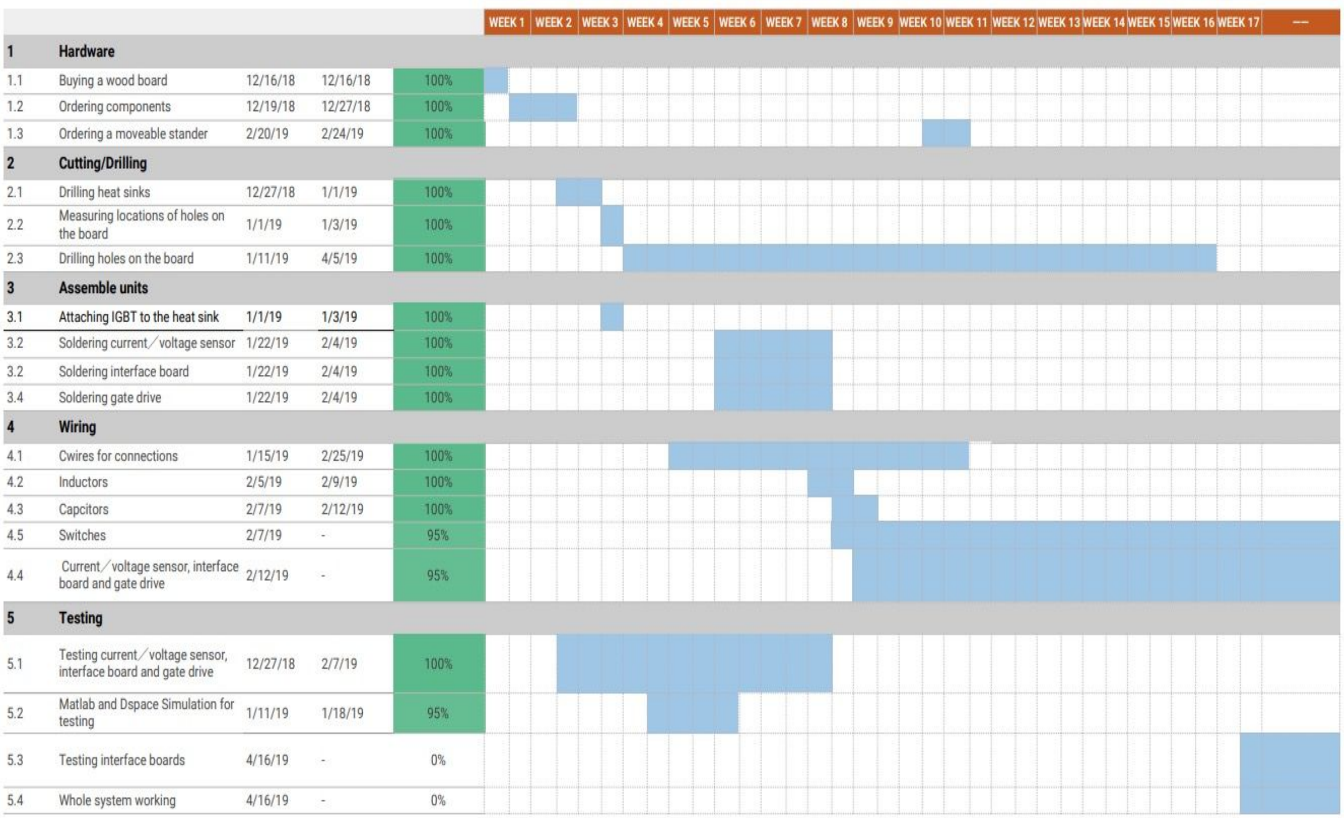
4.Wiring

- Three phases in their correct connection
- Inverter connected properly
- Current and voltage sensors connected properly
- All the interface board in their correct connection

5.Testing

- Interface boards can run without any errors
- Whole system working properly

-Gantt Chart:



1	**Hardware**			
1.1	Buying a wood board	12/16/18	12/16/18	100%
1.2	Ordering components	12/19/18	12/27/18	100%
1.3	Ordering a moveable stander	2/20/19	2/24/19	100%
2	**Cutting/Drilling**			
2.1	Drilling heat sinks	12/27/18	1/1/19	100%
2.2	Measuring locations of holes on the board	1/1/19	1/3/19	100%
2.3	Drilling holes on the board	1/11/19	4/5/19	100%
3	**Assemble units**			
3.1	Attaching IGBT to the heat sink	1/1/19	1/3/19	100%
3.2	Soldering current/voltage sensor	1/22/19	2/4/19	100%
3.2	Soldering interface board	1/22/19	2/4/19	100%
3.4	Soldering gate drive	1/22/19	2/4/19	100%
4	**Wiring**			
4.1	Cwires for connections	1/15/19	2/25/19	100%
4.2	Inductors	2/5/19	2/9/19	100%
4.3	Capcitors	2/7/19	2/12/19	100%
4.5	Switches	2/7/19	-	95%
4.4	Current/voltage sensor, interface board and gate drive	2/12/19	-	95%
5	**Testing**			
5.1	Testing current/voltage sensor, interface board and gate drive	12/27/18	2/7/19	100%
5.2	Matlab and Dspace Simulation for testing	1/11/19	1/18/19	95%
5.3	Testing interface boards	4/16/19	-	0%
5.4	Whole system working	4/16/19	-	0%

As the Gantt Chart, our final project has completed the work of hardware, punching, and wiring. We bought a suitable movable rack, board and hardware by measuring. Depending on the size of the device, we measured where the device should be fixed and punched holes in the measured position. We use different colored lines to connect different devices, trim the lines according to the position and shape and connect according to the circuit diagram. Only a part of the interface board assembly line is in progress, and we will finish it next week. Once the assembly work is completed, we will begin to test the result of the project next week.

WBS status Update:

Section	Activity/Task	Description	Deliverable(s)
1	Hardware		**Done 100% complete all Hardware**
1.1	Metal board stand	Installing the board stand	A complete moveable stand
1.2	Buying stand board	Measuring and layout the board with precise measuring	To measure the correct parts sizes for all components
1.3	Purchase Components	12 capacitors 12 capacitors metal attachments 1 big inductor 12v wires	To have all the components we need to build the converter
1.4	The show stand	A standing board that holds all devices on it	A stander with the measured size
2.0	Cutting/ Drilling		**Done 100% complete cutting/Drilling**
2.1	Metal for gate drivers	Measure and make it fit perfectly on the metal 3 sheets	Attaching all 12 gate drivers

2.2	Drilling holes on the board for components	Drilling the correct for all converter components	Make it easier and faster to attach the components
2.3	Cutting metal sheet for the safety device	Cutting and drilling the sheet to make it fit	Attaching the safety board to the metal sheet
2.4	Wooden board for the stander	Cutting from a big wooden board by a measured size.	The complete wooden board in a measured size
3.0	Assemble units		**Done 100% complete all assemble Unitis**
3.1	Attaching components	6 Small Inductors 1 big Inductor 12 capacitor 12 gate drivers All on the wooden board in the correct positions	Attaching 100% of the inverter components
3.2	Attaching the IGBTs On the Heat sinks	All 12 IGBTs on the 3 heat sinks and then on the board	To fix the heat sink / IGBTs on the board
3.3	Preparing for wiring	Tidy the board, leave enough space for wiring between the components	In good positions.
4.0	Wiring		**Done 100% complete Wiring**
4.1	Wiring Phase 1	4 IGBT 2 inductors 4 Capacitors 4 gate drivers	Wiring all the converter three phases
4.2	Wiring Phase 2	4 IGBT 2 inductors 4 Capacitors	Set up all the components properly

		4 gate drivers	
4.3	Wiring Phase 3	4 IGBT 2 inductors 4 Capacitors 4 gate drivers	Set up all the components properly as well
4.4	Wiring the 3 Phases to Sensors	Connect the Phases to current and Voltage sensors	Making sure all phases are connected to the sensors
4.5	Wiring phases to the interface board	Wiring with high precision	Wire all 3 phases
5.0	Testing		**In progress**
5.1	Interface board testing	Testing the interface board base on the MATLAB Simulink	Simulink running well without any errors
5.2	System testing	Running the complete system with MATLAB and Dspace control	The system running without any errors

As we can see in the WBS we clearly identified the Activities/Task, the description and deliverables above. We as a group wa made a really good progress in our project we are almost done with all the Activities and tasks in the WBS such as Hardware, Cutting/Drilling, Assemble units,Wiring , and we are in the last stage now which is testing the inverter. The building process was a little bit challenging , because we are trying to meet the client requirements for the PV inverter, but our team managed to finish it before the due date. Our clinet Dr.Yarams he came last lab meeting and check the Finished Inverter and he was very happy about our work.

Conclusion:

So far, our team have done all of the hardware devices and next step is to start working on the testing for photovoltaic inverter system base on the MATLAB simulink. Since we already built the simulink model at the beginning of the project, we can directly start testing and if there is any errors show up, the team will be able to fix it. Otherwise, we will have to check the simulation and try to rebuild it to see if there were anything wrong. In case of the issue, we may ask Dr.Yaramasu for help to figure out problems that out of our knowledge. At the end, the team will be responded for any possible issues in the system and finally deliver a complete photovoltaic system device which is working properly.

References:

[1] B. Gutierrez and S.-S. Kwak, "Modular Multilevel Converters (MMCs) Controlled by Model Predictive Control With Reduced Calculation Burden," Jan. 2018.

[2] Website Title: https://magna-power.com/products/magnadc/xr

Article TitleXR Series - 2U High Voltage Power Supply up to 10 kV

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