User Manual

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Project: Photovoltaic Inverter

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1 Introduction:

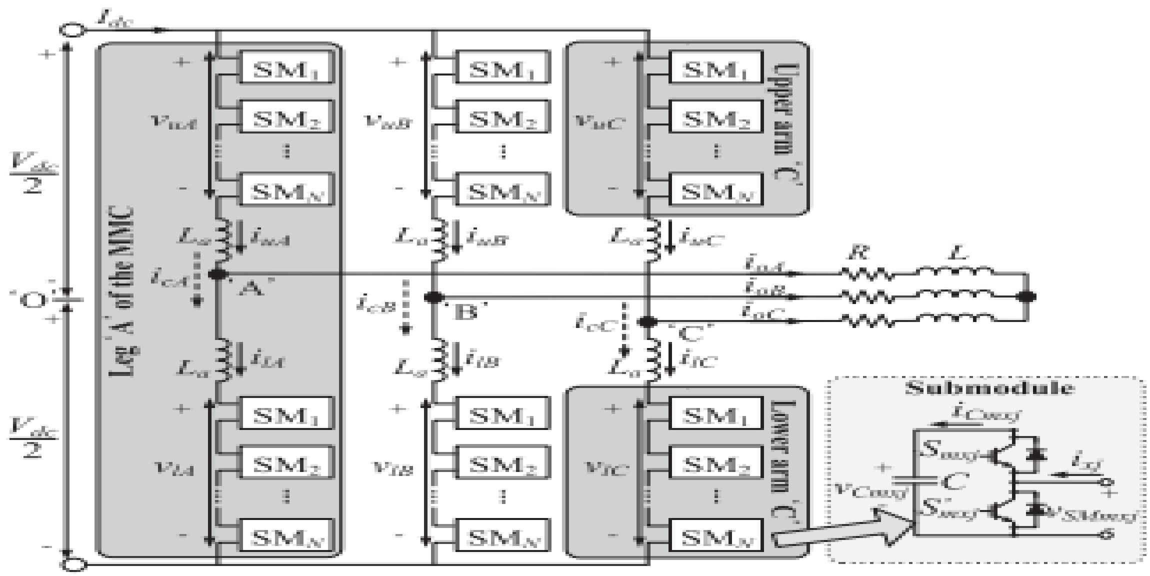
We would like to take this opportunity to thank you for choosing Solar hero team for building your project. Our main task was to build and deliver a modular multilevel converter for a PV system, we have chosen this project because all the team member are interested in power conversion systems, and also after taking your classes such as power systems and wind power it gave a lot of knowledge about these systems, which led us to choose to work on your project, the purpose of this user manual is to help you successfully use and maintain the modular multilevel converter in your laboratory. And our aim is to make sure that you are able to benefit from our converter for many years to come!

2 Problem Statement:

In the recent years, clean energy became more available in the market and had shown a great decrease in the prices of the installation and an increase of the efficiency of the power output, also it causes less impact on the environment, which one day will help to decrease the effect of global warming.

Our project is to build and study the next generation of central inverter for a utility-scale photovoltaic energy system, we were asked to build a Modular Multilevel converter and our client is going to test it with a photovoltaic system to prove its efficiency, reduced manufacturing cost, enhanced system reliability, and grid code compliance with proper control.

3 Modular Multilevel Converter (MMC):



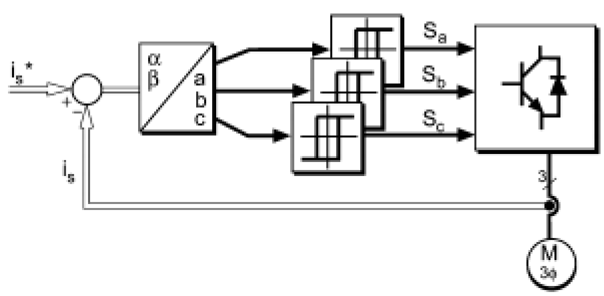
As a new multi-level topology, Modular Multilevel Converter (MMC) has been widely used in HVDC transmission. Its modular construction is not only easy to expand, but also increases system unit capacity and voltage levels. It also has the common features of multi-level converters: low switching frequency, low harmonic content, low voltage change rate, and low switching loss. Modular multilevel converter (MMC) modular structure has great flexibility, can achieve active and reactive power control, and can achieve switching from low voltage to high voltage by the number of control modules, MMC has very good prospect.

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. The central PV inverters based on modular multilevel converters (MMC) are available with input voltages from 3.5 MW and 1500 V DC.

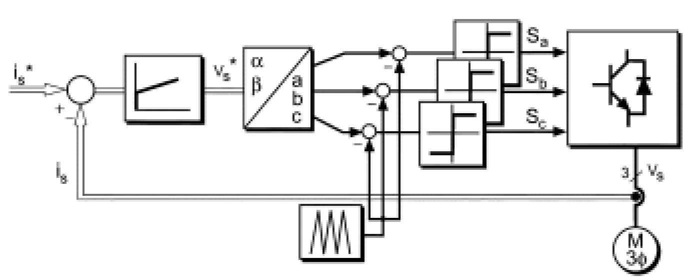
4 Predictive Current Control (PCC):

The model predictive control uses the non-parametric model based on impulse response as the internal model. It uses the past and future input and output information to predict the future output state of the system. After the feedback is corrected by the error of the measured system output and the predicted model output, Refer to the input trajectory for comparison, dynamically optimize the quadratic performance index, calculate the control action of the current time system, and complete the entire control cycle.

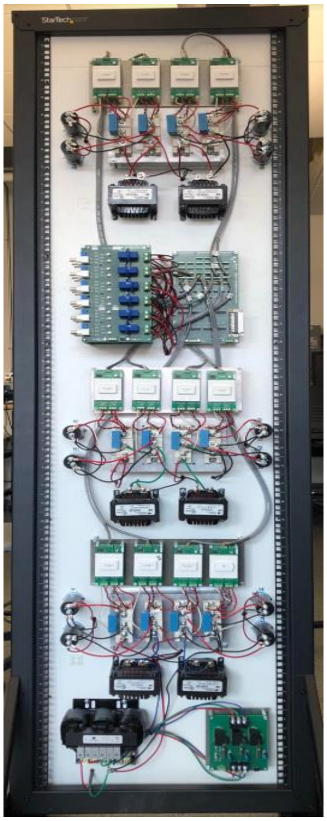
Hysteresis current control：



PWM current control：



5 Installation:



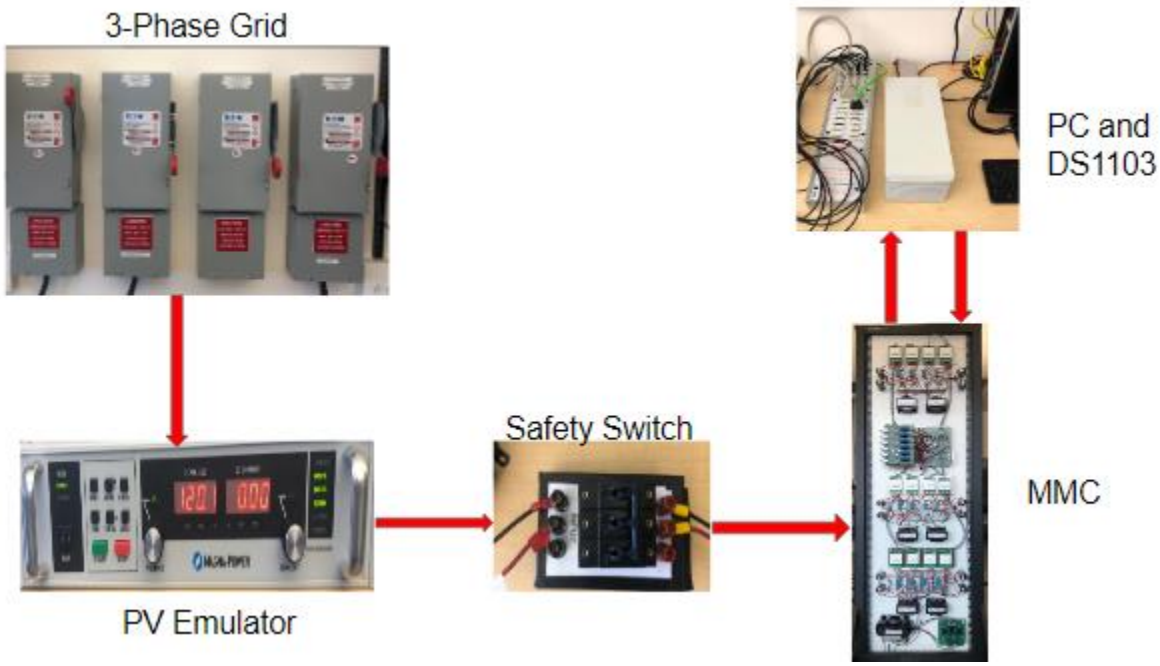
MMC Fig.[1]

As you can see in figure one, this is the overall design of the project, the project is fully working and is ready to operate, our converter is build to handle 5kW of power, and this

could change by replacing the wires and the IGBT, but the testing could be done by following the steps shown below:

6 Configuration and Use

6.1 Testing Setup:



As You can see in figure 2, those are the steps required to operate our converter, as a safety rule there must be two persons operating the converter in case of an electrical shock, the other person will turn off the power supply, our main task was to test all Gate drivers, IGBT's, Interface board, Voltage, and current sensor to make sure our client will not have any hardware problems. To test the converter you need to follow the following steps and later on, we will explain which software you should use to operate each subsystem:

1-Turn on dSpace and Then the PC.

2-Choose the desired module in Simulink and build into dSpace.

3-Connect the converter to a power source.

4-Switch on the DC supply (3-phase grid).

5-Switch on the PV emulator and setup the needed voltage and current.

6-After setting the voltage on the PV emulator, press to red button to set it back to zero.

7- Switch on the safety switch.

8-Go back to emulator and press the green button to send back the desired voltage or current.

9-Go online in dSpace to send signals to the subsystems.

Troubleshooting:

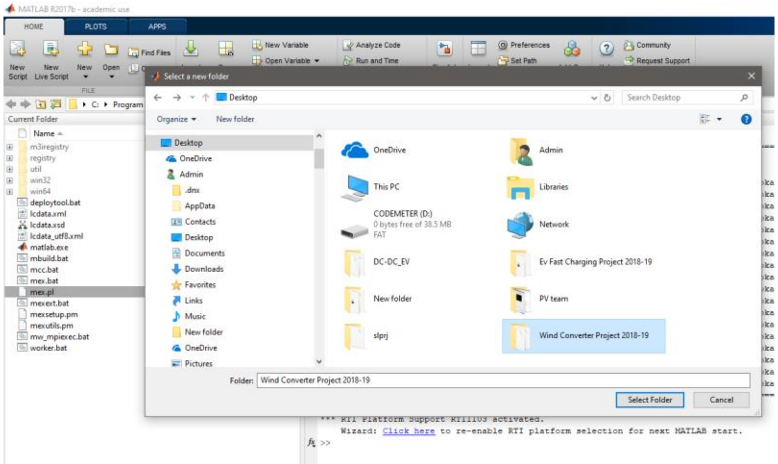
In case the result of testing is not satisfying. First checking and making sure all the wires are connected probably. Second, measuring the signals going thru each device. The devices should be checked and measured are:

1. IGBTs
2. Gate Drivers
3. Current sensor
4. Voltage sensor

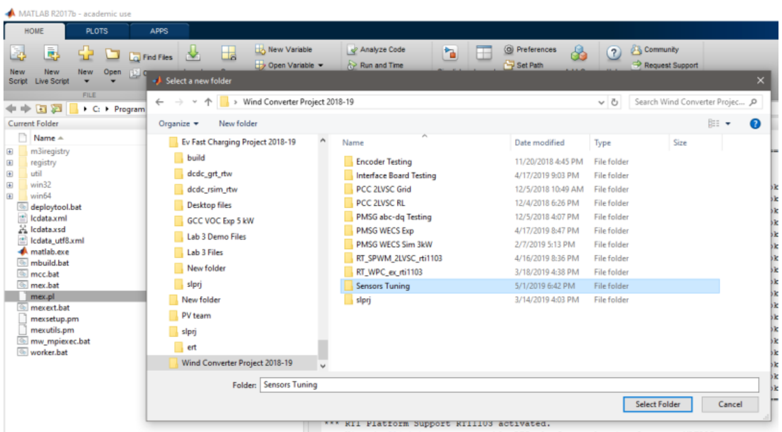
Example to test Voltage / Current sensors / IGBTs / Gate Drivers:

a. Software part:

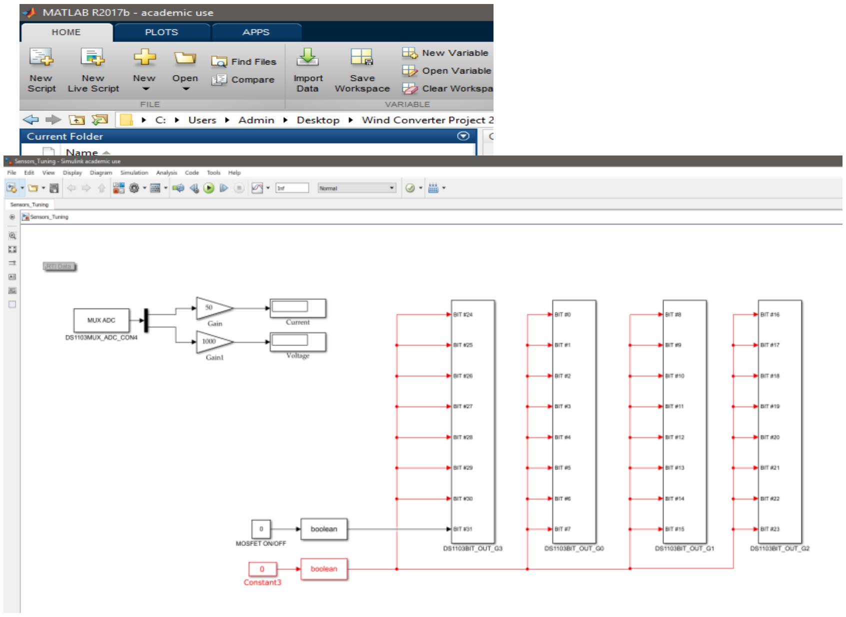
1. Turn on dSpace and then the computer.
2. Open Matlab and dSpace



3. In Matlab, open the file (Wind Converter Project 2018-19) which is located on desktop.



4. Select Sensor Tuning file and then click (Select Folder).



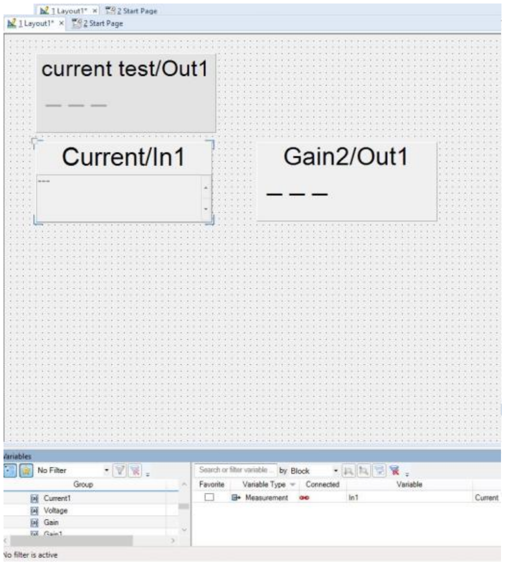
5. On the left side of the screen select the file (Sensors_Tuning.slx) to open the schematic.

6. Now when the sensrs_Tuinng is open. First, we need to send a signal to the gate that we want to test, by connecting it with [boolean block] that is coming from the MOSFET ON/OFF, and we need to connect the other gated that we are not testing to Zero (the red wires).

7. Click on the build, and make sure it is 100% complete.

8. Go to dSpace

9. Go to Open file > desktop> Wind Converter Project 2018-19 > Sensore Tuning file and then click (Open Folder)



10. Then you should see this layout, and if you need to test either current or voltage sensor, you need to go down to Group and drag (Voltage or Current file) to any of the blocks in the screen. The block should change to Voltage or Current as it showing in the picture above.

11. Now, by clicking on (Go Online) from the top left the screen, the dSpace should be sending signals to the gates selected in the converter.

B. Hardware part:

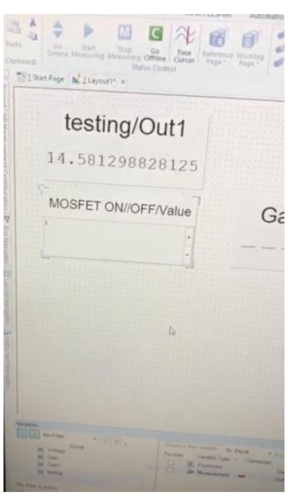
1. After, finishing part (A.Software)
2. Make sure the Converter in connected probably to the power supply.

Testing Current / Voltage sensors:

1. Connect to dSpace and connect the voltage or current sensor gate needed.

2. Turn ON three-phase power supply.

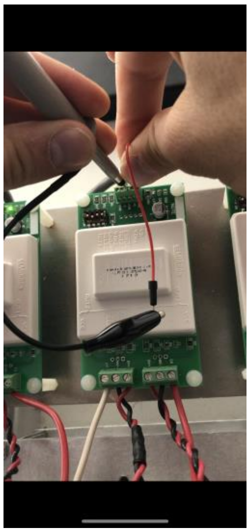
3. Turn On the PV emulator and set the correct Voltage and Current. For Current sensor 120 V and for Voltage sensor 100 V.
4. Make sure to connect 15-ohm resistor if you are testing the current sensors.
5. Connect each of the positive and negative wire comentign from the PV emulator to the wanted gate in the current or voltage sensor.



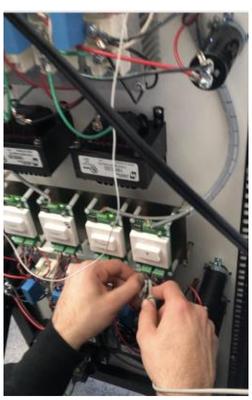
6. Now you should be getting reading on the computer screen of how much voltage or current the gate is receiving.

Testing Gate Driver:

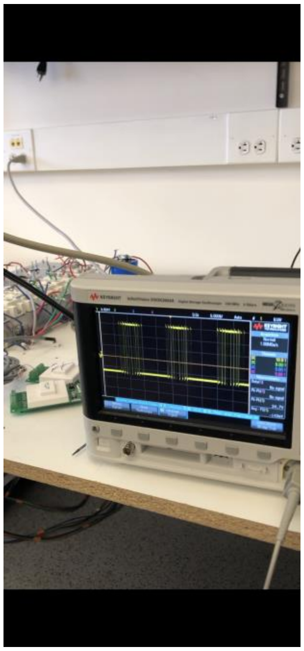
1. Turn ON oscilloscope.



2. Place the probes on positive and then on the negative side of the input of the gate driver to see the signal.

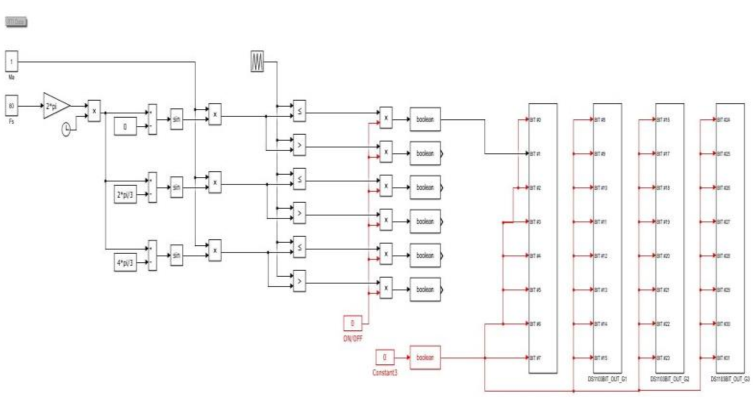


3. And repeat the same thing with the output side of the gate driver.

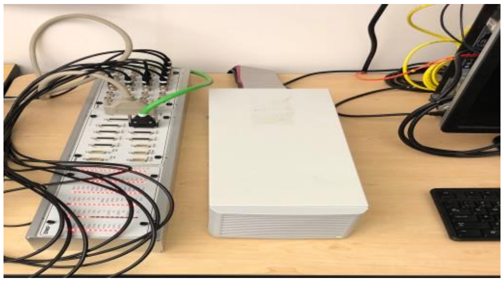


4. You should be getting signal as it is showing in the above picture. Other than that you need to test the IGBT as well.

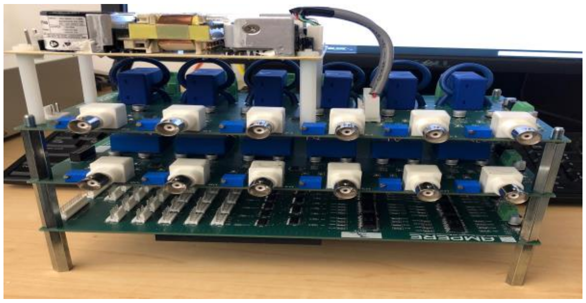
Testing IGBTs:



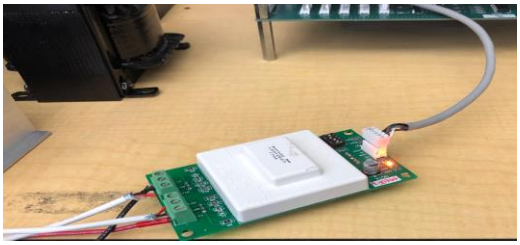
1. Turn on dSpace and find the WPS files and then open the circuit. Connect the wires to the pins needed.



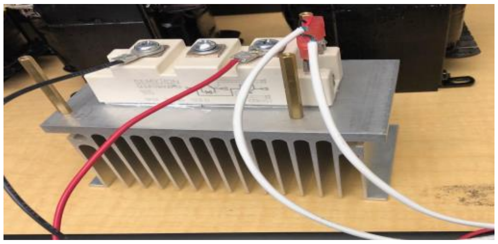
2. Turn ON dSpace.



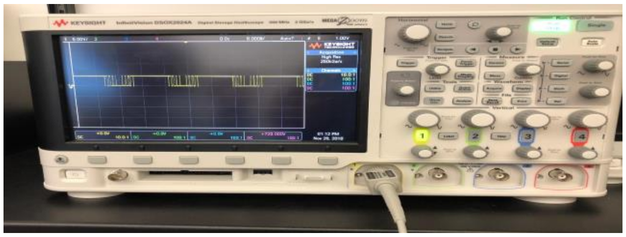
3. Connect the interface board to a power supply.



4. Wire gate driver to the chosen pin in the interface board. And wire all the CX+, CX- and G and connect them to IGBT.



5. After wiring the IGBT.



6. Use the Oscilloscope to see the signal going through the IGBT, and make sure it is a clear signal.

7 Requirements and Specifications:

Mechanical:

The client required the design meets industrial standards, so as a team we got together and came up with a design that will fit all the component on one wooden board, and also as you can see we ordered a steel stand that we attached the wooden board to, so it can move and stored easily in the lab.

Table1: Mechanical Specification

Criteria	Specifications
Length	72.8 inches
Width	23.6 inches
Overall Height	76 inches

Electrical:

The electrical requirements, the Modular Multilevel converter will operate at 5kW of power, also the converter needs to operate ar 50-60Hz frequency, and we will use surface mounted Circuit board, in case of failure we can disolder the part easily and replace them compared to the in hole soldered parts.

Table 2: Electrical Specifications

Criteria	Specification
Power	5kW
Voltage	DC Supply/Three Phase Voltage
Frequency	50-60 Hz

Electrical Component Requirements:

In table number 3 we will be including all the electrical components we used in our converter, one of the advantages of the MMC is the simplicity of each phase, which means we can replace the damaged part easily in short time and go back into operation.

Requirements	Unit of Measure	Standard
Capacitors	Farads	-12 count -1000µF
Snubber capacitor	Farads	-12 count
Inductors	Henry	-6 count -2.5mH
Three Phase Inductor	Henry	-1 count -15 mH
IGBT	Volts	-12 count -SKM75GB123D -1kV
Gate Drivers	Volts	-12 count -SKHI22BH4R -400 V

Software:

The converter will operate using MATLAB/Simulink software and dSPACE, we can build and implement the predictive current control in Simulink, and after building it according to the subsystem in the converter, we will build it in dSpace software, then signals will be sent through dSpace DS1103 to the converter.

Criteria	Specification
MATLAB/SIMULINK	Simulation
dSPACE DS1103	Rapid Prototyping for digital control

Documentation:

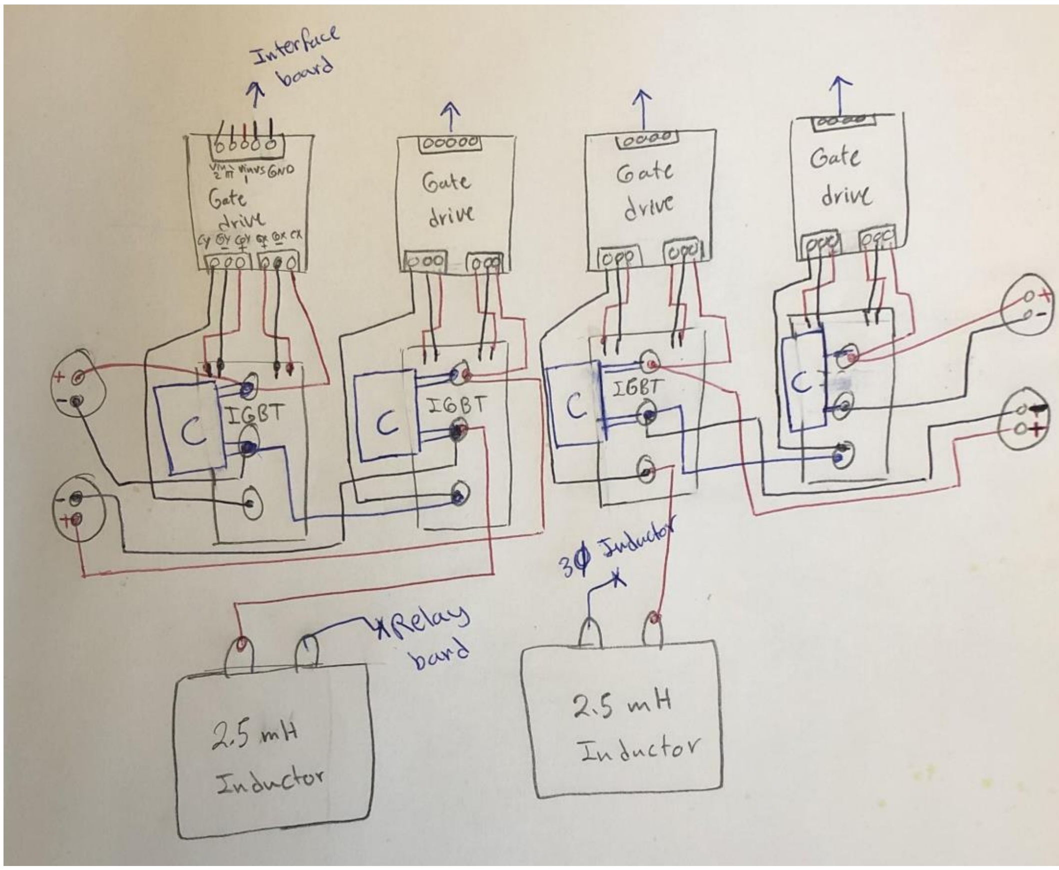
The converter operate on high voltages. It operates at voltages and current that can electrical shock if not properly handled. Always use the equipment with caution and with another person in present with you, some of the converter component may reach high temperature, during and after operation avoid touching the converter.

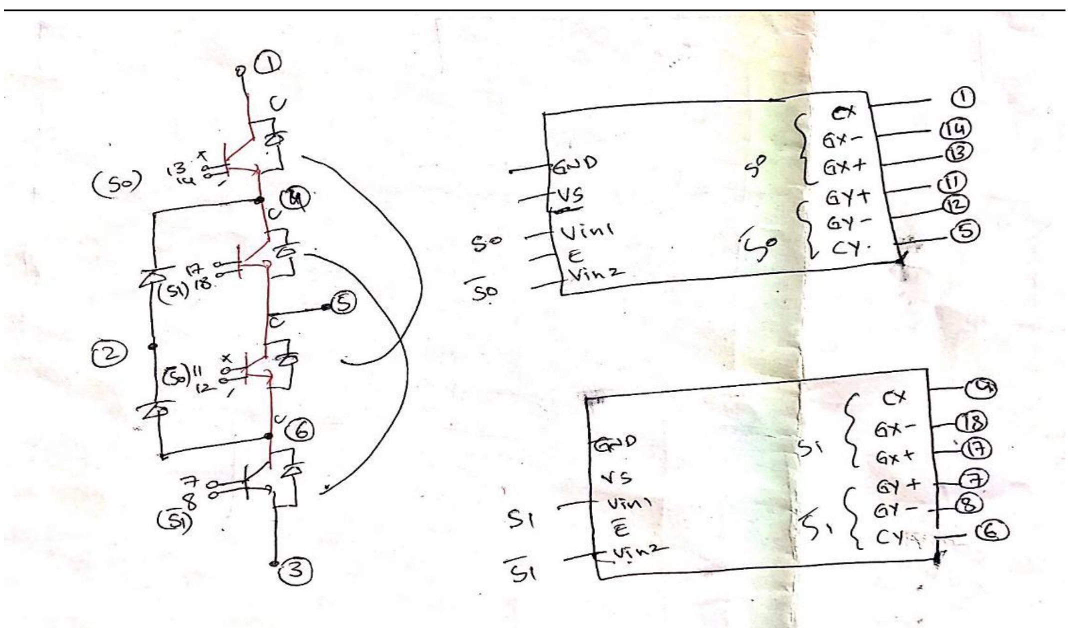
Documentation
Operator's Manual
Power supply must be off before connecting the any input cable. Converter must be of before connecting the control power.
Maintenance Manual
To maintain the converter and making it working properly: 1-When moving the converter try to move it carefully without hitting it to any other objects in the lab. 2-Making sure all the phases are connected and no loose wires. 3-When moving parts from the converter such as IGBTs, gate drivers, etc. Make sure to remove them carefully. 4-When you are connecting sensors wires to the current or voltage sensors try to be careful, because the pins on the boards they may break with small pressure. 5-Be sure to use the correct softwares to whatever test you are doing with Matlab and dSpace. 6-Store the converter in a safe place away from other moving objects.
Warranties on this product are based on the contract with the client. The Warranty will be void if the problem is caused by: 1-Using the converter beyond its capabilities 2-In case of natural disaster 3-Incorrect use and not following the steps given in this document 4-Incase the fault is caused by other hardware/software outside the converter

8 Conclusion:

The Team is done building and testing the converter, the team met with the client and got approval on the work done, team from next year capstone will be using our converter to do more testing and they will use the converter to study power storage, we made sure to explain all the testing procedures in this document to make sure our client will not face any difficulties while operating the converter.

9 Appendices:





These are the schematic for the converter phases. All 3 phases in the converter have the same wire connections.

References:

[1]"Maximum power point tracking", En.wikipedia.org, 2019. [Online]. Available: https://en.wikipedia.org/wiki/Maximum_power_point_tracking. [Accessed: 19- Apr- 2019].

[2]"IEEE Xplore Digital Library", Ieeexplore.ieee.org, 2019. [Online]. Available: https://ieeexplore.ieee.org/Xplore/home.jsp. [Accessed: 19- Apr- 2019].

[3]Falahi, Ghazal, and Alex Huang. "Low voltage ride through control of modular multilevel converter based HVDC
systems." Industrial Electronics Society, IECON 2014-40th Annual Conference of the IEEE. IEEE, 2014