Grid Connected Converter

Mohammed Abu Radhi
Sayaf Almari
Fahad Alghareeb
Di Miao
Kaiqiong Ji

Project Mentor:

Ashwija Reddy Korenda

Client

Dr.Venkata Yaramasu
Assistant Professor at NAU
Director of AMPERE Lab
School of Informatics, Computing, and Cyber Systems

Research Interests
Research interests include renewable energy, high power converters, variable-speed drives, electric vehicles, power quality, smart grid, and model predictive control.

Education
PhD, Electrical Engineering, Ryerson University, Toronto, Canada
ME, Electrical Engineering, S.G.S. Institute of Technology and Science, India
B.Tech, Electrical and Electronics Engineering, Jawaharlal Nehru Technological University, India

Introduction

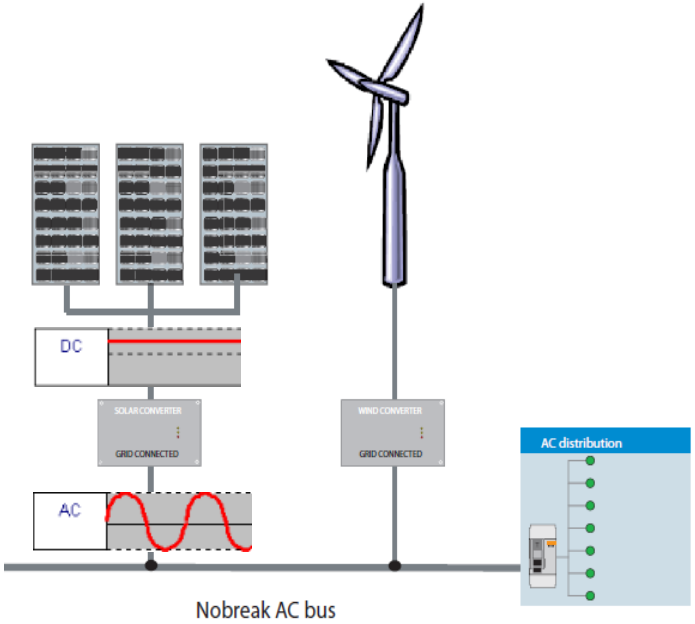
- **Power conversion systems consists of two main parts:**

A- converter. (GCC)

- Connected to the utility grid and to the power supply.
- Converts the input (AC/DC) to AC with specific frequency and voltage phase that matches the current flowing in the utility grid.

B- controlling unit. (PCC)

- A control unit is the brain of the converter.
- Regulate the current output so it matches the reference current (utility grid current).



[1-2]

Problem Definition

Client's Research Focus:

A- Wind Power Systems.

B- Photovoltaic Systems.

C- Motor Drives.

[3]

Problem

- There is no laboratory scale prototype converters available in the market that fits all of these applications.
- Needs plug and play converter to fit the three power conversion applications.
- Having such converter will help our client to develop new power converter topologies and test new controlling schemes such as model predictive control.

Goal

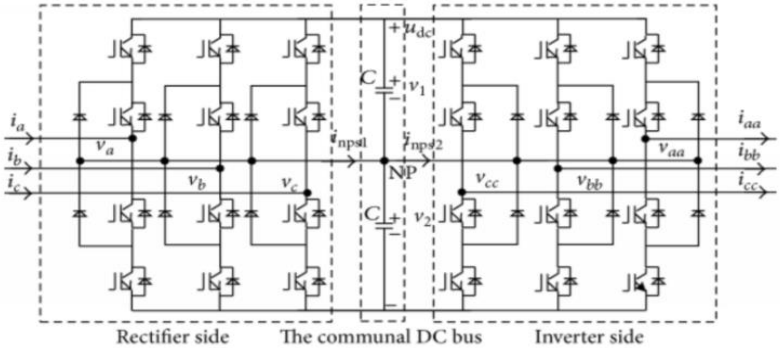
- Implement and build a prototype of multilevel converter for high power applications and test it using model predictive control.
- Practical power level is at 5 MW.
- Prototype power level is at 5 kW.

Client Needs & Constraints

- A functional prototype power converter fits three different power applications.
- Improving simulation models for the predictive current control topology, and test it.
- Constraints include improving efficiency, reliability, size, and simplicity of multilevel converters.
- Dr. Yaramasu emphasized on keeping the design simple and use surface mounted electrical components.
- Writing and publishing an IEEE paper.

Solution: a Back-to-Back NPC Converter

NPC Converter Schematic



[4]

A- Motor Drives.
AC (fixed v,f) => DC => AC (variable v,f)

B-Wind Power Systems.
AC (variable v,f) => DC => AC (fixed v,f)

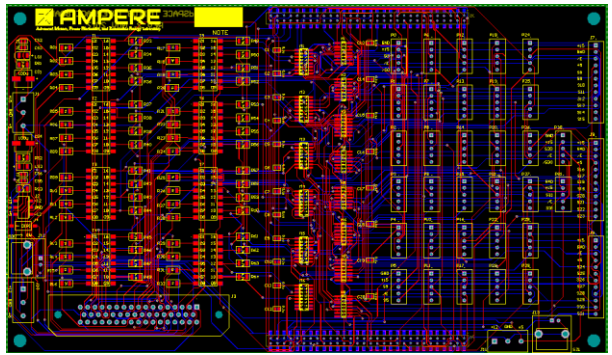
C- Photovoltaic Systems.
DC => AC (fixed v,f)

Features:

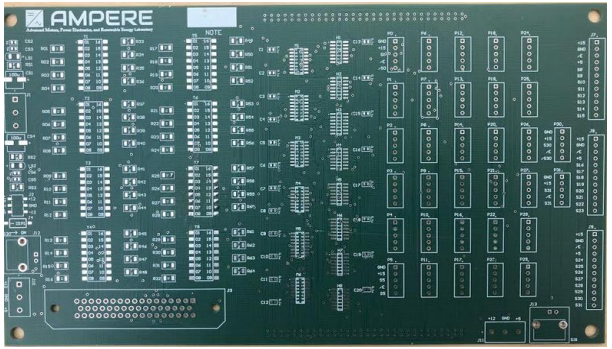
- Fitting photovoltaic, wind turbine, and motor drives power systems.
- Ability to improve efficiency, and reduce harmonic distortion through improved versions of simulation models.
- Small size of IGPT's

Hardware Implementation

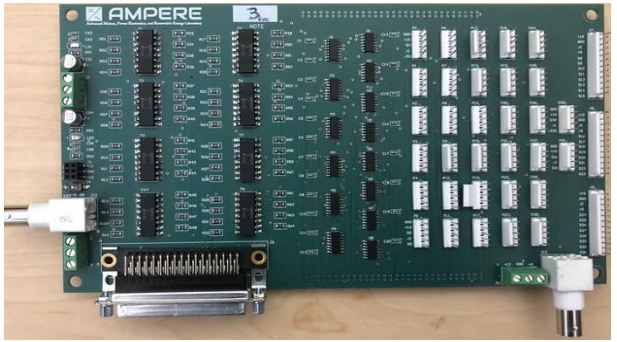
Stage 1: Designing PCB's



Stage 2: Before soldering



Stage 3: After soldering

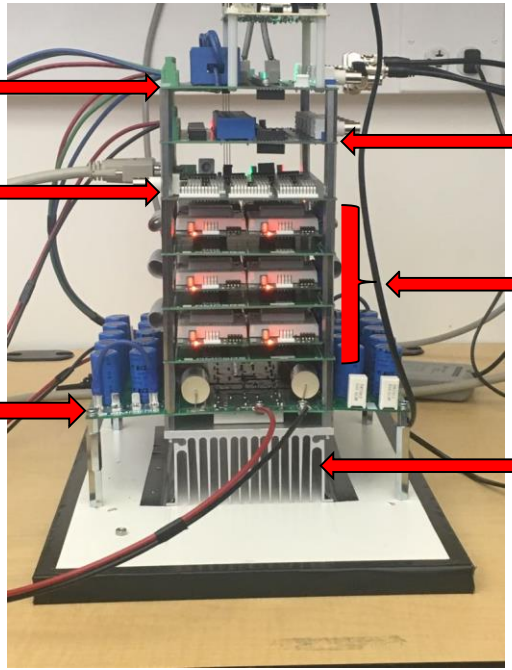


Overall Design

Current sensors :send current measurements to the control unit

dSPACE Interface Board: Convert TTL logic signals from the dSPACE DS1103-based to CMOS logic

NPC Power Board:contains IGPT converting to AC



Voltage sensors: send voltage measurements to the control unit

Gate Drivers : Provides electrical isolation , turn on/off switching devices

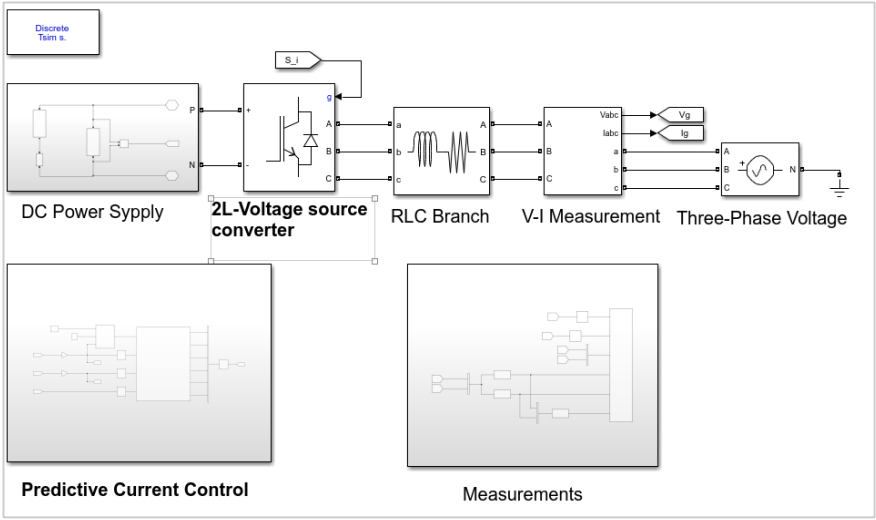
Heatsink: cool down power board

Simulation & Testing

1. Grid connected 2L-VSC with PCC

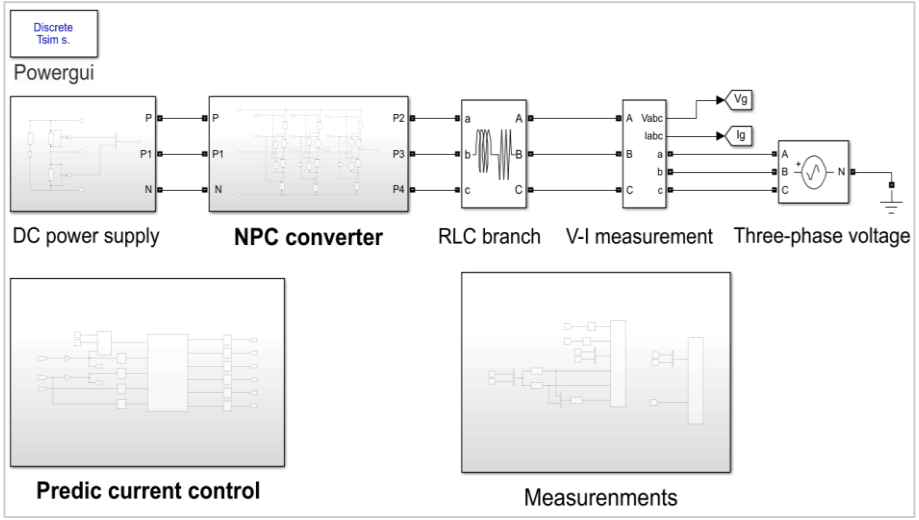
Implement the stationary frame predictive current control (PCC)

- **lower switching frequency**
- **Does not require any kind of linear controller or modulation technique**



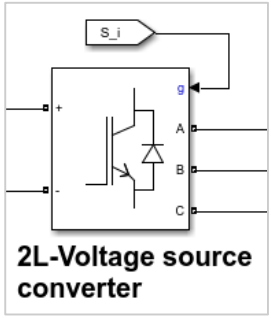
The complete simulation model of **Grid connected 2L-VSC with PCC** scheme

2. Grid connected NPC with PCC



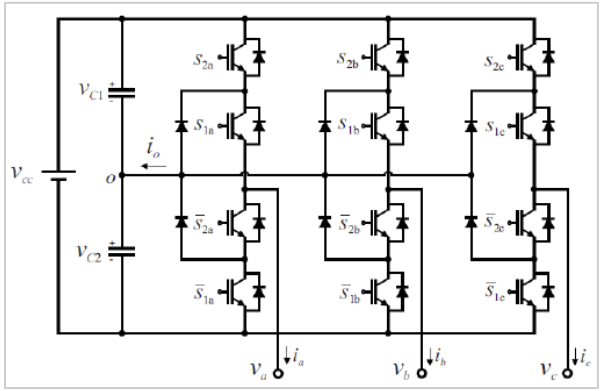
The complete simulation model of **Grid connected NPC with PCC** scheme

PCC for NPC with grid



2L-VSC

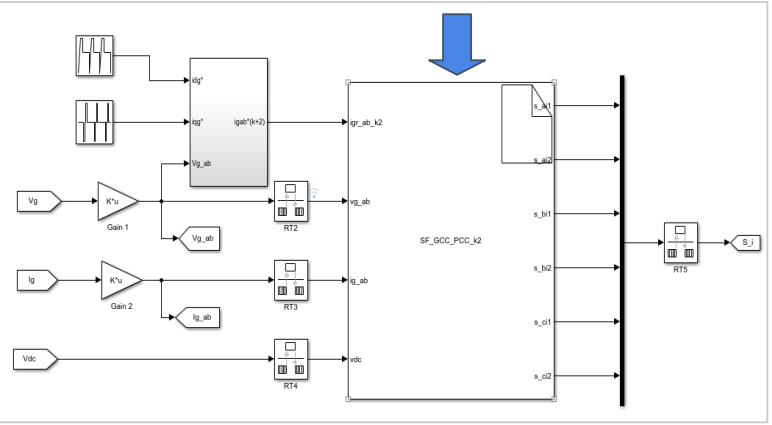
NPC converter



Advantages:

- more efficiency
- more adjustable
- faster dynamic response

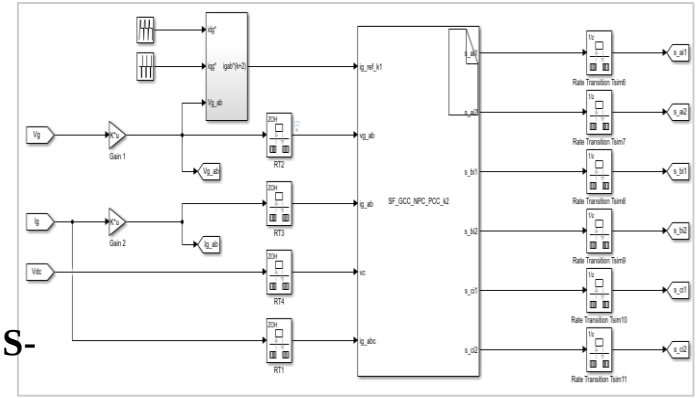
S-function



8 Switching states

27 Switching states

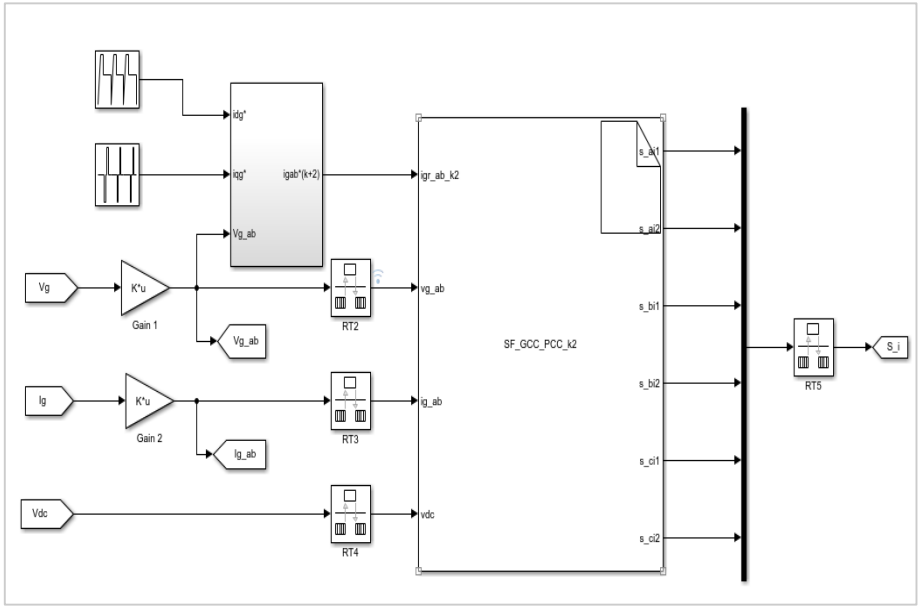
By changing codes in S-function



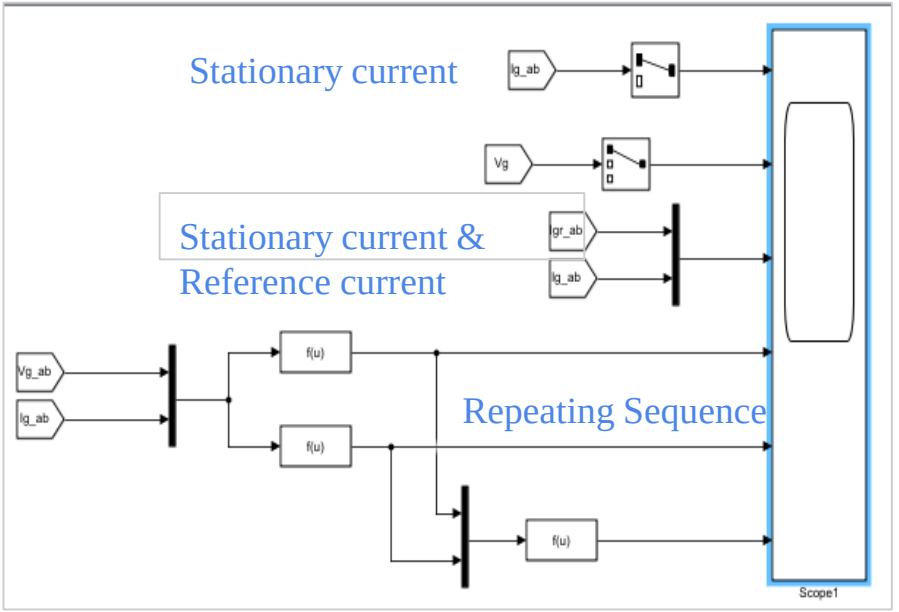
Predictive Current Control(PCC)

The algorithm is based on a model of the system. From that model, the behavior of the system is predicted for each possible switching state of the inverter.

Model of PCC (Stationary frame)

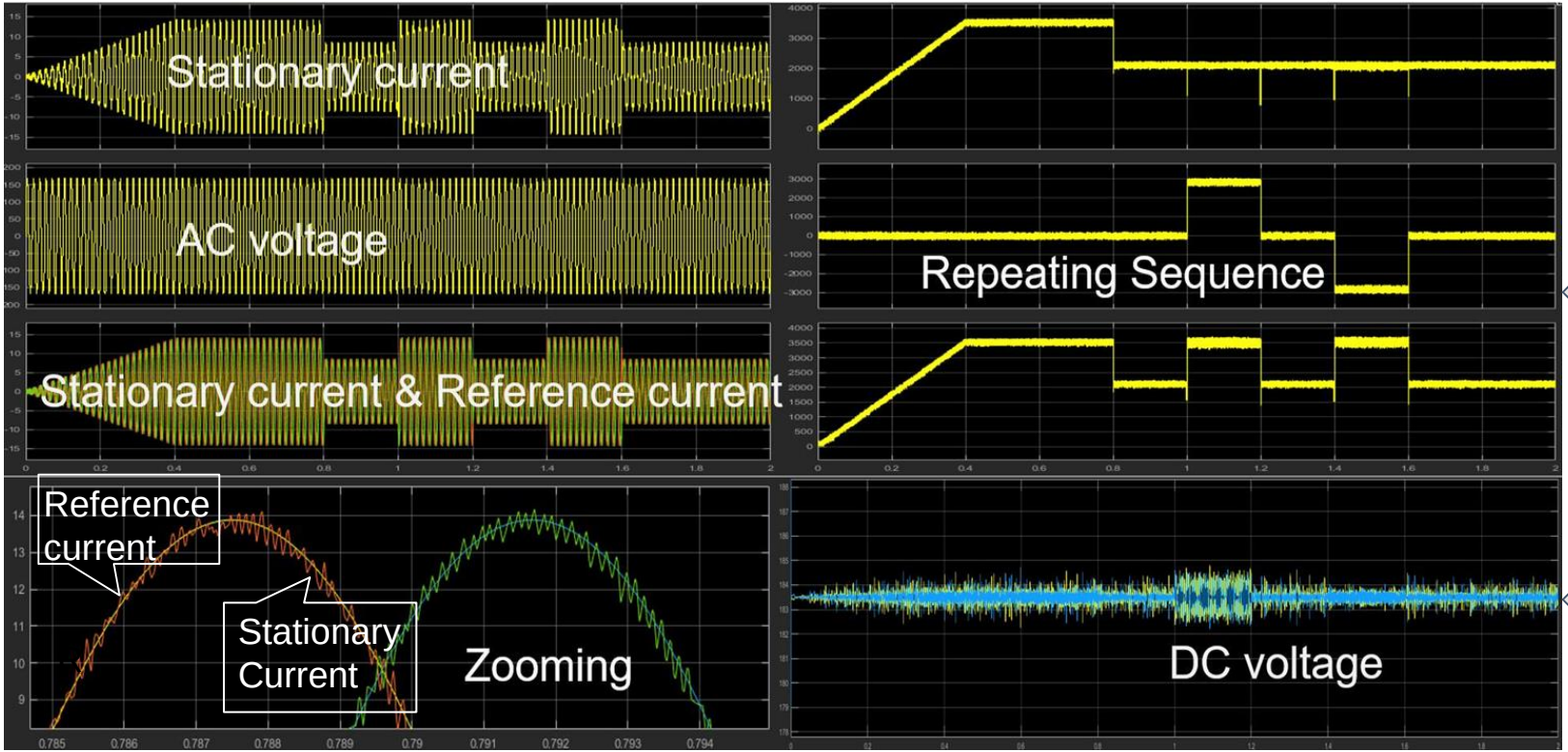


Measurements



Results & Analysis

1.Grid connected NPC with PCC

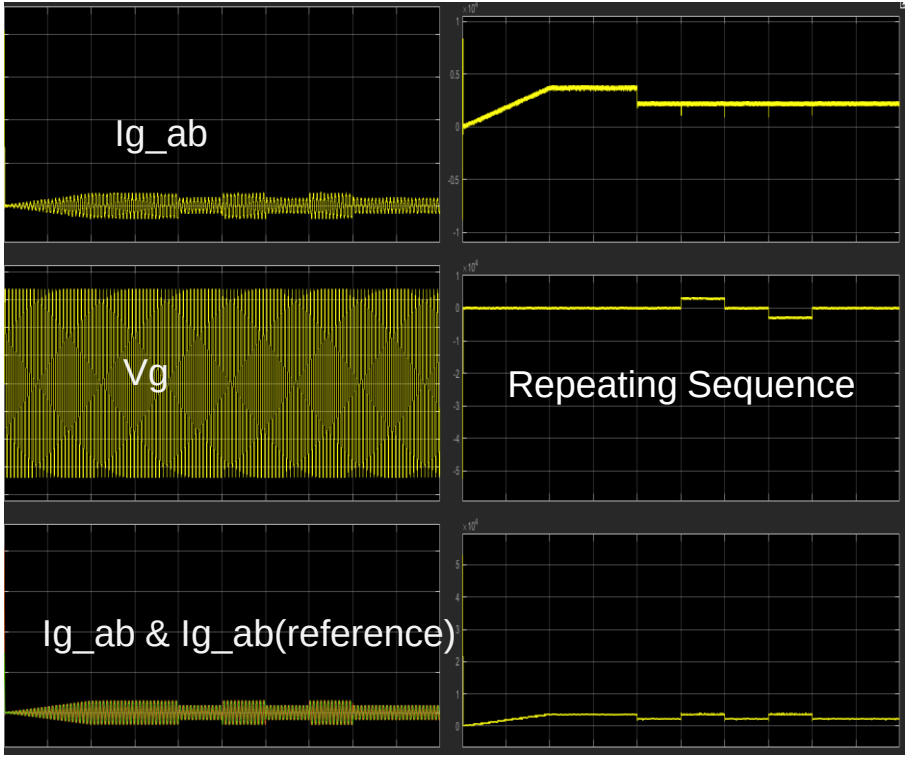


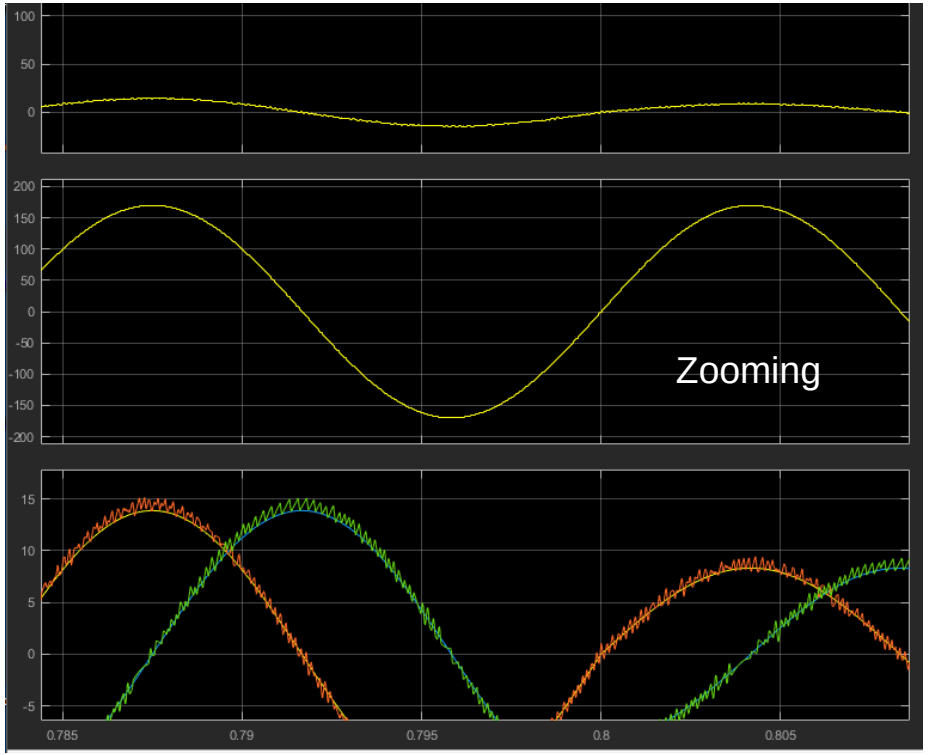
It is used to generate reference current

AC to DC

Results & Analysis

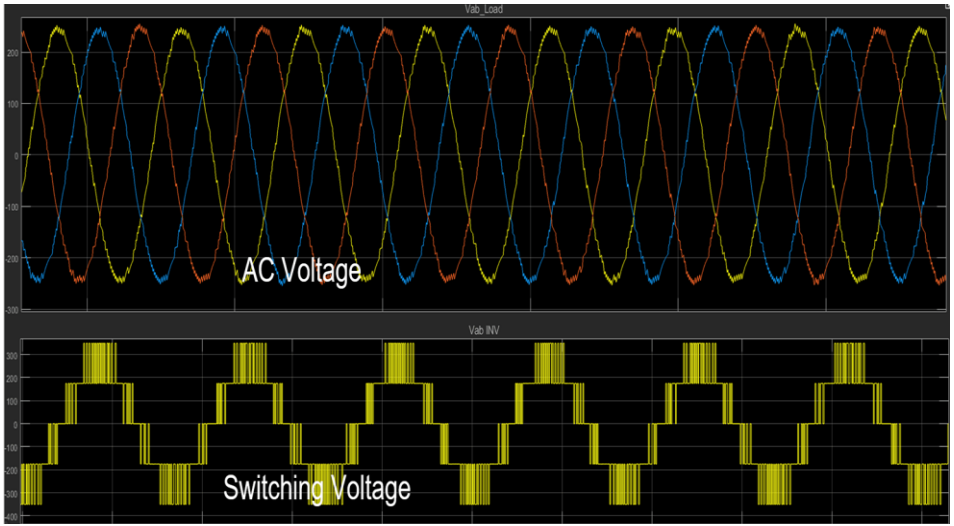
2. Grid connected 2L-VSC with PCC (Same waveform with Grid connected NPC)





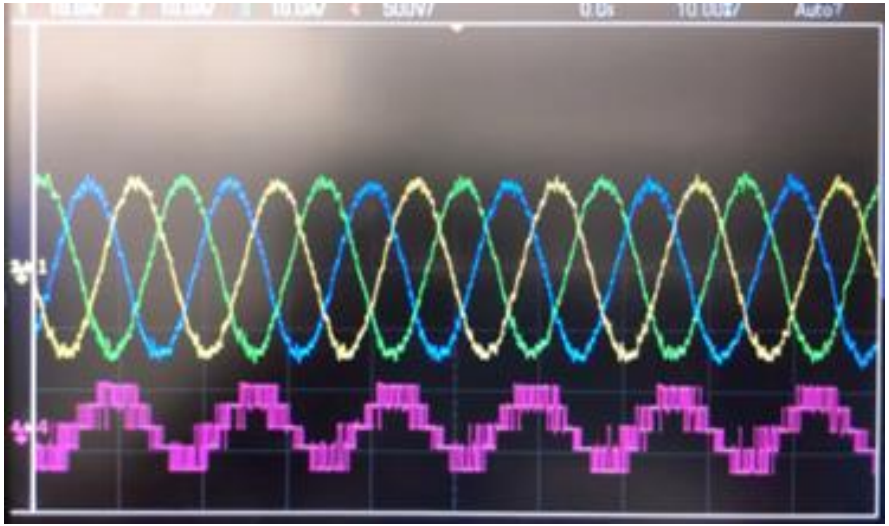
Results & Analysis

Simulation



1. The converter was supplied with 350 V and 10 Amp DC power.
2. Three phase AC waveforms.
3. 5 level line to line AC waveform

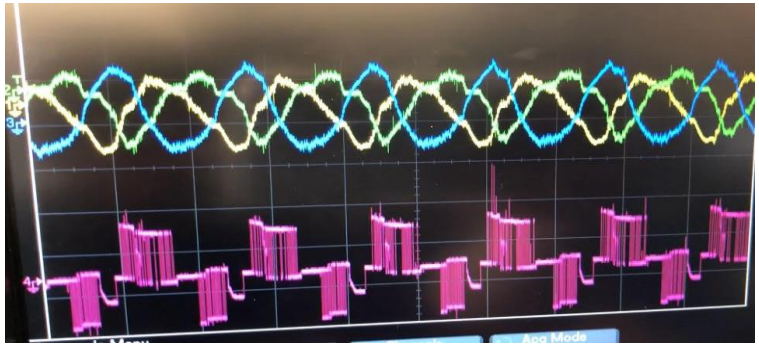
Actual Results



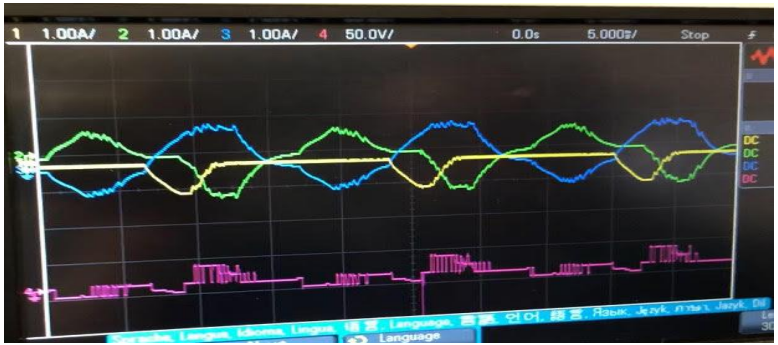
- Successful conversion of a 3500 watt to AC that can be fed to the utility grid.

Issues

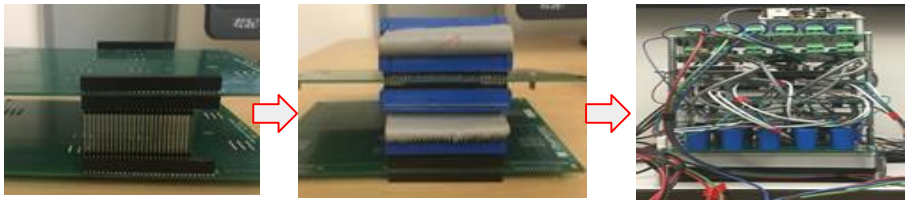
Noise problem:



Phase E disfunctionality:



Solutions:

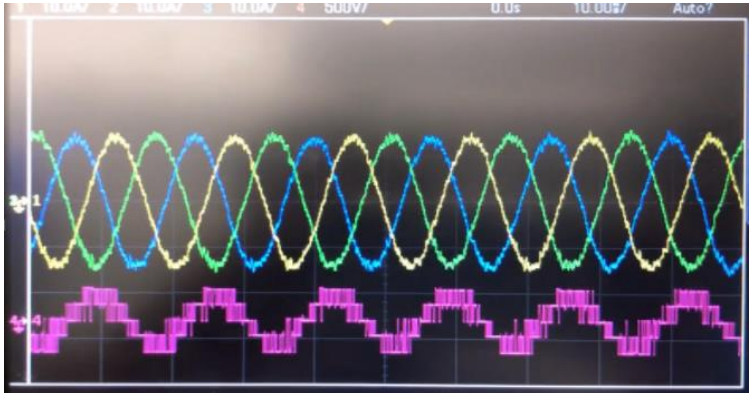


Problem:

- The postive half of phase E is not working in the inverter side of the converter.
- Still working on the problem.
- An IGPT might be replaced.

Rectifier Demo

Results

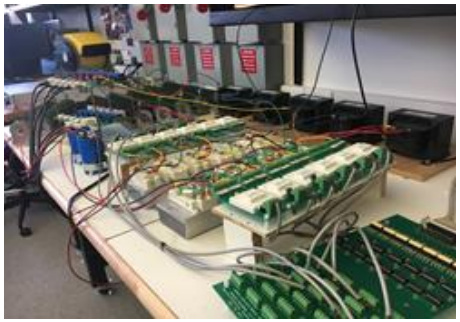


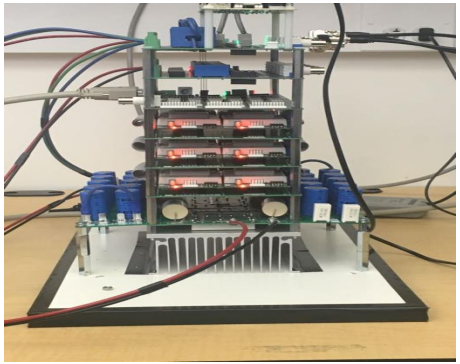
- Three phase AC waveforms.
- 5 level line to line AC waveform.

Demo Video

Conclusion

- The NPC power converter has met our client major requirements, and will be delivered to Dr.Yaramasu by the end of Spring2018 semester.
- Team is still trying to solve the disfunctional phase, and hopefully we will have it working before deadline.
- Simulaion files are all completed, and improved.
- The new converter has a smaller size, weight , and more simple compared to the last year Capsone design.
- Also, the team is writing an IEEE paper, and it will be delivered to Dr.Yaramasu as required.





References

[1]"Multi with grid connected converter for solar and/or wind turbine", *Victronenergy.com*, 2017. [Online]. Available: https://www.victronenergy.com/upload/documents/multi-with-grid-connected-converter-for-solar-and-or-wind-turbine.pdf. [Accessed: 06- Nov- 2017].

[2] "Solenoids and Actuators", *Homepages.which.net*, 2017. [Online]. Available: http://homepages.which.net/~paul.hills/Solenoids/SolenoidsBody.html. [Accessed: 06- Nov- 2017].

[3] Ukconstructionmedia.co.uk. (2018). £557M funding for new renewable energy projects - UK Construction Online. [online] Available at: https://www.ukconstructionmedia.co.uk/news/557m-funding-new-renewable-energy-projects/ [Accessed 17 Apr. 2018].

[4] Wang, Yingjie, et al. "A novel neutral-point potential balance strategy for three-level NPC back-to-back converter based on the neutral-point current injection model." Mathematical Problems in Engineering, 2015. Academic OneFile, Accessed 17 Apr. 2018.

Thank You

Questions?