THREE-PHASE INVERTER USING DQ0 CONTROL

PROGRESS REPORT

Submitted by

AYUSH SINGH RAJPUT
224102105

Under the guidance of

DR. RAVINDRANATH ADDA

DEPARTMENT OF ELECTRONICS AND ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
ASSAM-781039

1. Introduction

An inverter is an converter mainly used to change power from DC to AC. The inverter is generally used in many applications like variable-frequency drive, HVDC power transmission, responsible for controlling an electric motor's torque or speed and many more applications. These are categorized into two types depending on the source of power supply within the power circuit and the associated topology like single phase and three phases.
A DC -to -AC converter which uses a DC power source to generate 3-phase AC power is known as a 3-phase inverter. This type of inverter operates by using a power semiconductor switching topology. So, the gate signals within this type of topology are simply applied at 60-degree intervals in a correct series to the power switches to obtain the necessary 3-phase AC signal.

2. Three Phase Inverter

The three-phase inverter with filter inductor converts a DC input voltage into an AC sinusoidal voltage by means of appropriate switch signals to make the output current in phase with the grid voltage to obtain a unity power factor.
These types of inverters are applicable in HVDC-based power transmission, variable frequency drive, AC motor drive, compensator, fixed VAR generator, fuel cell, UPS, high-frequency based induction heating and active harmonic filter applications. The Three phase Inverter consists of 6 switches spread across three legs as each legs consists of 2 switches which is shown in the fig. 1.

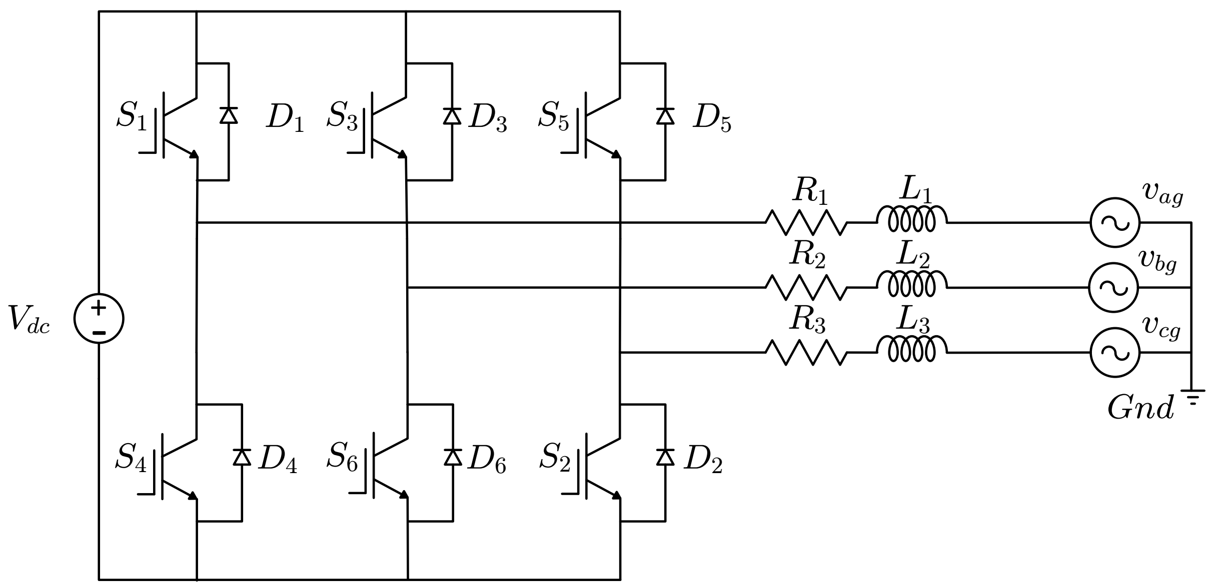

Fig. 1: Three-phase Inverter

3. Control Technique

A Three-phase grid connected inverter system is shown in fig. 2 which consists of dc voltage source, a three phase PWM inverter and L filter which will be connected to the grid.

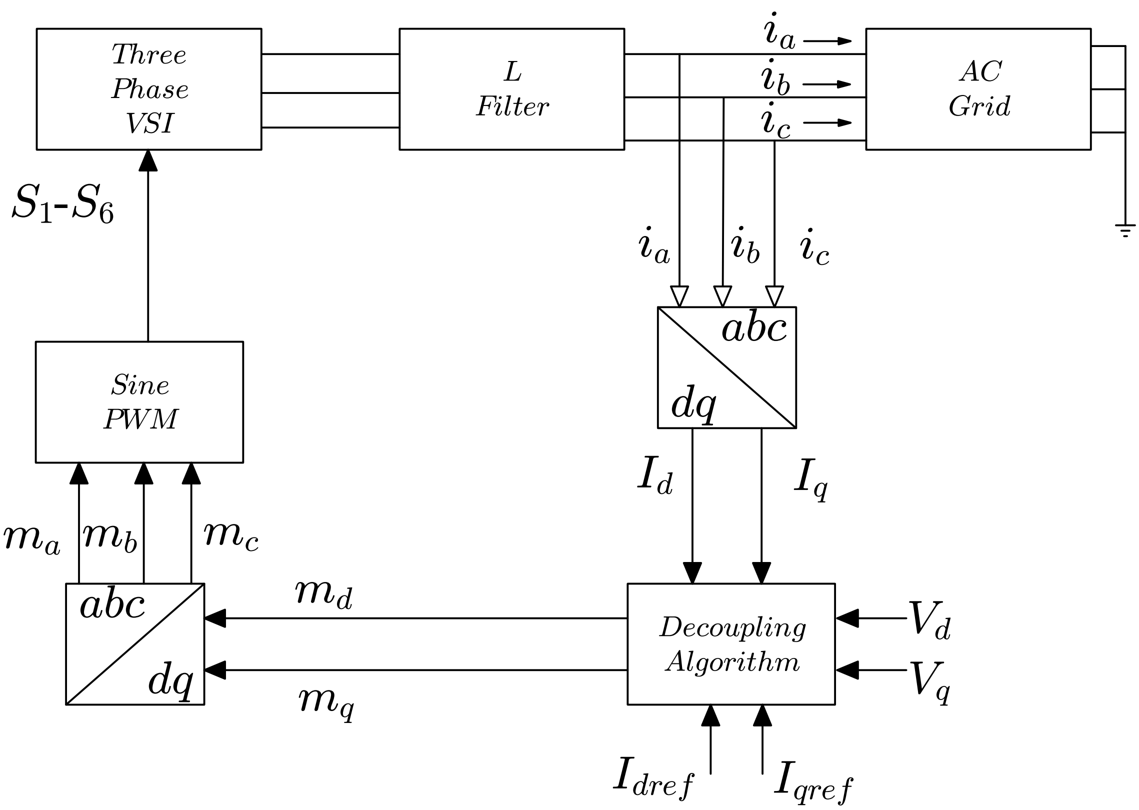

Fig. 2: Three-phase Inverter with current control loop

The control system consists of PLL controller. A PLL controller is used to synchronize the phase of inverter output voltage with a grid voltage or generate a desired inverter voltage. Grid voltages will be converted to $\alpha\beta0$ reference frame voltages by clarke's transformation which will further be converted to dq0 reference frame voltages using park's transformation. To synchronize the grid and inverter voltages, we require the error to be reduced to zero and will be given to PI controller which will give us the frequency. The angle can be obtained by integrating the frequency. This angle will be needed for the park's transformation which is shown in fig. 3.

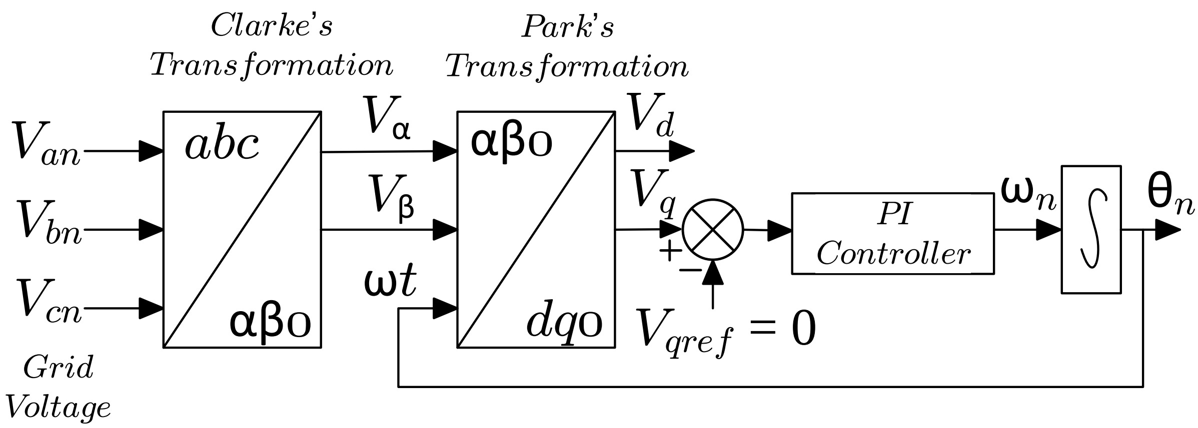

Fig. 3: Three-phase Inverter

The control technique which will be used here is dq control. The actual currents have been taken from the system, converted to dq0 reference frame and being compared to the reference currents. The reference currents can be obtained from desired power requirements. The error will be given to the PI controller. With the help of equations mentioned in eq. 1 and eq. 2 we obtain reference voltage signals which will be converted to abc domain and give us the PWM signals for switches.

$$m_d = Ri_d + L\frac{di_d}{dt} - \omega L i_q + V_d \tag{1}$$

$$m_q = Ri_q + L\frac{di_q}{dt} + \omega L i_d + V_q \tag{2}$$

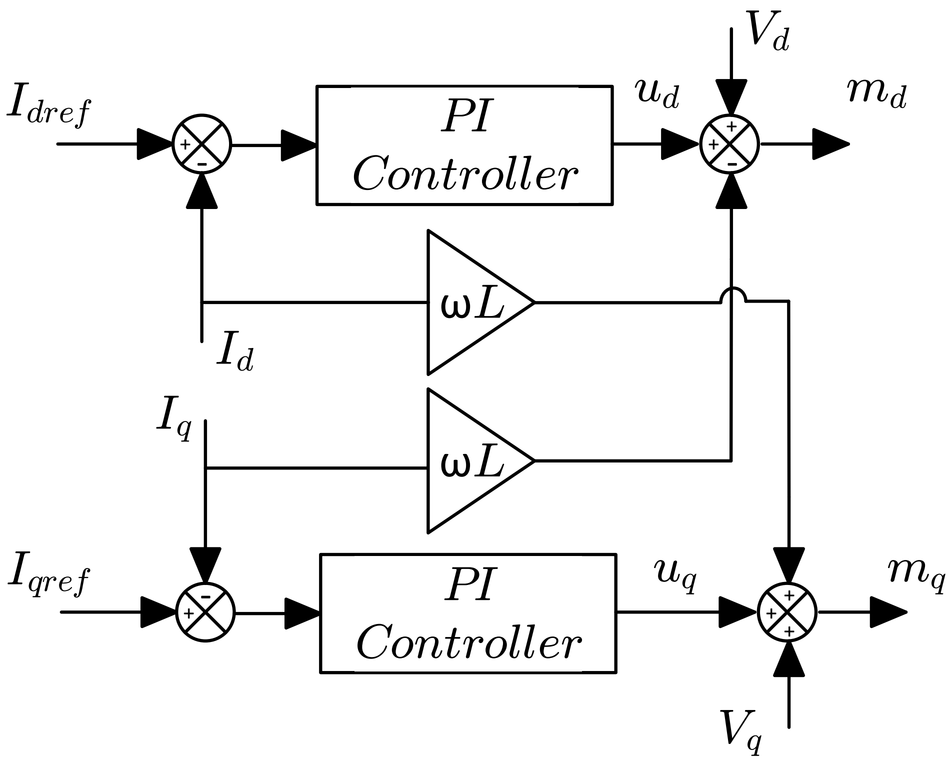

Fig. 4: Three-phase Inverter

4. Calculations

4.1. Reference currents

The reference currents can be obtained for power 2 kW using the formula given in eq. 3.

$$I_{phase-ref} = \frac{P_{ref}}{\sqrt{3}V_{phase-rms}} \tag{3}$$

$$I_{phase-ref} = \frac{2000 * \sqrt{3}}{3 * 415}$$

$$I_{phase-ref} = 2.7824A$$

Similarly, for 4 kW power currents can be obtained as

$$I_{phase-ref} = \frac{P_{ref}}{\sqrt{3}V_{phase-rms}} \tag{4}$$

$$I_{phase-ref} = \frac{4000 * \sqrt{3}}{3 * 415}$$

$$I_{phase-ref} = 5.564A$$

4.2. DC-link Voltage

The DC link voltage can be obtained as

$$V_{dc} = \frac{2V_{phase-peak}}{m_a} \tag{5}$$

$$V_{dc} = \frac{2 * 415 * \sqrt{2}}{\sqrt{3} * 0.8}$$

$$V_{dc} = 847.115V$$

where m_a is the modulation index which is chosen as 0.8.

4.3. Filter Inductor

The filter inductor can be obtained from eq.

$$L = \frac{m_a V_{dc}(1 - m_a)}{2\Delta i_p f_s} \tag{6}$$

where m_a is the modulation index, V_{dc} is the dc-link voltage, f_s is the switching frequency and Δi_p is the peak value of inductor ripple current.

$$\Delta i_p = I_{hrms}\sqrt{3} \tag{7}$$

$$I_{hrms} = THD_i I_{phase-ref}$$

$$I_{hrms} = 5$$

$$I_{hrms} = 0.278A$$

$$\Delta i_p = 0.278\sqrt{3}$$

$$\Delta i_p = 0.4818A$$

$$L = \frac{0.8 * 847.115 * (0.2)}{2 * 0.4818 * 5 * 1000} \tag{8}$$

$$L = \frac{0.8 * 847.115 * (0.2)}{2 * 0.4818 * 5 * 1000}$$

$$L = 28.18mH$$

The value of Filter Inductor can be chosen as 28.18 mH

5. Simulation results

To verify control technique provided here a simulation is performed in the MATLAB software. In this particular simulation initially power is taken to be 2 kW and will be increased to 4 kW at 0.5s. The circuit ratings and parameters used in the simulation are provided in the table 1.

Converter Parameters	
Parameters	Values
Rated Power	2kW and 4kW
Grid voltage(line-line rms)	415V, 50 Hz
Fundamental frequency	50 Hz
Switching frequency	10 kHz
Filter Inductance L	28.18 mH

Table 1: Parameters

The results obtained are shown in figures below.

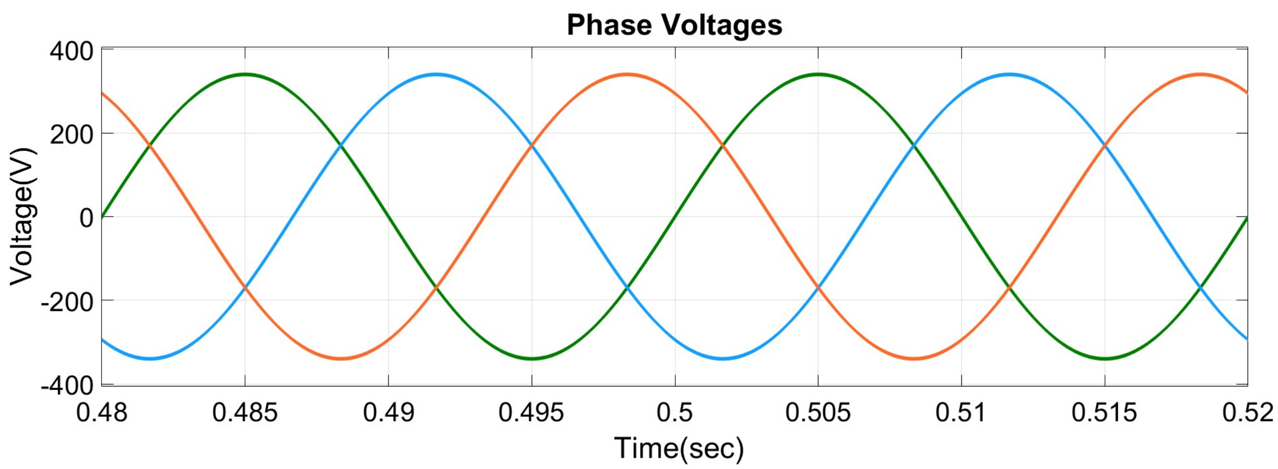

Fig. 5: Phase Voltages

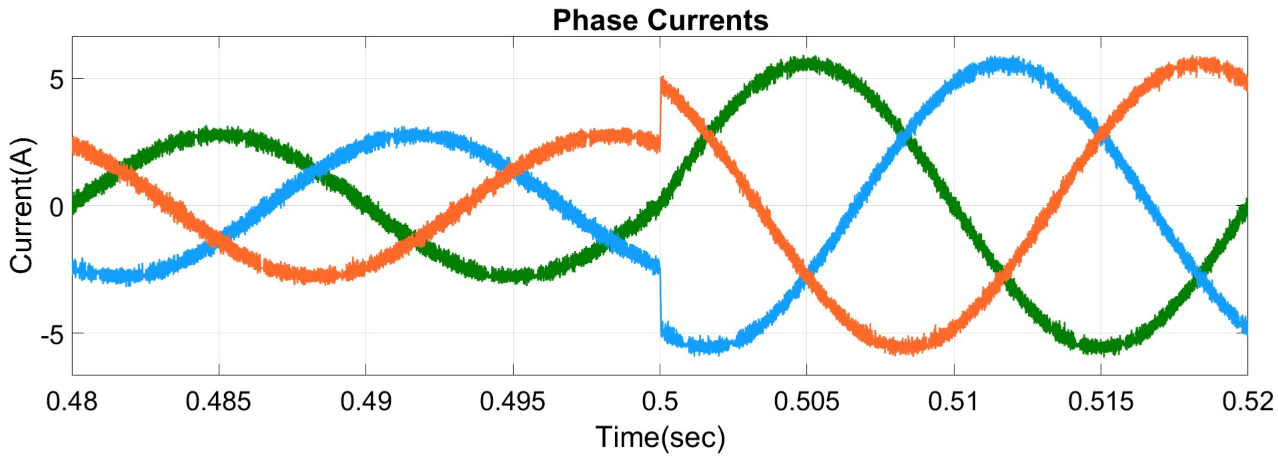

Fig. 6: Phase currents

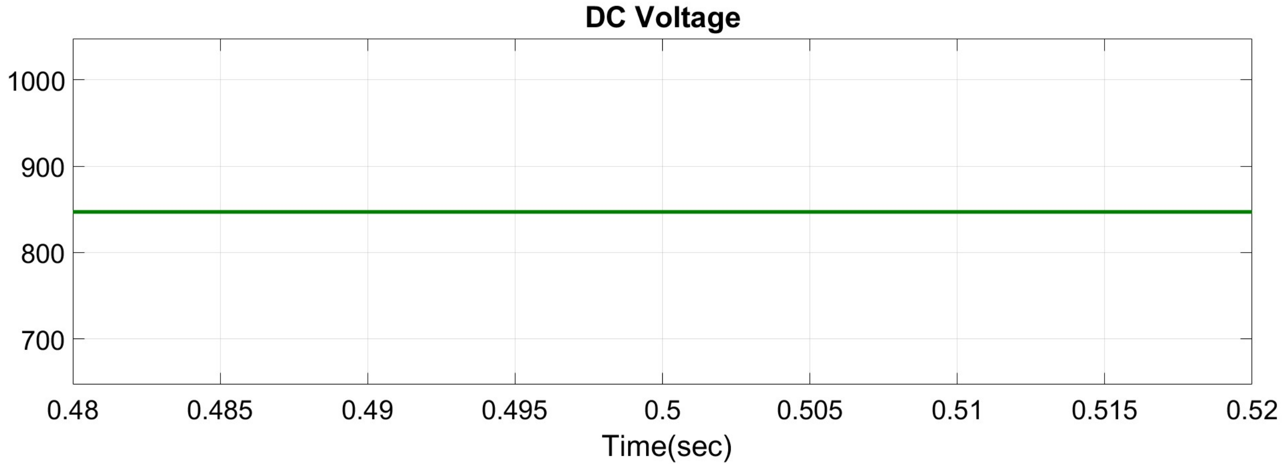

Fig. 7: DC voltage

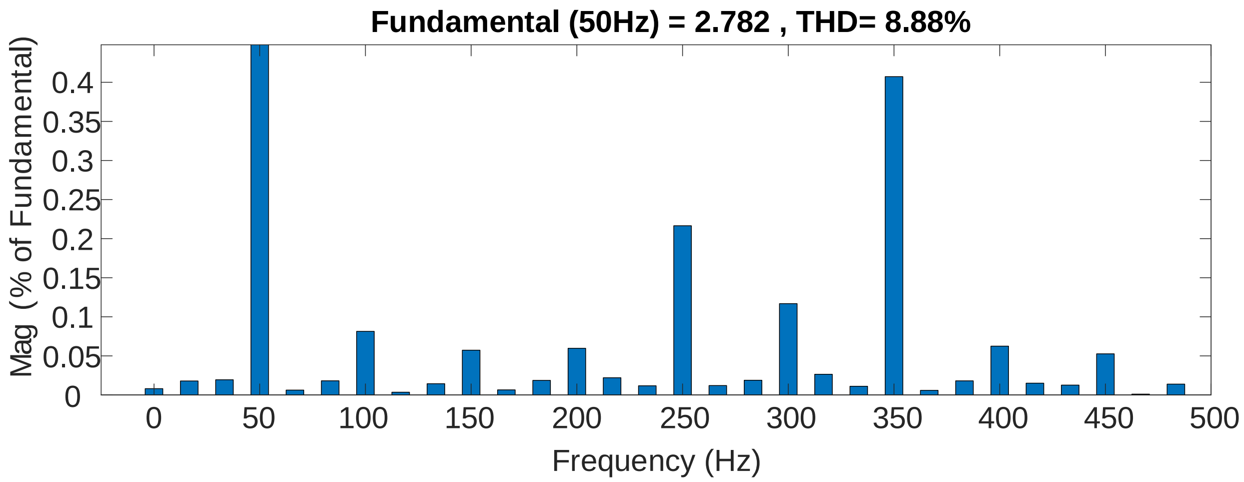

Fig. 8: THD in currents for 2kW power

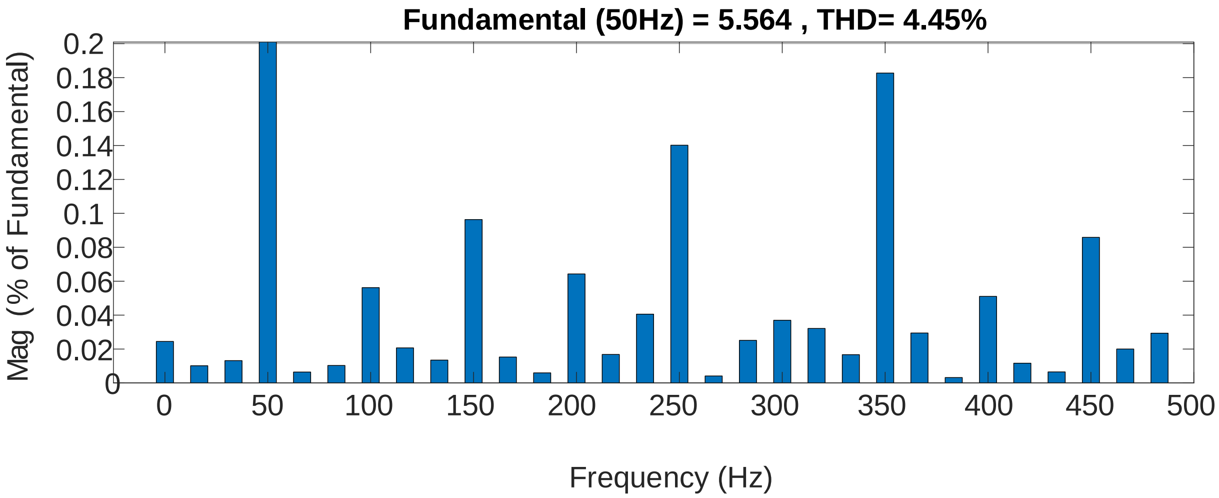

Fig. 9: THD in currents for 4 kW power

6. PCB Design

The PCB design has been implemented using Altium Designer and has been shown in fig. 10 and fig. 11

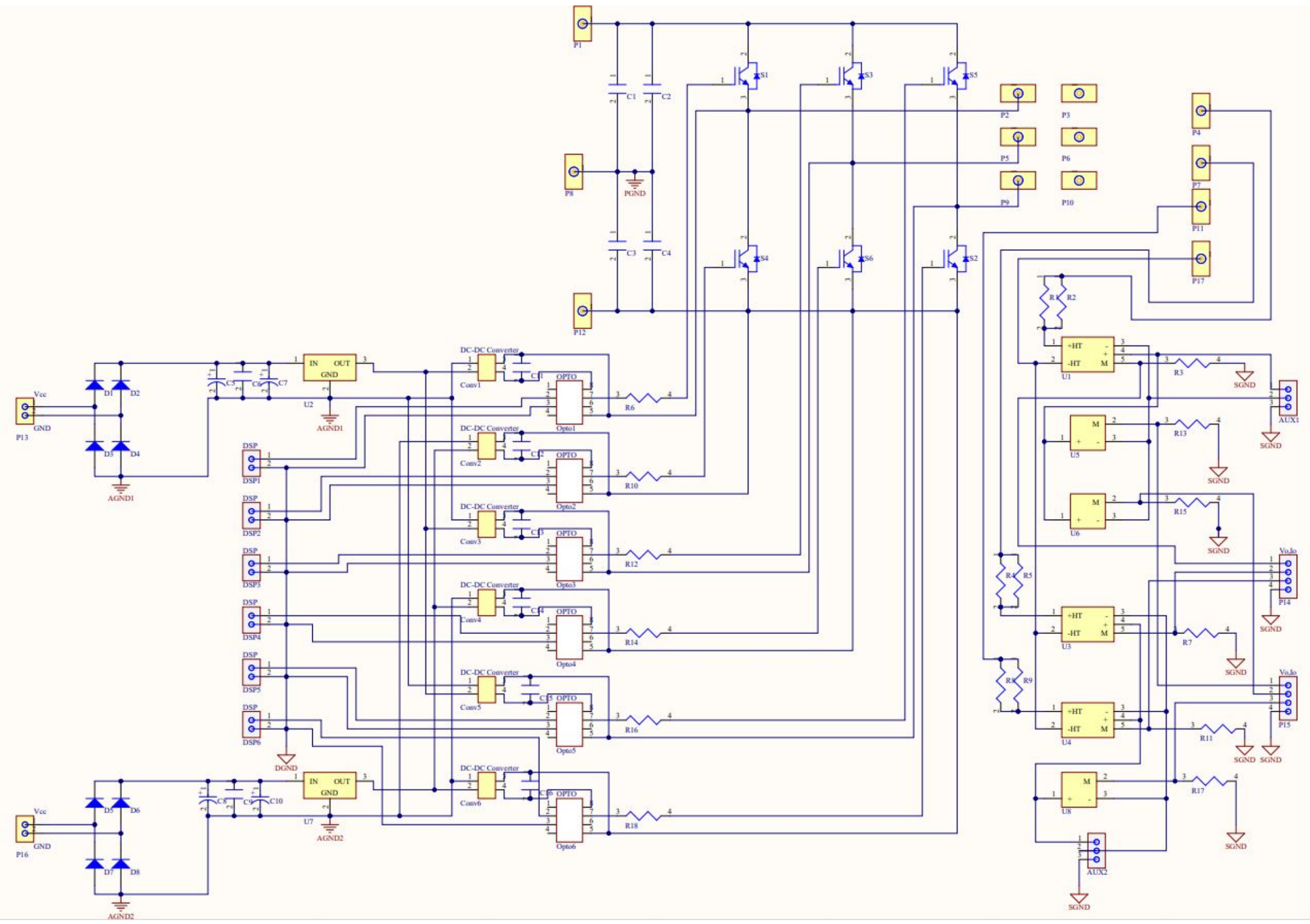

Fig. 10: Schematic Diagram

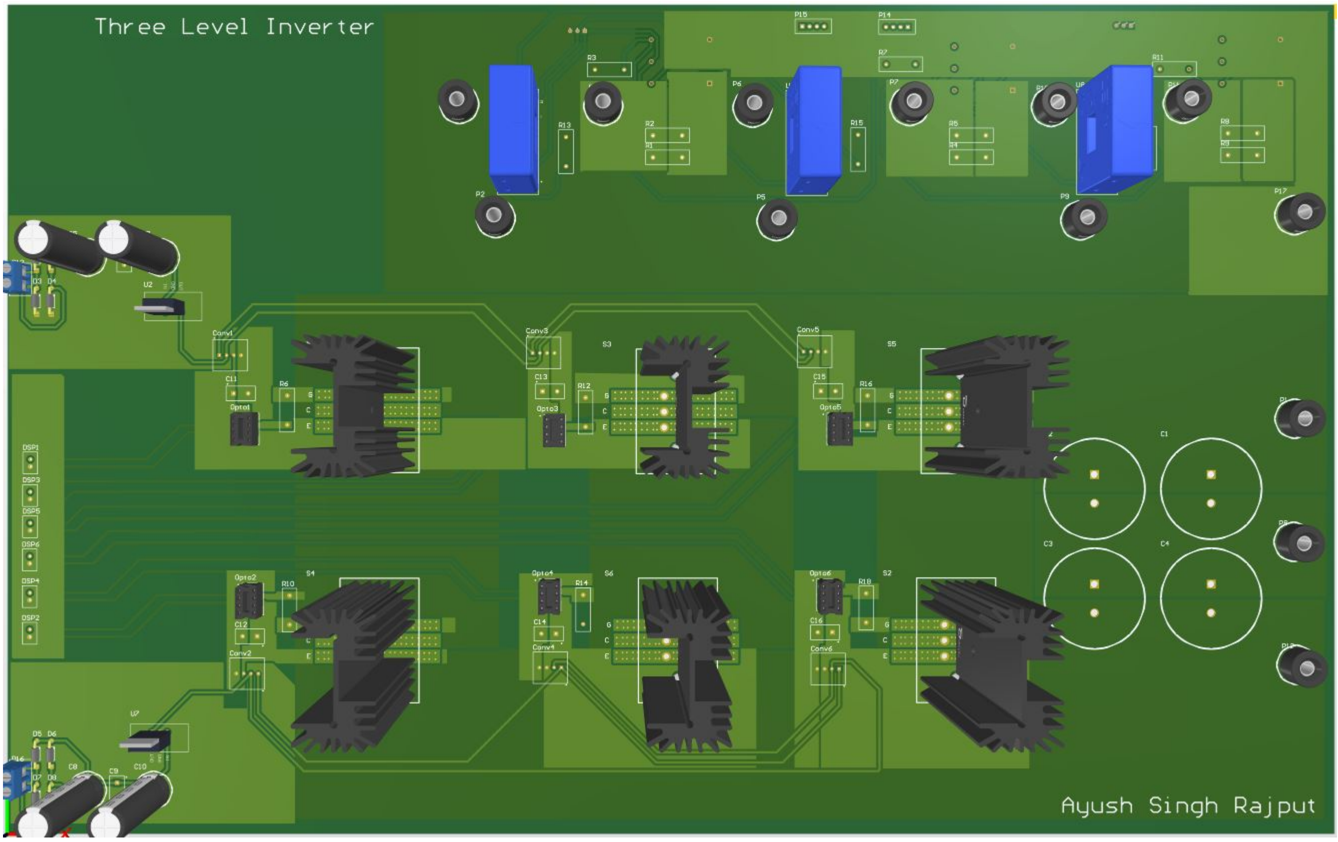

Fig. 11: PCB Top view

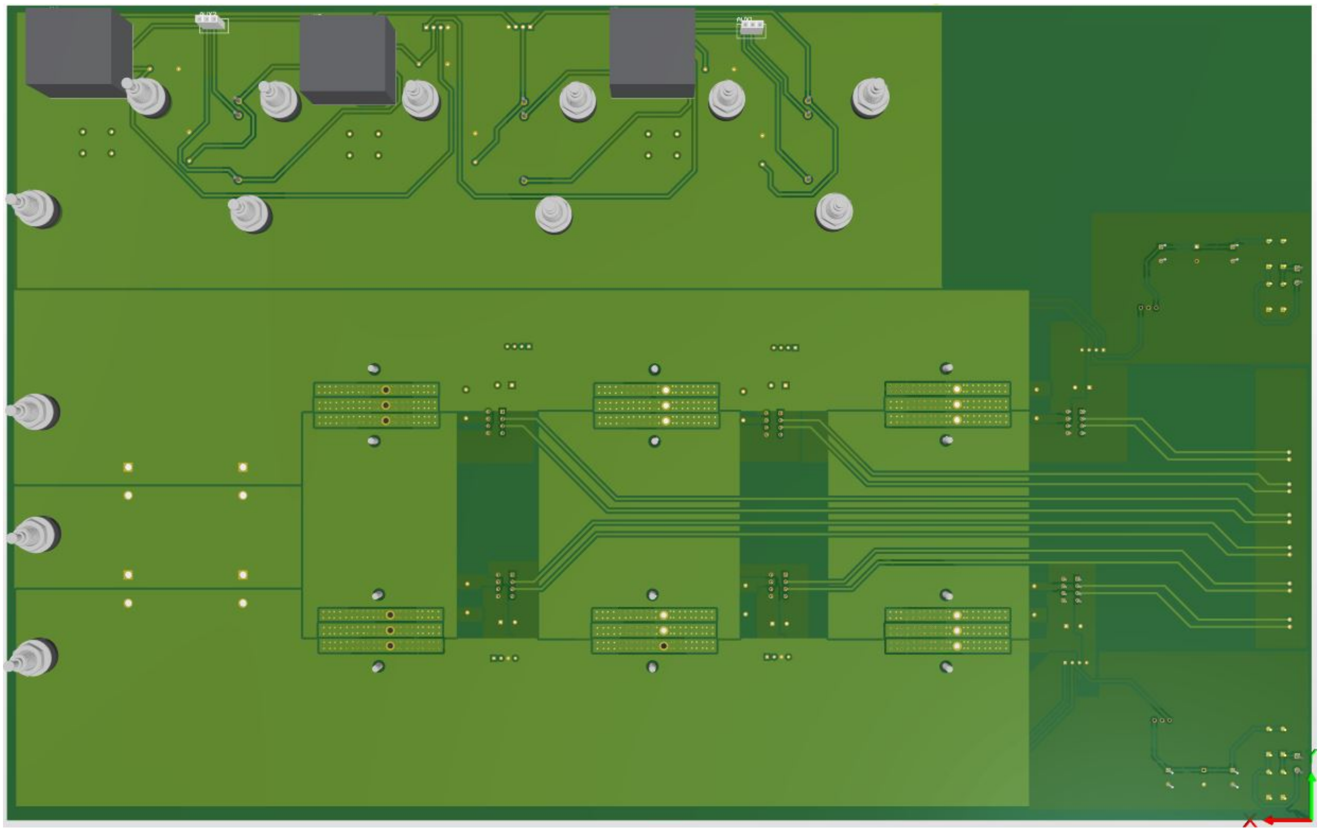

Fig. 12: PCB Bottom View

7. References

1. Thanh-Vu Tran, Tae-Won Chun, Hong-Hee Lee, Heung-Geun Kim and Eui-Cheol Nho, ”Control for grid-connected and stand-alone operations of three-phase grid-connected inverter,” 2012 International Conference on Renewable Energy Research and Applications (ICRERA), Nagasaki, Japan, 2012, pp. 1-5, doi: 10.1109/ICRERA.2012.6477348.

2. F. L. Paukner, C. Nardi, E. G. Carati, C. M. O. Stein, R. Cardoso and J. P. da Costa, ”Inductive filter design for three-phase grid connected power converters,” 2015 IEEE 13th Brazilian Power Electronics Conference and 1st Southern Power Electronics Conference (COBEP/SPEC), Fortaleza, Brazil, 2015, pp. 1-5, doi: 10.1109/COBEP.2015.7420189.