## Objective:

- Design a pure sine wave three-phase inverter of 2.2 Kwtt.
- The switching frequency is 50 khz. calculate the losses in the inverter and filter.
- Use PLECS to model the magnetics and give the performance table for unipolar Sine PWM and Space Vector PWM.

## Software Required:

PLECS

**Introduction:** • Inverter is a device which convert a DC input supply voltage into symmetric AC voltage of desired magnitude and frequency at the output side. It is also known as DC-AC converter.

• Ideal and practical inverter have sinusoidal and non-sinusoidal waveforms at output respectively.

• If the input dc is a voltage source, the inverter is called a Voltage Source Inverter (VSI). One can similarly think of a Current Source Inverter (CSI), where the input to the circuit is a current source. The VSI circuit has direct control over 'output (ac) voltage' whereas the CSI directly controls 'output (ac) current.

**Classifications of inverter:**

Inverter can be mainly classified into two types-

1) Single-phase inverter

2) Three-phase inverter

**Three phase inverter Simulink Model:** - (VSI) :

The load fed by the inverter is a resistive load with a resistance of 12.15 ohm per phase (Star Connected Load)

Considering : $V_{dc} = 230\ volt$

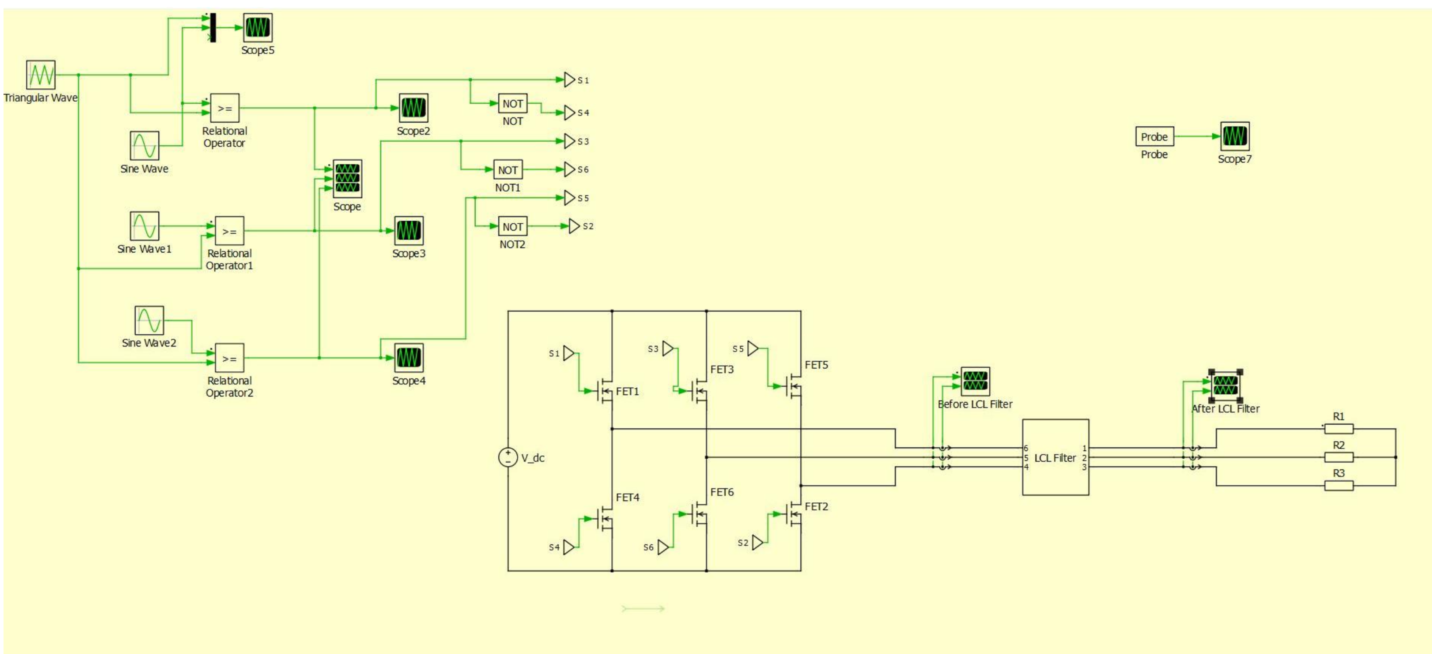



Fig: Simulation model of 3 phase inverter

**Sine PWM Waveform**

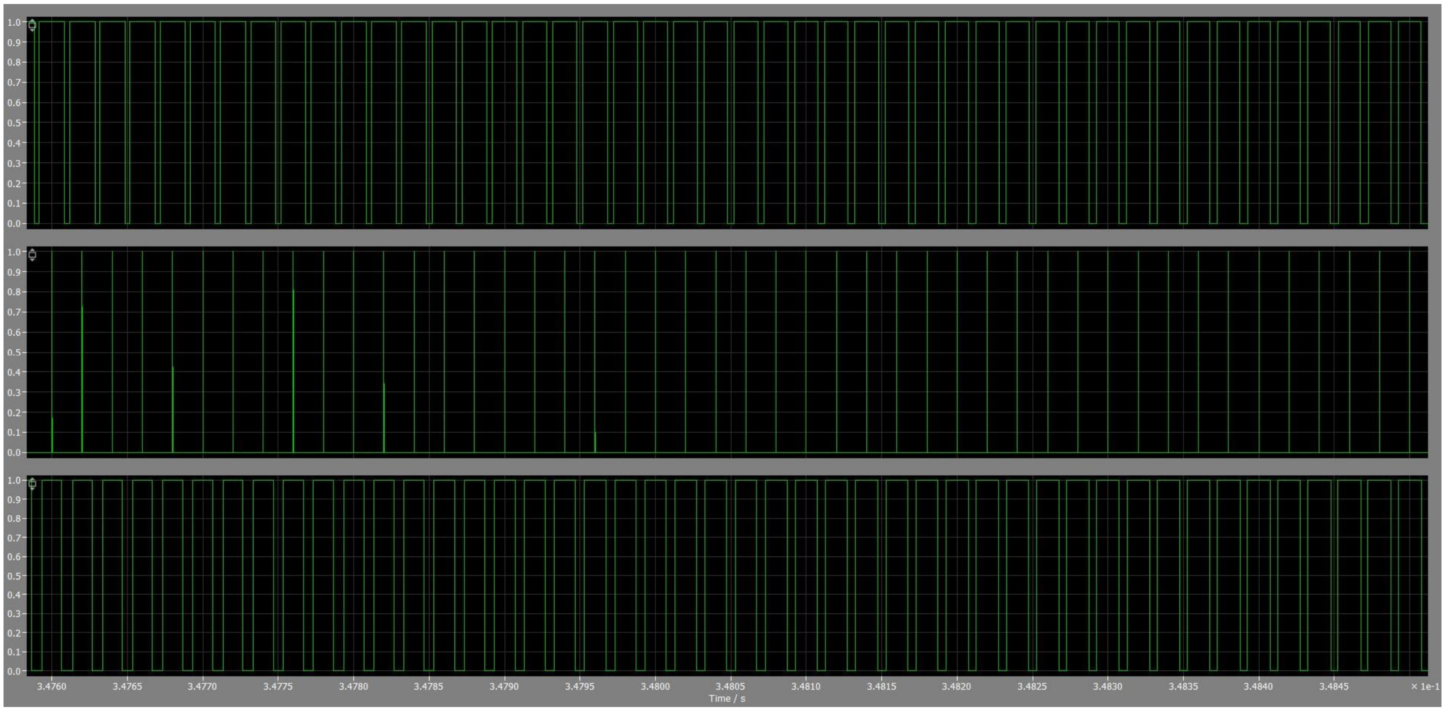



Fig: 3 phases of sine PWM

**Before LCL Circuit Voltage and cuurent waveform:**

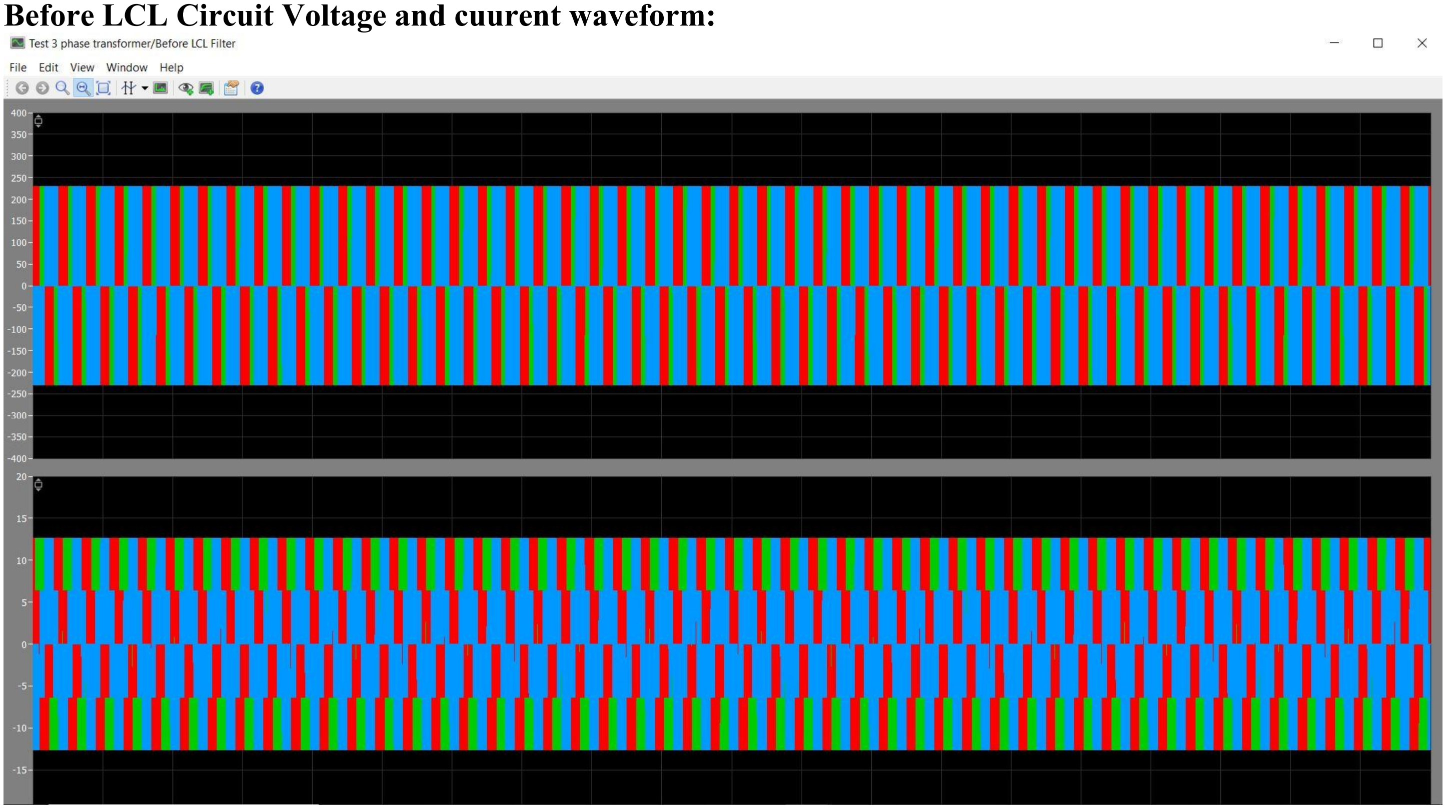
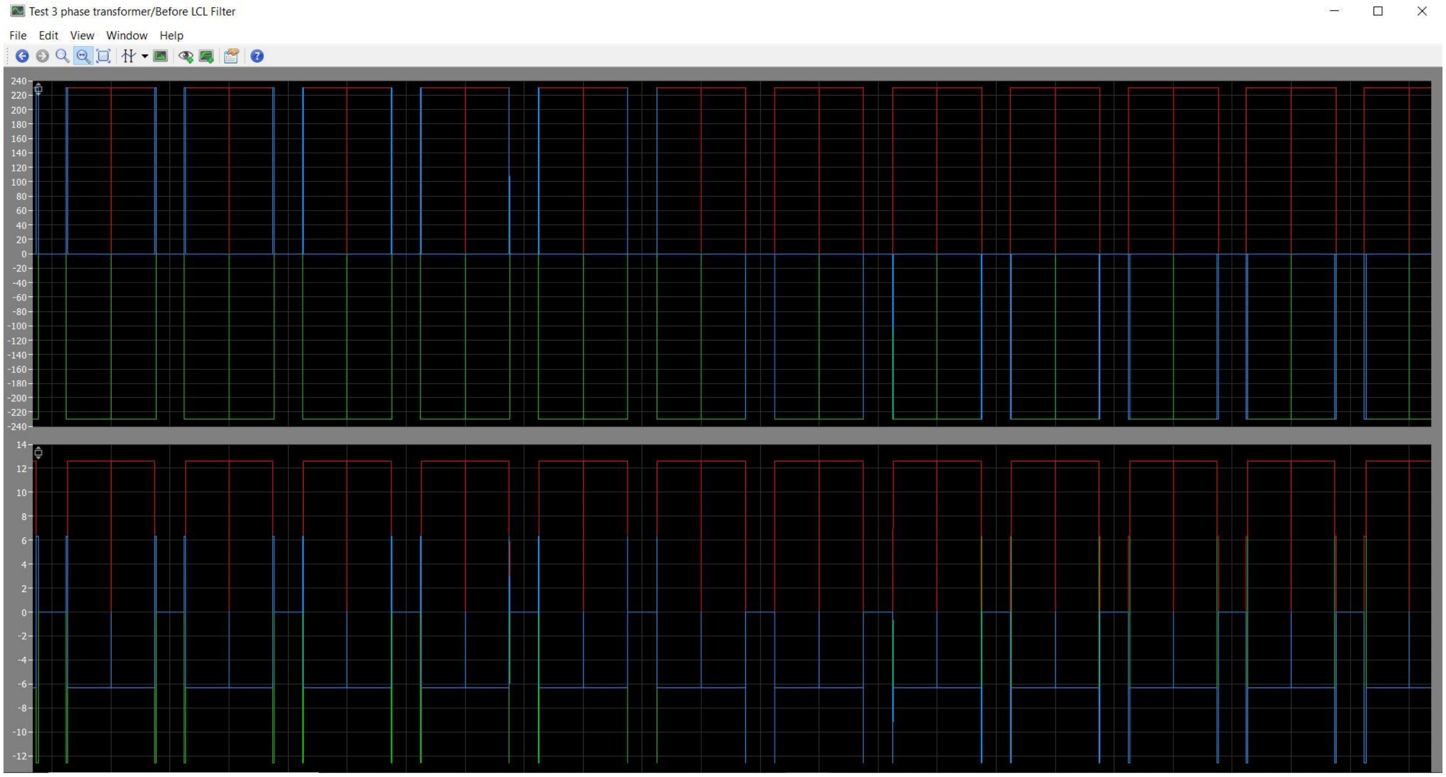



Fig: Before filter Output voltage and current waveform

**Output Voltage : Vp-Vp =230 volt**

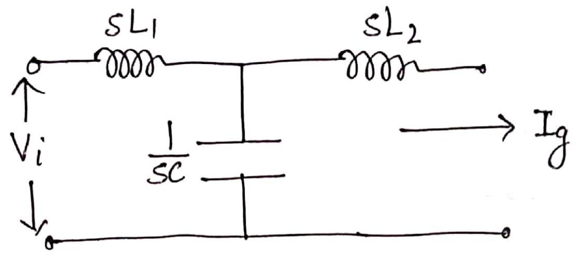
## With Zoom



Test 3 phase transformer/Before LCL Filter
File Edit View Window Help
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12

# DESIGING OF LCL FILTER:

LCL-Filter design




$$\frac{I_g}{V_i} = \frac{1}{s^3 L_1 \cdot L_2 C + s(L_1 + L_2)}$$

Let.

$$\boxed{L_1 + L_2 = L \quad \& \quad L_p = \frac{L_1 \cdot L_2}{L_1 + L_2}}$$

$$\boxed{\frac{I_g}{V_i} = \frac{1}{sL(1 + s^2 C L_p)}}$$

$$\boxed{\omega_{res} = \frac{1}{\sqrt{C L_p}}}$$

Given Switching freq : $F_{sw} = 50\ kHz$.

Resonant freq $= \frac{F_{sw}}{10} = \underbrace{5\ kHz. = f_{res}}$

Value of Capacitance – Let $\boxed{S = 2.2\ kVA}$

Let Reactive power = 5% of Rated Power.

$$Q = \frac{V^2}{1/2\pi f c} \Rightarrow \boxed{C = \frac{0.05 \times S}{V^2 \times 2 \times \pi \times f}}$$

$\boxed{V_{P\text{-}P} = 230V}$

$$C = \frac{0.05 \times 2200/3}{230 \times 2 \times \pi \times 50}$$

$$\boxed{C = 507\ \mu F}$$

## Finding Value of Inductance :

$$\frac{I_g}{V_i} = \frac{1}{sL\left(1+s^2 L_p \cdot C\right)} \quad , \quad \omega_{res} = \frac{1}{\sqrt{C L_p}}.$$

Puting $s = j\omega$.

$$\left|\frac{I_g}{V_i}\right| = \left|\frac{1}{\omega_{sw} \cdot L\left(1 - \frac{\omega_{sw}^2}{\omega_{res}^2}\right)}\right|$$

$$\boxed{L = \left|\frac{1}{\omega_{sw} \frac{I_g(sw)}{V_i(sw)}\left(1 - \frac{\omega_{sw}^2}{\omega_{res}^2}\right)}\right|}$$

Current $I_g = \dfrac{2200/3}{230} = 3.18$

$I_g(sw) = 0.3\%$ of $I_g =$

$= 9.54\ mA.$

$V_i(sw) = 0.9$ times of $V_g$

$= 0.9 \times 230$

$= 207\ V.$

$$L = \dfrac{1}{2\times\pi\times 50000 \times \dfrac{9.54\times10^{-3}}{207} \times \left[1-\left(\dfrac{2\times\pi\times 5000}{2\times\pi\times 5000}\right)^2\right]}$$

~~$L = 69.76\ m$~~

$\boxed{L = 697.6\ \mu H}$ $\quad L_1 = L_2 = \dfrac{L}{2}$

$L_1 = L_2 = 348.80\ \mu H.$ [Minimum Value]

$$L_{max} = \dfrac{0.2 \times V_{in}}{2\times\pi\times 50 \times I}$$

$\boxed{L_{max} = 46\ mH.}$ [Maximum Value].

taking $L_1 = L_2 = 2.85\ mH$

$C = 507\ \mu F.$

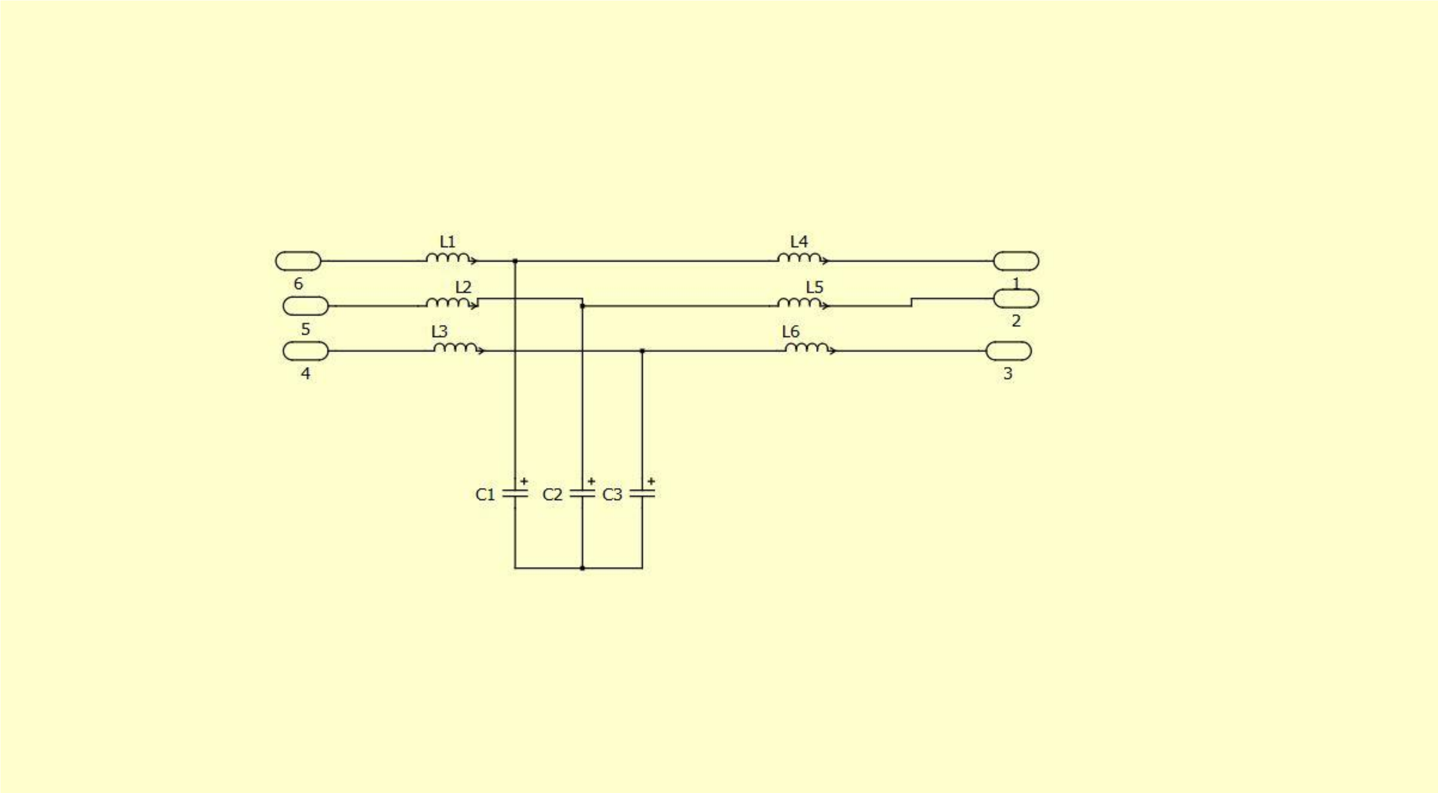
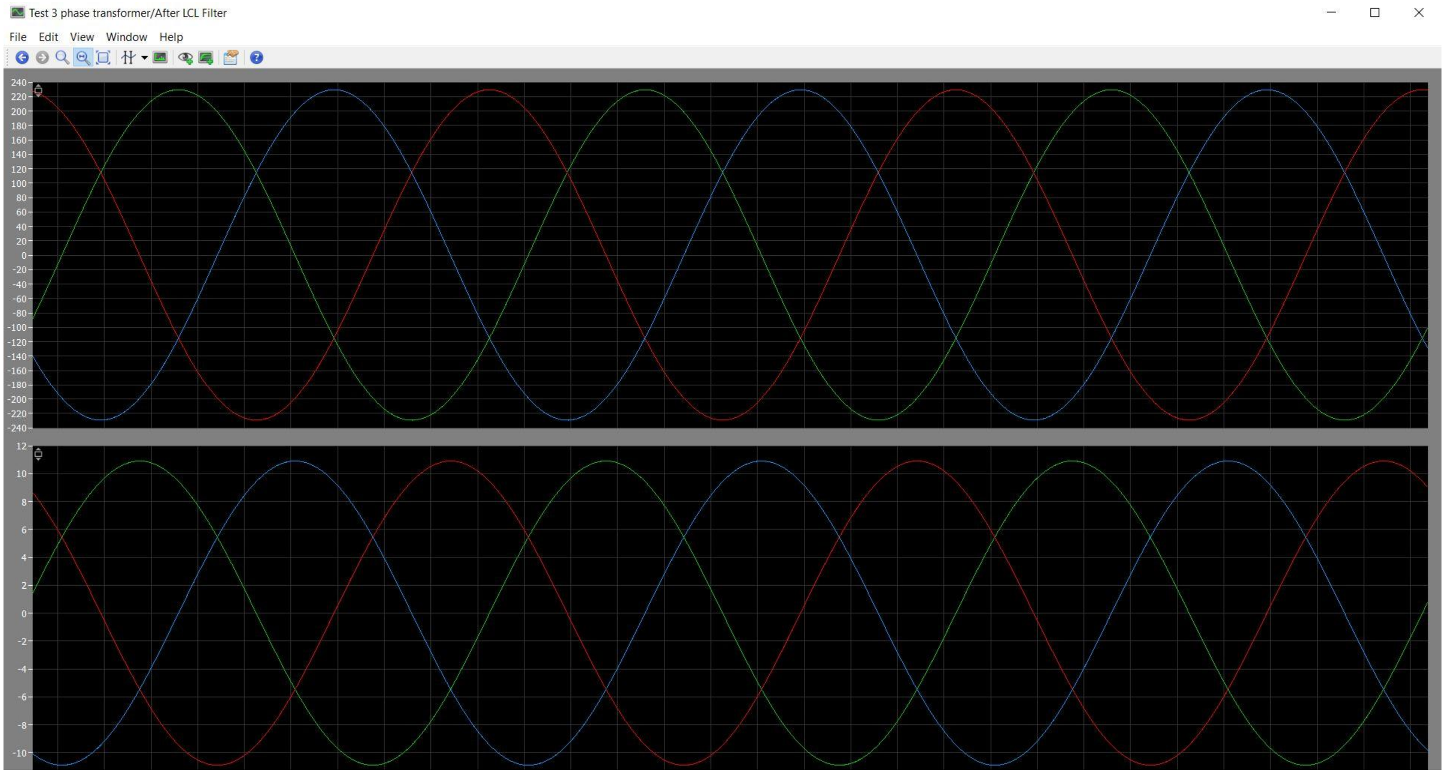



Fig: LCL filter

After calculating the value we taken;
Invetre Side : L= 2.85 mH  per phase
   Load Side :  L= 2.85 mH  per phase
Capacitor vale  C= 507 uF

## With LCL output voltage and current waveform :



**Maximum Output Voltage** : 229.412 volt
**RMS Output Voltage** : 162.356 volt
**Maximum Output Current** :10.9013 amp
**RMS Output Current** : 7.7386 amp

Data

| Name | | Cursor 1 | Cursor 2 | Max | RMS |
|---|---|---|---|---|---|
| Time | | 0.333335 | 0.666665 | | |
| Plot 1 | ☑ | | | | |
| 3ph Meter1:Measured voltage:1 | ☑ | -82.0634 | 226.524 | 229.412 | 162.356 |
| 3ph Meter1:Measured voltage:2 | ☑ | -144.499 | -81.839 | 229.412 | 161.58 |
| 3ph Meter1:Measured voltage:3 | ☑ | 226.562 | -144.685 | 229.412 | 162.717 |
| Plot 2 | ☑ | | | | |
| 3ph Meter1:Measured current:1 | ☑ | -8.46709 | 10.1841 | 10.9013 | 7.7386 |
| 3ph Meter1:Measured current:2 | ☑ | -1.7129 | -8.4599 | 10.9013 | 7.68463 |
| 3ph Meter1:Measured current:3 | ☑ | 10.18 | -1.72418 | 10.9013 | 7.70184 |

## Output Power:

$$P = \sqrt{3} V_{rms} I_{rms}$$
$$P = 2176.61 \text{ watt}$$

Following points may be noted from the output waveform of three phase bridge inverter with LCL Filter:

- Phase voltages have sinusoidal nature as desired.
- The line voltages represent a balanced set of three phase alternating voltages.

## Losses in Switch :

| Name | | Cursor 1 | Cursor 2 | Max | Mean | RMS |
|---|---|---|---|---|---|---|
| Time | | 0.333335 | 0.666665 | | | |
| Plot 1 | ☑ | | | | | |
| FET1:MOSFET junction temp | ☑ | 177.217 | 273.847 | 335.732 | 234.753 | 237.978 |
| Plot 2 | ☑ | | | | | |
| FET1:MOSFET conduction loss | ☑ | 0 | 0.35366 | 190.826 | 40.4606 | 72.2343 |
| Plot 3 | ☑ | | | | | |
| FET1:MOSFET switching loss | ☑ | 0 | 0 | 0.000290973 | 9.67296e-06 | 3.69218e-05 |

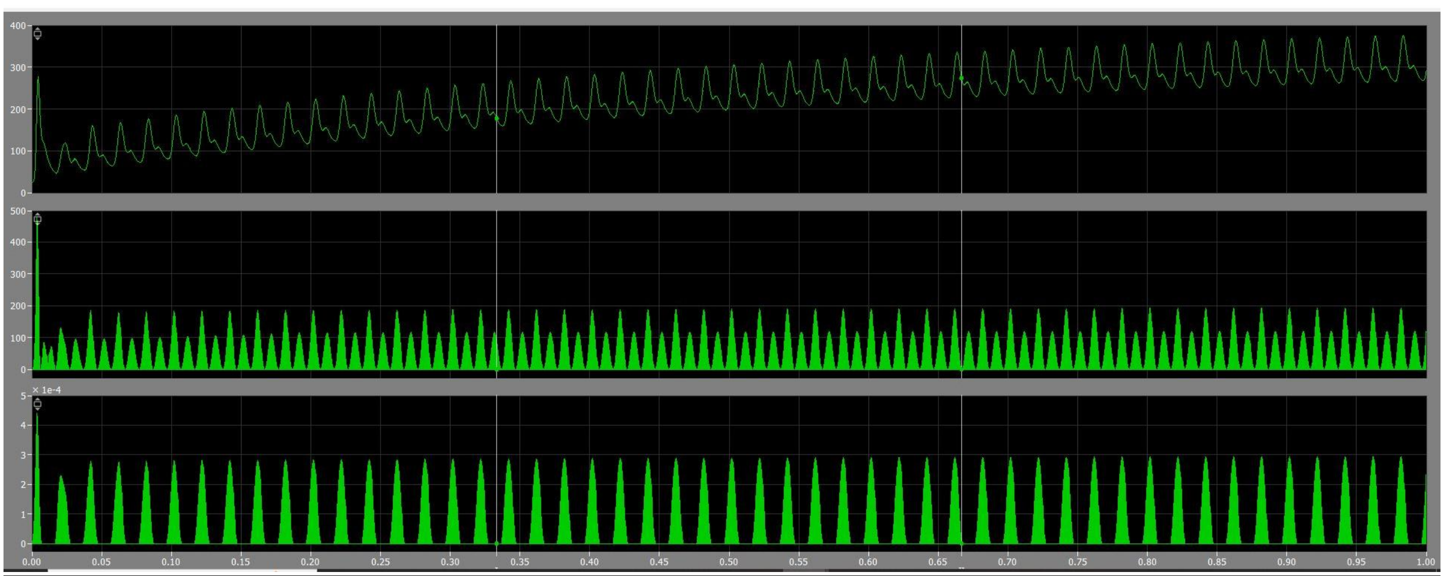


Fig:1. Switch Junction Temp, 2.Switch Conduction Loss, 3. Swticing loss

Total Loss in Inverter :
Conduction Loss: 40.46 w
Sw Loss : 9.67 uW

## C**onclusion:**

In conclusion, the successful design and simulation of a 3-phase inverter with a 2.2 kW power rating, featuring a pure sine wave output and an LCL filter, represents a noteworthy achievement in the realm of power electronics. The integration of advanced control strategies and the inclusion of the LCL filter not only fulfill the specified power requirements but also ensure a high-quality output waveform with reduced harmonic distortion.