SINGLE AND THREE PHASE VOLTAGE SOURCE INVERTER

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Contents

1.Introduction to Voltage Source Inverter

1.Voltage Source Inverter abbreviated as VSI is a type of inverter circuits that converts a dc input voltage into its ac equivalent at the output. It is also known as a voltage-fed inverter (VFI), the dc source at the input of which has small or negligible impedance.

2. The DC input source can be batteries stacked in series or parallel, photovoltaic cells, or rectified output from another AC power source. It can be used in both single phase and three phase topologies.

3.There are two types in Voltage source Inverter

1.Single Phase Voltage Source Inverter

2.Three Phase Voltage Source Inverter

2.Single Phase Voltage Source Inverter

It consists of 1 DC voltage source, 4 transistors S1, S2, S3, S4, and 4 anti-parallel diodes D1, D2, D3, D4 for switching purpose and one large DC link capacitor "C" as shown below

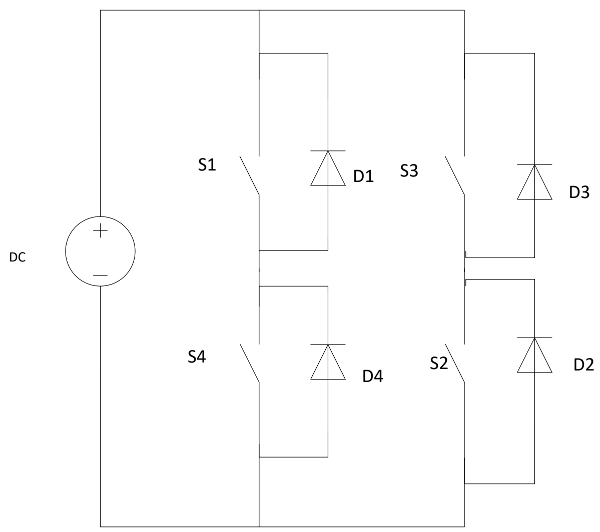

Figure 1: Single Phase VSI

2.1 Working Principal of Single Phase Voltage Source Inverter

1.It consists of four choppers. Full bridge converter is also basic circuit to convert dc to ac. An ac output is synthesized from a dc input by closing and opening switches in an appropriate sequence.There are also four different states depending on which switches are closed.
2.When transistors T1 and T2 are turned on simultaneously, the input voltage appears across the load. If transistors are turned on at the same time, the voltage across the is reversed and is -Vs.
3.Transistor T1 and T2 acts as switches S1 and S2 respectively.

3.Three phase Voltage Source Inverter

voltage source inverter can operate in any of 2 conduction mode, i.e, 180 degree conduction mode. 120degree conduction mode.
Let us consider the scenario of 180-degree conduction mode in a three-phase inverter. The three-phase inverter is represented in 180-degree conduction mode because both switches S1 and S2 conduct at 180 degrees. Whereas in a full-bridge voltage source inverter all the 4 switches S1, S2, S3, S4 conducts at 180 degrees. The figure is as shown below.

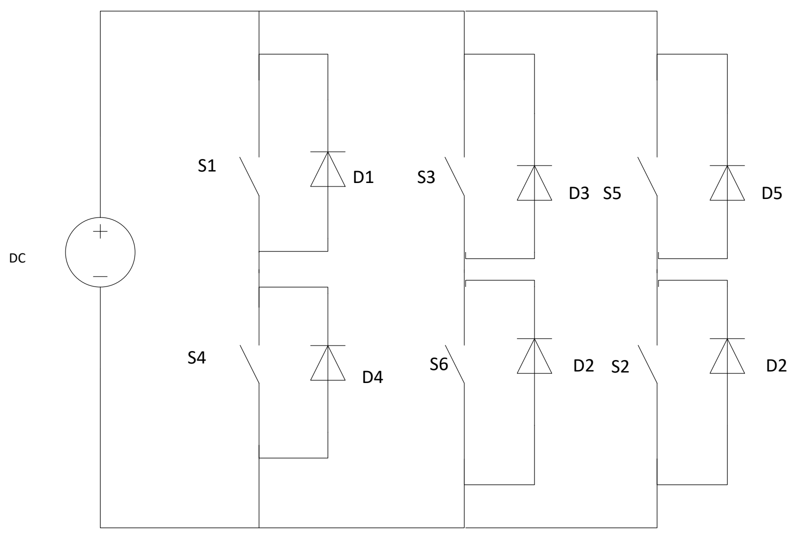

Figure 2: Three Phase Voltage Source Inverter

3.1 Working Principle of Three Phase Voltage Source Inverter

T1 conducts from 0 to 180 deg.

T4 conducts from 180 to 360 deg.

For a balanced output, A phase and B phase must have a phase shift of 120 That is when angle A is 0, angle B should be 120 and angle C should be -240.

Therefore, T3 will start conducting from 120 to 300. After this phase, T6 starts conducting from 3000 to 3600. T6 also conducting from 0 to 120 T5 starts conducting after 240 to 360 and also conducts from 0 to 60 T2 conducts from 60 to 240.

From the above graph, we can conclude that at a time 3 SCR switches are conducting.

4.Is the phase and line voltages for single and Three phase Inverters same or different? :

1.The phase and line voltages are different in single and three-phase inverters due to the difference in the number of power lines and the phase angles between them.

2.In a single-phase inverter there is only one power line supplying the load. The voltage waveform produced by the inverter has a sinusoidal shape and a constant frequency. This voltage is typically referred to as the phase voltage and it is measured between one phase and the neutral point or ground.

3.On the other hand a three-phase inverter has three power lines supplying the load. The voltages produced by the inverter are three separate sinusoidal waveforms each with a phase difference of 120 degrees. These voltages are known as the line voltage.

4.In summary the phase and line voltages differ in single and three-phase inverters due to the number of power lines and the phase angles between them. The phase voltage is present in single-phase systems while the line voltage is present in three-phase systems and it is necessary to divide the line voltage by $\sqrt{3}$ to obtain the phase voltage in a three-phase system.

5.Pulse Width Modulation in Inverters

Output voltage from an inverter can also be adjusted by exercising a control within the inverter itself. The most efficient method of doing this is by pulse-width modulation control used within an inverter. In this method, a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is the most popular method of controlling the output voltage and this method is termed as Pulse-Width Modulation (PWM) Control.

The advantages possessed by PWM techniques are as under:

(i) The output voltage control with this method can be obtained without any additional components.

(ii) With the method, lower order harmonics can be eliminated or minimized along with its output voltage control.

As higher order harmonics can be filtered easily, the filtering requirements are minimized.

The main disadvantage of this method is that SCRs are expensive as they must possess low turn- on and turnoff times.

PWM inverters are quite popular in industrial applications. PWM techniques are characterized by constant amplitude pulses. The width of these pulses is however modulated to obtain inverter output voltage control and to reduce its harmonic content.

The different PWM techniques are as under:

(a) Single-pulse modulation

(b) Multiple-pulse modulations.

(c) Sinusoidal pulse width modulation (Carrier based Pulse Width Modulation Technique)

6.To find DC Current in Single phase Inverter using SPWM

1. Let us Take Single Phase Full Inverter With RL load. the figure is shown below

2.For RL Load there are different power factors

3.We will find I_{Dc} for different Phase angles that is 0,30,90,180,360.

4.For phase angles 0,360,180 the load will be purely resistive load. Hence the I_{Dc} will be **Square Wave**.

5.For Phase angle 30 the load remains RL. Hence the I_{Dc} Waveform is **Saw Tooth**.

6.For phase angle 90 the load will be purely Inductive Load. Hence the I_{Dc} Waveform will be **Triangular**

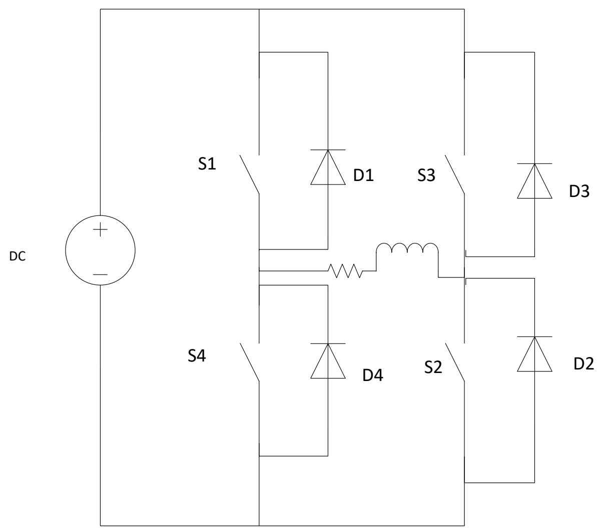

Figure 3: Single Phase full converter with RL load

6. Mathematical Analysis of Voltage Source Inverter

Assume Input voltage=48v; Frequency=50Hz;

Find Line and Phase Voltages and Fundamental Voltage and THD

- Line Voltages of Voltage Source Inverter

  $V_{ab} = \sum_{n=1,2,3}^{n} \frac{4v_s}{n\pi} cos\frac{n\pi}{6} sinn(wt + \frac{\pi}{6})$

  $V_{bc} = \sum_{n=1,2,3}^{n} \frac{4v_s}{n\pi} cos\frac{n\pi}{6} sinn(wt - \frac{\pi}{2})$

  $V_{ca} = \sum_{n=1,2,3}^{n} \frac{4v_s}{n\pi} cos\frac{n\pi}{6} sinn(wt + \frac{5\pi}{6})$

- Phase voltages of Voltage Source Inverter

  $V_{ao} = \sum_{n=6k+/-1}^{\infty} \frac{2v_s}{n\pi} cos\frac{n\pi}{6} sinnwt$

  $V_{bo} = \sum_{n=6k+/-1}^{\infty} \frac{2v_s}{n\pi} cos\frac{n\pi}{6} sin(wt + \frac{2\pi}{3})$

  $V_{co} = \sum_{n=6k+/-1}^{\infty} \frac{2v_s}{n\pi} cos\frac{n\pi}{6} sin(wt + \frac{4\pi}{3})$

Assume v_{dc} =600v M=0.8

- fundamental Line Voltages of Voltage Source Inverter using SPWM

  $V_{ab} = \frac{\sqrt{3}v_{dc}}{2} Mcos(wt - \frac{\pi}{3})$

  $V_{bc} = \frac{\sqrt{3}v_{dc}}{2} Mcos(wt - \pi)$

  $V_{ca} = \frac{\sqrt{3}v_{dc}}{2} Mcos(wt + \frac{\pi}{3})$

- fundamental Phase voltages of Voltage Source Inverter using SPWM

$V_{ao} = \frac{v_{dc}}{2} M sin(wt) + \frac{v_{dc}}{2}$
$V_{bo} = \frac{v_{dc}}{2} M sin(wt - \frac{2\pi}{3}) + \frac{v_{dc}}{2}$
$V_{co} = \frac{v_{dc}}{2} M sin(wt + \frac{2\pi}{3}) + \frac{v_{dc}}{2}$

- RMS values of Load Currents

  $I_{a_{Rms}} = I_{b_{Rms}} = I_{c_{Rms}} = \frac{\sqrt{2}}{4} \frac{M v_{dc}}{\sqrt{R^2+(wL)^2}}$

- Fundamental voltage of Voltage Source Inverter

  $V_{ao_{1Rms}} = \sqrt{\frac{(V_{Rms}^2 - V_{1,Rms}^2)}{V_{1,Rms}^2}}$

- I_{dc} in different loads in single phase VSI

  For R Load

  $phaseangle = tan^{-1} \frac{wl}{R}$

  $I_{dc} = \frac{V_{dc}}{R}$

  Diodes do not conduct.Each Switch conducts at T/2 sec

  For L Load

  $I_{dc} = \frac{V_{dc}}{4fL}$

  Diodes and Switches conduct for equal interval T/4 sec

  For RL Load $I_{dc} = \frac{V_{dc}}{R}(\frac{1-e^{-\frac{T}{2t}}}{1+e^{-\frac{T}{2t}}})$

7.Simulation Results

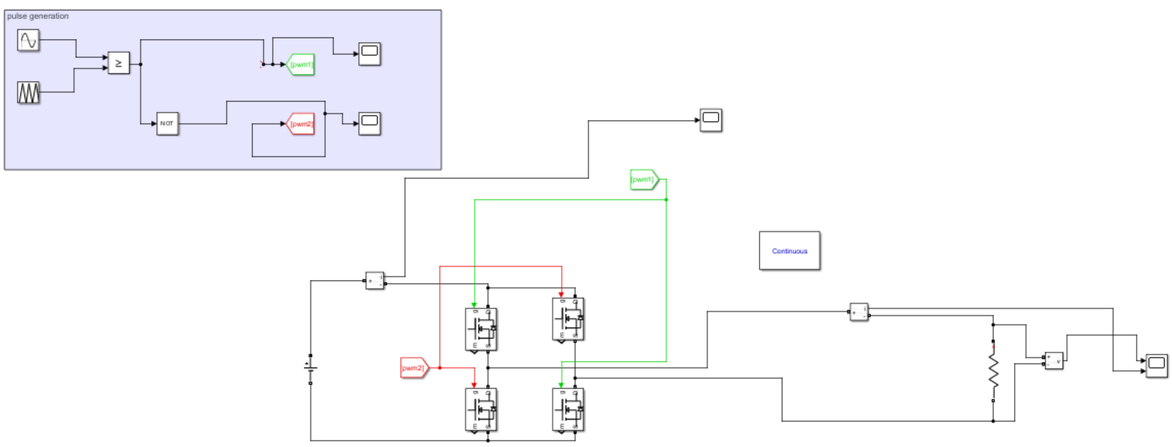

Figure 4: Simulation Diagram For Phase angle 0 using PWM **R=20**

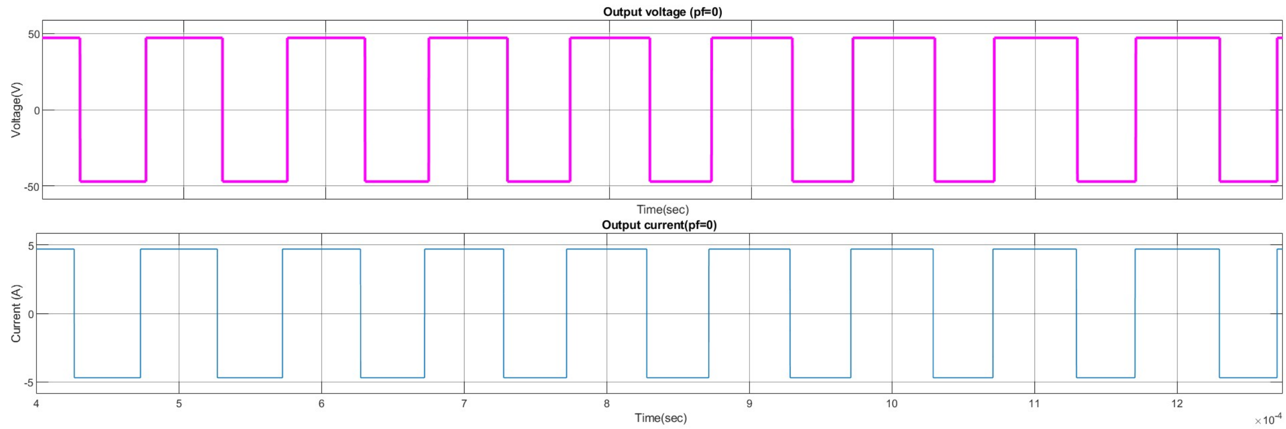

Figure 5: Output Voltage and Current For Phase angle 0

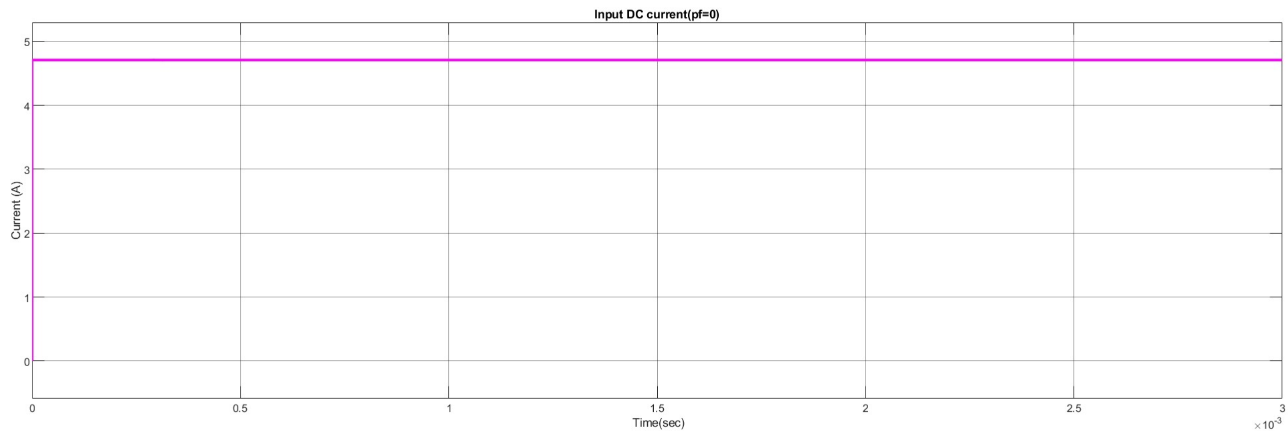

Figure 6: Input Current For Phase angle 0

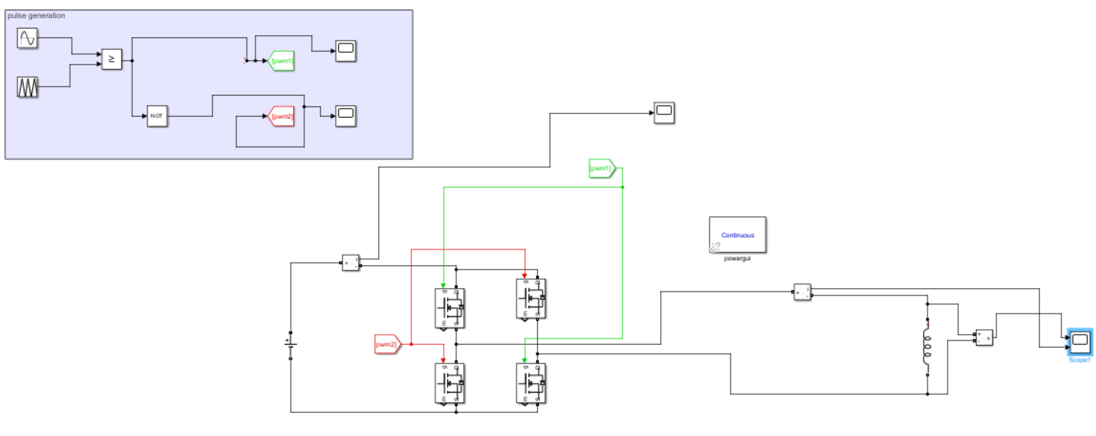

Figure 7: Simulation Diagram For Phase angle 90 using PWM**L=2mH**

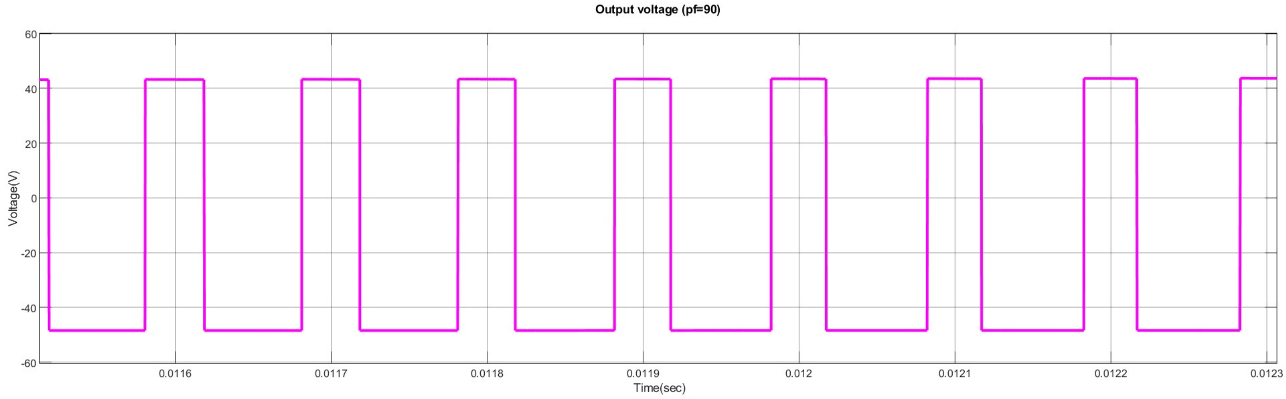

Figure 8: Output Voltage For Phase angle 90

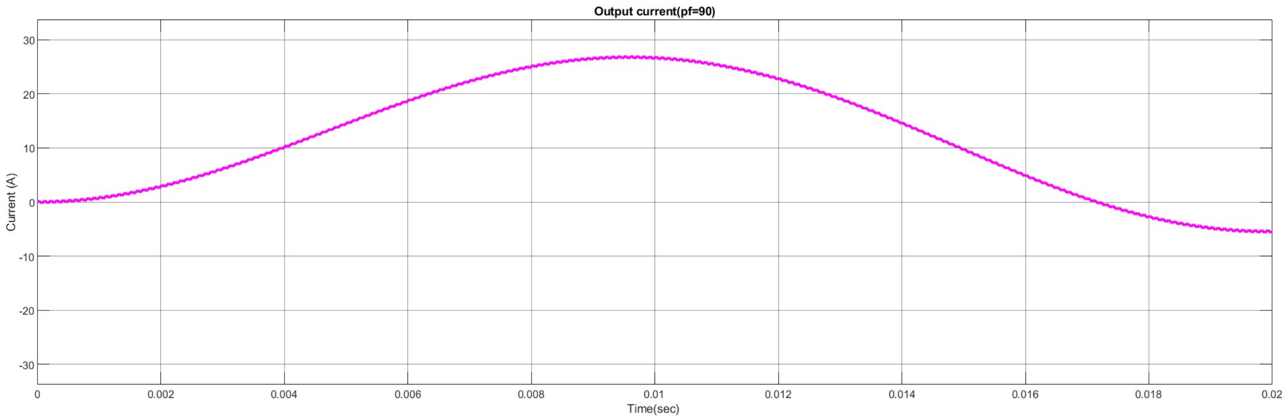

Figure 9: Output Current For Phase angle 90

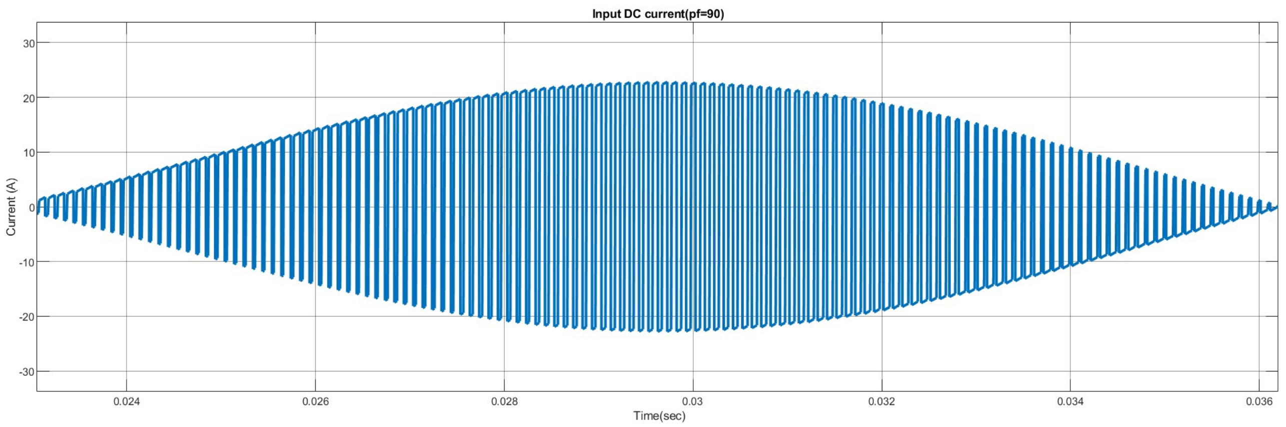

Figure 10: Input Current For Phase angle 90

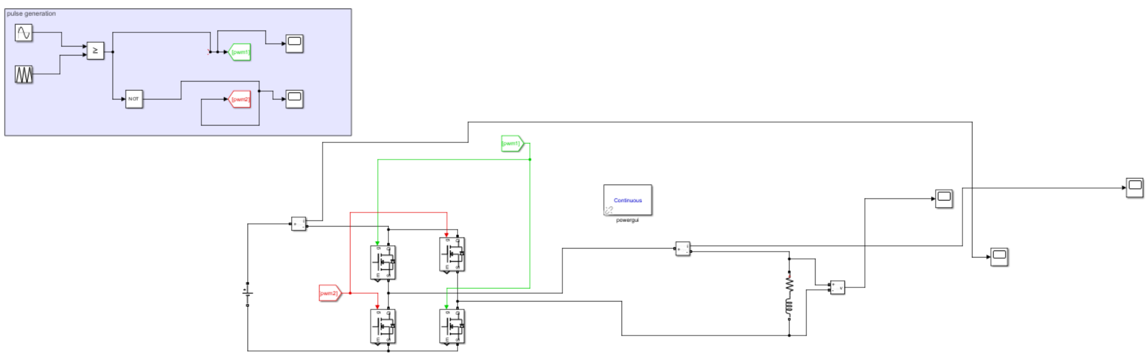

Figure 11: Simulation Diagram For Phase angle 30 using PWM**R=3.6,L=2.3mH**

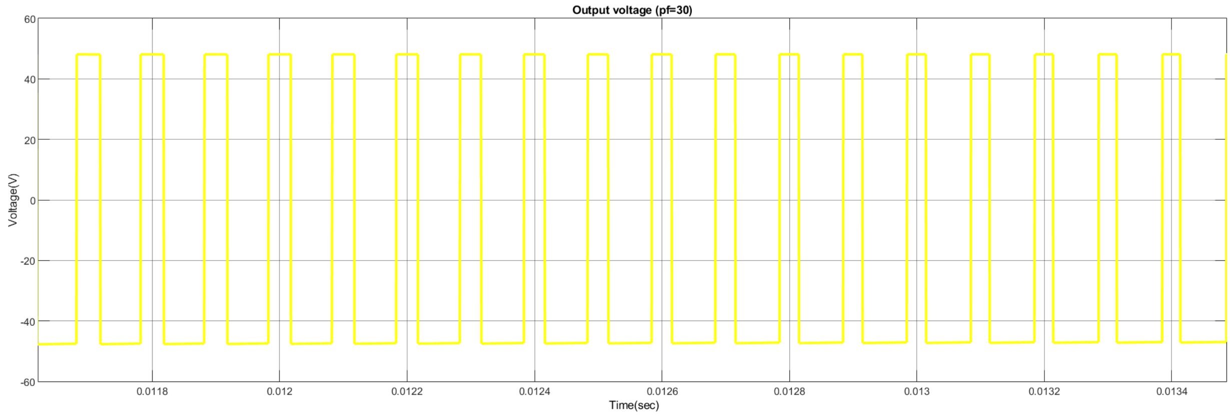

Figure 12: Output Voltage For Phase angle 30

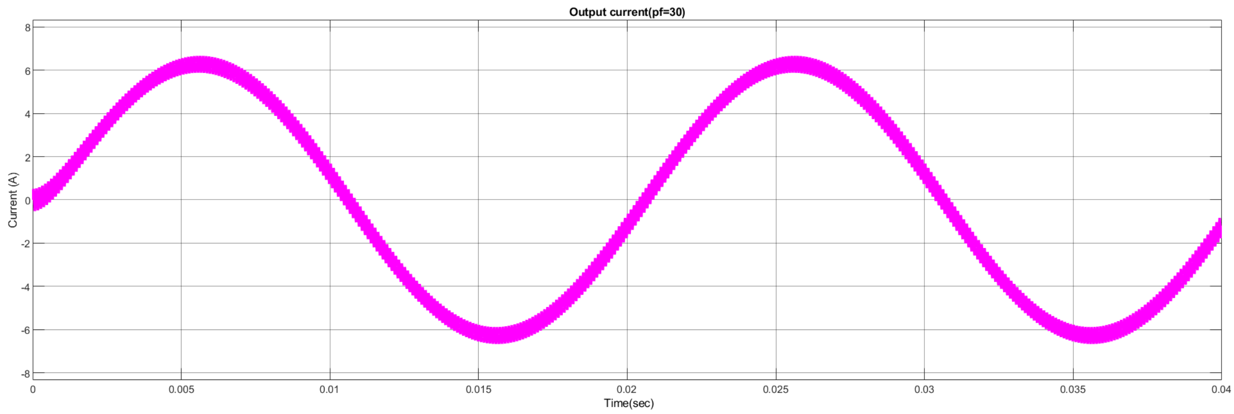

Figure 13: Output Current For Phase angle 30

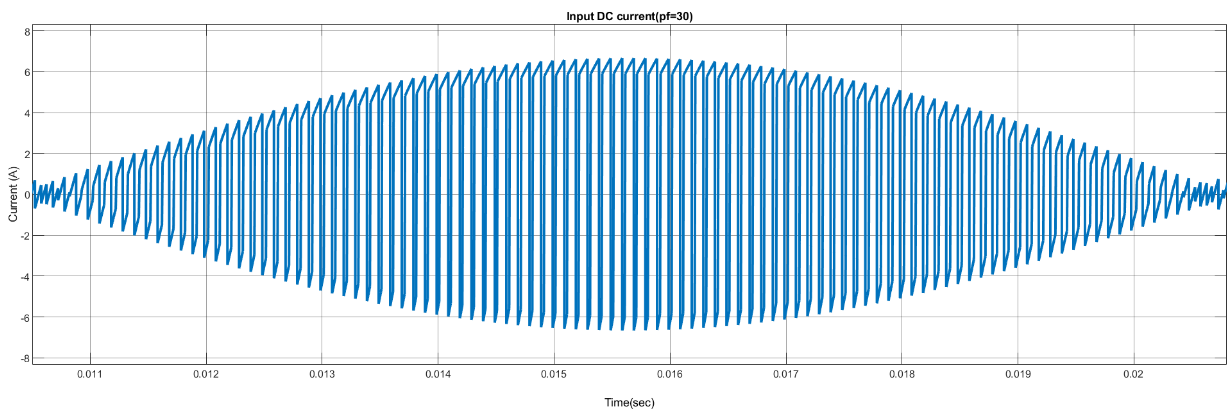

Figure 14: Input Current For Phase angle 30

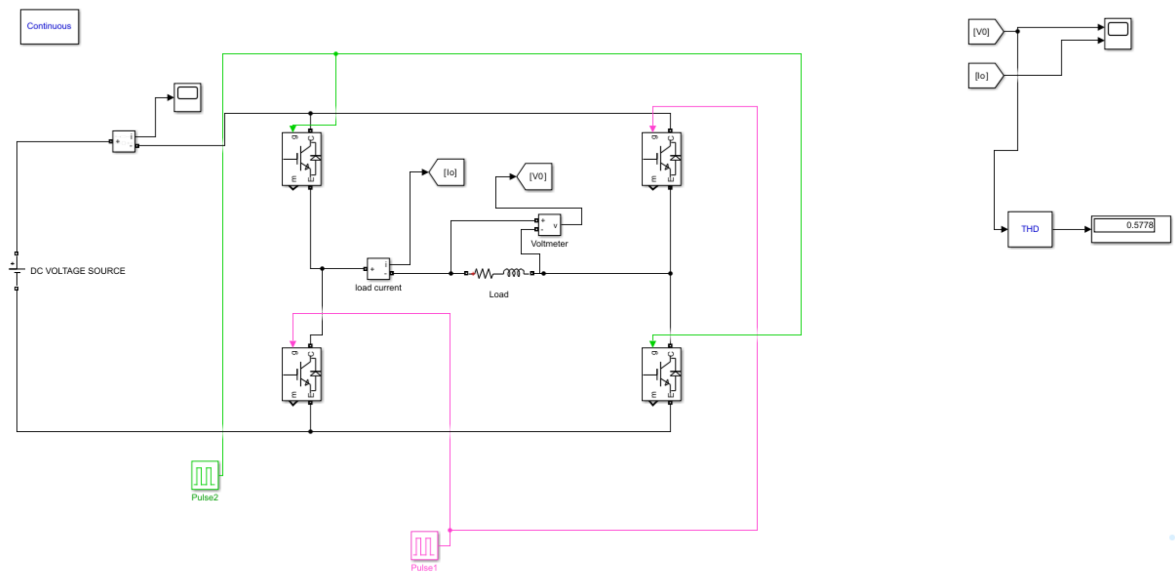

Figure 15: Single Phase Voltage Source Inverter

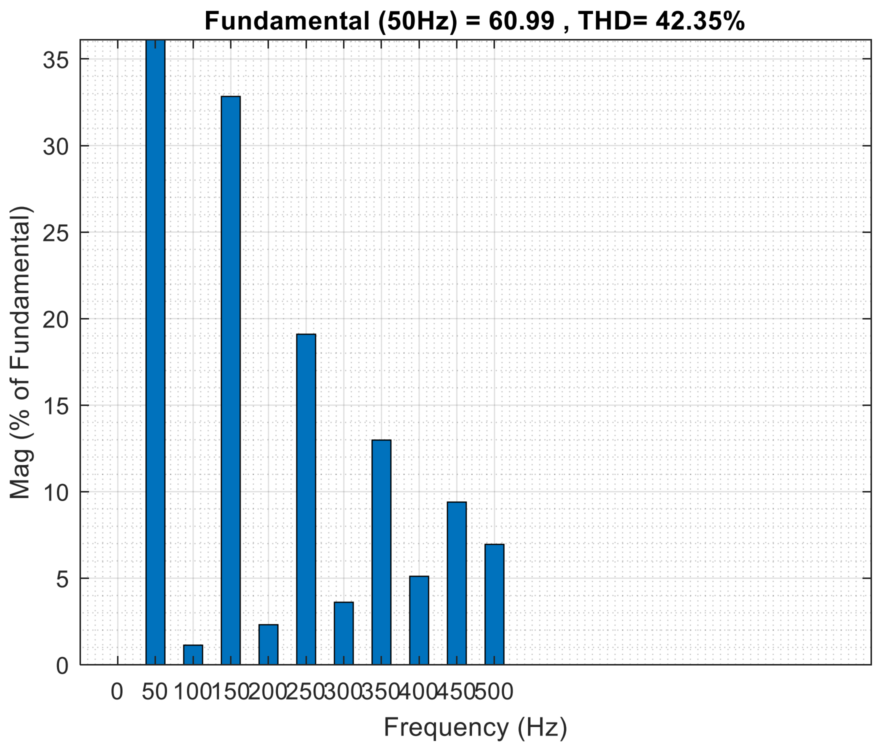

Figure 16: Fourier Analysis for phase angle 30

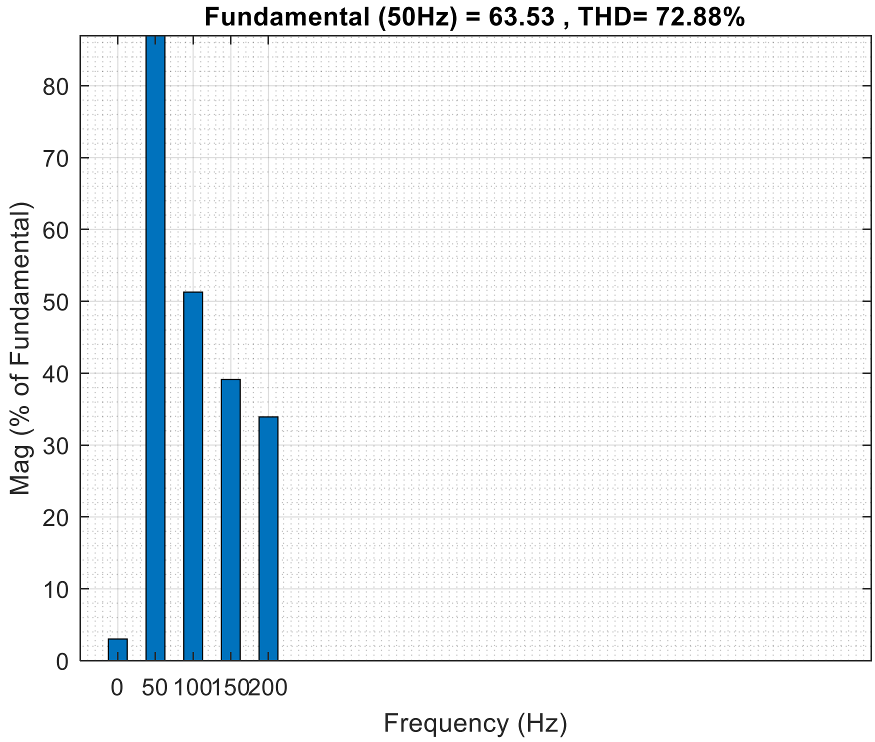

Figure 17: Fourier Analysis for phase angle 90

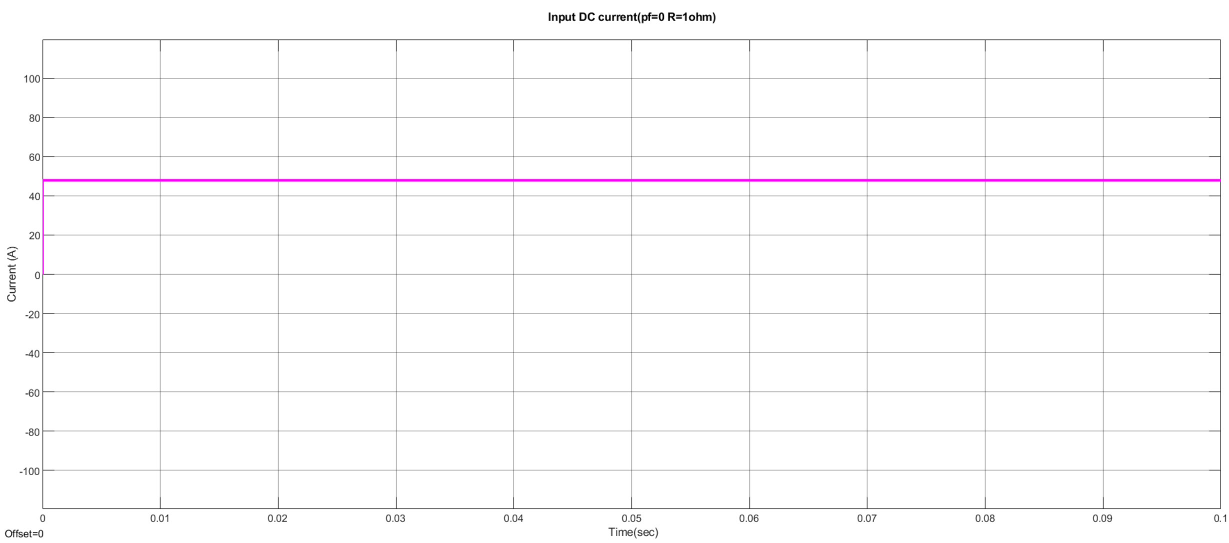

Figure 18: DC current for phase angle 0

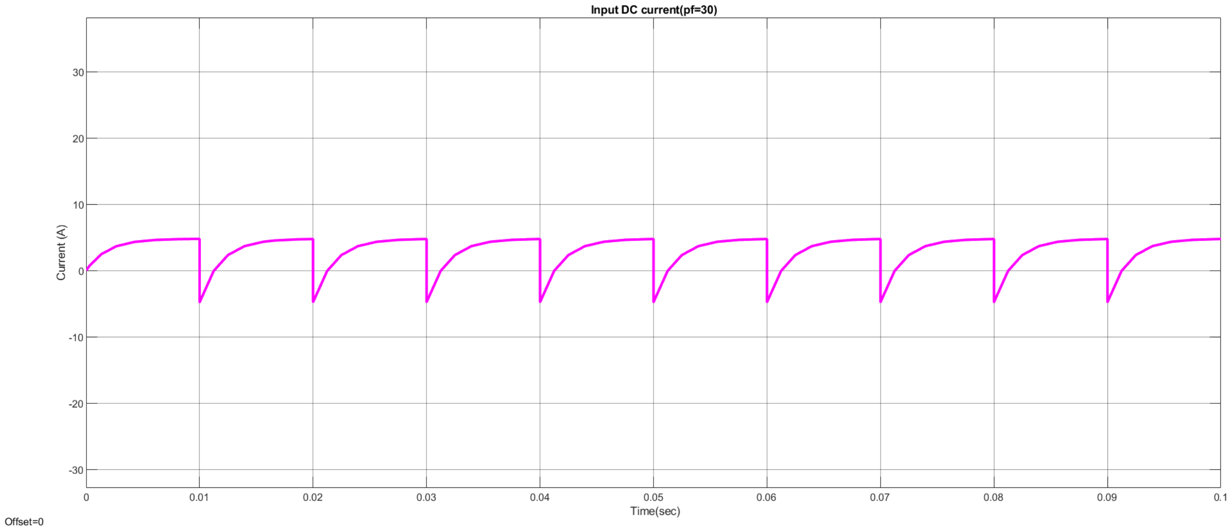

Figure 19: DC current for phase angle 30

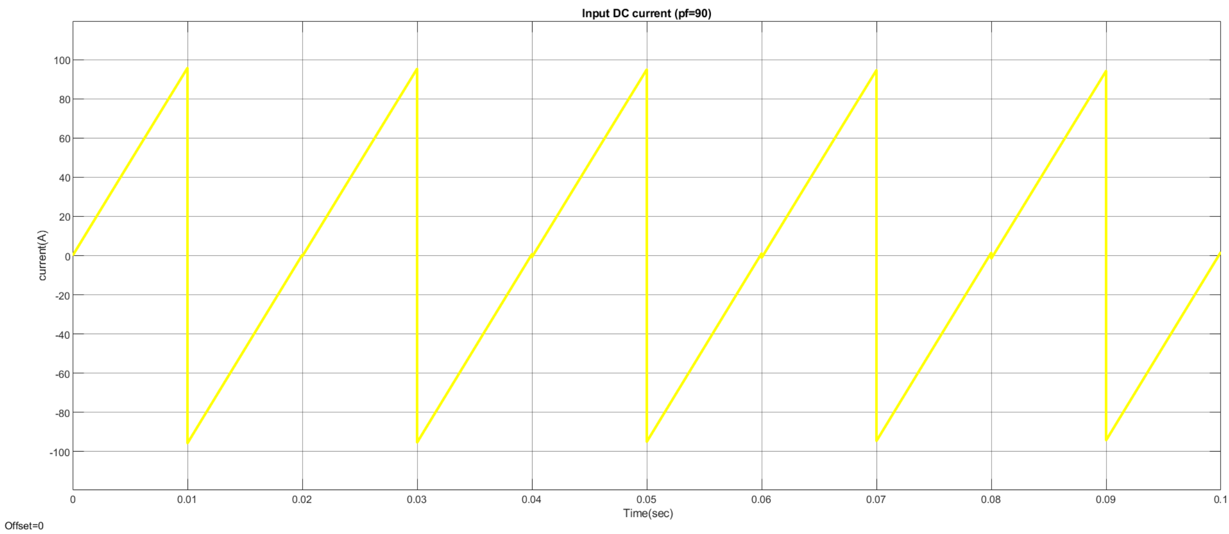

Figure 20: DC current for phase angle 90

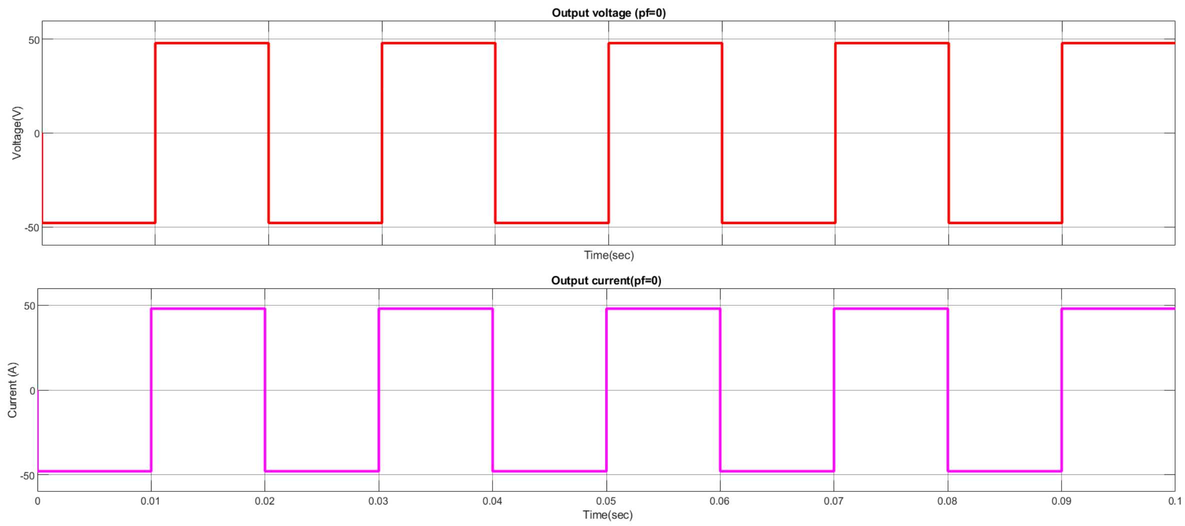

Figure 21: output current and voltage for phase angle 0

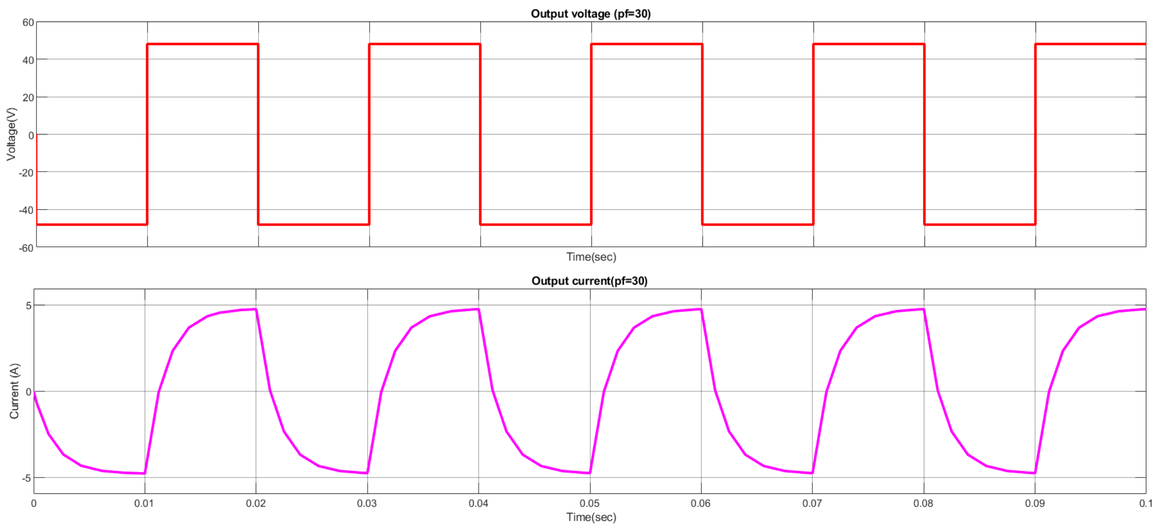

Figure 22: output current and voltage for phase angle 30

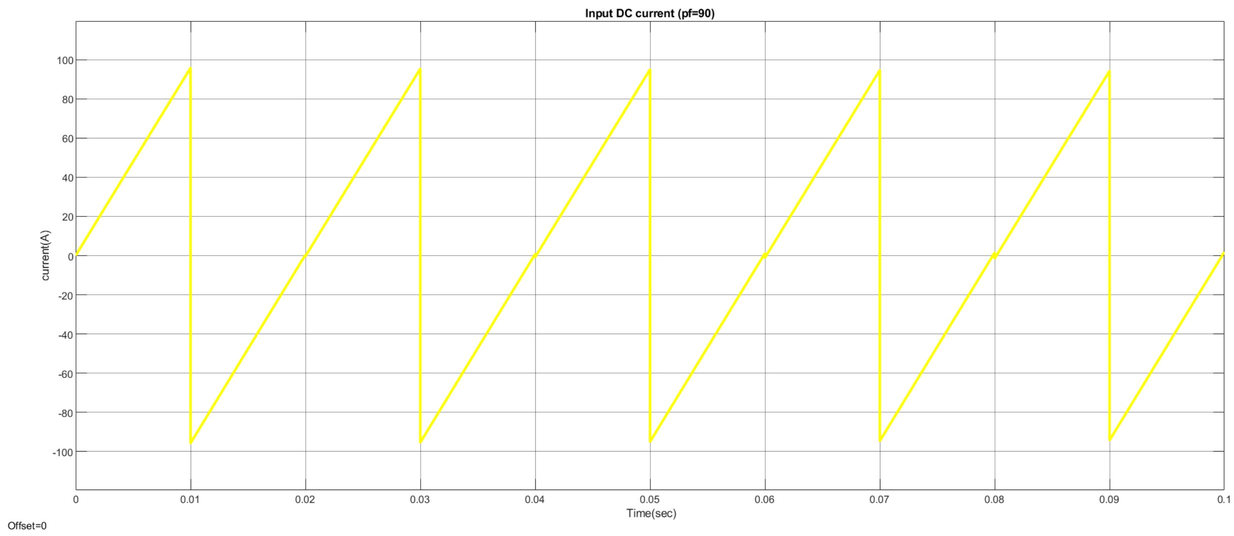

Figure 23: output current and voltage for phase angle 90

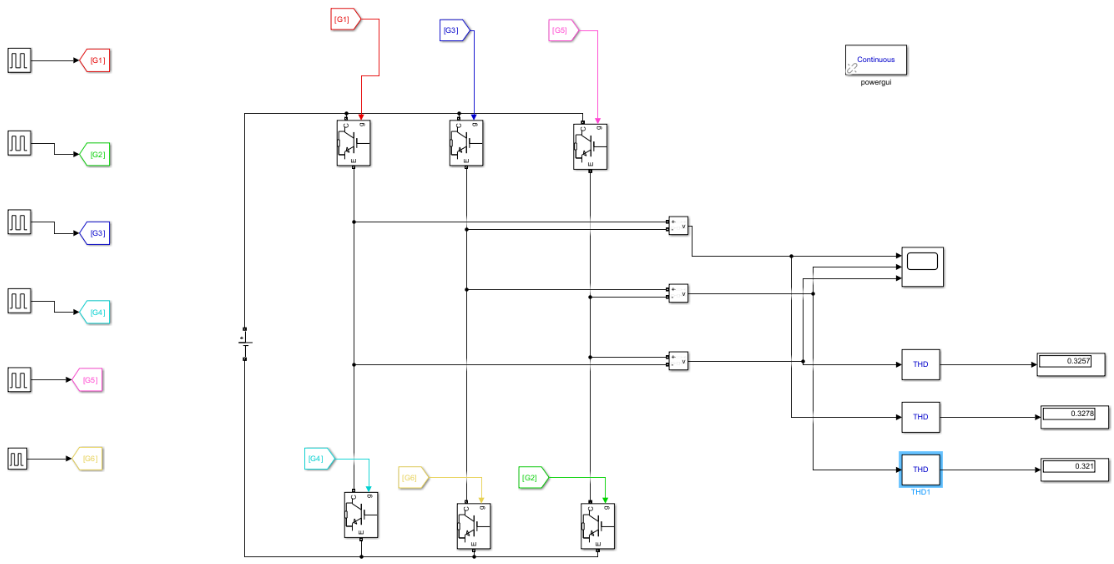

Figure 24: Simulation for 3p line voltages

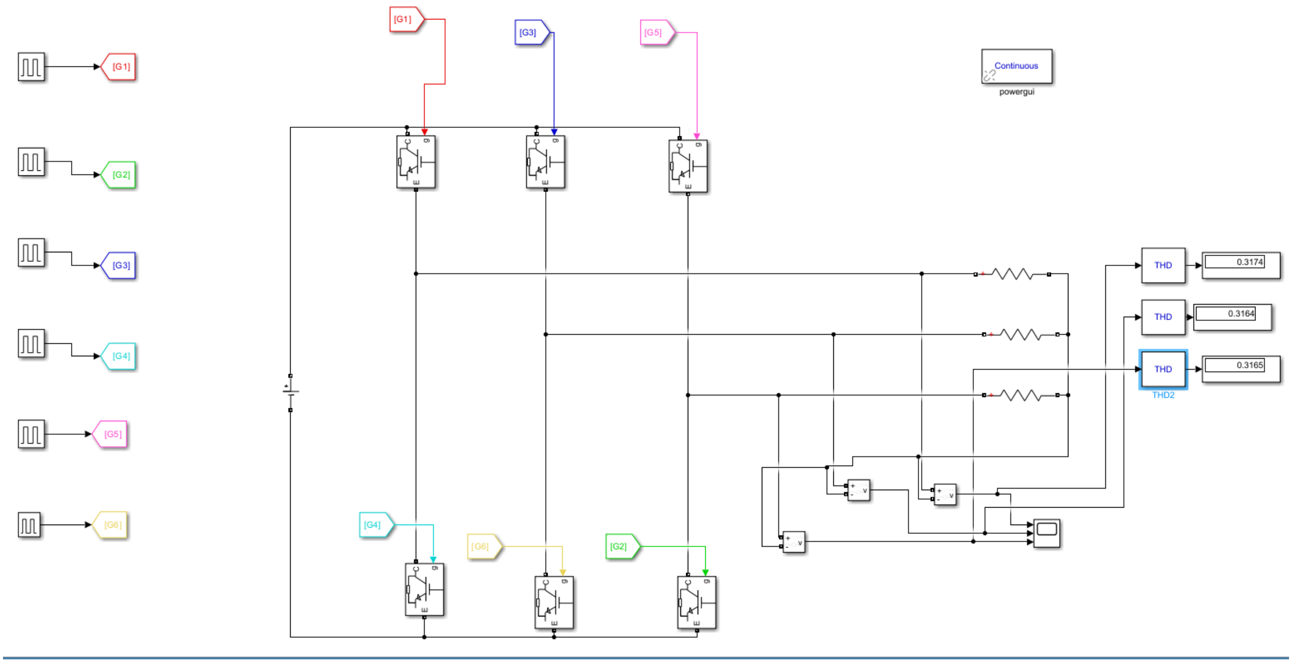

Figure 25: Simulation for 3p Phase Voltages

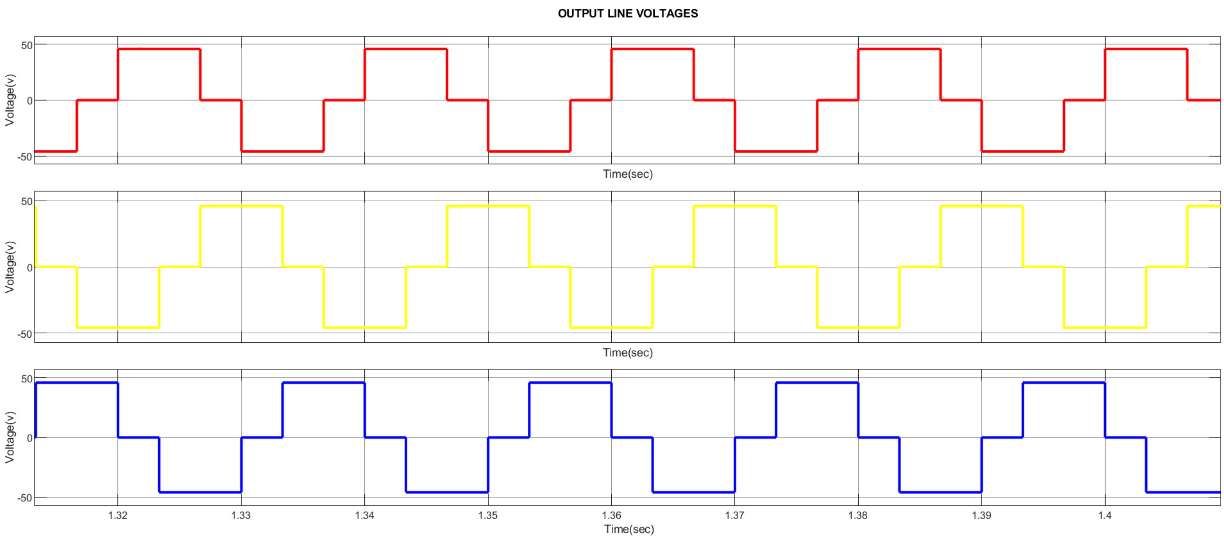

Figure 26: output Line Voltage for 3p Inverter

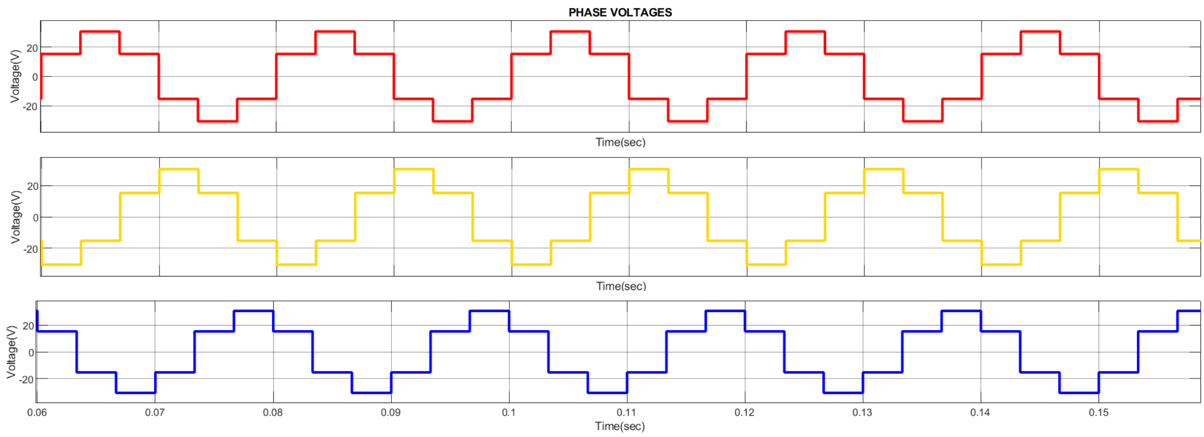

Figure 27: output Phase Voltage for 3p Inverter

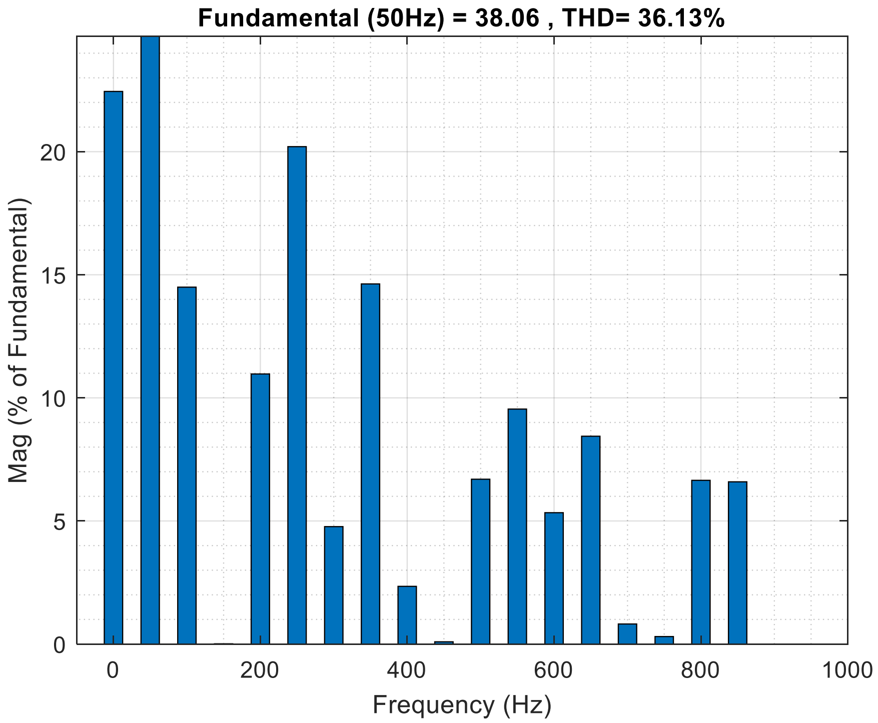

Figure 28: THD for Line Voltage in 3p Inverter

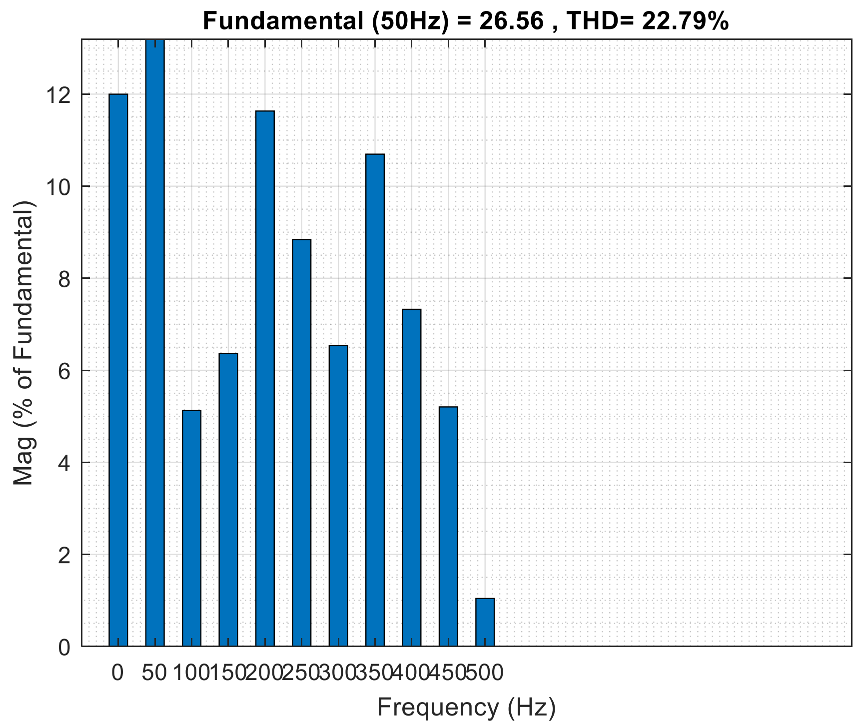

Figure 29: THD for Phase Voltage in 3p Inverter

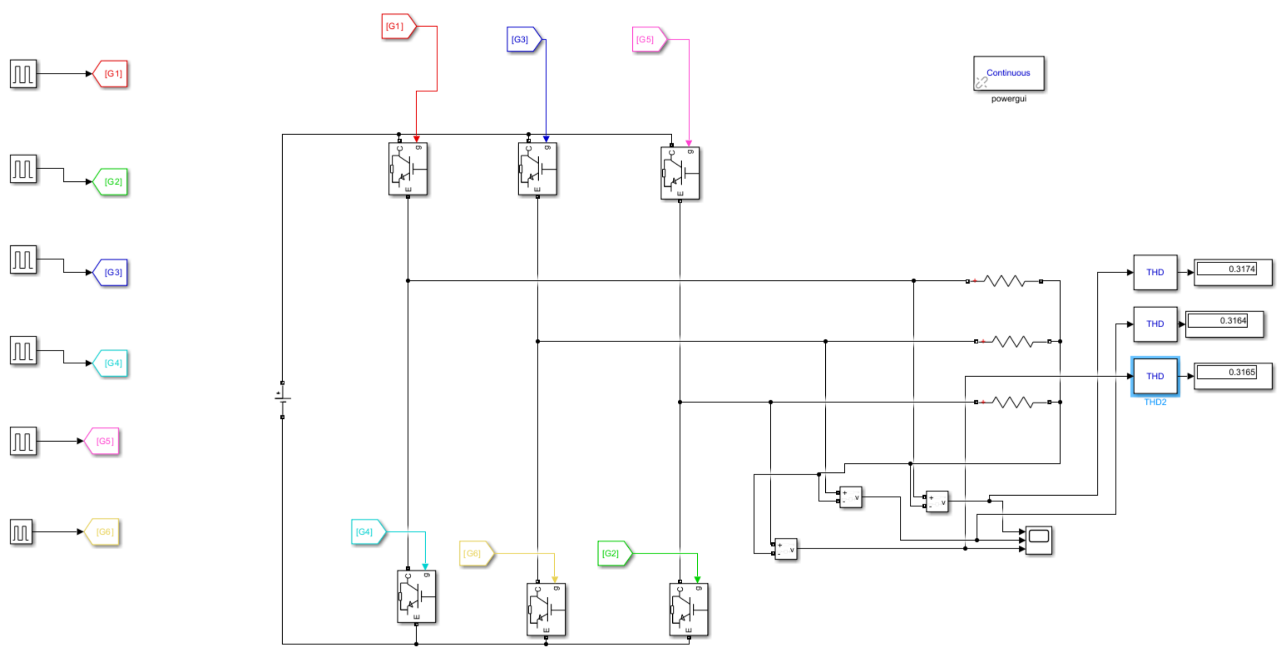

Figure 30: Simulation of Three Phase VSI using SPWM

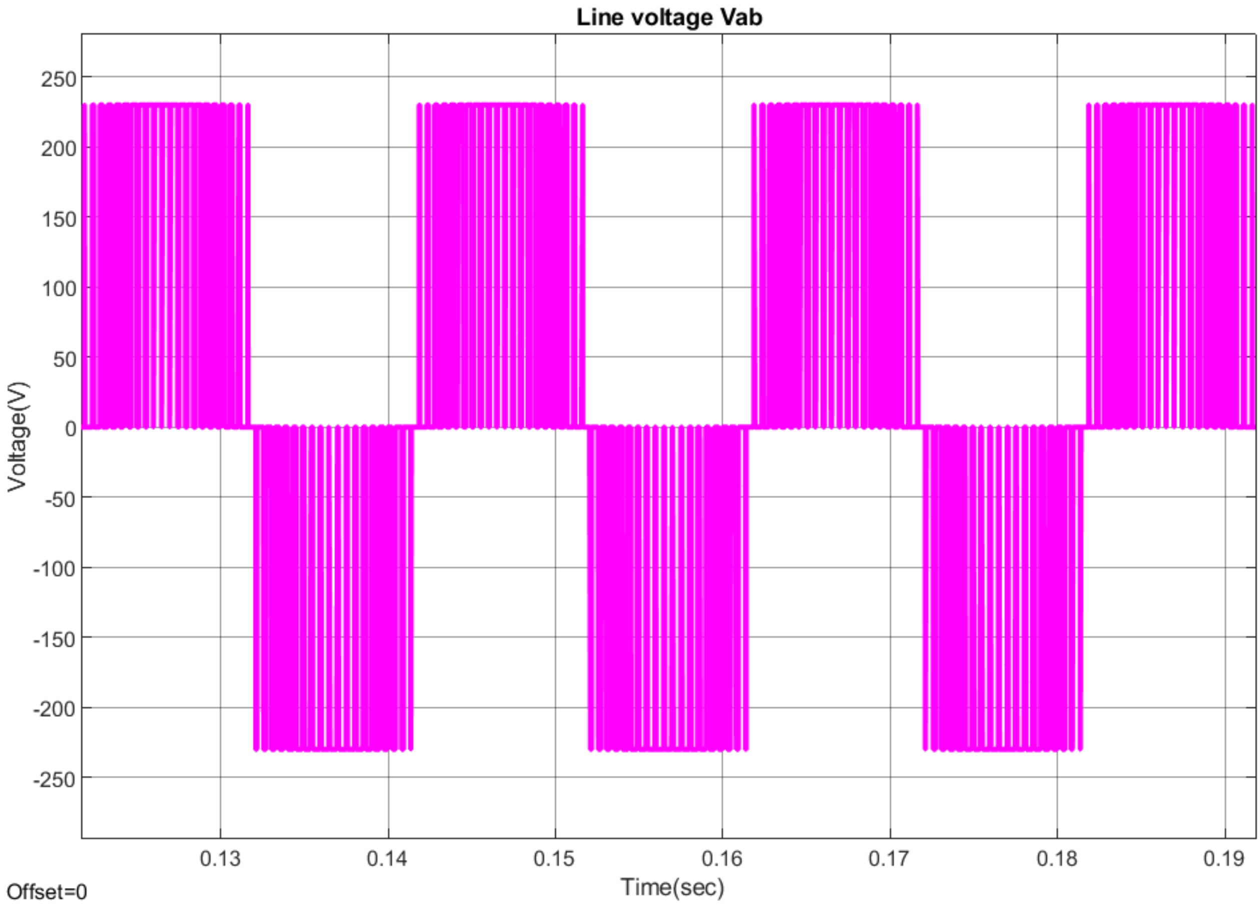

Figure 31: Line Voltage v_{AB}

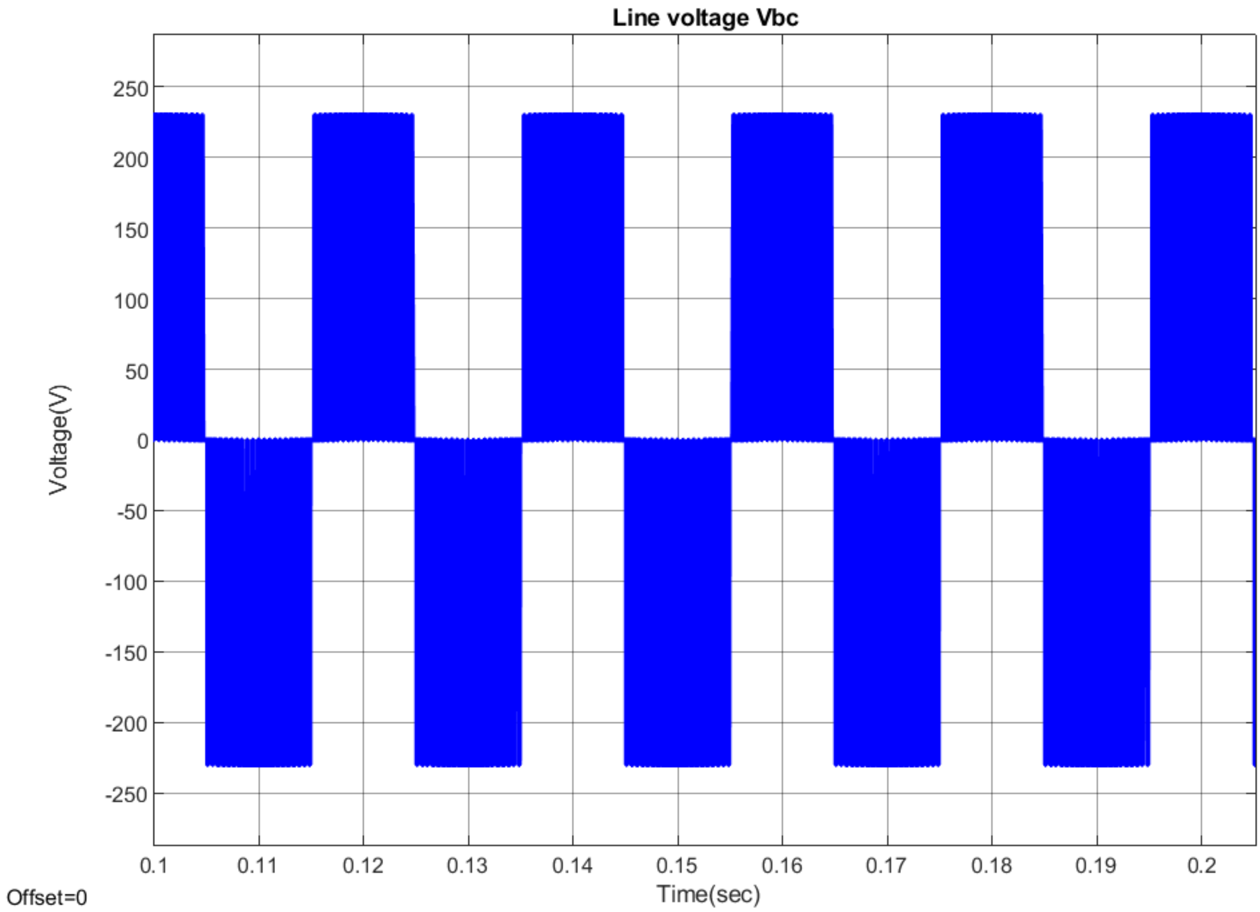

Figure 32: Line Voltage v_{BC}

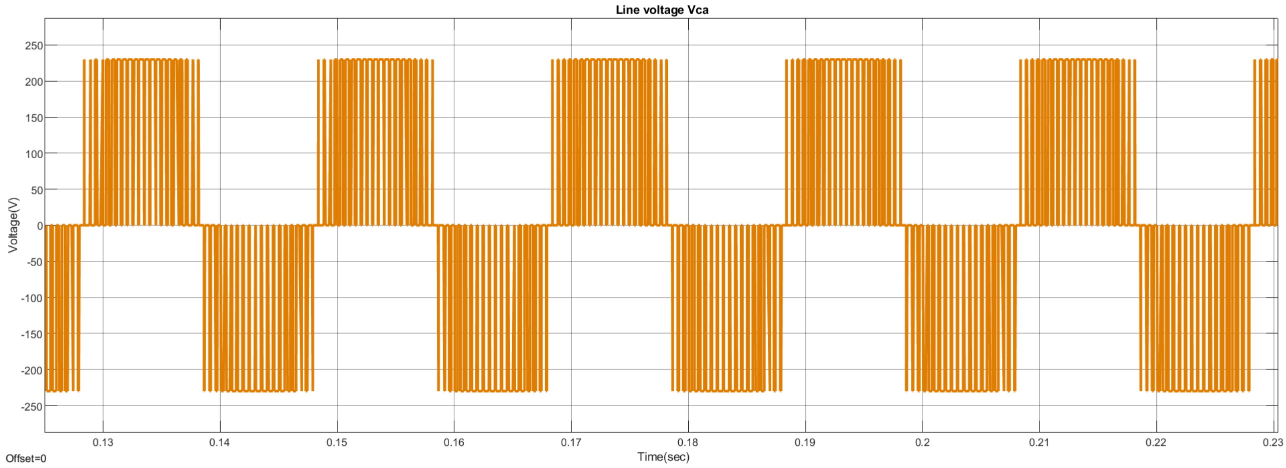

Figure 33: Line Voltage v_{CA}

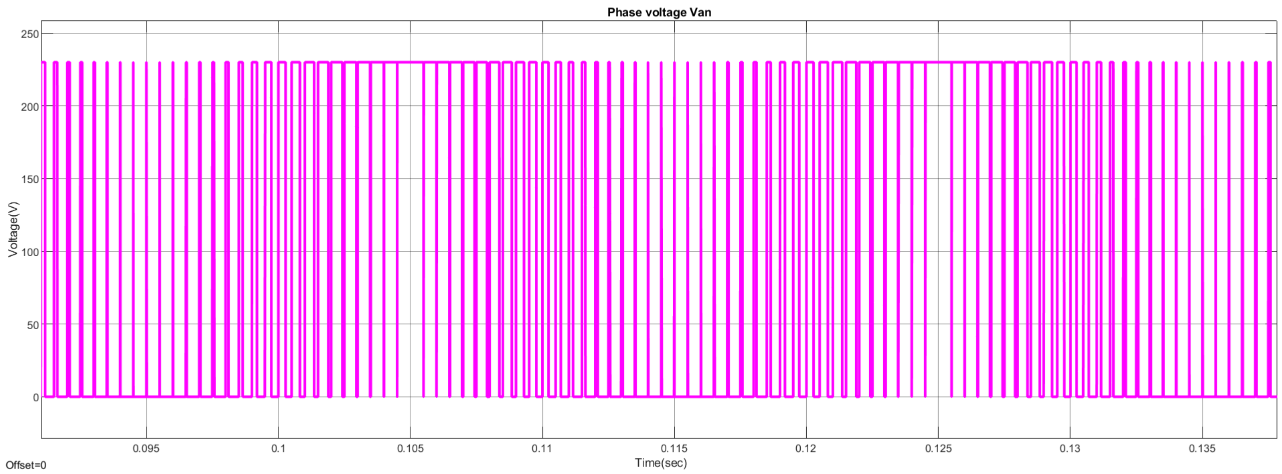

Figure 34: Phase Voltage v_{AN}

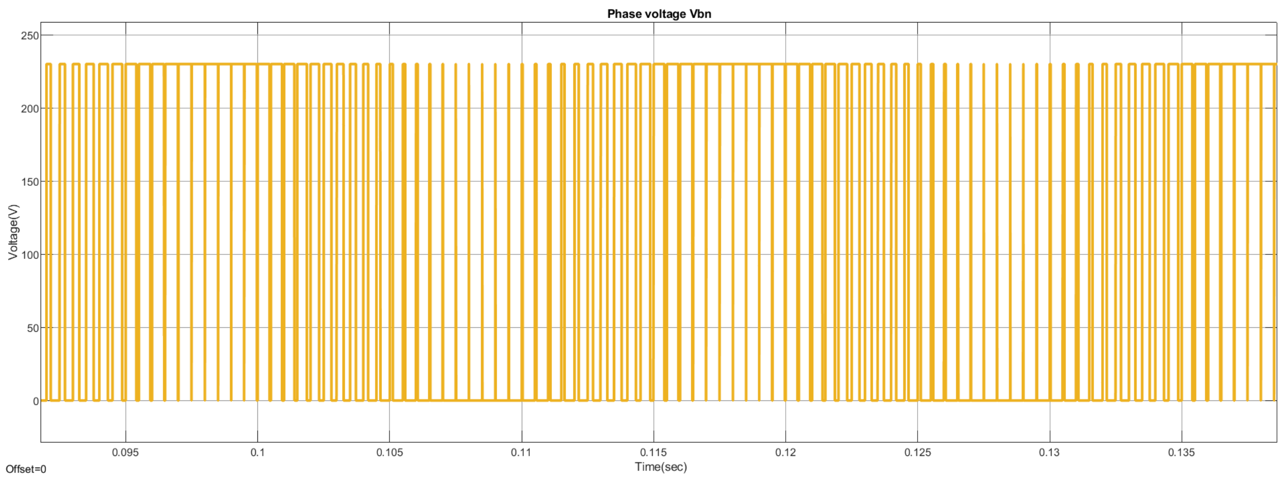

Figure 35: Phase Voltage v_{BN}

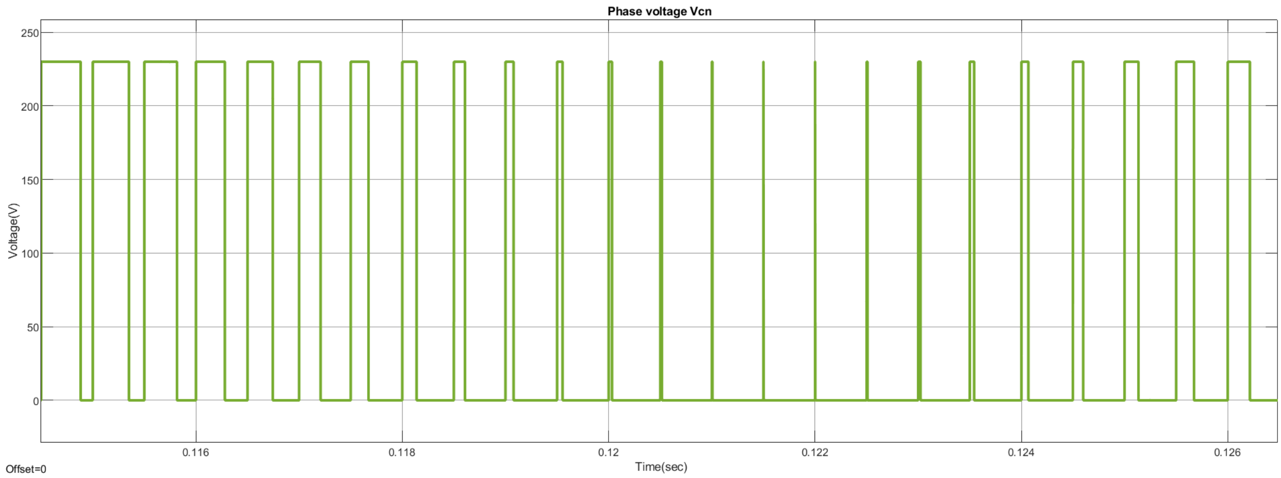

Figure 36: Phase Voltage v_{CN}

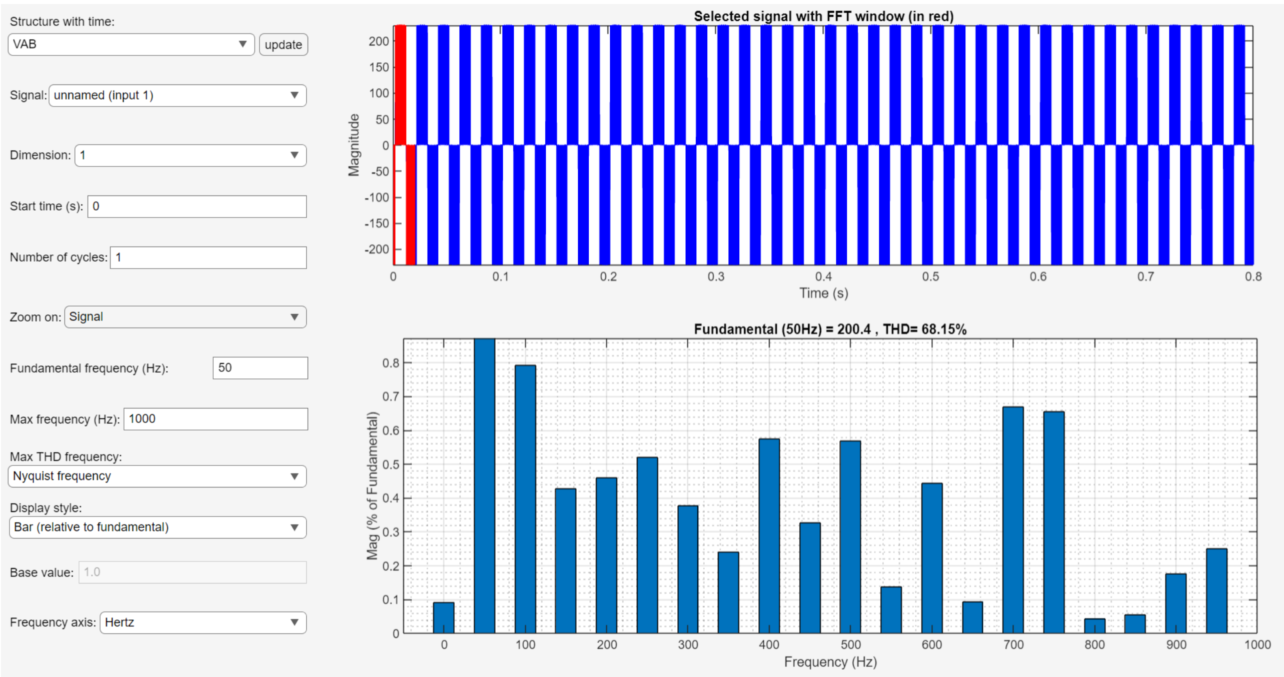

Figure 37: THD v_{AB}

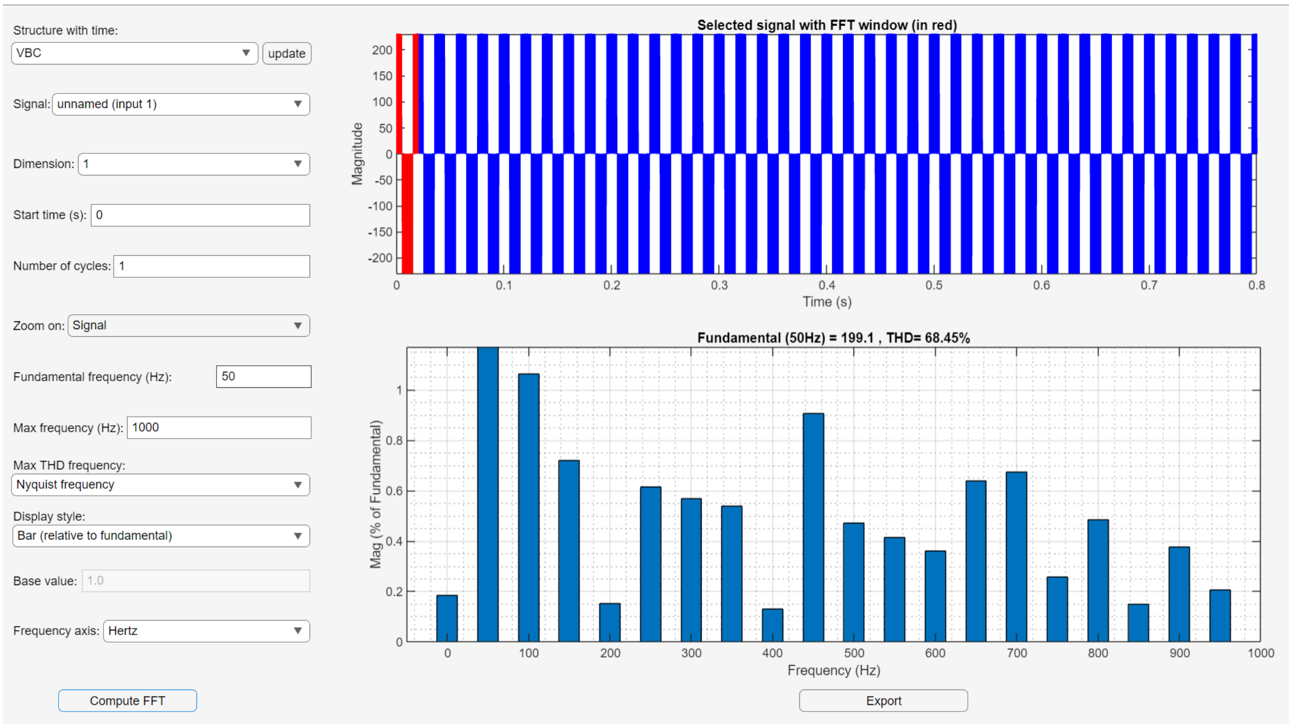

Figure 38: THD v_{BC}

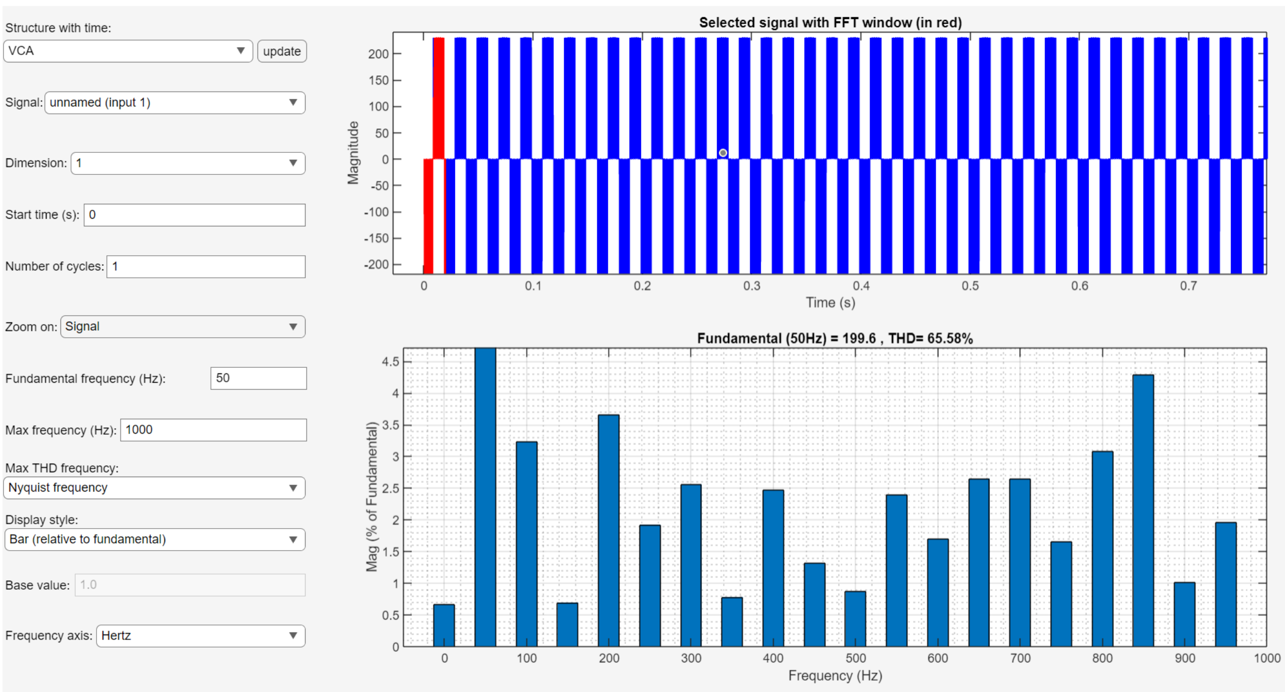

Figure 39: THD v_{CA}