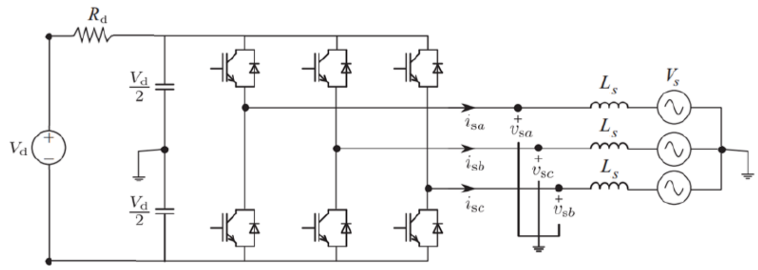
Simulate a three-phase DC/AC converter with SPWM
Data:
Rd = 0.1 ohm
Vs = 1200 V peak phase-to-phase
C = 1mF
Grid freq = 50Hz
Carrier Freq = 30*50Hz
Ls = 10mH/7,8 ohms



a) Build the circuit (based on previous week lab), adding protection against dead time. Without generators at the output, only the load.
b) Tune Vdc such that the output voltage at M=0.8 is equal to Vgrid
c) Create a chart of Ma vs Vo(L-L and L-N)

Question 1: Build the circuit based on previous week lab adding protection against dead time. Without generators at the output, only the load.

Answer 1:

Sinusoidal Pulse Width Modulation (SPWM) - technique for generating AC-like signals from a DC source using a series of high-frequency pulses. The pulse widths are modulated based on a sinusoidal reference signal to approximate an AC waveform. It is widely used in DC/AC inverters for applications such as motor drives and renewable energy systems.

Key components of SPWM:

1. **Reference Sine Wave**: Defines the desired AC output voltage waveform (50 Hz sinusoidal wave)
2. **Carrier Wave**: Typically, a high-frequency triangular wave. Determines the switching frequency of the inverter (10–20 kHz).
3. **Comparator**: Compares the reference sine wave with the carrier wave.

Advantages of SPWM:

1. Smooth control of output voltage and frequency.
2. Reduced harmonics in the output waveform.
3. Simple implementation in both analog and digital systems.

Dead – Time Protection - Dead time refers to a small delay added between the switching of complementary transistors in the same inverter leg. Its purpose is to prevent a condition where both transistors in a leg are ON simultaneously, causing a short circuit across the DC bus. The upper and lower transistors (S1 and S2) are complementary (one should be ON while the other is OFF). We are implementing dead time protection with NOT block.

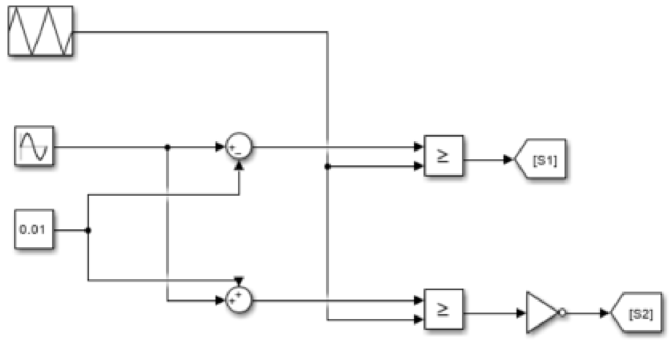


Figure 1. PWM controller with Dead Time Protection (one phase)

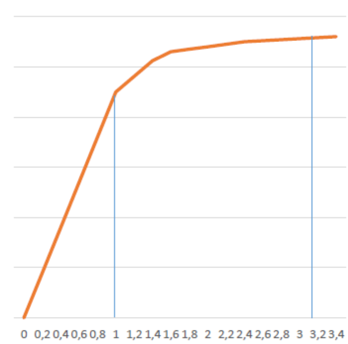
Question 2: Tune Vdc such that the output voltage at M= 0 8 is equal to Vgrid.

Answer 2:

The modulation index (M) is a key parameter in Pulse Width Modulation (PWM) that describes the relationship between the amplitude of the reference signal (sinusoidal waveform) and the carrier signal (triangular waveform). It determines the output waveform's amplitude.

For a **DC/AC inverter**, the modulation index directly affects the **output AC voltage** in relation to the **DC bus voltage**. Specifically, the modulation index M is used in the following equation for the peak phase voltage:

- $m_a \leq 1$: linear range modulation
  - $V_{LN}(peak) = m_a * \frac{V_s}{2}$
  - $V_{LL,rms} = m_a * \frac{\sqrt{3}}{\sqrt{2}} * \frac{V_s}{2}$ $(with\ a\ maximum\ of\ 0.612V inside\ the\ linear\ region)$
- $m_a > 1$: overmodulation range
  - The number of harmonics increases
- $m_a > 3.24$: square wave range
  - Square waveform



$$V_{source} = \frac{2}{\sqrt{3}} \cdot \frac{1}{m_a} \cdot V_{LL(peak)} = 1732\ V$$

I have succeeded with 2732 V.

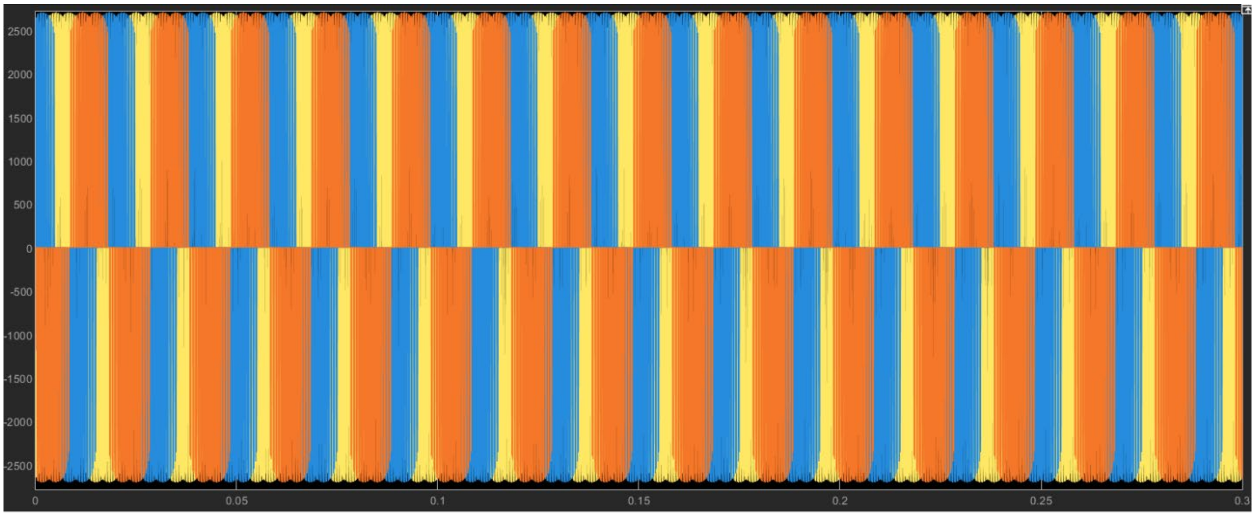


Figure 2. Output Voltage Before Filter

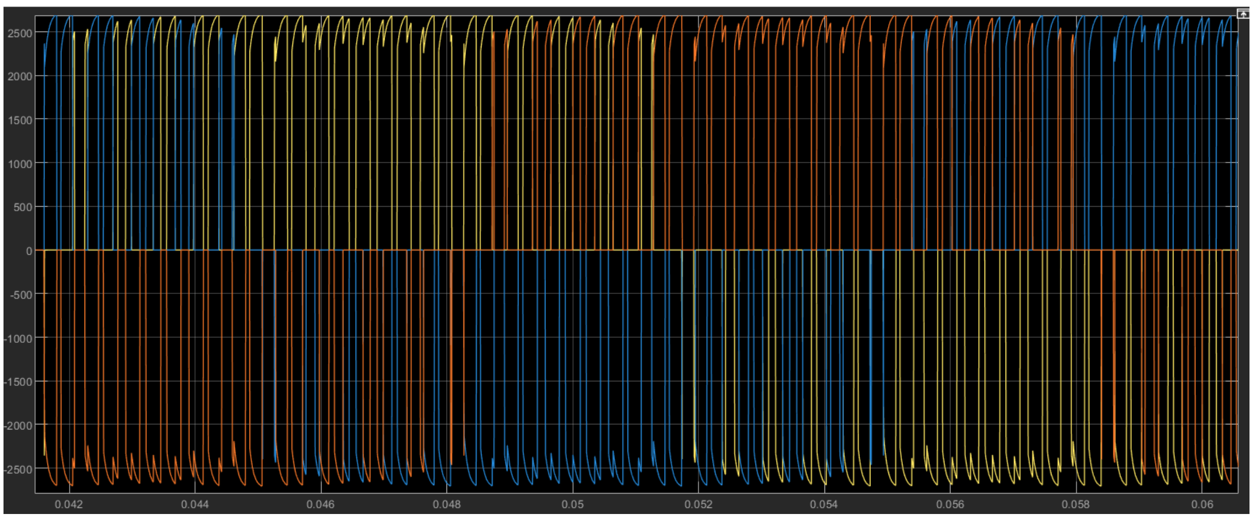


Figure 3. Output Voltage Before Filter

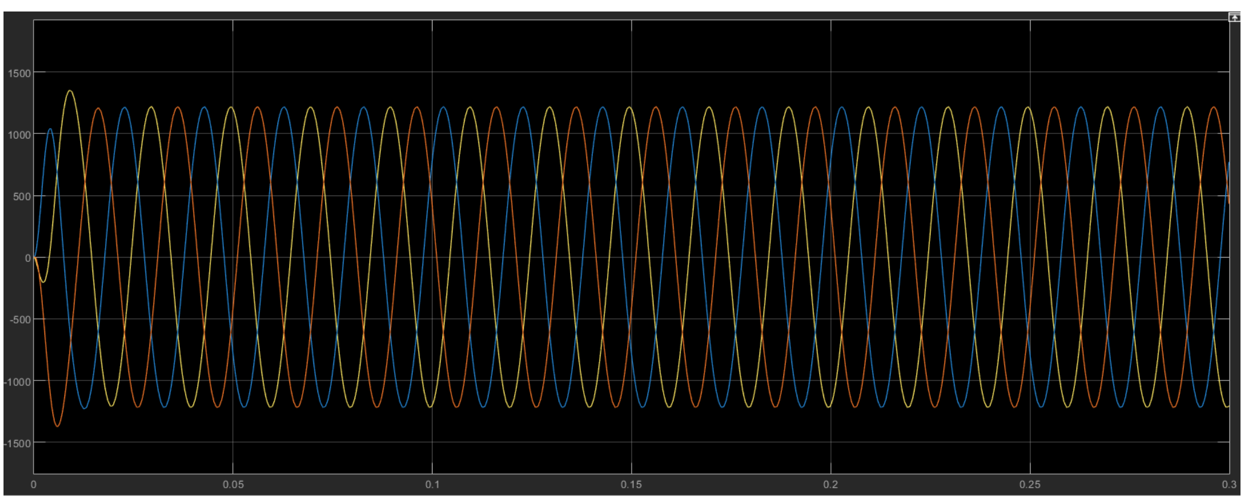


Figure 4. Output Voltage after Filter

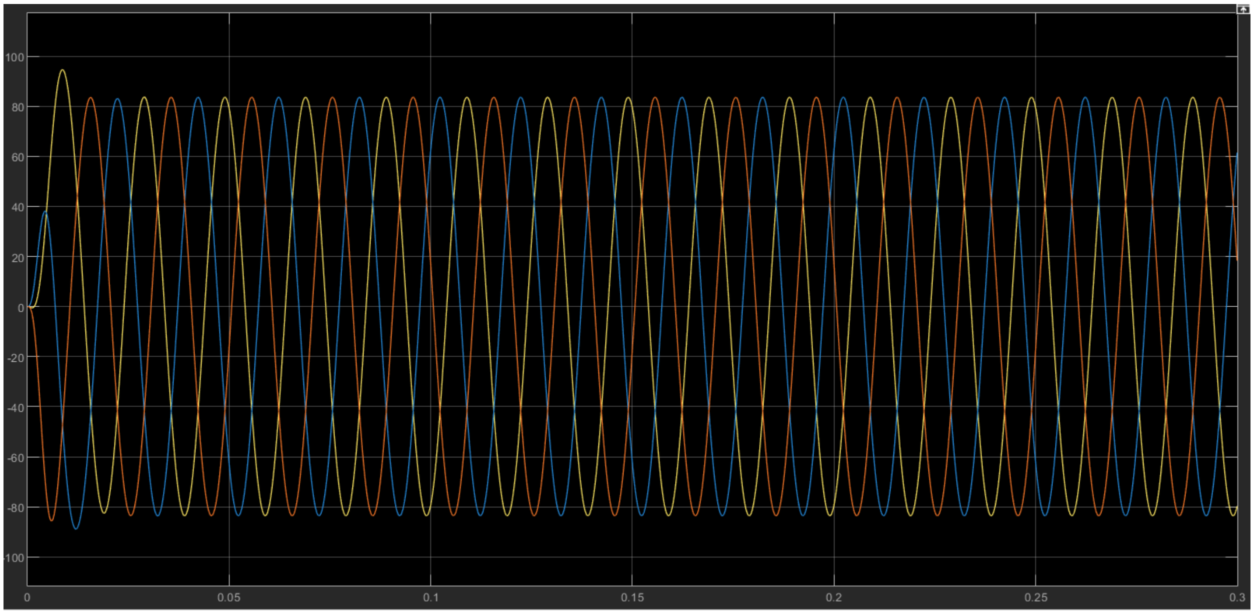


Figure 5. Output Current After Filter

Question 3: Create a chart of Ma vs Vo (L-L and L-N)

Answer 3:

```
% Constants
V_dc = 2742;  % DC voltage in volts
Ma = linspace(0, 1, 100);  % Modulation index from 0 to 1

% Line-to-Neutral Voltage
V_ln = Ma * (V_dc / 2);

% Line-to-Line Voltage
V_ll = Ma * (V_dc / 2) * sqrt(3);

% Create the plot
figure;
hold on;
```

Figure 6. Matlab Code

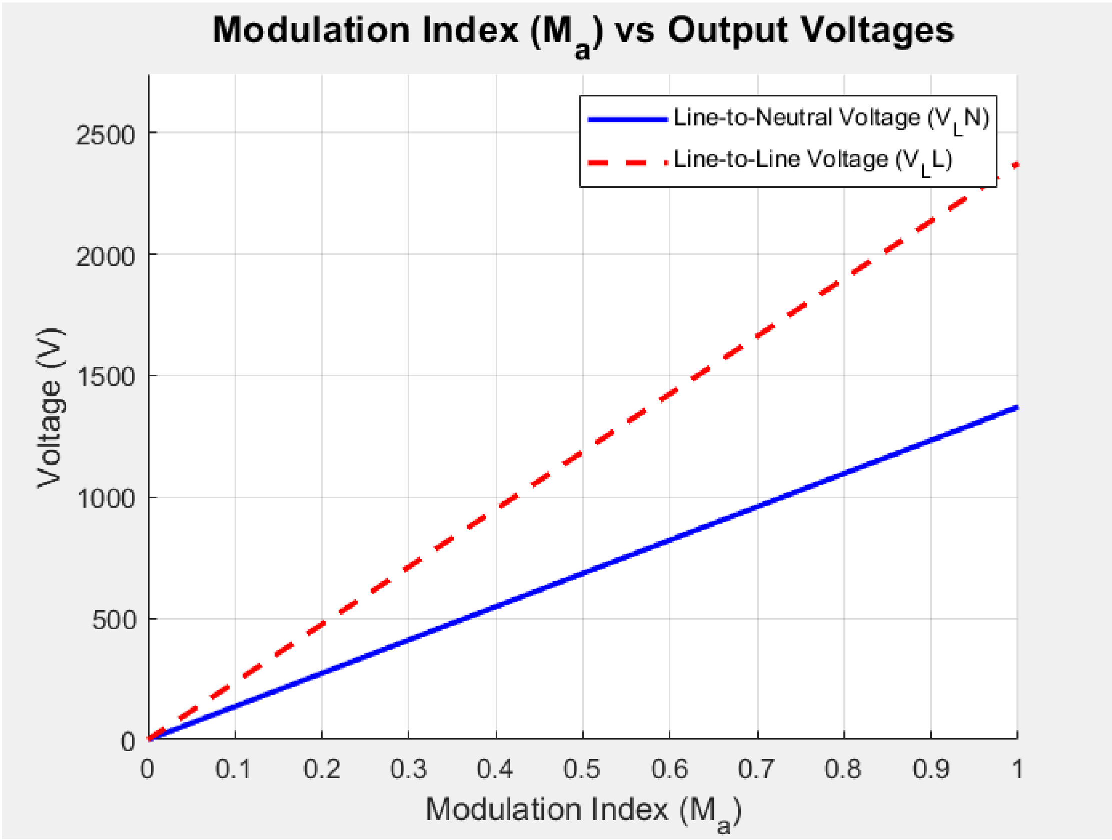


Figure 7. Modulation Index vs Output Voltage