EE171 Project: Single-phase SPWM Modulation Inverter

梁家伟

2019.06.11

Contents

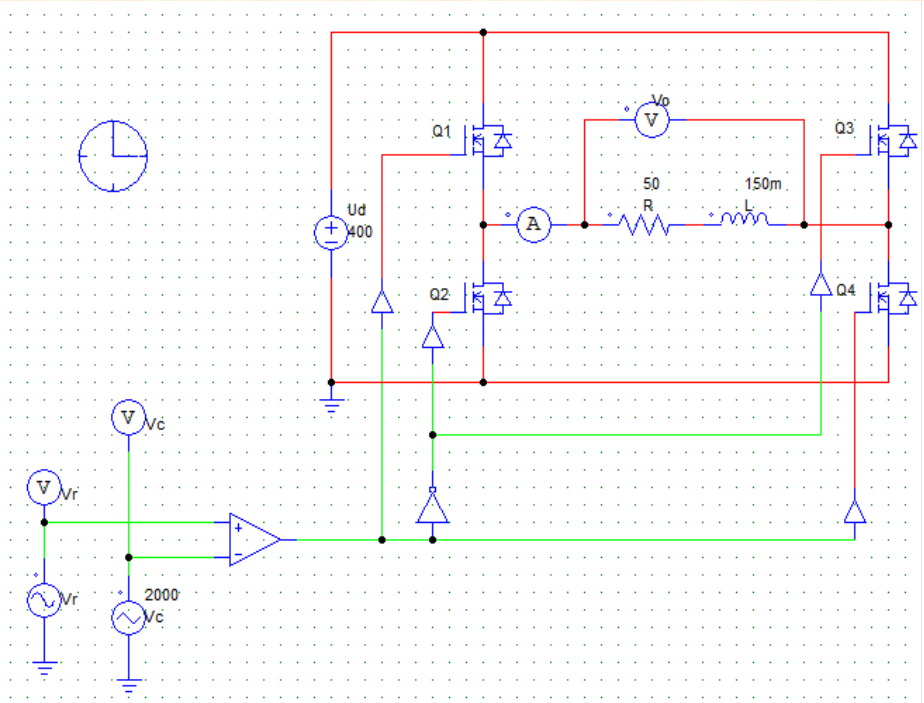
- Design an inverter using bipolar modulation.
- Design an inverter using unipolar modulation.
- Design an inverter to eliminate 5th and 7th order harmonics of Uo and present your results.
- Have a brief discussion or comparison about the simulation results.

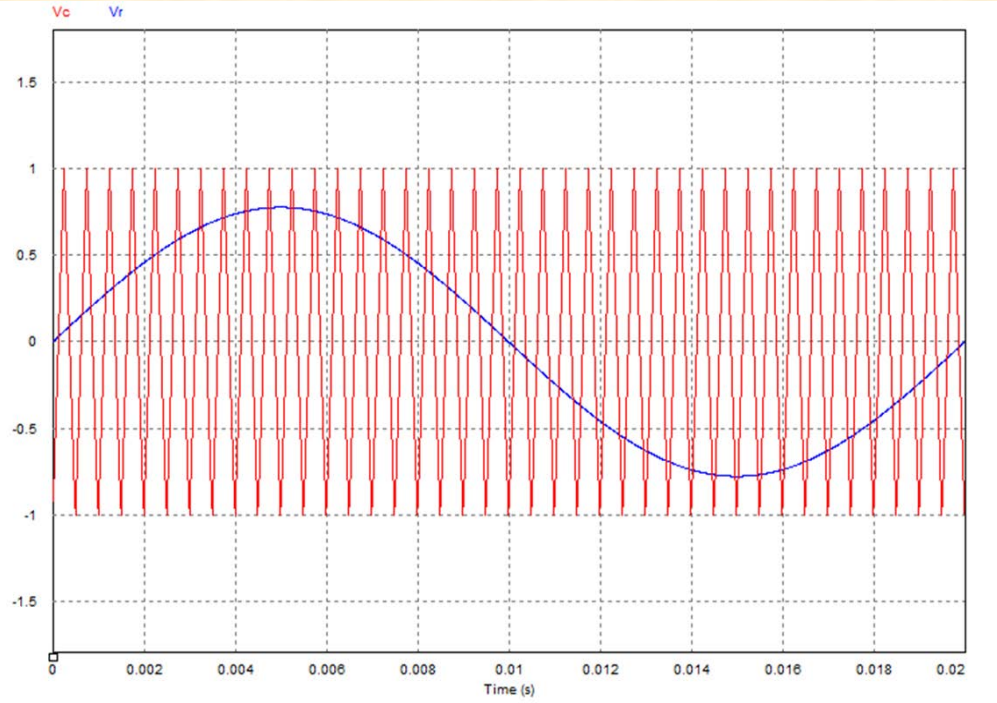
Parameter

Parameter	Value
DC input U_d	$400V$
Fundamental wave RMS $U_{o1,rms}$	$220V$
Modulation wave Frequency f_r	$50Hz$
Carrier wave Frequency f_c	$2000Hz$
Amplitude Modulation Index	$m_a = \frac{A_r}{A_c} = \frac{U_{o1}}{U_d} \approx 0.778$
Frequency Modulation Index	$m_f = \frac{f_c}{f_r} = \frac{2000}{50} = 40$

Bipolar PWM Simulation Model

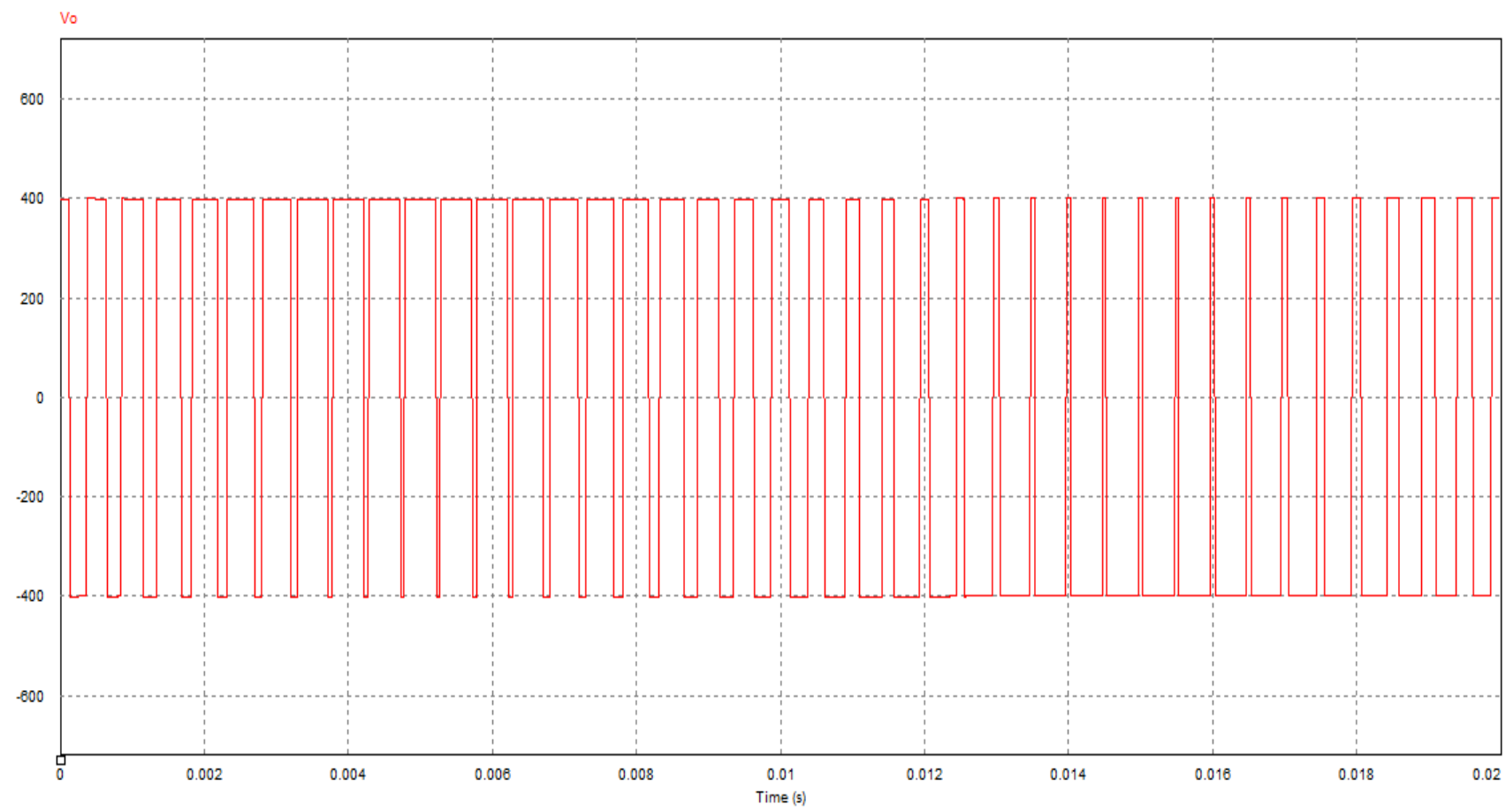
- $V_r > V_c$, turn on Q_1, Q_4 and turn off Q_2, Q_3.
- $V_r < V_c$, turn on Q_2, Q_3 and turn off Q_1, Q_4.





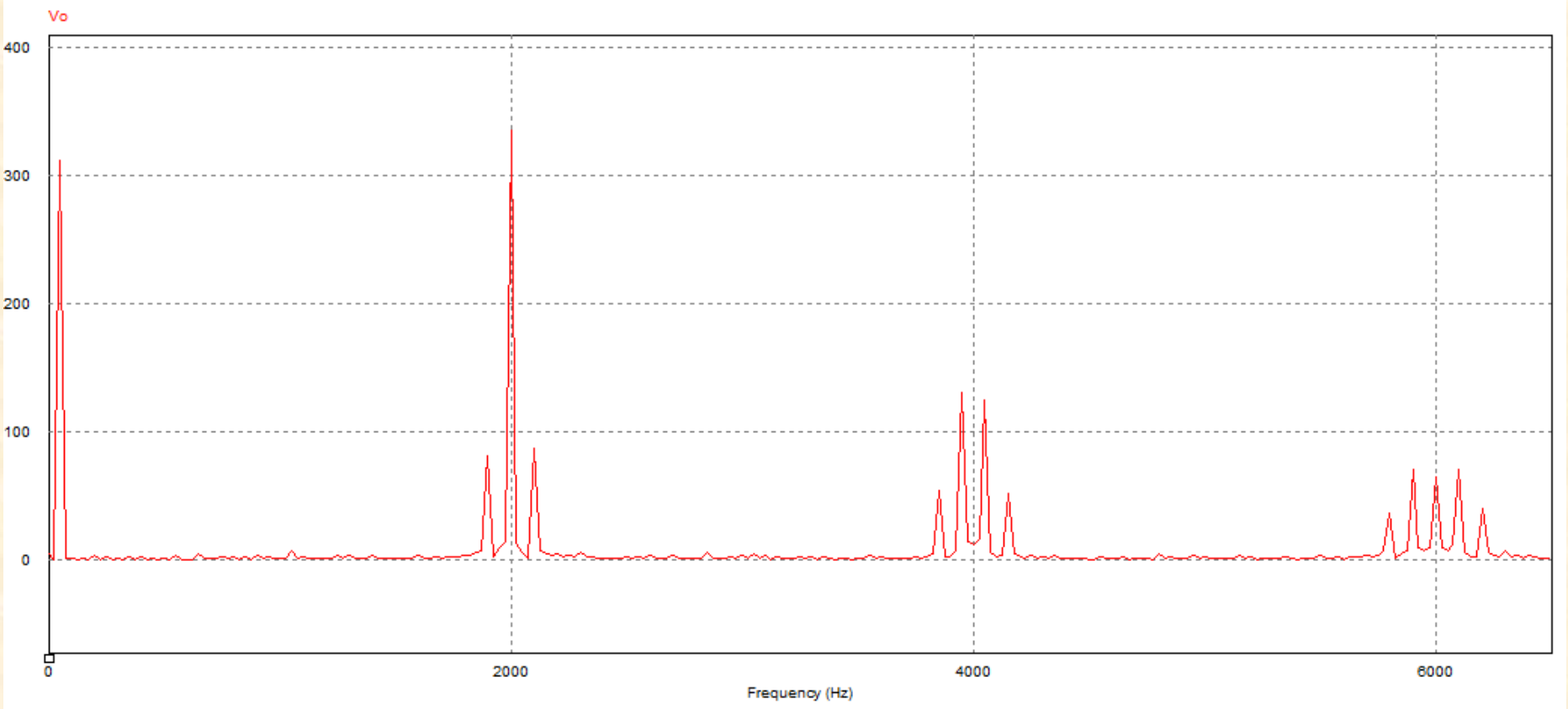
Bipolar PWM Simulation Results

- Output PWM wave



Bipolar PWM Simulation Results

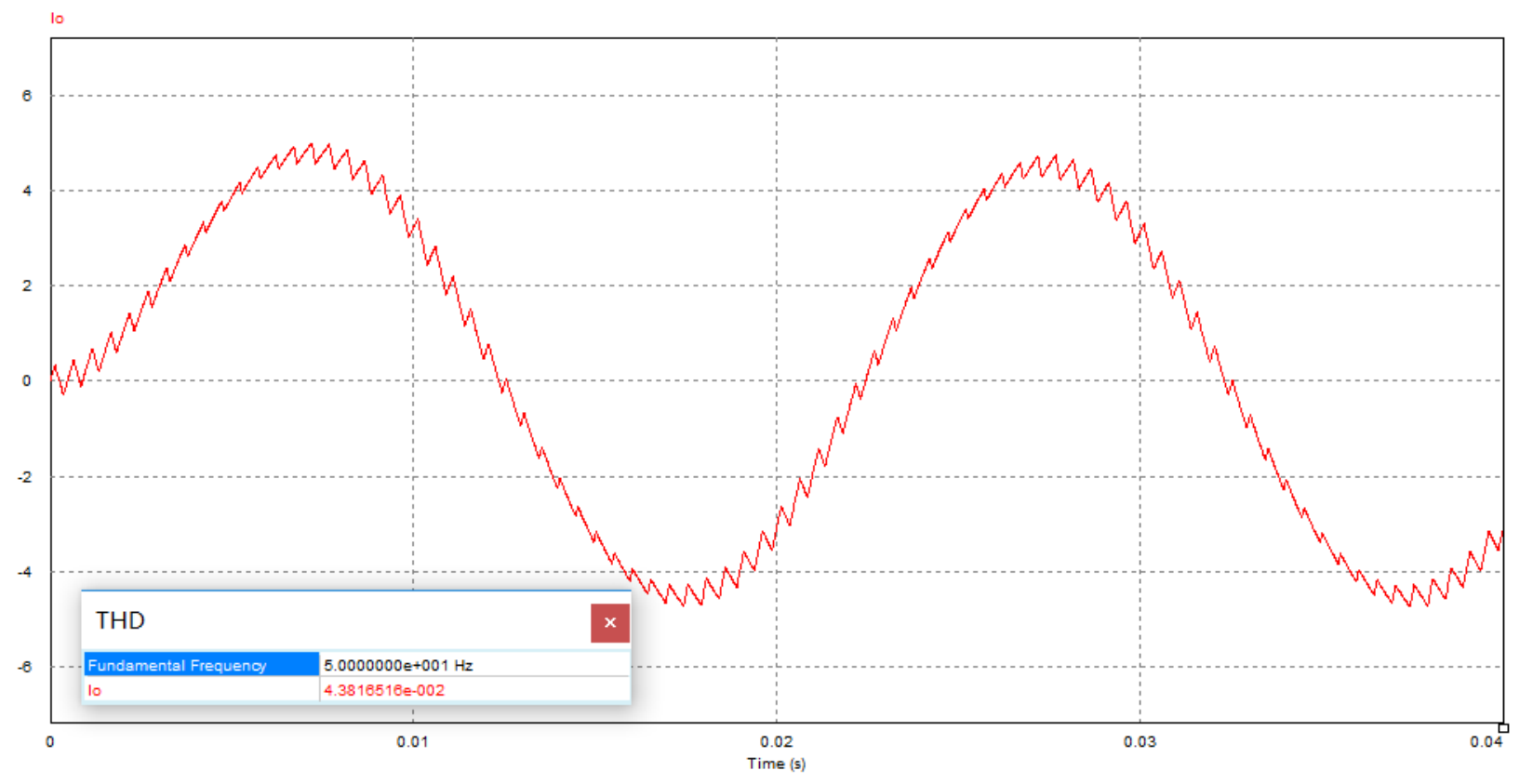
- FFT analysis



- $U_{o1} = 303V,\ RMS = \frac{303}{\sqrt{2}} \approx 214.25V$

Bipolar PWM Simulation Results

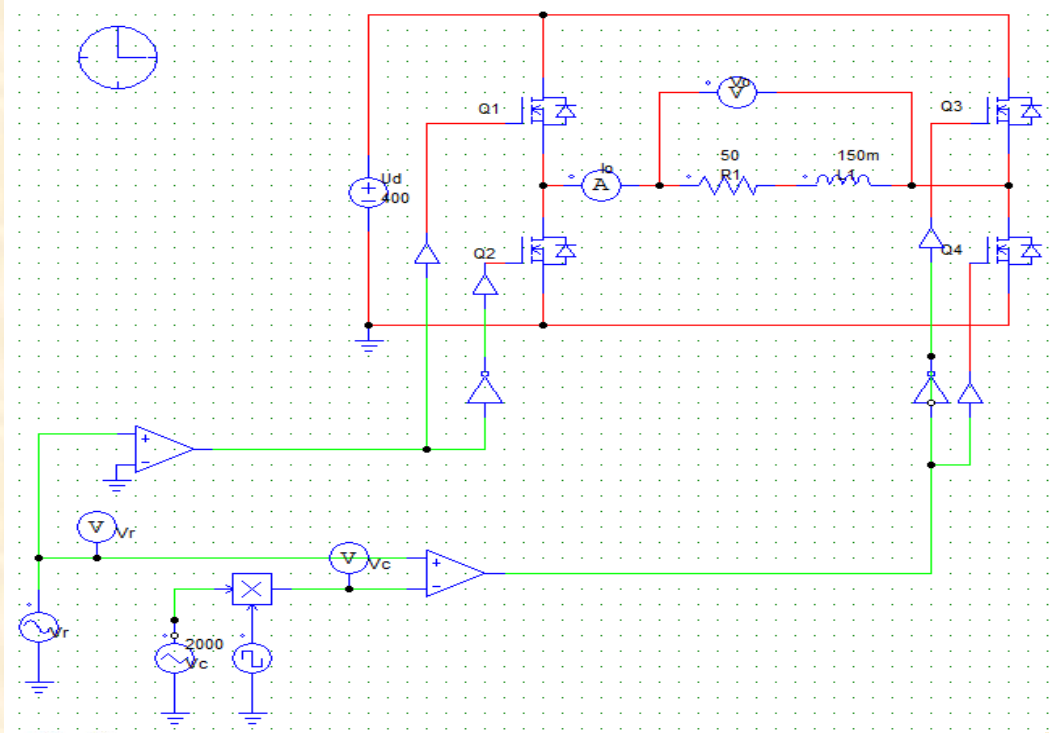
- Output current I_o

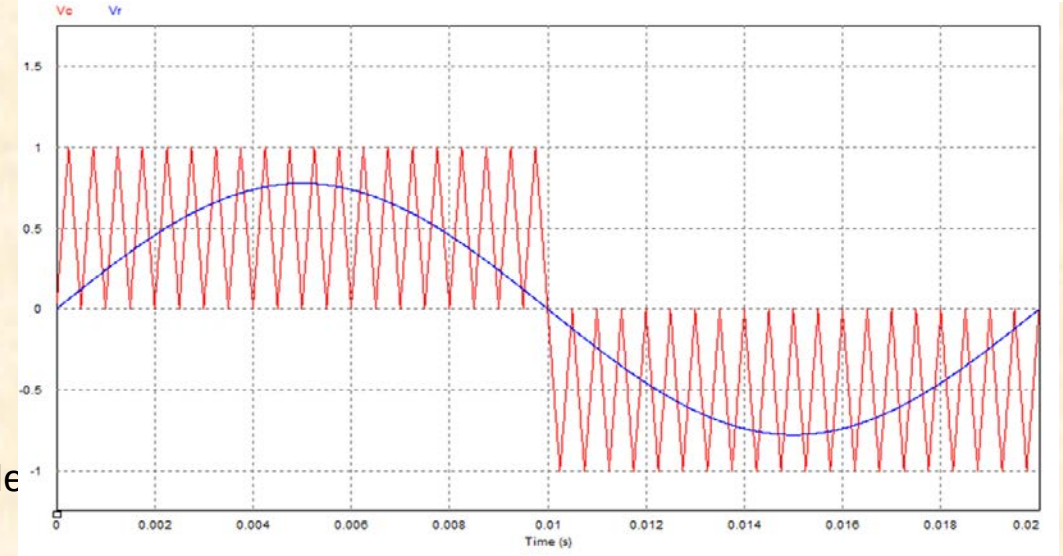


$THD = 4.38\%$

Unipolar PWM Simulation Model

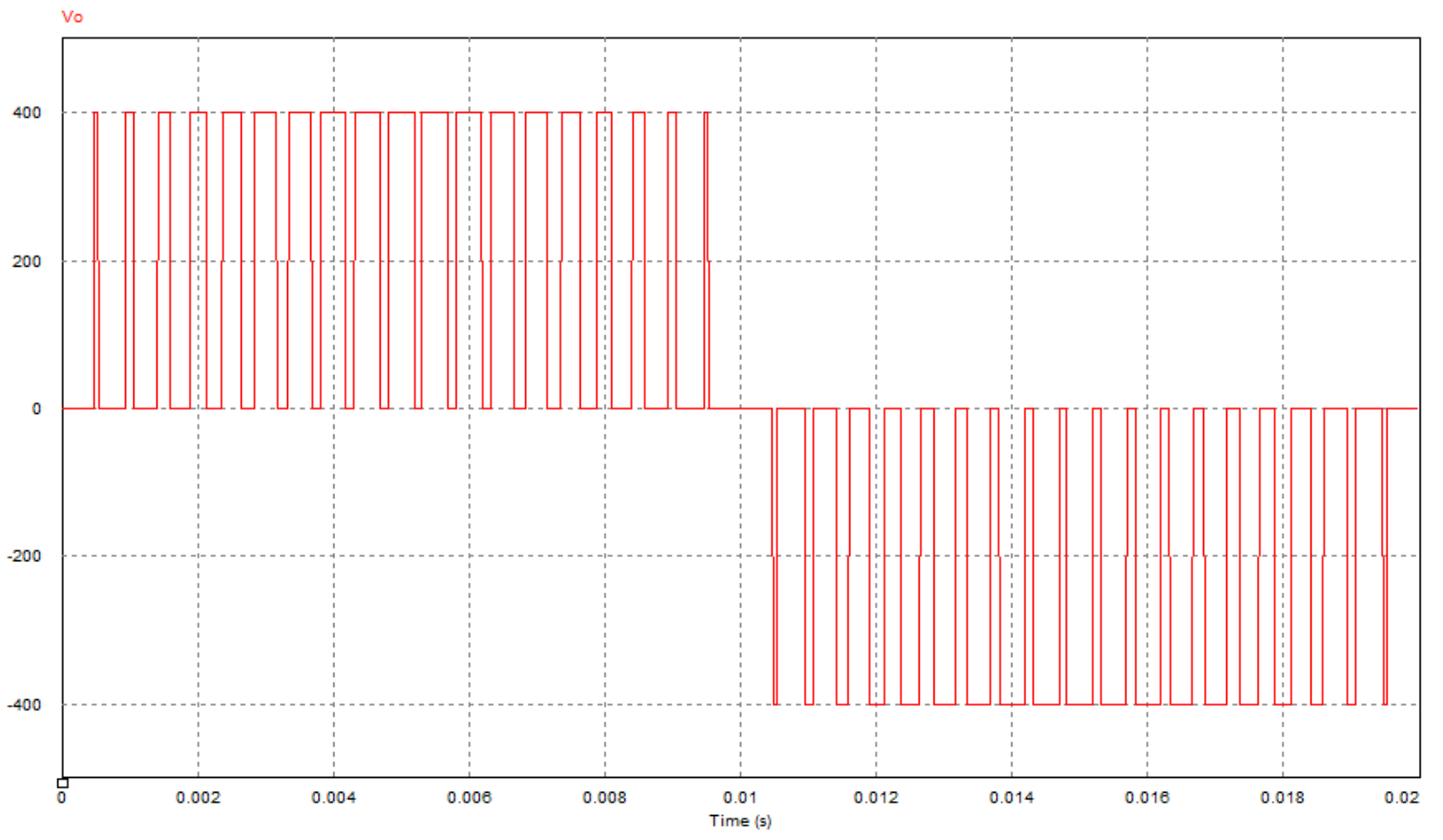
- $V_r > 0$, keep Q_1 on and Q_2 off.
  - When $V_r > V_c$, turn on Q_4 and turn off Q_3 , $U_0 = U_d$.
  - When $V_r < V_c$, turn on Q_3 and turn off Q_4 , $U_0 = 0$.
- $V_r < 0$, keep Q_2 on and Q_1 off.
  - When $V_r > V_c$, turn on Q_4 and turn off Q_3 , $U_0 = 0$.
  - When $V_r < V_c$, turn on Q_3 and turn off Q_4 , $U_0 = U_d$.





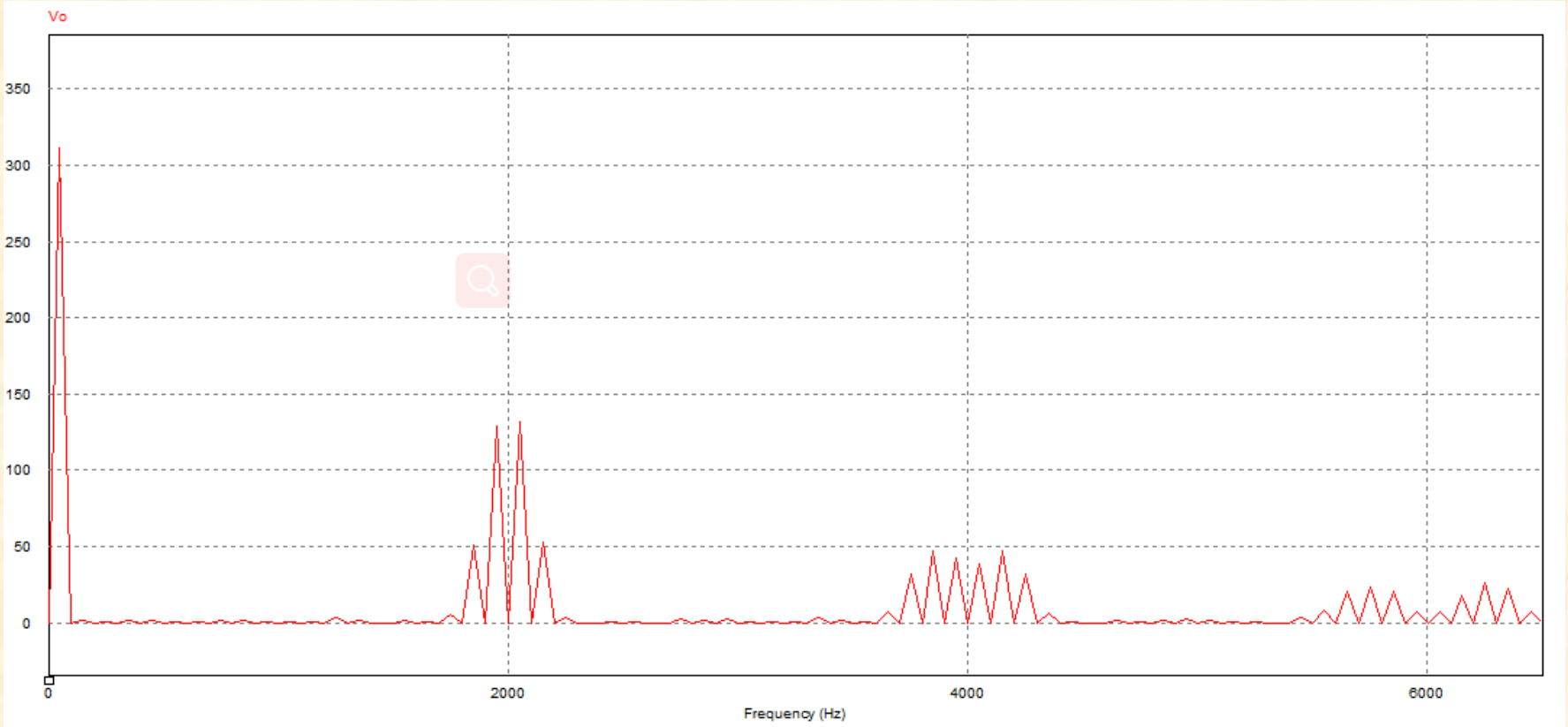
Unipolar PWM Simulation Results

- Output PWM wave



Unipolar PWM Simulation Results

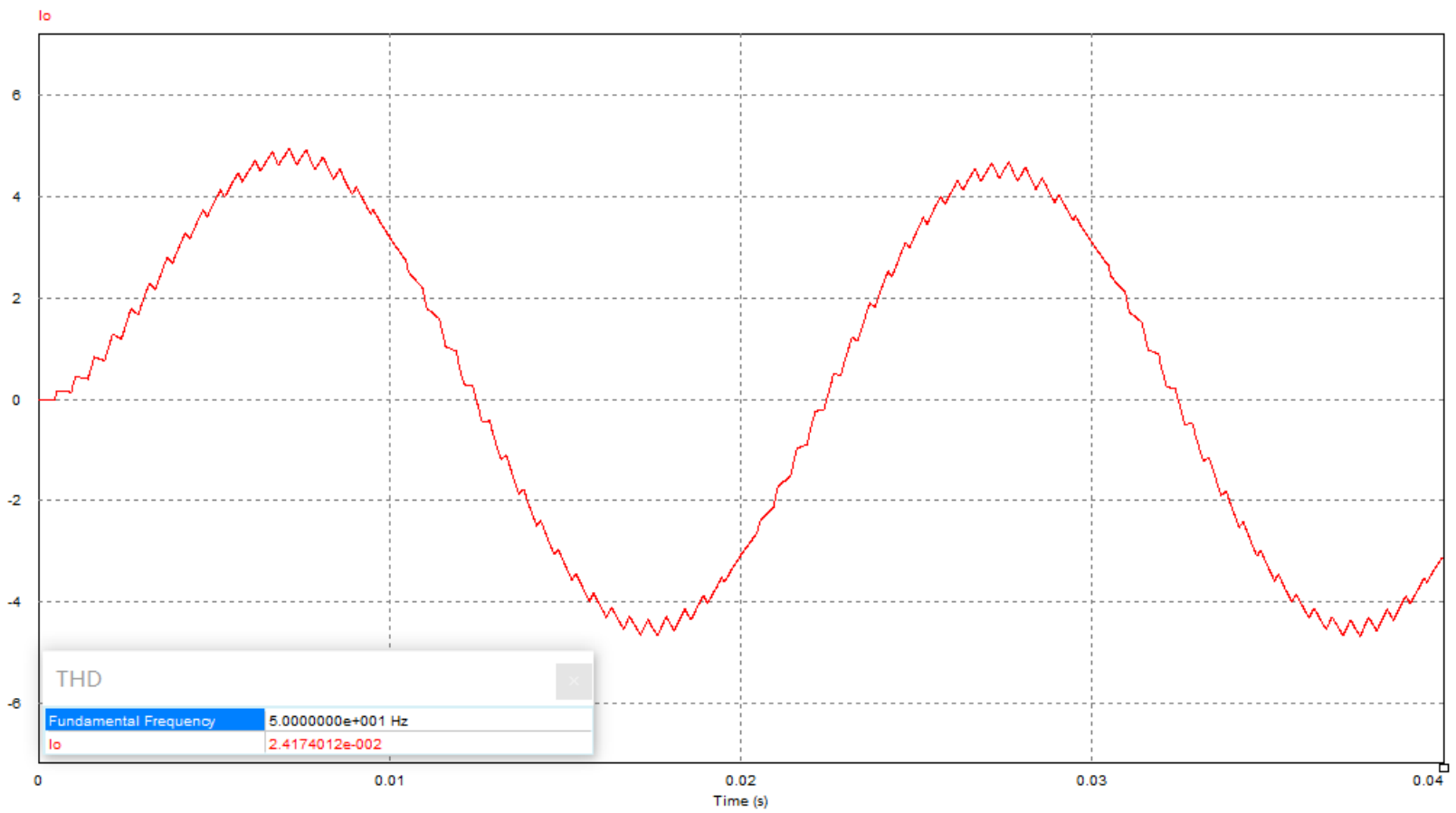
- FFT analysis



- $U_{o1} = 303V,\ RMS = \frac{303}{\sqrt{2}} \approx 214.25V$

Unipolar PWM Simulation Results

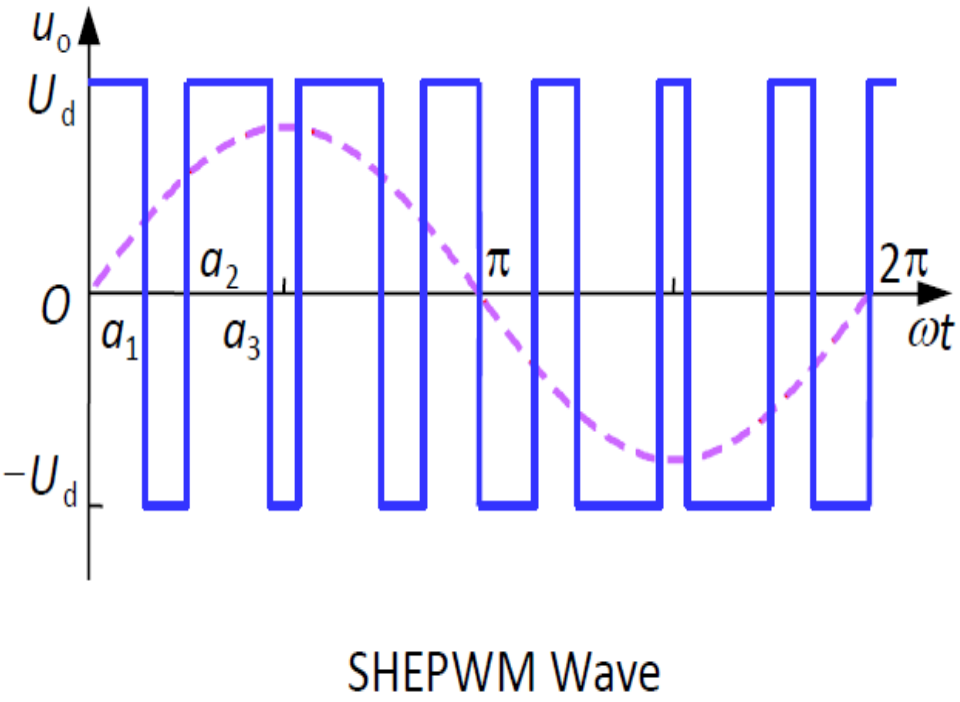
- Output current I_o



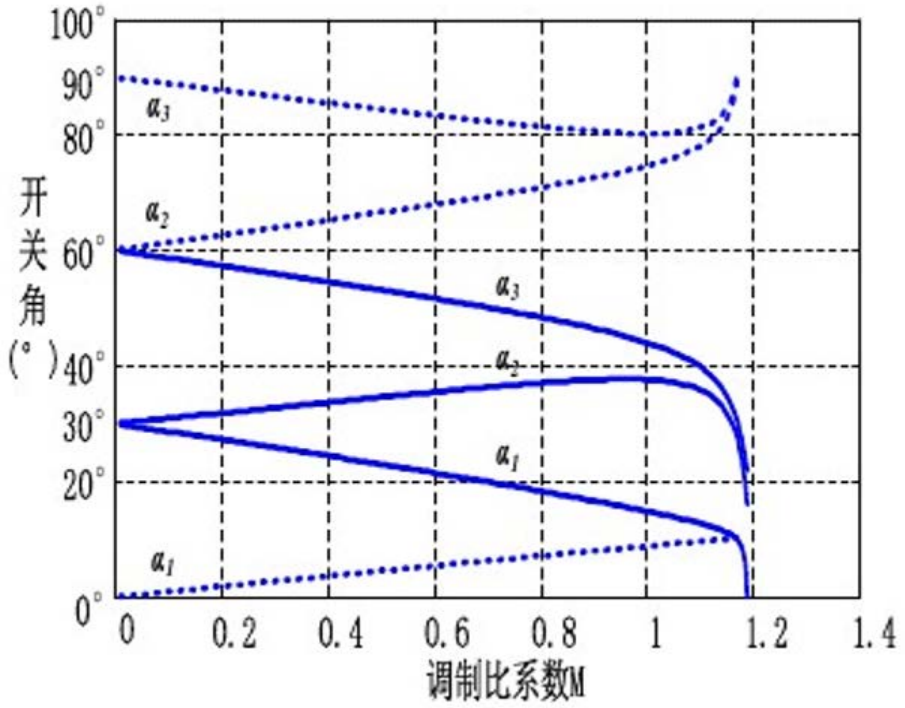
$THD = 2.42\%$

Selected Harmonics Elimination PWM

- In a half cycle , each device is turned on or off for three times



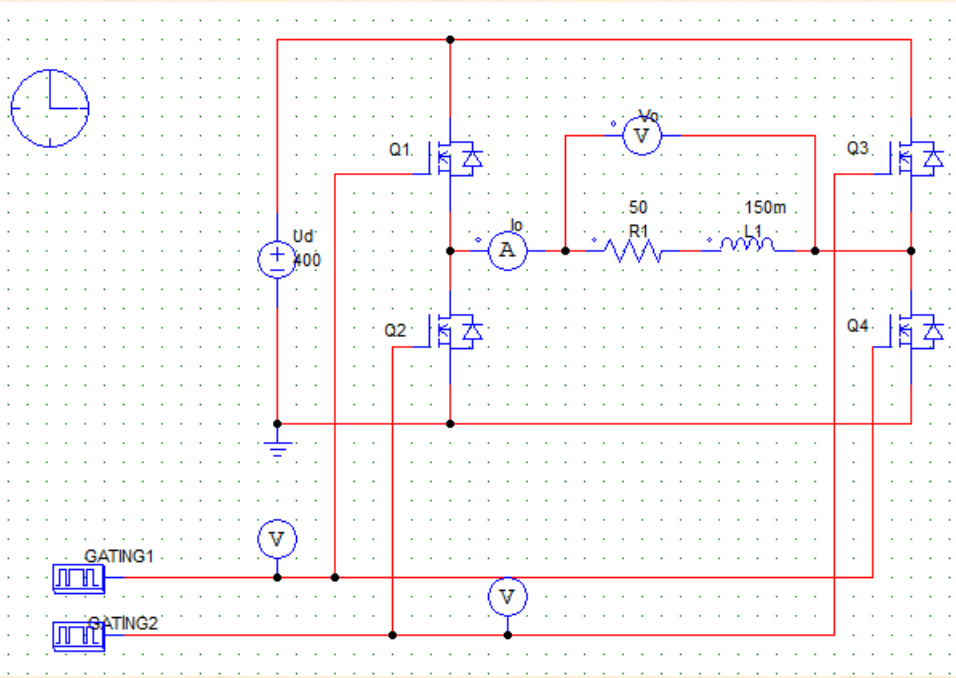
SHEPWM Wave

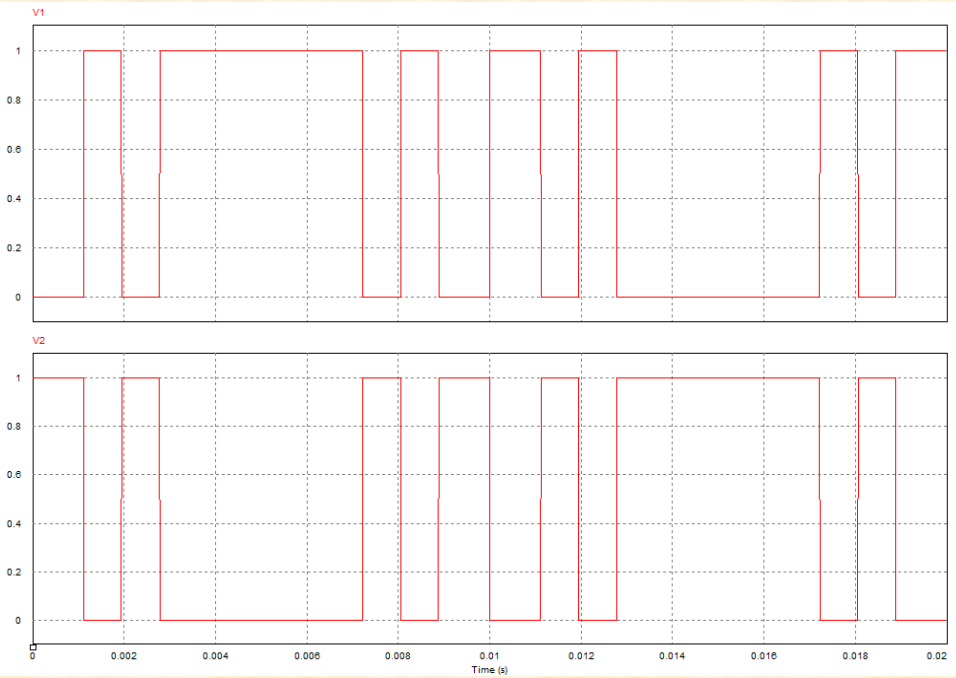


- When $m_a = 0.778,\ \alpha_1 = 20°, \alpha_2 = 35°, \alpha_3 = 50°.$

SHEPWM Modulation Model

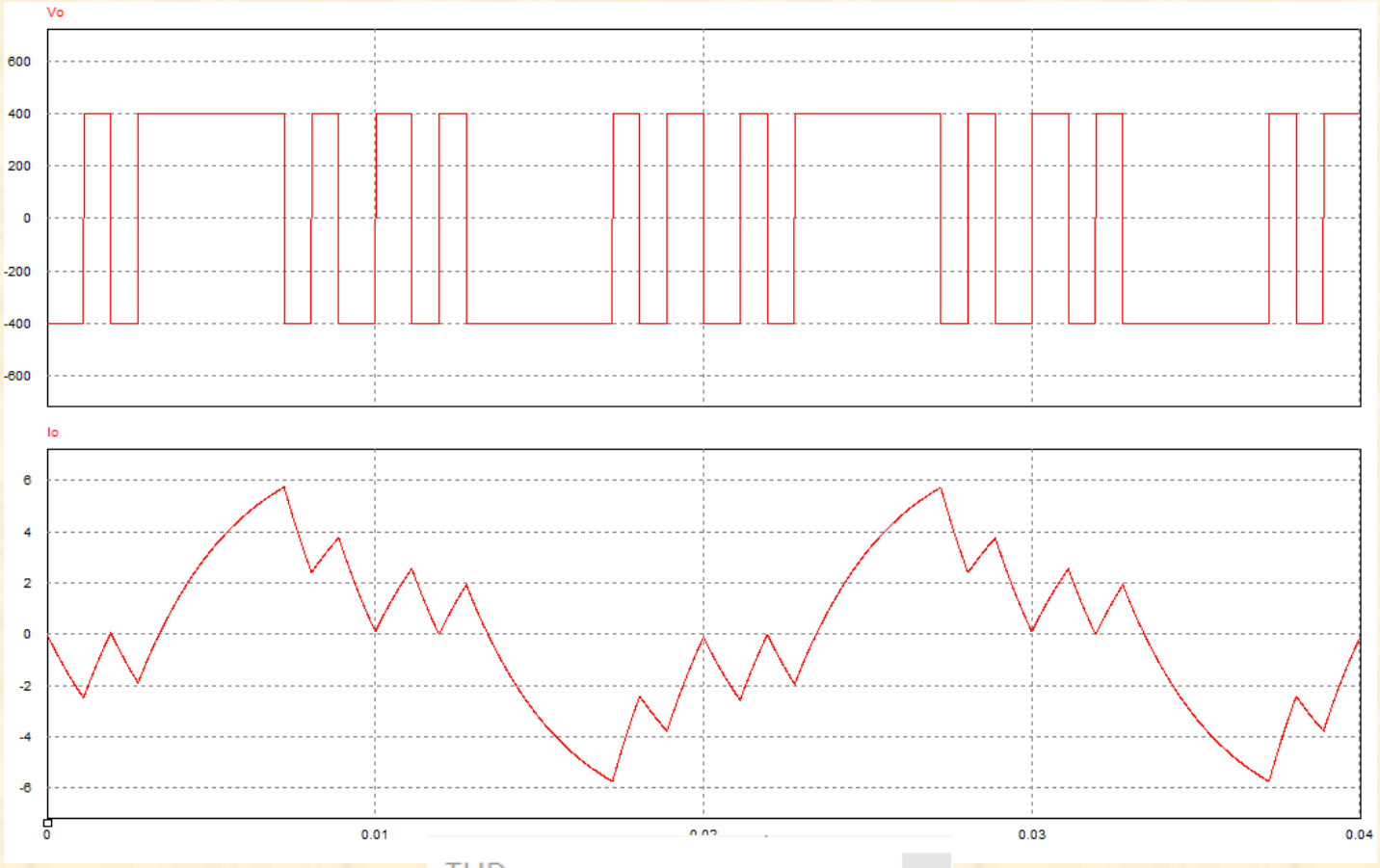
- Gating1=1 , Q_1 and Q_4 on, $U_o = U_d$
- Gating2=1 , Q_2 and Q_3 on, $U_o = -U_d$





SHEPWM Simualtion Result

- Output PWM voltage and current



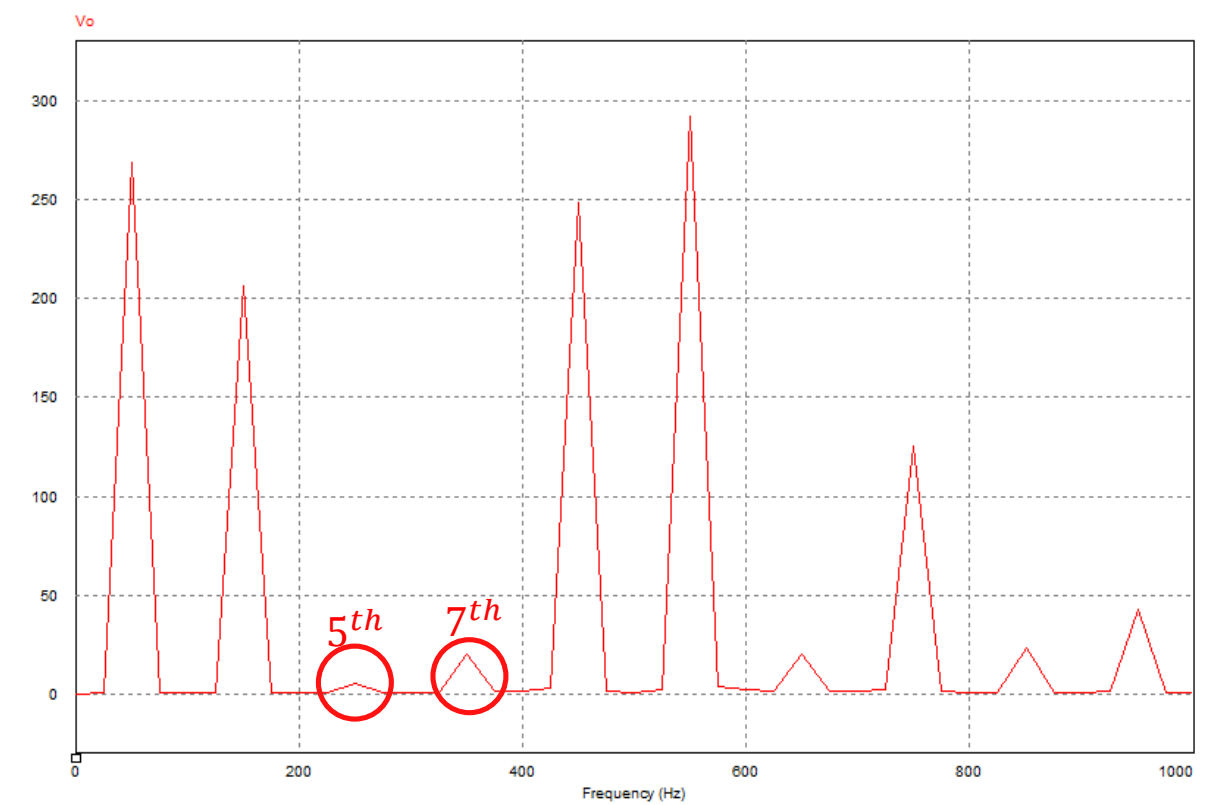
THD

Fundamental Frequency	5.0000000e+001 Hz
Vo	1.8554689e+000
Io	4.1355340e-001

SHEPWM Simulation Result

- FFT analysis

	Frequency	Vo
1	50	268.79
3	150	206.38
5	250	5.79
7	350	20.24
9	450	248.29
11	550	292.22
13	650	20.02
15	750	125.42
17	850	23.62



- The 5^{th} and 7^{th} order harmonics of U_o are almost zero.(read the switch angle inaccurately)

Conclusion

- Bipolar PWM：
  - The modulation circuit is easy to implement
- Unipolar PWM：
  - Lower THD
  - Lower amplitude of the minimum order harmonic
- SHE PWM
  - Lower switch frequency
  - Elimination selected harmonics
  - Three-phase can eliminate 3^{th} order harmonics

Thanks for your kind attention!

Jiawei Liang
ShanghaiTech University, July 11th,2019