Power Electronics Lab

Lab Report 4: STUDY OF SINGLE-PHASE AC TO DC CONVERTER (HALF-CONTROLLED & FULL-CONTROLLED)

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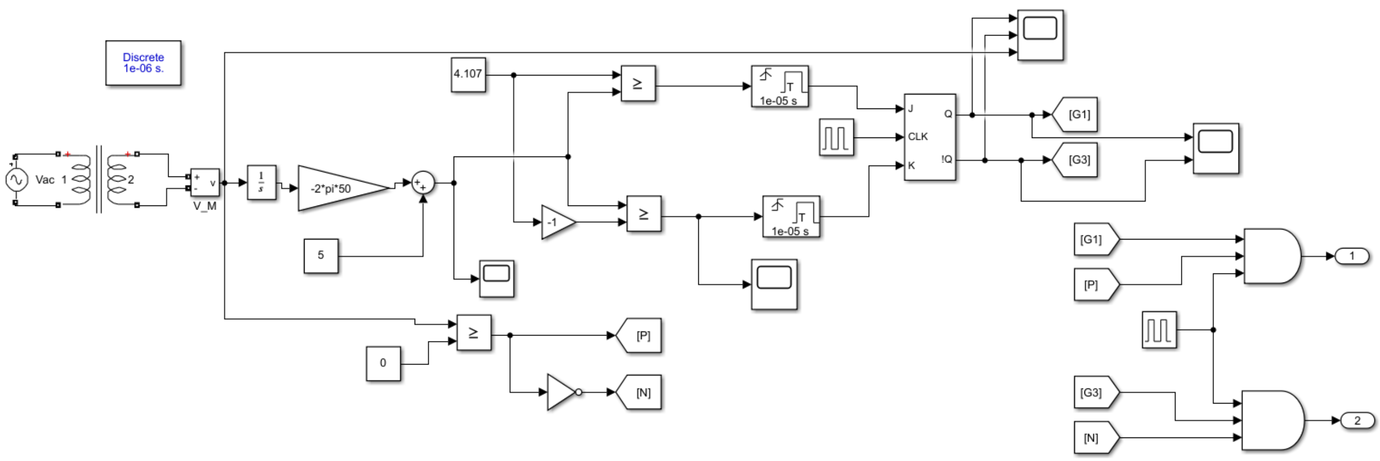
Part A: Triggering Circuit

Section 1:



$P_n = 4\ VA, f_n = 50\ Hz, V_1 = 230\ V, R_1 = 6.9\ \Omega, L_1 = 7.1\ mH,$

$V_2 = 3.605\ V, R_2 = 1.7\ m\Omega, L_2 = 2.1\ \mu H,$

$R_m = 600\ \Omega\ , L_m = 1.145\ H$

1. Given VO = 185V and Vin (RMS) = 230V

$$Vout = \frac{Vm}{\pi}(1 + \cos\alpha)$$

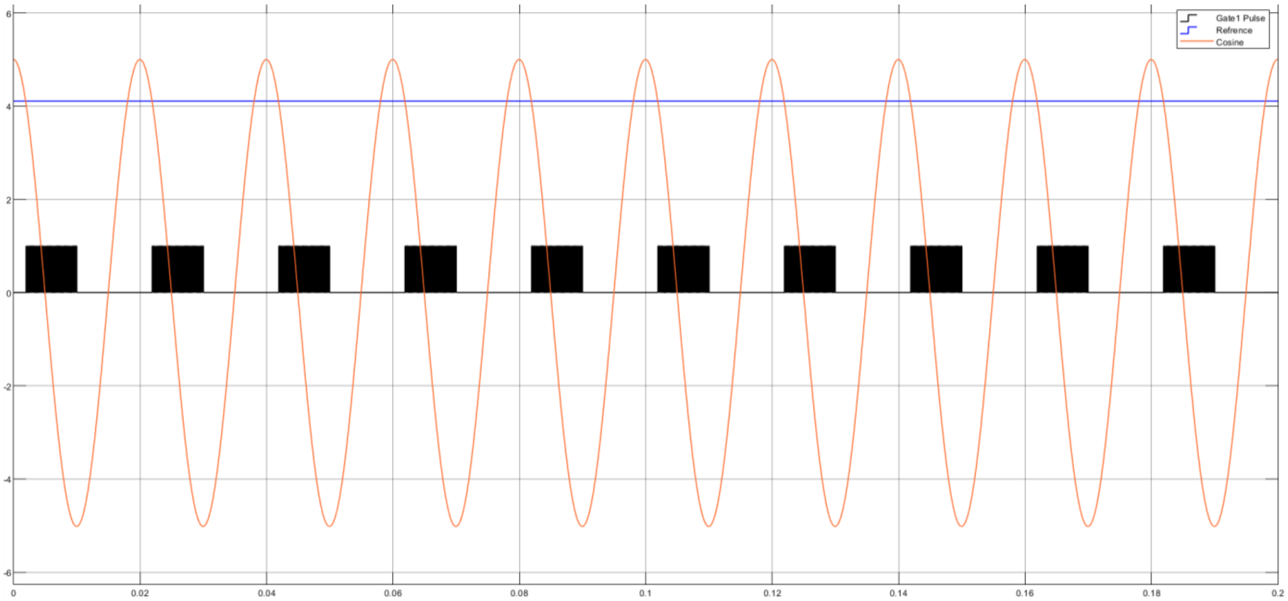
$$\alpha = \cos^{-1}\left(\frac{185 * \pi}{230 * \sqrt{2}} - 1\right)$$

So, firing angle is equal to 38.11 degrees

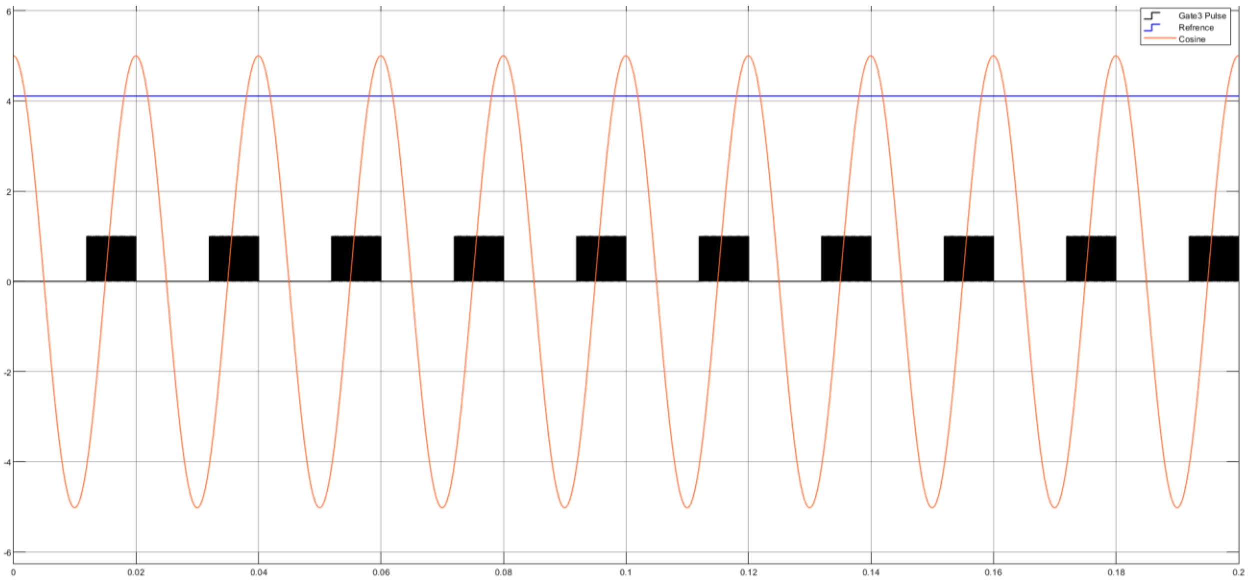
Vref = 3.605 * $\sqrt{2}$ * cos α = 4.107

2.

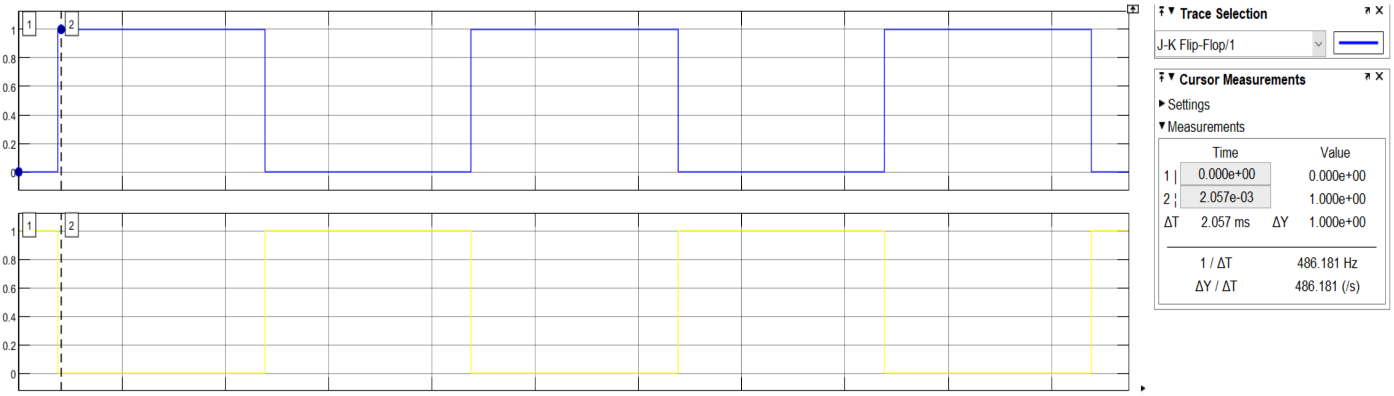
Gate pulse 1 with respect to Cosine and reference signal: -



Gate pulse 3 with respect to Cosine and reference signal: -



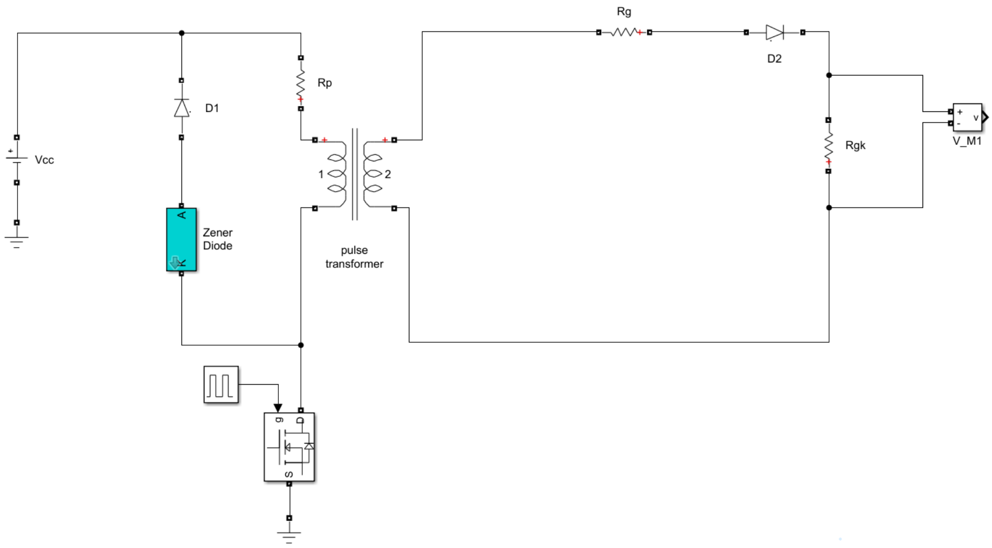
It is observed from both the gate pulses, thyristor 1 triggers when the input voltage is in the positive half cycle after firing angle α. And, the thyristor 3 triggers when input voltage is in negative half cycle after firing angle α.



The firing time
firing time = 2.057 ms , so
firing angle = (360/20)*(2.057) degrees = 37.026 degrees

3. Value of reference voltage is 4.107V and firing angle(α) is equal to 37.026 ° which we can observe from the SIMULINK plots also.

Section 2



Pulse transformer specifications: L_m = 1.5mH, L_{lp} = L_{ls} = 20μH, R_{pri} = R_{sec} =0.8 Ω, R_{core} = 400 Ω, N_1:N_2 = 1:1

Auxiliaries Specifications: V_{cc} = 20 V, R_p = 10 Ω, R_g = 20 Ω, R_{gk} = 10 Ω

1. For the driver circuit we need to choose a Zener voltage so that the primary winding current is reset to zero within 30% of the pulse duration.

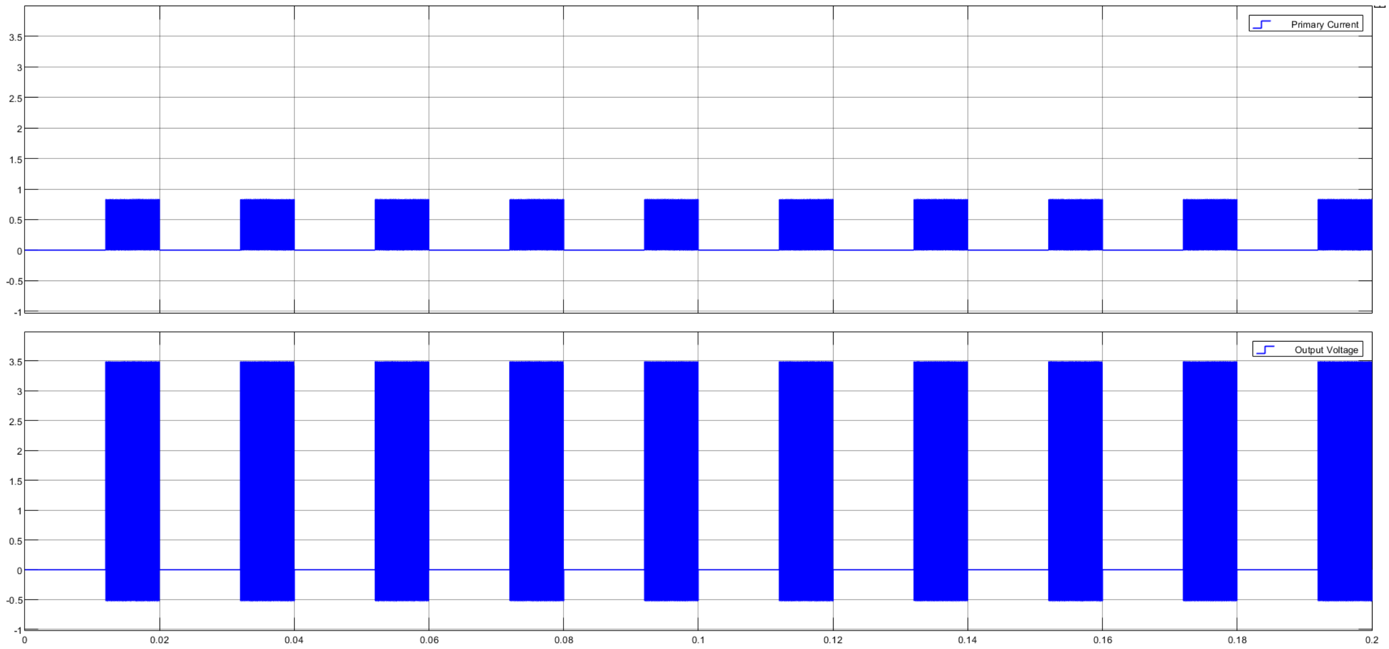
$$\boldsymbol{VCC \times T_{pulse} = V_Z \times T_{demag}}$$

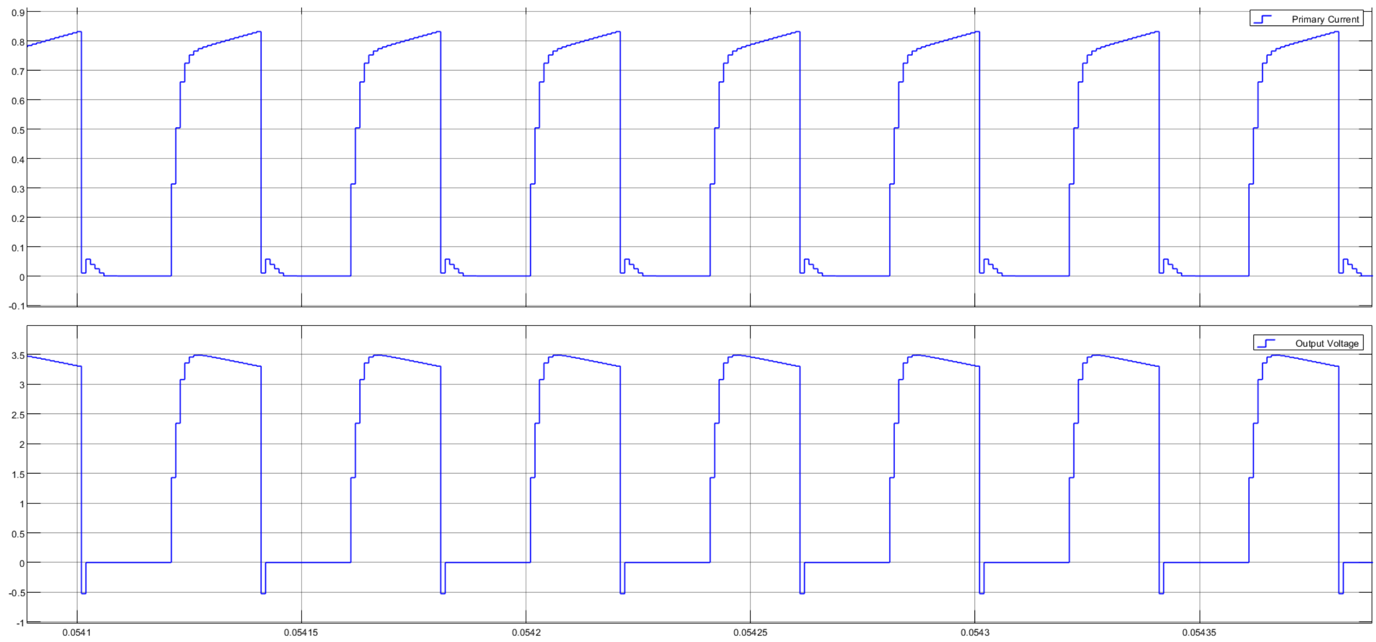
Here the duration of pulse is 50% of the time period and duration of demagnetization of the transformer is 30% of the time period of the gate pulse generated by the control circuit.

Hence, V_{Zener}= 33.34V

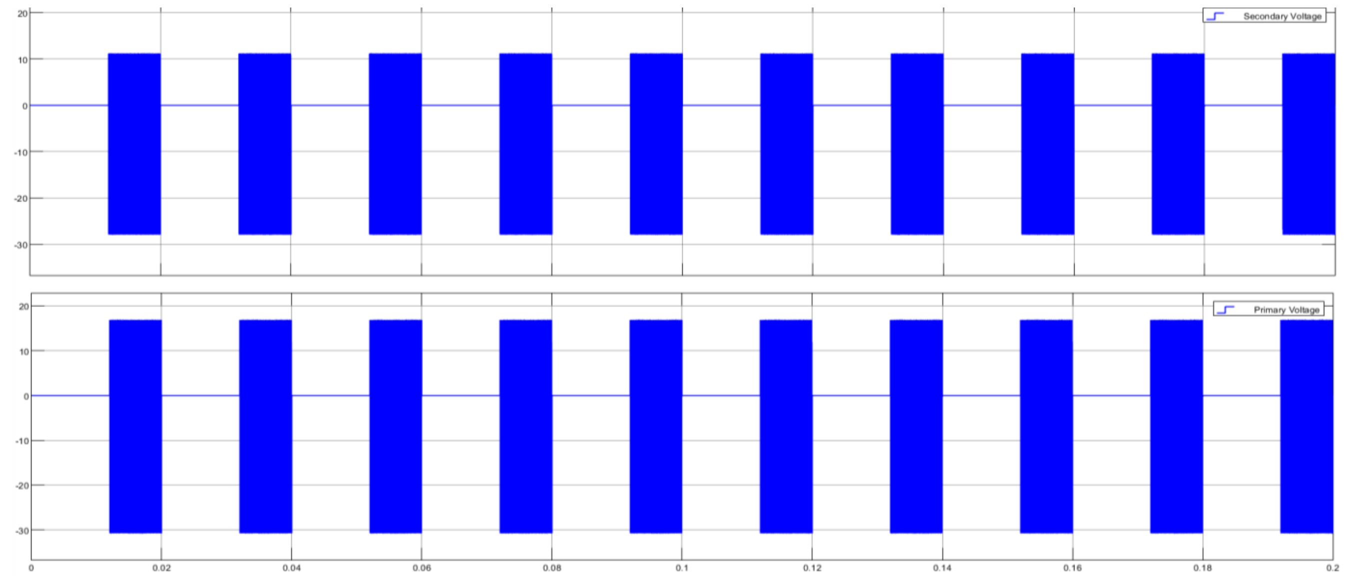
2. Save primary current and output voltage Vgk waveform. Also, save the primary voltage and secondary voltage of pulse transformer together in another plot.

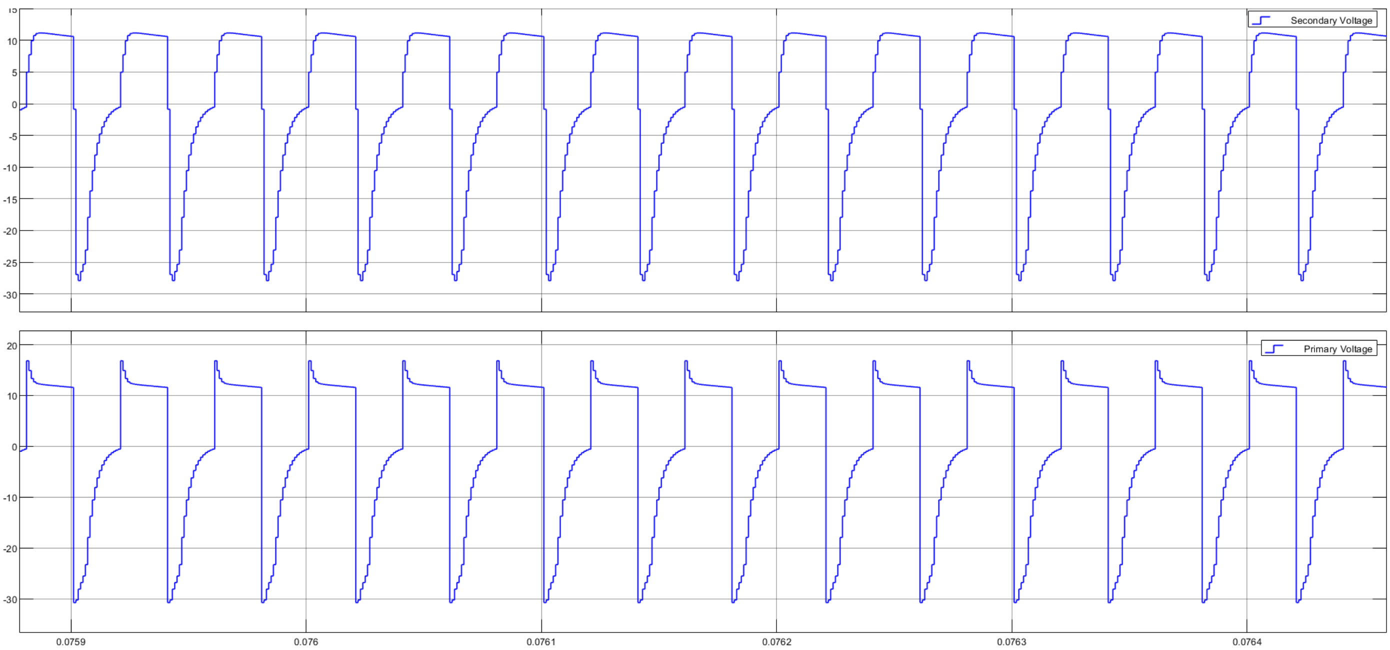
Vgk and primary current:





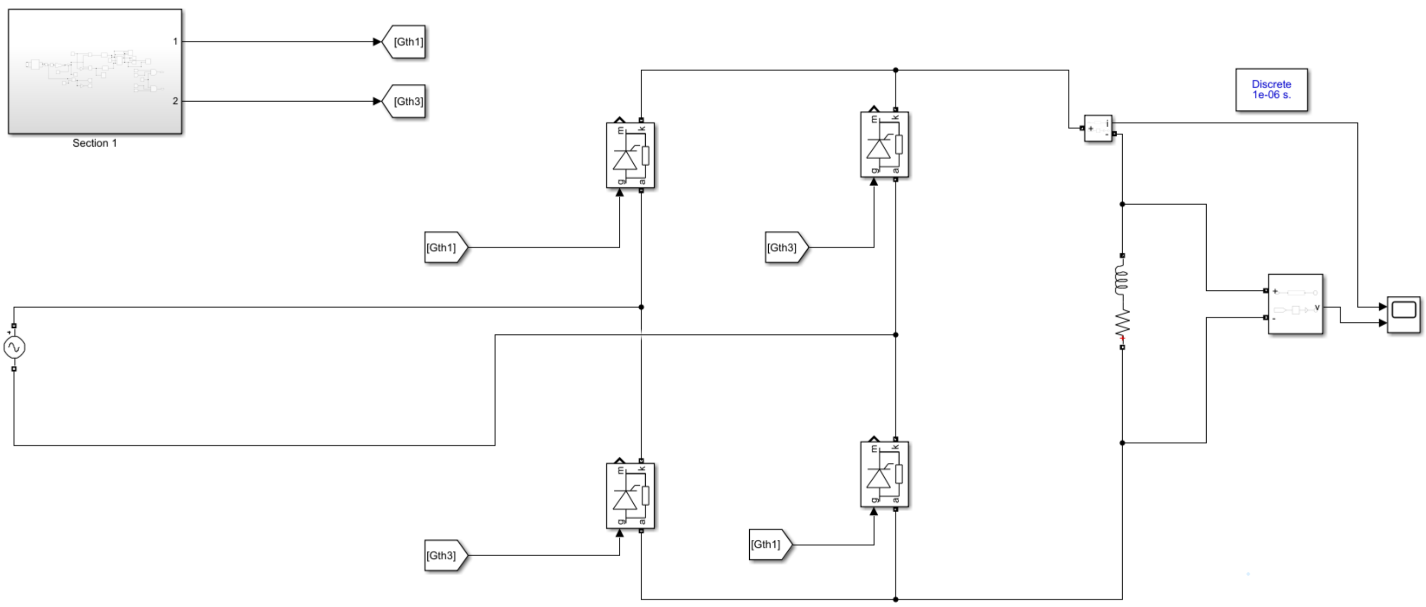
Primary Voltage and Secondary Voltage:





Part B: Full-controlled converter

Circuit Diagram:



1. Without source inductance and freewheeling diode for **L= 60 mH**

The given value of Vin = 230V and α**=30**,

$$Vout = \frac{2\sqrt{2}}{\pi} * \mathbf{230} * (\cos 30) = 179.33V$$

$$\text{Hence, } RLoad = \frac{\mathbf{179.33}}{\mathbf{8}} = 22.42\ \mathbf{\Omega}$$

Also,

$$Vref = 3.605 * \sqrt{2} * \cos 30 = 4.414V$$

Now simulating the circuit, we get

V_{DC} = 183.9V

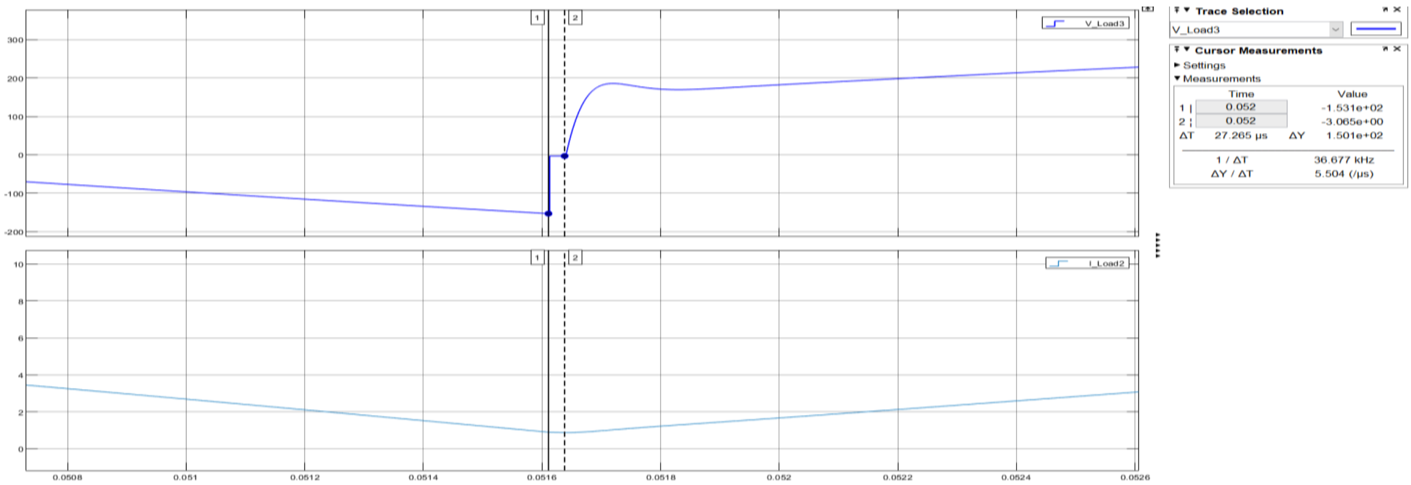
I_{DC} = 8.32A

2. With 2.5 mH source inductance,

Simulating the circuit we get,

$V_{DC} = 182.8V$

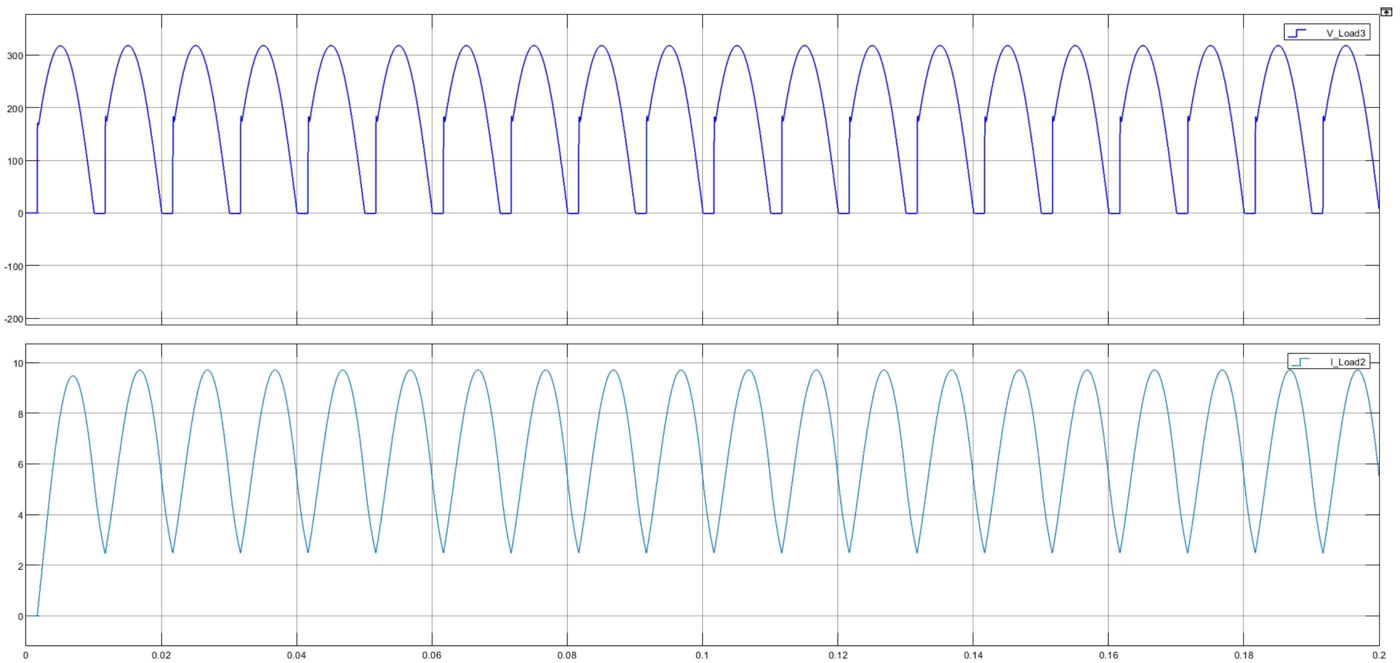
$I_{DC} = 8.315A$



Overlap angle (**μ**) = (360/20ms)*(27.265microseconds) = 0.49 degrees

3. Voltage drop due to source inductance: (179.1-177.9) V = 1.2 V

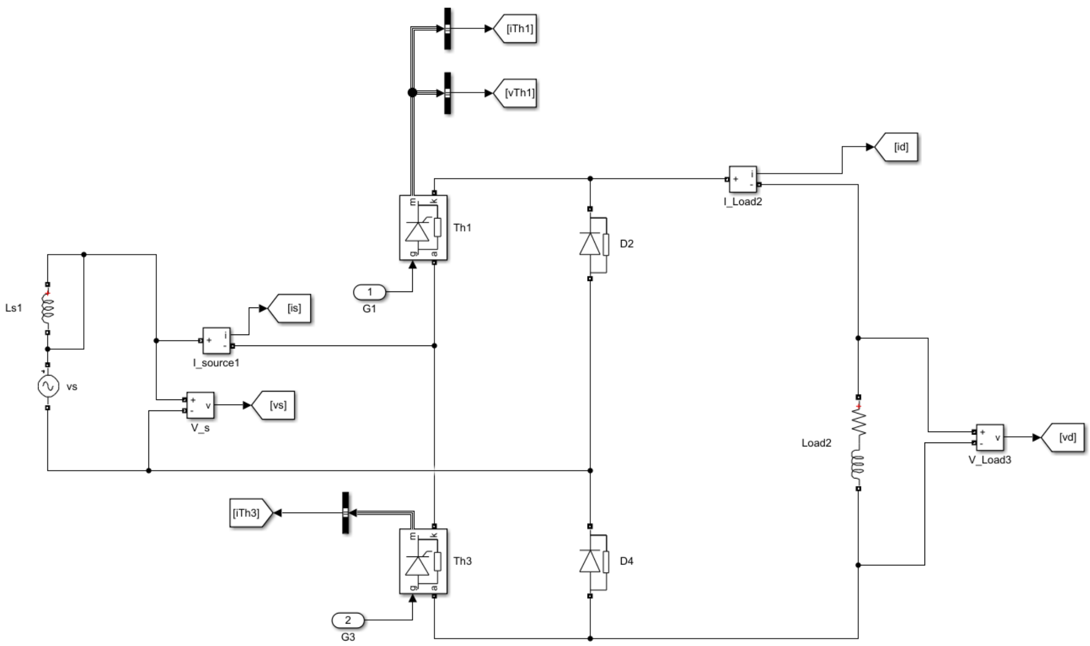
4. With Freewheeling diode in the same circuit



Parameter	Load voltage (V) Ideal case	Load voltage (V) With source inductance	Load voltage (V) With source inductance and freewheeling diode
Firing angle (Degree)	30	30	30
Average load voltage (V)	183.9	182.8	183.8
Average load current (A)	8.32	8.315	8.315
Input rms current	9.98	9.944	9.947
Fundamental input current	13.86	13.84	13.85
Distortion factor	0.9998	0.99984	0.99984
THD (%)	19.58	18.07	18.17
DPF	0.866	0.866	0.866
PF	0.827	0.827	0.827
P1 (W)	1898.29	1891.45	1892.02
Q1 (VAR)	1290.4	1285.82	1286.21
S1 (VA)	2295.4	2287.12	2287.81

Part C: Asymmetric half-controlled converter

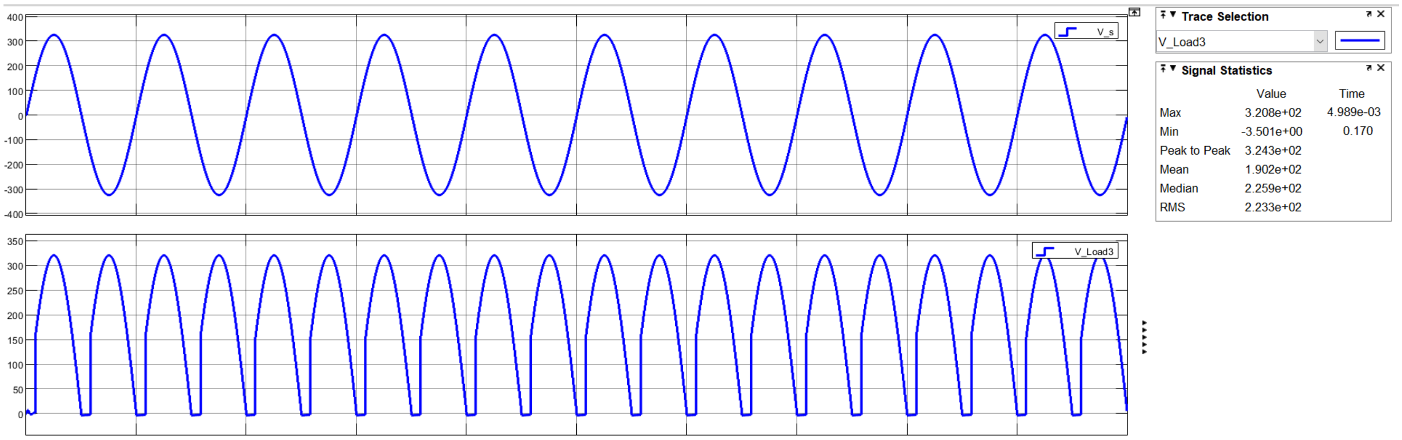
Circuit Diagram:



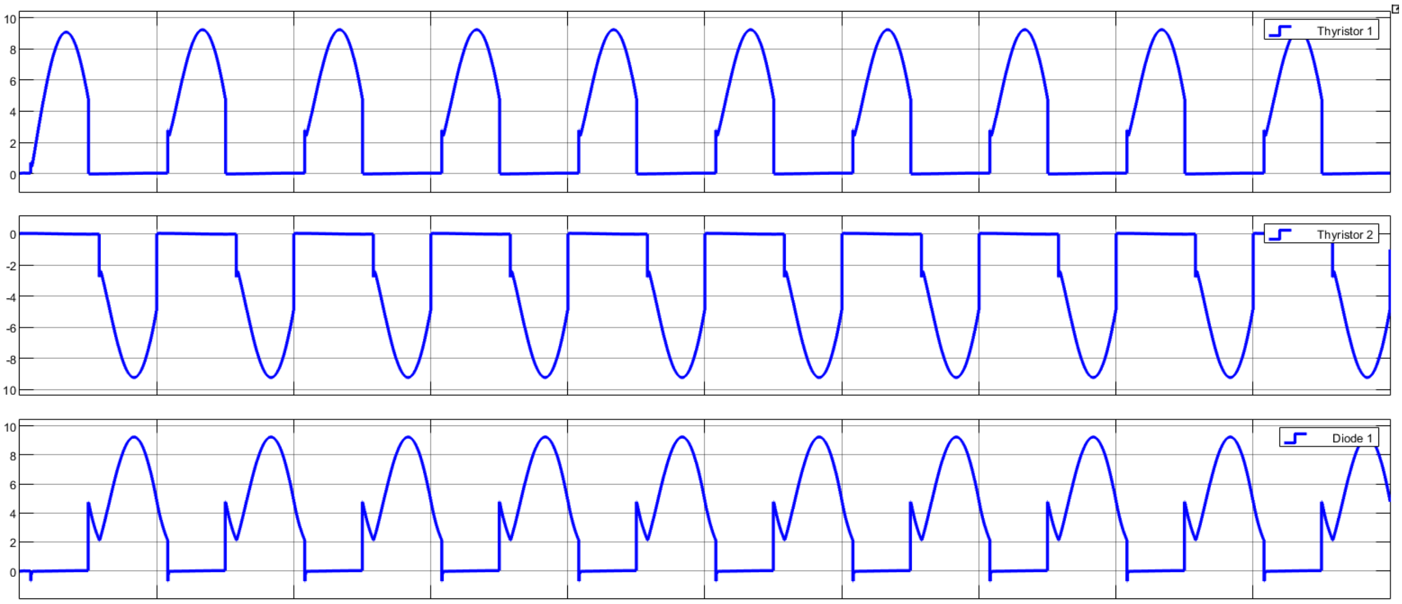
1. $Vout = \frac{Vm}{\pi}(1+\cos\alpha) = 193.2\text{V}$

a) for the firing angle $\boldsymbol{\alpha} = 30^{\circ}$

Simulated average Vout =190.2 V



b)



Thyristor 1 : RMS value = 4.661 A

Thyristor 3 : RMS value = 4.677 A

Diode 2 : RMS value : 4.857 A

Diode 4 : RMS value = 4.848 A

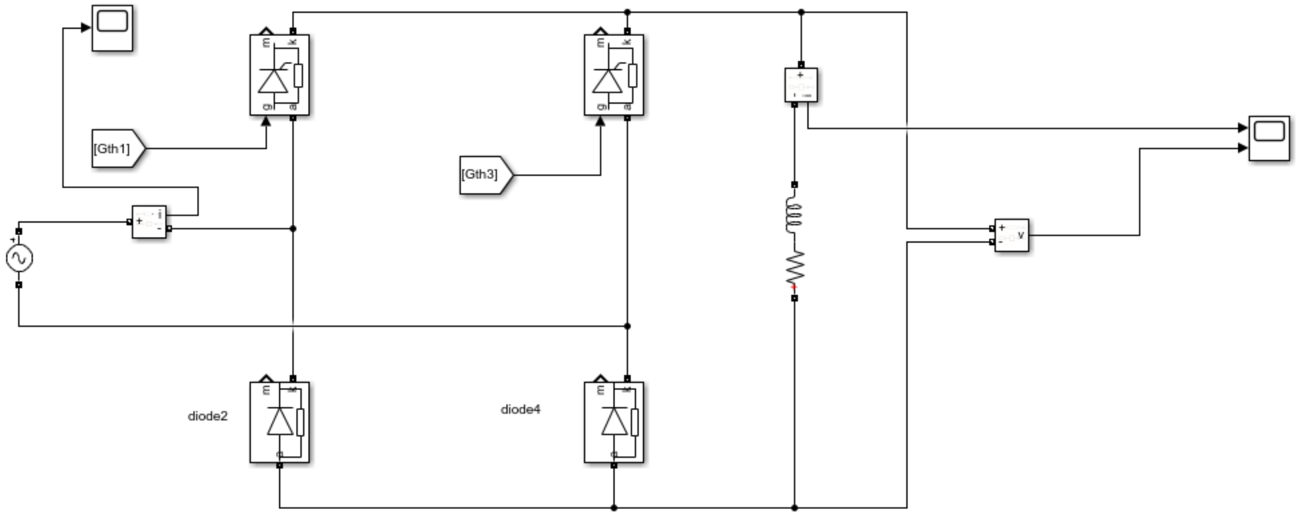
c) Considering a source reactance drop of 5% of rated line voltage:

$\text{Vm} = 0.95*230*\sqrt{2} = 309$ v

$\text{Vout} = \frac{Vm}{\pi}(1+\cos\alpha) = 183.54$ volt

2. Symmetric Semi Controlled Converter

Circuit Diagram:



Q. Tabulate Source current FFT (till 5th harmonic) at **α**= 45˚ for an ideal Symmetric semi-controlled converter connected to R-L load (R=30**Ω**, L=60mH) (i) with Free-wheeling diode and (ii) without Free-wheeling diode.

Without freewheeling diode:

```
Sampling time      = 1e-06 s
Samples per cycle = 20000
DC component      = 0.02662
Fundamental       = 8.59 peak (6.074 rms)
THD               = 19.19%

     0 Hz  (DC):          0.03    270.0°
    10 Hz                 0.05    254.7°
    20 Hz                 0.05    239.4°
    30 Hz                 0.05    224.1°
    40 Hz                 0.05    208.9°
    50 Hz  (Fnd):         8.59    -28.5°
    60 Hz                 0.04    179.3°
    70 Hz                 0.04    165.2°
    80 Hz                 0.04    151.9°
    90 Hz                 0.04    139.3°
   100 Hz  (h2):          0.03    127.8°
   110 Hz                 0.03    116.2°
   120 Hz                 0.03    105.4°
   130 Hz                 0.03     95.0°
   140 Hz                 0.03     84.7°
   150 Hz  (h3):          0.98     68.3°
   160 Hz                 0.02     64.0°
   170 Hz                 0.02     53.6°
   180 Hz                 0.02     43.1°
   190 Hz                 0.02     32.7°
   200 Hz  (h4):          0.02     23.0°
   210 Hz                 0.02     12.1°
   220 Hz                 0.02      1.9°
   230 Hz                 0.02     -8.1°
   240 Hz                 0.02    -17.9°
```

With freewheeling diode:

```
Sampling time      = 1e-06 s
Samples per cycle = 20000
DC component      = 0.02701
Fundamental       = 8.584 peak (6.07 rms)
THD               = 19.13%

     0 Hz  (DC):          0.31%    270.0°
    10 Hz                 0.61%    254.7°
    20 Hz                 0.60%    239.4°
    30 Hz                 0.59%    224.1°
    40 Hz                 0.57%    208.9°
    50 Hz  (Fnd):       100.00%    -28.3°
    60 Hz                 0.52%    179.3°
    70 Hz                 0.48%    165.3°
    80 Hz                 0.45%    151.9°
    90 Hz                 0.42%    139.3°
   100 Hz  (h2):          0.40%    127.8°
   110 Hz                 0.36%    116.2°
   120 Hz                 0.34%    105.4°
   130 Hz                 0.32%     95.0°
   140 Hz                 0.30%     84.6°
   150 Hz  (h3):         11.27%     68.3°
   160 Hz                 0.28%     63.9°
   170 Hz                 0.27%     53.5°
   180 Hz                 0.26%     43.0°
   190 Hz                 0.25%     32.6°
   200 Hz  (h4):          0.24%     22.9°
   210 Hz                 0.23%     11.9°
   220 Hz                 0.22%      1.8°
   230 Hz                 0.21%     -8.3°
   240 Hz                 0.20%    -18.1°
```

Discussion questions:

1. Capture (i) source voltage, (ii) load voltage, (iii) voltage across thyristor in one scope for one cycle and also capture (i) load current, (ii) source current (iii) thyristor current (iv) freewheeling diode current in another scope for full-controlled converter.

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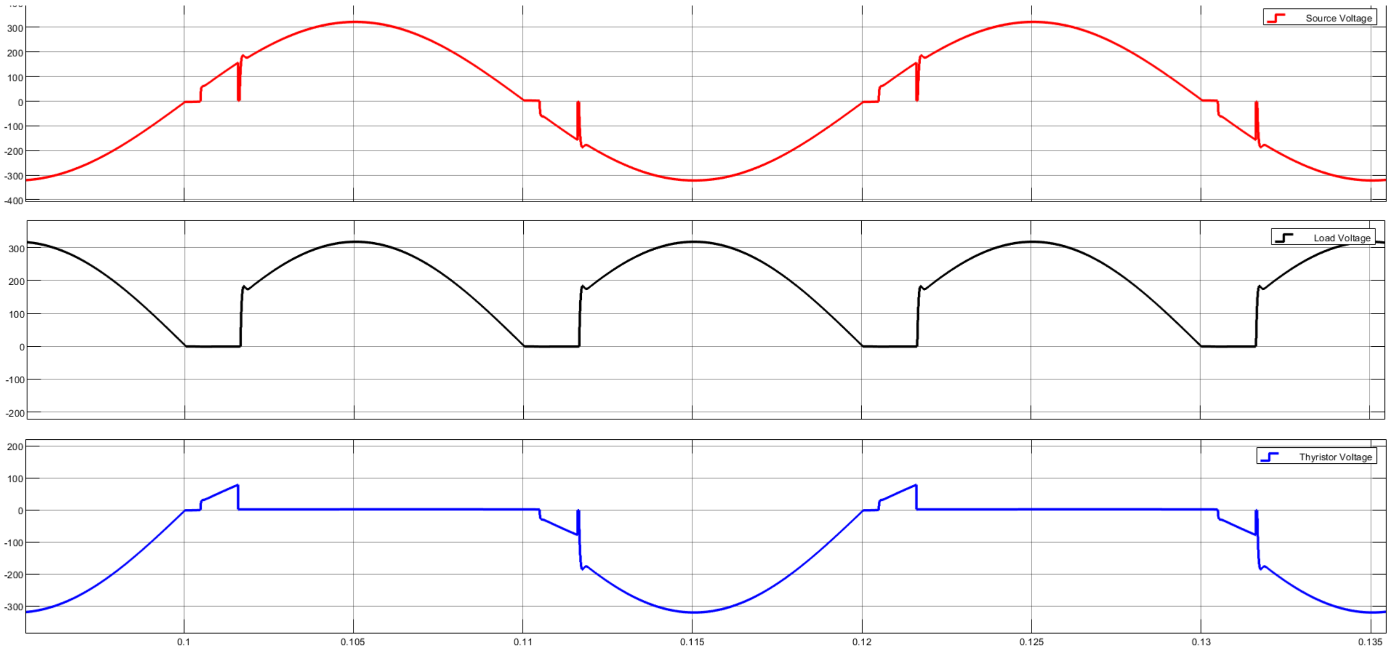
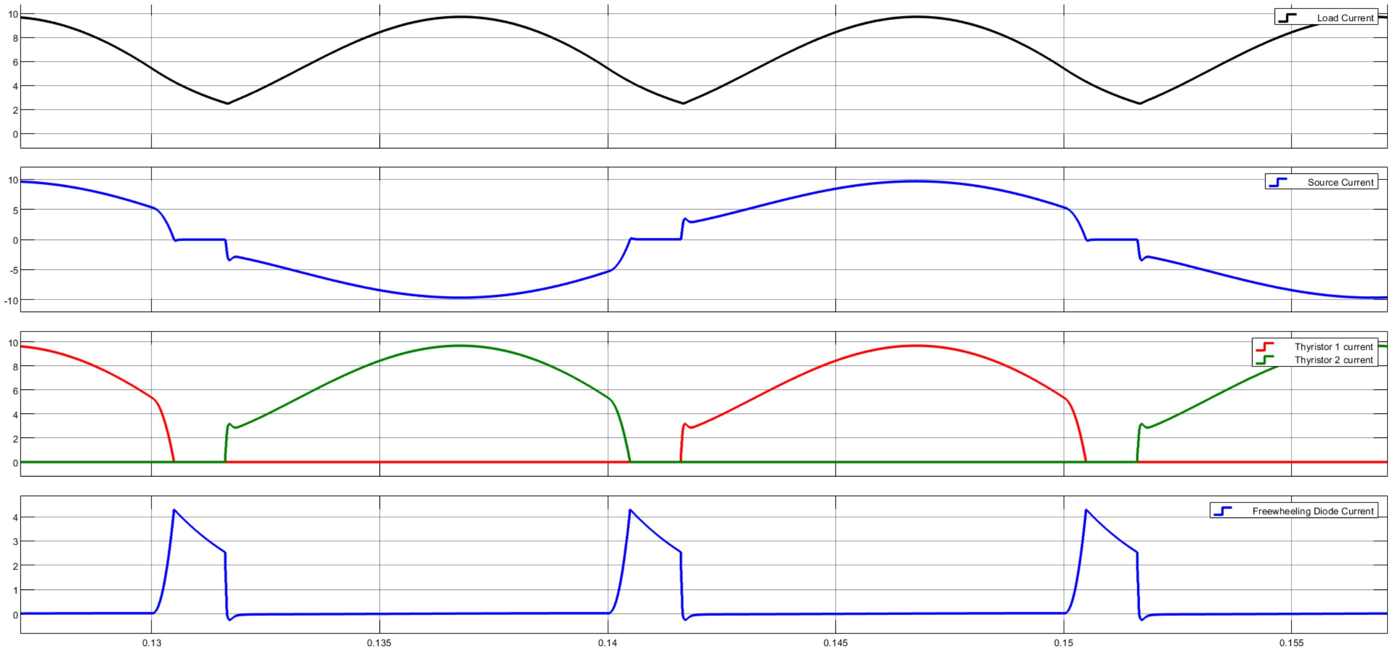




2. Make a comparative study between full-controlled and Asymmetric half-controlled converter in terms of load voltage, source current, power factor, THD.

- Considering Ideal Full controlled converter: R = 22.4 OHM, L = 60mH, vin(RMS) = 230 V , $\boldsymbol{\alpha}$=30˚

Asymmetric half controlled converter: R = 22.4 OHM, L = 60mH, vin(RMS) = 230 V ,$\boldsymbol{\alpha}$=30˚

PARAMETERS	FULL-CONTROLLED	ASYMMETRIC HALF CONTROLLED
LOAD VOLTAGE (AVG)(V)	179.3	190.8
RMS SOURCE CURRENT (A)	8.439	8.586
THD (%)	11.49	17.44
POWER FACTOR	0.840	0.915
DISPLACEMENT FACTOR	0.841	0.928

We Observe that the asymmetric half controlled gives more output voltage and also improved power factor than the full controlled.

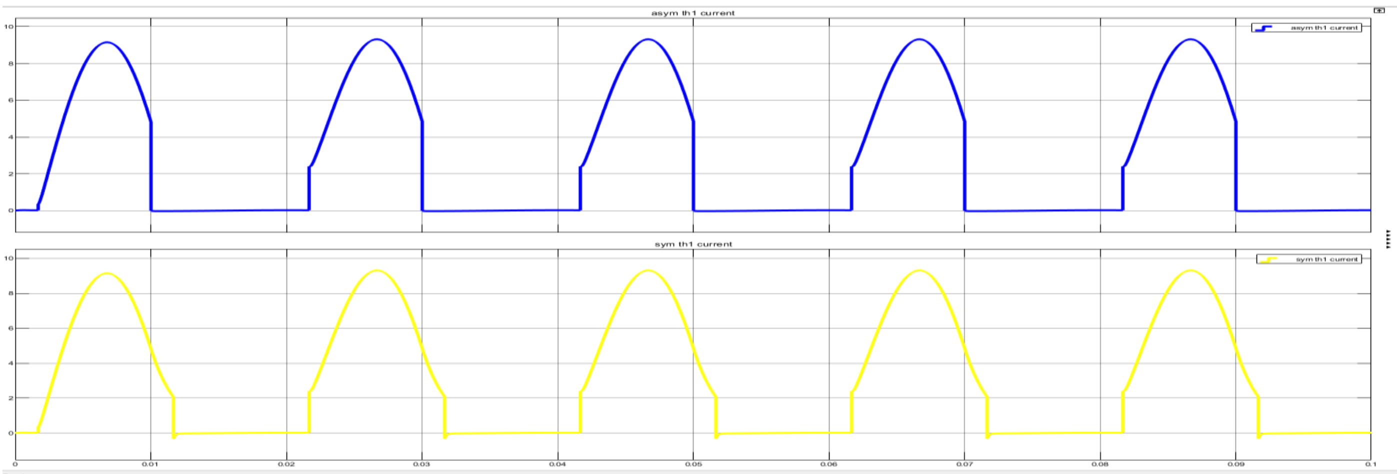
3. Why train of pulses are used to turn on the thyristor instead of a single pulse?

- We use a train of pulses to turn on the thyristor due to following reasons.
  1. Holding the gate at trigger voltage for longer duration will cause huge power dissipation within the thyristor and draw excess power from the trigger circuit.
  2. At the start of a conduction interval, thyristor may not latch on with the first firing pulse because the current may not reach the minimum holding current. So, we need to keep on triggering until it latches on.

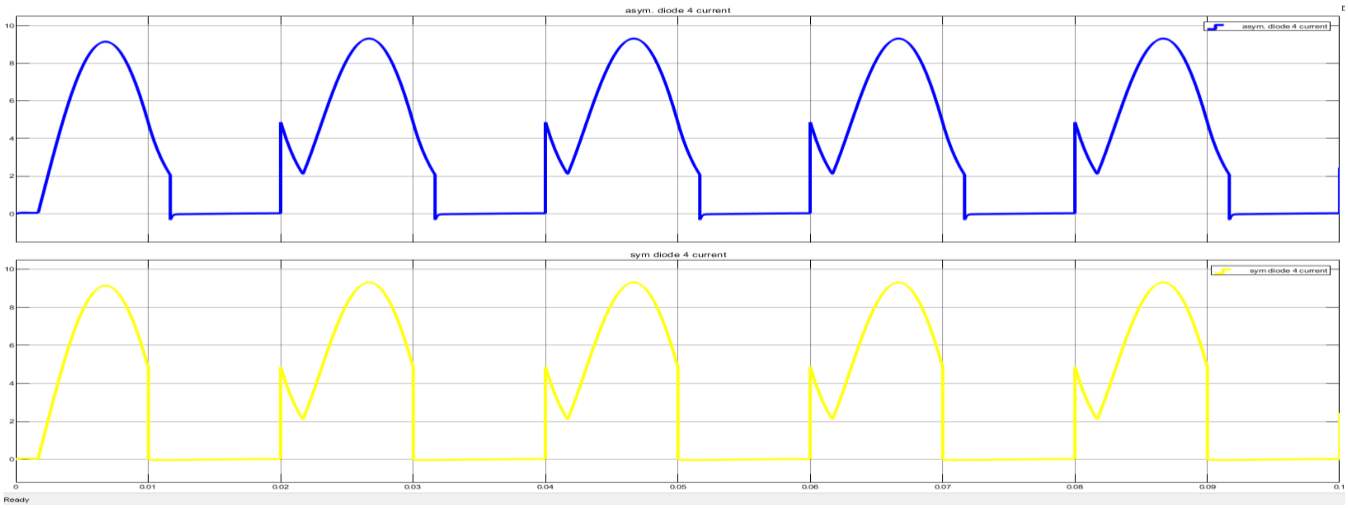
4. List key differences between asymmetric and symmetric semi-controlled rectifiers

- The Load current as well as Load voltage waveforms are exactly same for both the asymmetric and symmetric semi-controlled rectifiers. There is a difference when Diode current and Thyristor currents are observed.

Thyristor Currents:



Diode Currents:



- The conduction time for thyristor is more in symmetrical topology which leads to higher rms and average thyristor currents.
- The conduction time for diode is less in symmetrical topology which leads to lower rms and average diode currents.

It is evident from conduction time periods that:

1. average and RMS thyristor current in symmetrical configuration is higher. So SCR current rating should be higher in symmetrical configuration.
2. The average and RMS diode current in asymmetrical configuration is higher. So, diode current rating should be higher in asymmetrical configuration.

The freewheeling path in symmetrical configuration is through a (thyristor-diode) combination and in asymmetrical configuration is through a (diode-diode) combination. This is because during freewheeling, devices belonging to the same leg will conduct in both configurations.