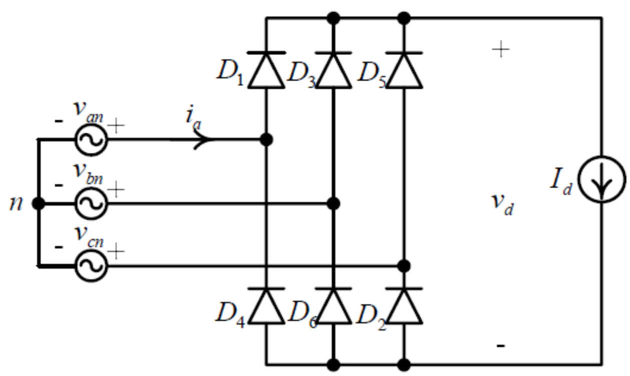
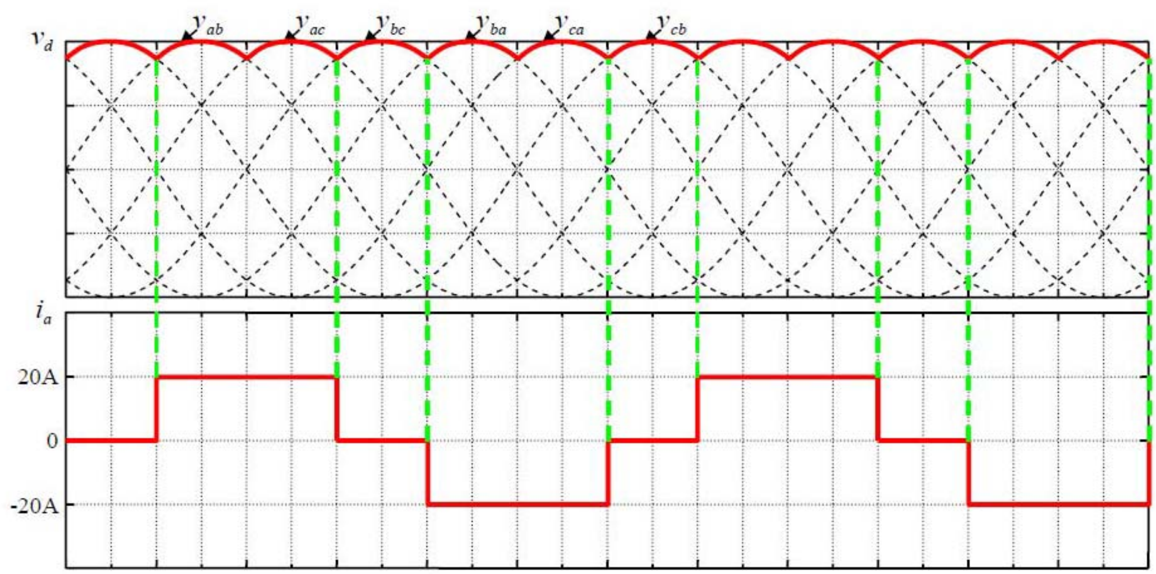
**Question 1**

Consider the three-phase full-bridge diode rectifier shown below. Assuming the input line-to-line voltage $V_{LL} = 208$ V (60 Hz), and dc current $I_d = 20$ A. All the diodes are ideal. Answer the following questions.




1) Using the waveform template below, draw the following waveforms.

   Voltage waveform $v_d$, and line current waveform $i_a$




2) Calculate the **average** value of $v_d$

$V_{d,avg} = \underline{280.9\quad}$ V

Solution:

$$V_{d,avg} = \frac{3\sqrt{2}}{\pi} V_{LL} = 1.35 V_{LL} = 1.35 \times 208 = 280.9 \text{ V}$$

3) Calculate the **rms** value of $v_d$

$V_{d,rms}$ = <u>281.15</u> V

<u>Solution:</u>

$$V_{d,rms} = \sqrt{\frac{1}{\pi/3}\int_{\pi/3}^{2\pi/3}\left(\sqrt{2}V_{LL}\sin\omega t\right)^2 d\omega t}$$

$$= \sqrt{\frac{V_{LL}^2}{\pi/3}\int_{\pi/3}^{2\pi/3} 2\sin^2\omega t d\omega t} = \sqrt{\frac{V_{LL}^2}{\pi/3}\int_{\pi/3}^{2\pi/3}(1-\cos 2\omega t)d\omega t}$$

$$= \sqrt{\frac{V_{LL}^2}{\pi/3}\left(\omega t - \frac{\sin 2\omega t}{2}\right)\Bigg|_{\pi/3}^{2\pi/3}} = V_{LL}\sqrt{1+\frac{3\sqrt{3}}{2\pi}}$$

$$= 1.3517V_{LL} = 1.3517\times 208 = 281.15\text{V}$$

4) Calcuate the **rms** value of line current $i_a$

$I_{a,rms}$ = <u>16.33</u> A

<u>Solution:</u>

$$I_{a,rms} = \sqrt{\frac{2}{3}}I_d = 0.816I_d = 0.816\times 20 = 16.33\text{A}$$

5) Calculate the **total** input power of the converter, $P_{in}$

$P_{in}$ = <u>5.62</u> kW

<u>Solution:</u>

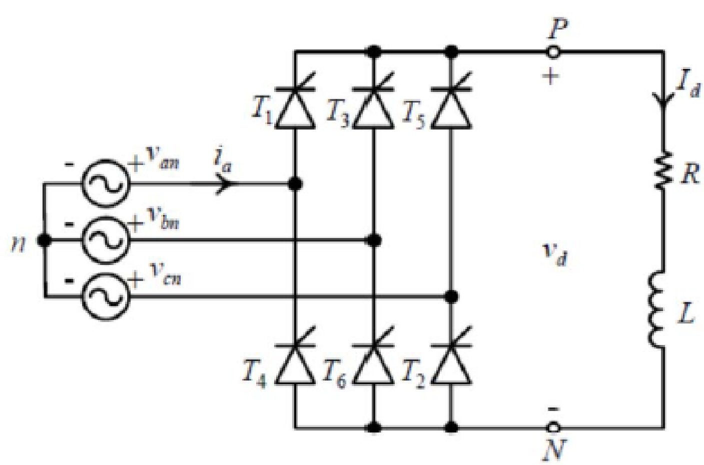
$$PF = \frac{3}{\pi} = 0.955$$

$$P_{in} = \sqrt{3}V_{LL}I_{a,rms}PF = \sqrt{3}\times 208\times 16.33\times 0.955 = 5.62\text{kW}$$

$$\text{or } P_{in} = P_{out} = V_{d,avg}I_d = 280.9\times 20 = 5.62\text{kW}$$

**Question 2**

A three-phase full bridge SCR rectifier with RL load is shown below. The load resistance is 20 Ω and inductance is very large. The input **line-to-line** voltage of the rectifier is 480 V (60 Hz). The firing angle for the SCR devices is 60 degree. Answer the following questions.



1) Find the load current $I_d$

$I_d$ = 16.2 A

Solution:

$$V_d = 1.35 V_{LL} \cos\alpha = 1.35 \times 480 \times \cos 60° = 324\text{ V}$$

$$I_d = \frac{V_d}{R} = \frac{324}{20} = 16.2\text{ A}$$

2) Calculate the total power factor at the line side (input side), $PF$ = ___________

PF= 0.4475

Solution:

$$\text{PF} = 0.955 \cos\alpha = 0.955 \times \cos 60° = 0.4775$$

3) Calculate the total input power $P_{input}$

$P_{input}$= 5.25 kW

Solution:

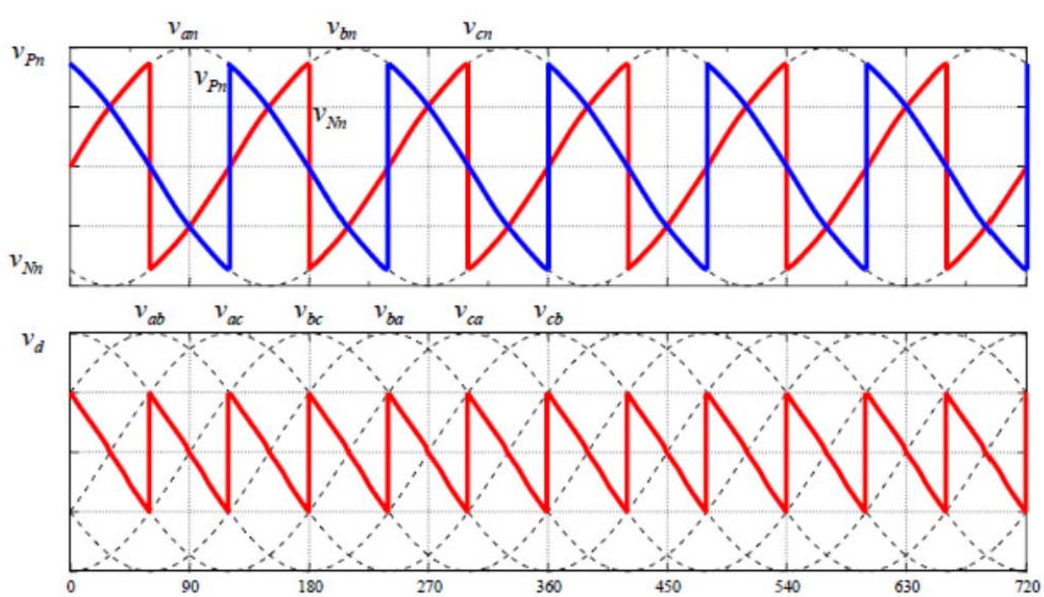
$$I_L = \sqrt{\frac{2}{3}} I_d = \sqrt{\frac{2}{3}} \times 16.2 = 13.2272\text{ A}$$

$$P_{input} = \sqrt{3} V_{LL} I_L \times \text{PF} = \sqrt{3} \times 480 \times 13.2272 \times 0.4775 = 5.25\text{kW}$$

or

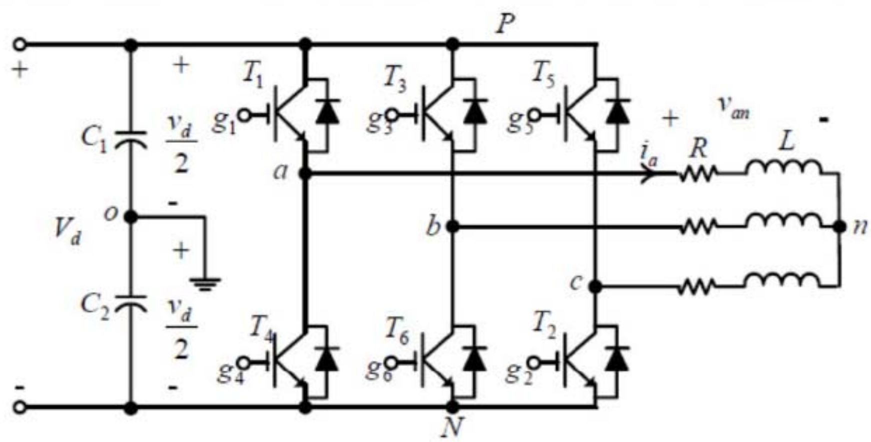
$$P_{input} = P_{out} = V_d I_d = 324 \times 16.2 = 5.25\text{ kW}$$

4) Using the waveform template below draw the voltage waveforms of $v_{Pn}$, $v_{Nn}$ and $v_d$, assuming the firing angle is 90 degrees and load current is constant.



**Question 3**

In the three-phase full bridge inverter shown below, the dc voltage $V_d$ = 300 V, the amplitude modulation index $m_a$ = 0.8, the frequency modulation index $m_f$ = 39, and the frequency of three-phase sine modulating wave is 60 Hz. The load is three-phase Y-connected RL load, the resistance is 10 Ω and the inductance is 28 mH. Answer the following questions.




1) Determine the rms values of the output line-to-line voltage and line current at fundamental frequency.

$V_{LL,1}$ = 147 V

$I_{L,1}$ = 5.84 A

Solution:

From table 8-2,

$$V_{LL,1} = 0.49V_d = 0.49 \times 300 = 147 \text{ V}$$

$$Z = \sqrt{R^2 + (\omega L)^2} = \sqrt{10^2 + (2 \times \pi \times 60 \times 28 \times 10^{-3})^2} = 14.54\Omega$$

$$I_{L,1} = \frac{V_{LL,1}/\sqrt{3}}{Z} = \frac{147/\sqrt{3}}{14.54} = 5.84 \text{ A}$$

2) Calculate the output power considering only fundamental component.

$P_{out}$ = 1.02 kW

Solution:

$$\text{Load angle } \theta = \tan^{-1}\frac{2\pi fL}{R} = \tan^{-1}\frac{2\pi \times 60 \times 28 \times 10^{-3}}{10} = 46.55°$$

$$\text{PF} = \cos\theta = \cos 46.55° = 0.6877$$

$$P_{out} = \sqrt{3}V_{LL,1}I_{L,1} \times \text{PF} = \sqrt{3} \times 147 \times 5.84 \times 0.6877 = 1.02\text{kW}$$

or

$$P_{out} = 3I_{L,1}^2 R = 3 \times 5.84^2 \times 10 = 1.02\text{kW}$$