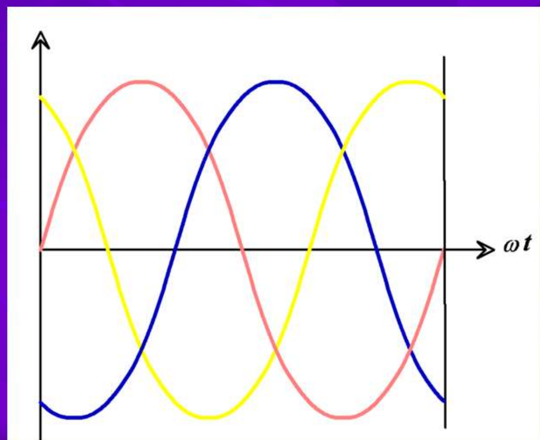
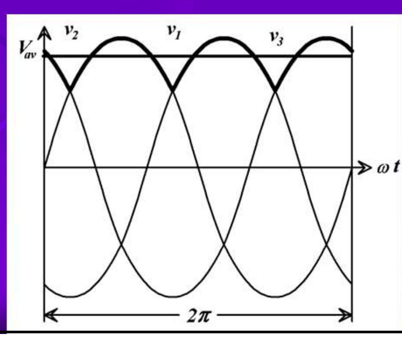
Poly-Phase Rectifiers

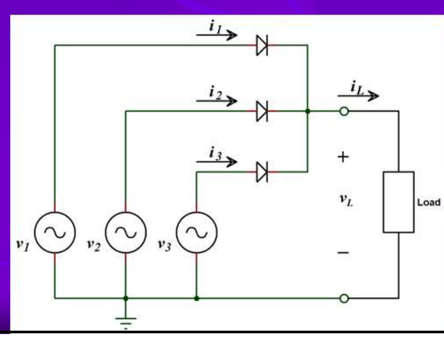
- Consider the 3-phase supply of sinusoidal waveforms.
- Phases are displaced by 120 degrees from each other.



3-Pulse Rectifiers

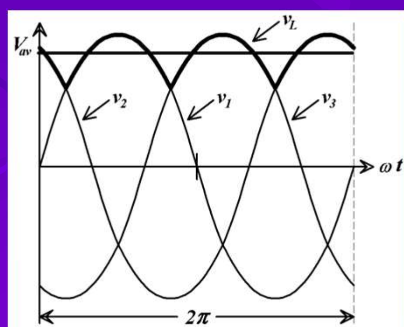
- The poly-phase rectifier operation is similar to diode or-gate operation.
- The output assumes the value of the highest input at any instant in time.
- Therefore there will be three pulses in the output voltage waveform.
- The output ripple frequency is therefore 150 Hz.
- In practice, the poly-phase AC sources are displaced symmetrically in phase, however, this condition is not necessary for the basic operation of the circuit below.

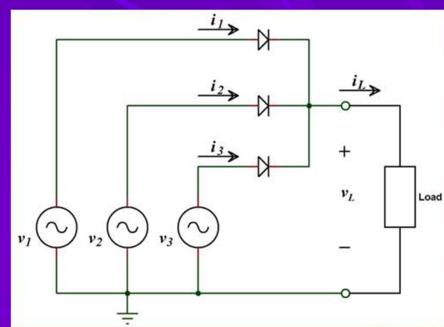




3-Pulse Rectifiers

- If it is assumed that the load is highly inductive and the inductance approaches infinity, the load current becomes constant.
- This circuit is known as 3-phase, half-wave, 3-pulse rectifier.





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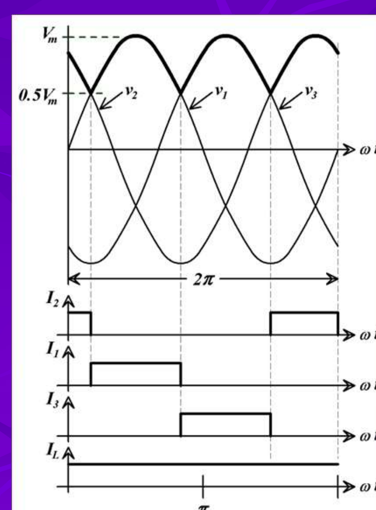
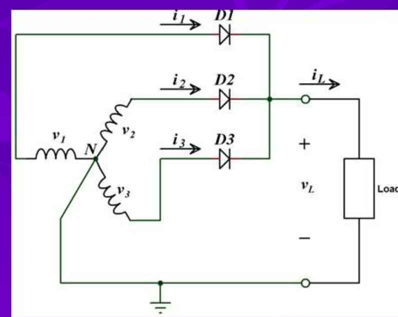
3-Pulse Rectifiers

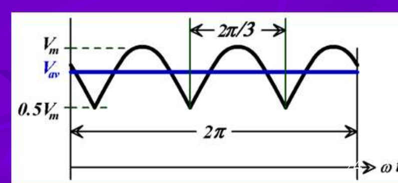
- The load current and phase current waveforms w.r.t. voltages are shown.
- It can be seen that the circuit draws unidirectional current from the sources.
- Therefore, this circuit is not used in practice for high power outputs.
- In practice, a full-wave circuit is used.
- The full-wave circuit draws AC current from the sources.



3-Φ, 3-Pulse Converter

- The connections of a 3-pulse converter using three diodes and a three phase transformer are shown.
- The secondary winding of the power transformer is Y-connected using the common N point as the negative of the load point.
- The output is has three pulses per cycle with a pulse width of $2\pi/3$ radians.
- Note that the pulses do not touch the zero level.
- The peak of the output DC is nearly the peak value of the AC.
- The minimum DC voltage is $V_m \sin(2\pi/6)=V_m/2$





3-Φ, 3-Pulse Converter

The average DC voltage can be calculated as

$$V_{av} = \frac{1}{(2\pi/3)} \int_{\pi/6}^{5\pi/6} V_m \sin\theta d\theta \quad (14)$$

$$V_{av} = \frac{3\sqrt{3}}{2\pi} V_m \quad (15)$$

The peak to peak ripple voltage is

$$V_{r(P-P)} = V_m - V_m \sin\left(\frac{\pi}{6}\right) = \frac{V_m}{2} = \frac{\sqrt{2}}{2} V_{rms} \quad (16)$$

And rms value of the ripple voltage is

$$V_{r(rms)} = \frac{V_{r(p-p)}}{2\sqrt{2}} = \frac{\sqrt{2}}{2\times 2\times \sqrt{2}} V_{rms} = \frac{V_{rms}}{4} \quad (17)$$

For phase voltage of 230 Volts, the rms ripple is 57.5 Volts @150Hz.

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3-Φ, 6-Pulse Converter

- 6-pulse, full-wave converter can be constructed by connecting two-half wave converters in series.
- The six pulses in the output are obtained by using two, 3-pulse converters connected in series.
- Two sets of three pulses, displaced by 60^{O} if added, results 6-pulses per cycle.

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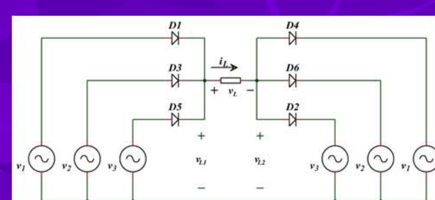
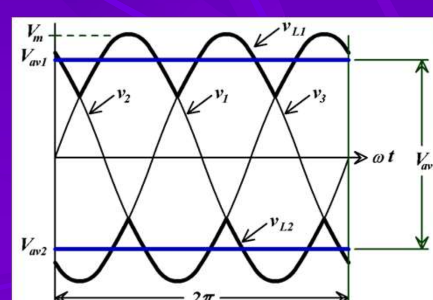
3-Φ, 6-Pulse Converter

- The evolution of 6-pulse converter from two 3-pulse converters is shown with input and output voltage waveforms.
- The average value of the voltage at positive terminal of load ***w.r.t.*** common point is v_{av1}.
- And the average voltage at negative terminal of the load ***w.r.t.*** common point is v_{av2}.
- The average voltage across the load can be calculated by adding the two 3-phase half-wave voltages.





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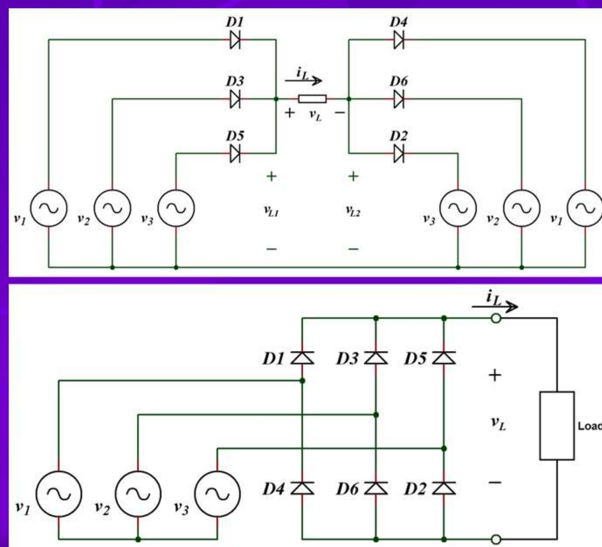
3-Φ, 6-Pulse Converter



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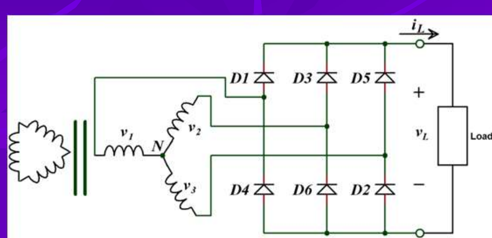
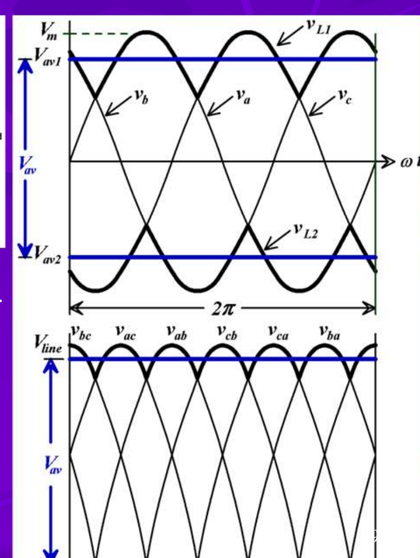
3-Φ, 6-Pulse Converter





- The practical circuit of the 6-pulse converter using a delta-star transformer is shown with output load voltage waveform.
- It can be seen that the output have six pulse per cycle.
- Therefore, the ripple will have a frequency of 300Hz.
- The ripple is small compared to 3-pulse converter.

Analysis of 6-Puse Converter

$$V_L = V_{L1} + V_{L2} \qquad (17)$$

$$V_{av} = 2\left[\frac{3\sqrt{3}}{2\pi}V_m\right] \qquad (18)$$

Where V_m is the peak value of the Phase to neutral voltage V_{ph}.

$$V_{av} = \left[\frac{3\sqrt{3}}{\pi}V_{ph}\right] = \frac{3}{\pi}V_{line} \qquad (19)$$

The ripple in the output voltage can be calculated by calculating the voltage at cross-points of the output waveform

$$V_{line(60^o)} = 0.866V_{line(pk)} \qquad (20)$$

$$V_{r(p-p)} = (1-0.866)V_{line} = (1-0.866)\sqrt{3}V_{ph} \qquad (21)$$

$$V_{r(p-p)} = (1-0.866)\sqrt{3}\sqrt{2}V_{rms} \qquad (22)$$

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Analysis of 6-Puse Converter

$$V_{r(rms)} = \frac{V_{r(p-p)}}{2\sqrt{2}} \qquad (23)$$

$$V_{r(rms)} = \frac{(1-0.866)\sqrt{3}}{2}V_{rms} = 0.166V_{rms} \qquad (24)$$

For V_{rms} of 230 volt, the rms ripple is

$$V_{r(rms)} = 26.8V \qquad (25)$$

As there are six pulses per cycle, the frequency of the ripple is 300 Hz.

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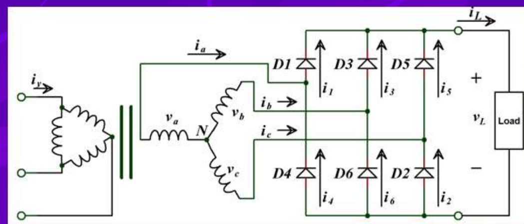
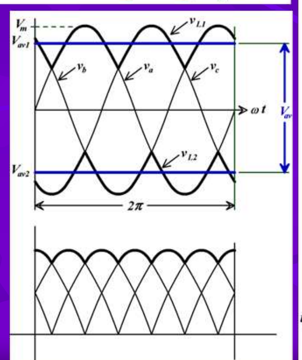
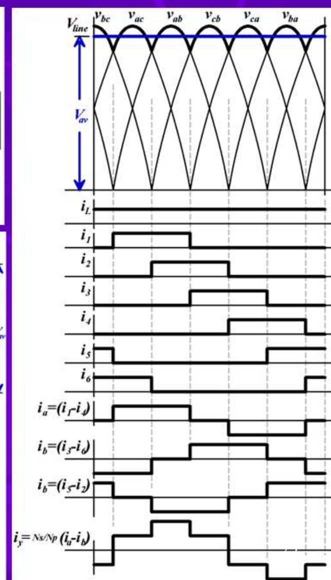
Currents Waveforms







Practical circuit of
6-puse converter with
Phase Voltage, Line Voltage,
and phase current and line
current waveforms

Analysis of Current Waveform

If we perform the Fourier analysis of the line current waveform, the following equation represents the nth harmonic of the current waveform.

$$I_n = \frac{4I_d}{n\pi}\sin\left(\frac{n\pi}{2}\right)\bullet\cos\left(\frac{n\pi}{6}\right) \qquad \textbf{(26)}$$

For n=1,2,3,4….∞

- ‘sin’ term in equation (26) indicates that the even harmonics are zero.
- ‘cos’ term indicates that the 3rd and its multiple (triplen) harmonics are zero.
- However, all other odd harmonics are present in the spectrum.
- The distortion factor will be more closer to 1 as compared to square wave.
- The distortion factor can be improved by increasing the number of steps in the current wave and making is more closer to sinusoidal wave.
- This technique to improve the quality of current waveform is known as
- “***Selective Harmonic Cancellation Technique***”.

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