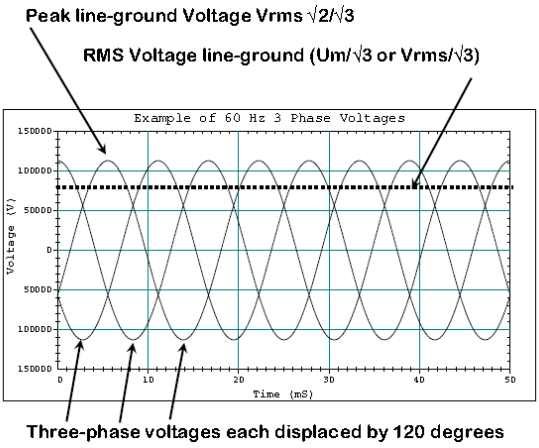
Review of 3-Phase Power Fundamentals

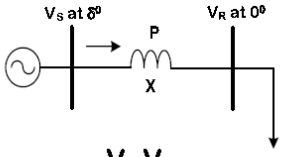
Note Title 2/2/2014

S = MVA $_{3-Ø}$ = 3-phase MVA
S = MVA $_{1-Ø}$ = 1-phase MVA
Q = MVAR $_{3-Ø}$ = 3-phase MVAR (reactive)
Q = MVAR $_{1-Ø}$ = 1-phase MVAR (reactive)
P = MW $_{3-Ø}$ = 3-phase MW (real)
P = MW $_{1-Ø}$ = 1-phase MW (real)
V_{L-L} = Line-to-line voltage
V_{L-G} = Line-to-ground voltage
I = Line (phase) current
Ø= Phase angle relationship between voltage and current
R, L, C = Resistance, inductance and capacitance
Z, R, X = Impedance, resistance, reactance
f = Frequency
δ = Relative phase angle of voltage phasors

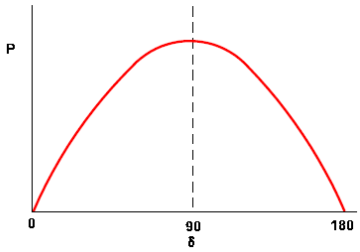
*Voltage



* Power Angel Curve



$$P = \frac{V_S V_R}{X} \sin\delta$$



* Impedance

		Circuit	Model	Energy
Resistor	i(t) →	+ v(t) -	$v(t) = R\, i(t)$	$E = RI^2 t$
Inductor	i(t) →	+ v(t) -	$v(t) = L \frac{di(t)}{dt}$	$E = \frac{1}{2} LI^2$
Capacitor	i(t) →	+ v(t) -	$i(t) = C \frac{dV(t)}{dt}$	$E = \frac{1}{2} CV^2$

* Some Basic Relationships:

$$MVA_{3\phi} = \sqrt{3}V_{L-L}I = \sqrt{P_{3\phi}^{\ 2} + Q_{3\phi}^{\ 2}}$$

$$P_{3\phi} = MW_{3\phi} = \sqrt{3}V_{L-L}I\cos(\phi) = MVA\cos(\phi)$$

$$Q_{3\phi} = MVAR_{3\phi} = \sqrt{3}V_{L-L}I\sin(\phi) = MVA\sin(\phi)$$

$$MVA_{3\phi} = \frac{V_{L-L}^{\ 2}}{Z}$$

$$MW_{3\phi} = \frac{V_{L-L}^{\ 2}}{R}$$

$$MVAR_{3\phi} = \frac{V_{L-L}^{\ 2}}{X}$$

$$\text{power factor(pf)} = \cos\left(\tan^{-1}\left(\frac{Q}{P}\right)\right)$$

$$Z = \sqrt{R^2 + X^2}$$

$$MVA_{1\phi} = V_{L-G}I$$

$$MVA_{1\phi} = \frac{V_{L-G}^{\ 2}}{Z}$$

$$MW_{1\phi} = \frac{V_{L-G}^{\ 2}}{R}$$

$$MVAR_{1\phi} = \frac{V_{L-G}^{\ 2}}{X}$$

$$V_{L-G} = \frac{V_{L-L}}{\sqrt{3}}$$

$$X_c = \frac{1}{2\pi fC} \qquad X_L = L2\pi f$$

* Per-Unit Relationships:

$$S_{base} = MVA_{base} = \text{Specified}$$

(usually 100 or 1000 MVA 3ϕ)

$$V_{base} = \text{Specified L-L or L-G}$$

$$I_{base} = \frac{S_{base1\phi}}{V_{baseL-G}} = \frac{S_{base3\phi}}{\sqrt{3}V_{baseL-L}}$$

$$Z_{base} = \frac{V_{baseL-G}}{I_{base}} = \frac{V_{baseL-L}}{\sqrt{3}I_{base}}$$

$$MVA_{pu} = \frac{MVA}{MVA_{base}}$$

MW and MVAR use the MVA base

$$V_{pu} = \frac{V}{V_{base}}$$

$$I_{pu} = \frac{I}{I_{base}}$$

$$Z_{pu} = \frac{Z}{Z_{base}}$$