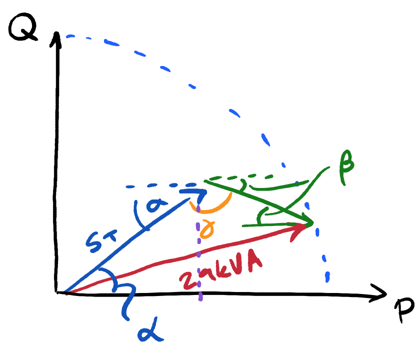
Assignment 1 - Phasors

Monday, January 11, 2016 10:52 AM

(10 pts)
A 29 kVA transformer supplies a load of 7.25 kW at a power factor of 0.45 lagging. If the additional loads have a power factor of 0.6 leading, how many kVA of these loads can be added to bring the transformer to its full load capacity?

kVA



$\alpha = acos(0.45) = 63.256°$ (+)ive b/c lagging

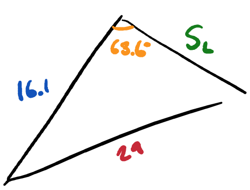
$P_T = 7.25kW$

$Q_T = P_T \tan\alpha = 7.25 \tan 63.256° = 14.3876$ kVAR

$S_T = \sqrt{P_T^2 + Q_T^2} = 16.\bar{1}$ kVA

$\beta = acos(0.6) = 53.13$ (-)ive b/c leading

$\gamma = 180 - \alpha - \beta = 63.6139°$



By cosine law: $\boxed{S_L = 32.31 \text{ kVA}}$

(10 pts)
A 35 kVA transformer is at full load with an overall power factor of 0.44 lagging. The power factor is improved by adding capacitors until the overall power factor becomes 0.9 lagging.

(a) Determine the $kVAr$ of capacitors required. , Q_c

(b) After correction of the power factor, what percentage of full load is the transformer carrying?

$\theta_o = acos(0.44) = 63.896°$

$S_o = 35\,kVA$

$P_o = S\cos\theta = 35k\cos 63.9 = 15.4\,kW$

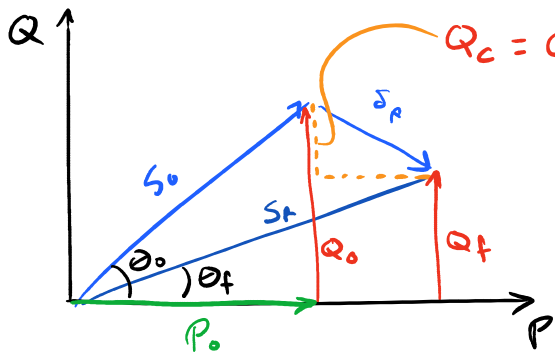
$Q_o = S\sin\theta = 35k\,\sin 63.9 = 31.43\,kVAR$

$\theta_f = acos(0.9) = 25.842^\circ$

$S_f = \dfrac{P_o}{\cos(25.842)} = \dfrac{15.4kW}{0.9} = 17.\bar{1}\,kVA$

$Q_f = S_f \sin\theta_f = 17.11k\,\sin 25.842 = 7.4586\,kVAR$

$Q_c = Q_o - Q_f = 23.97\,kVAR$



$\%\text{ full load} = \dfrac{S_f}{S_o} \times 100\%$

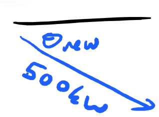
$= \dfrac{17.1 \times 100}{35} = 48.8889\%$

(10 pts)

A group of induction motors with a total of 500 kW and a power factor of 0.8 lagging is to be partially replaced with synchronous motors of the same efficiency but leading power factor of 0.7. As the replacement program continues, the overall power factor is constantly improving. What percentage of the load will have been replaced when the system power factor reaches 0.9 lagging?

[ ] %

"same efficiency" ie. also have 500kW .

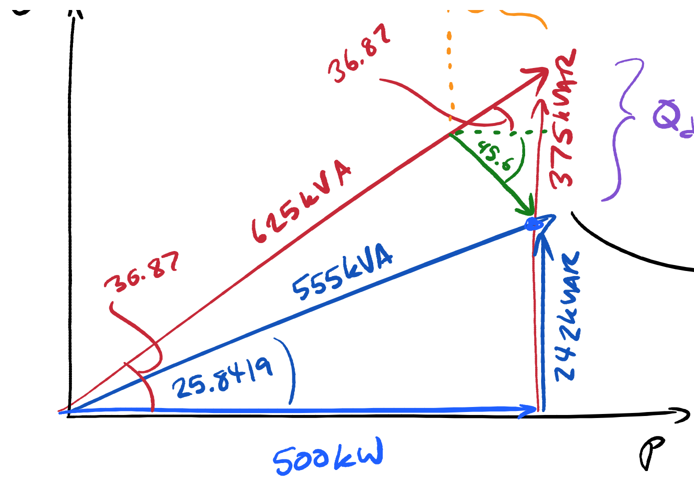


$\theta_{old} = acos(0.8) = 36.87^\circ$ lagging (+) , $S = \dfrac{500}{0.8} = 625\,kVA$,

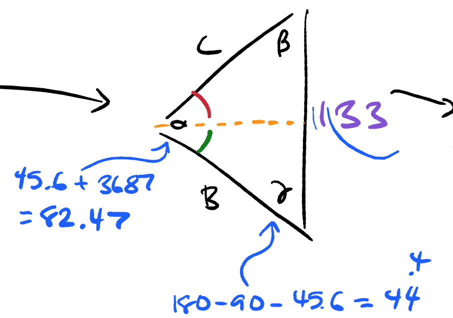
$\theta_{new} = acos(0.7) = 45.573$ leading (-) $Q = S\sin\theta_{old} = 625\sin 36.87 = 375.263\,kVAR$

$\theta_{final} = acos(0.9) = 25.8419$ lagging (+) , $S = \dfrac{500}{0.9} = 555.56\,kVA$,

$Q = 555.56\sin 25.84 = 242.14\,kVAR$



$Q_{diff} = 375k - 242k = 133\text{kVAR}$



cosine law

$C = 92.18$

$B = 108.71$

$P_{replaced} = 108.71 \sin 43.4 = 74.69$

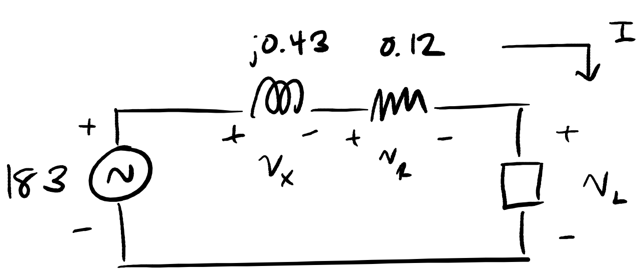
$$\%\text{ load replaced} = \frac{P_{replaced}}{P_o} = \frac{74.69}{500} = 14.9 \simeq 15\%$$

(10 pts)

A load with a lagging power factor of 0.82 is fed from a 183 V source through a cable that can be represented by a resistance Rc = 0.12 ohm in series with an inductive reactance Xc = 0.43 ohm. The power factor seen by the source is 0.62 lagging. What are the active and reactive power absorbed by the load?

Active =

Reactive =

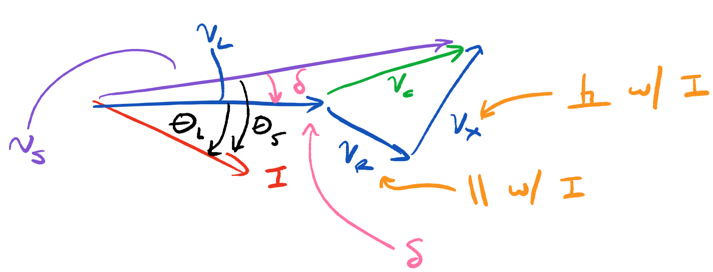


$\bar{V}_R = R\bar{I}$ ∴ $\bar{V}_R$ is in phase w/ $\bar{I}$

$\bar{V}_x = jX\bar{I}$ ∴ $\bar{V}_x$ is out of phase w/ $\bar{I}$

if not given any phases, you may choose one as reference arbitrarily.

so choose V_L as $\angle \emptyset$



$\theta_L = \text{acos}\, PF_L = \text{acos}\, 0.82 = 34.9152°$

$\theta_s = \text{acos}\, PF_s = \text{acos}\, 0.62 = 51.6838655°$

$\delta = \theta_s - \theta_L = 51.6839 - 34.9152 = 16.76866°$

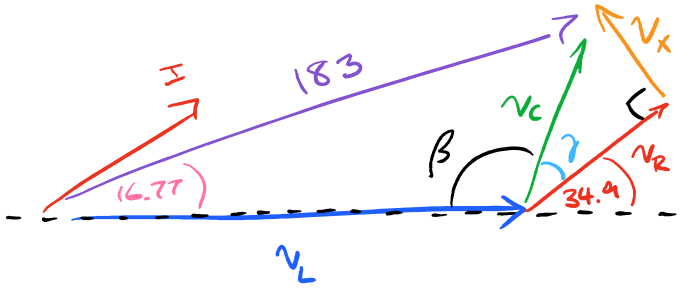
$\gamma = \text{atan}\frac{V_x}{V_R} = \text{atan}\frac{XI}{RI} = \text{atan}\frac{X}{R} = \text{atan}\frac{0.43}{0.12}$

$= 74.407°$

$\beta = 180 - \gamma + \theta_L = 140°$

V_x

= 74.407



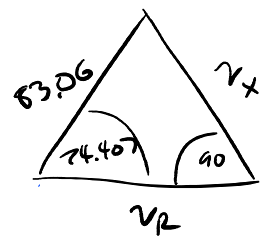
$\beta = 180 - \gamma + \theta_L = 140°$

└→ by cosine law

$V_c = 83.06$
$V_L = 111.11$

└→ by cosine law again

$V_R = 22.33$
$V_x = 80$



$$|I| = \frac{|V_R|}{R} = \frac{22.33}{0.12} = 186.08\bar{3}\ A$$

$S_L = V_L I = 111.11V \cdot 186A = 20.67\ kVA$

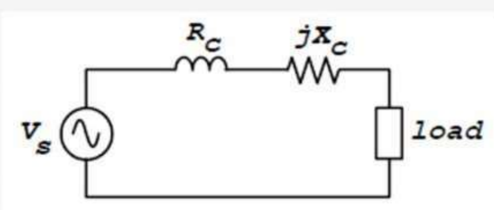
$P_L = S_L \cos\theta_L = 20.67k \cos 34.9 = \boxed{16.954\ kW}$

$Q_L = S_L \sin\theta_L = 20.67k \sin 34.9 = \boxed{11.834\ kVAR}$

(10 pts)

The secondary of a transformer is represented by the source on the left in Figure 1. It is feeding a load through a cable represented by the series $R_C + jX_C$. The voltage at the source is measured as 480 V. The voltage at the load is also 480 V. The current is 120 A. The power measured at the source is 55.5 kW. The power measured absorbed by the load (P) is 41.6 kW. Determine the values of R_C and X_C.

Figure 1:



R_C =

X_C =

$P = VI\cos\theta$

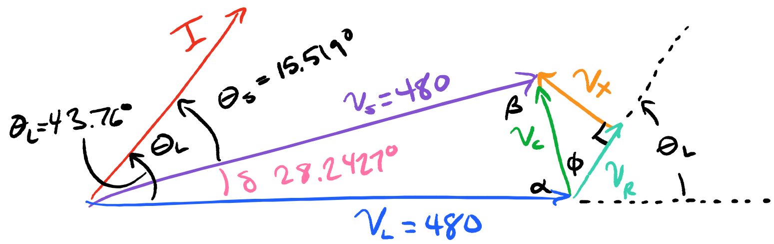
$$\theta_L = a\cos\left(\frac{P_L}{V_L I}\right) = a\cos\frac{41.6e3}{480 \cdot 120} = -43.764°$$

phase of I

current is leading ∴ both θs negative b/c capacitive

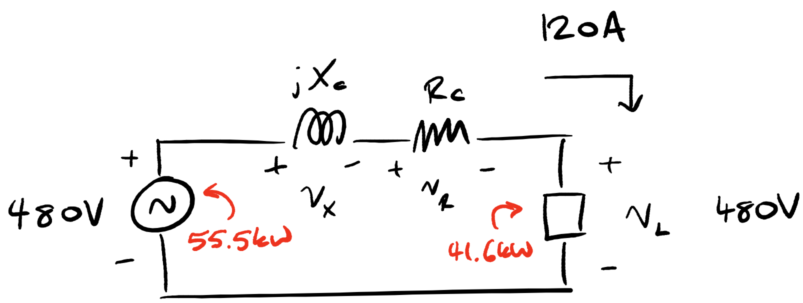
$$\theta_s = a\cos\left(\frac{P_s}{V_s I}\right) = a\cos\frac{55.5e3}{480 \cdot 120} = -15.519°$$

$\delta = \theta_s - \theta_L = 28.2427°$



$\beta = \alpha = 75.88$ $\phi = 180 - (\alpha - \theta_L) = 180 - \alpha + \theta_L = 60.3583$

$V_c = 234.22$



$$X = \frac{V_x}{I} = \frac{203.45}{120} = \boxed{1.6954\,\Omega}$$

$$R = \frac{V_R}{I} = \frac{116.05}{120} = \boxed{0.967\,\Omega}$$

(20 pts)

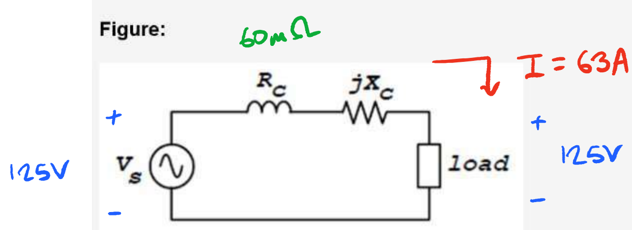
In a configuration like the one in Figure, the source and the load (factory) have the same RMS voltage value, 125 V. The cable has a resistance of 60 $m\Omega$ and the reactance of the cable is 5.5 times its resistance. If the load is taking 63 A:

(a) What is the power factor [redacted]e at the load?

(b) What is the power factor [redacted] at the source?

(c) What are the active and reactive power at the load and at the source (Just Magnitude)

Figure:



(a) PF =

(b) PF =

(c) P_{Source} =

(c) P_{Source} =

P_{Load} =

Q_{Source} =

Q_{Load} =

$\phi = \text{atan}\frac{X}{R} = \text{atan}\ 5.5 = 79.695$

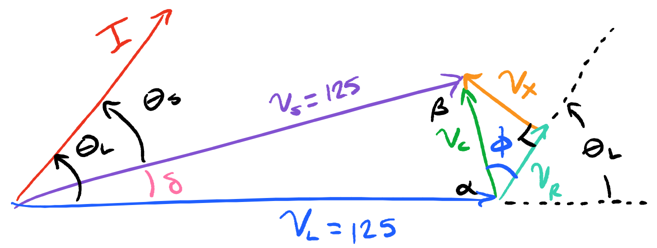
$V_R = RI = 60m \cdot 63A = 3.78V$

$V_X = jXI = j60m \cdot 5.5 \cdot 63A = 20.79V$

$V_c = \sqrt{V_R^2 + V_X^2} = 21.13084V$

↳ cosine law → $\delta = 9.70°$

$\alpha = \beta = 85.13°$



$\theta_L = \phi - 180 + \alpha = -15.175°$

$PF_L = \cos(\theta_L) = \cos(-15.175) = \boxed{0.965}$

$\theta_s = \theta_L + \delta = -15.175° + 9.70° = -5.475 \rightarrow PF = \cos(-5.475) = \boxed{0.995}$

$P_L = V_L I \cos\theta_L = 125 \cdot 63 \cos(-15.175) = 7.6kW$

$P_s = V_s I \cos\theta_L = 125 \cdot 63 \cos(-5.475) = 7.839kW$

$Q_L = V_L I \sin\theta_L = -751.56\ VA$

$Q_s = V_s I \sin\theta_s = -2.061kVA$

A1Q9. ✓

(10 pts)

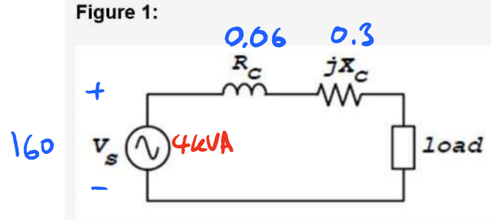
In a power system like Figure 1, the voltage of the source is 160 V. The power at the source is 4 kVA. The load is purely resistive, and the cable data is R = 0.06 Ω and X = 0.3 Ω.

(a) What is the voltage at the load?

(b) What is the voltage drop in this system, in percent?

(c) What is the active and reactive power of the load?

Figure 1:



(a) V_1 =

(b) V_r =

(c) Reactive =

Active =

$$I = \frac{S}{V} = \frac{4kVA}{160V} = 25A$$

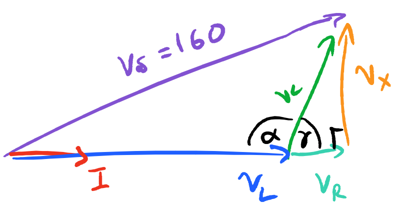
$$\gamma = \operatorname{atan}\frac{V_x}{V_R} = \operatorname{atan}\frac{X}{R} = \operatorname{atan}\frac{0.3}{0.06} = 78.69°$$

$$V_R = RI = 1.5V$$

$$\alpha = 180 - \gamma = 180 - 78.69 = 101.31°$$

↳ by cosine law

$$V_x = 7.5V$$
$$V_c = 7.65V$$



↳ by cosine law again

$$\boxed{V_L = 158.32}$$

b/c resistive

$$Q = \emptyset$$
$$P = V_L I = 3.958kW$$

$$\%\text{ voltage drop} = \frac{V_s - V_L}{V_s} = \frac{160 - 158.32}{160} = \boxed{1.05\%}$$