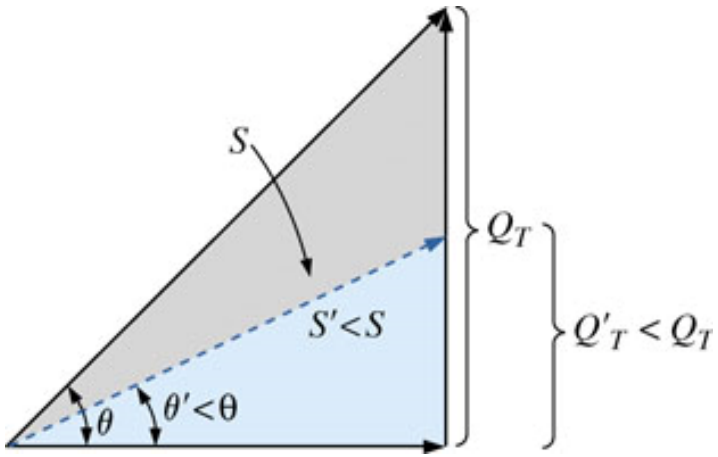
Power-Factor Correction

- Description
- Why
  - Primarily current (affects size, reliability, cost, etc)
- Example (use your calculator)
  - Lagging power factor (inductive)
  - Similar to Lab #6 coming up
- PFC Panels
  - Text and an internet search
- In Class Problem
  - Factory loading
  - Similar to a couple of homework problems

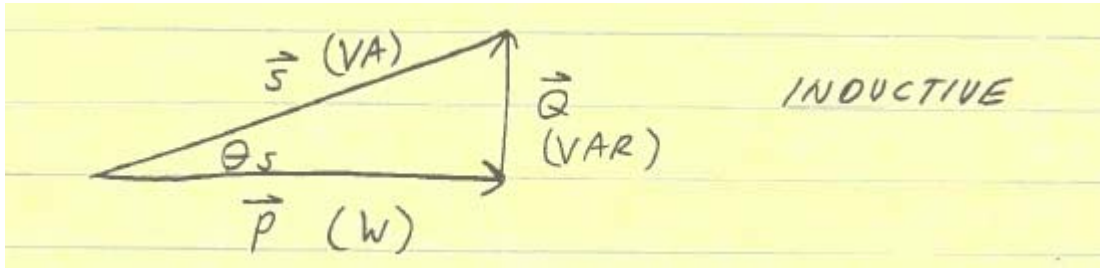
Power-Factor Correction - Description

- The design of any power transmission system is very sensitive to the magnitude of the current in the lines as determined by the applied loads.
- Increased currents result in increased power losses (by a squared factor since $P = I^2R$) in the transmission lines due to the resistance of the lines.
- The process of introducing reactive elements to bring the power factor closer to unity is called power-factor correction.
- Since most loads are inductive, the process normally involves introducing elements with capacitive terminal characteristics having the sole purpose of improving the power factor.



Power-Factor Correction – Why?

Consider:



But remember:

$$\vec{S} = \vec{V}\vec{I}^{*}$$

$$\vec{I}^{*} = \frac{\vec{S}}{\vec{V}}$$

Hence:

- MAGNITUDE OF $\vec{I}$ DEPENDS ON $|\vec{S}|$ NOT ON $|\vec{P}|$ $\therefore$ AS $\theta_S \uparrow$ ($\downarrow$ PF $\downarrow$) $|\vec{I}| \uparrow$. MORE CURRENT REQUIRED TO DELIVER THE SAME REAL POWER. (EFFICIENCY ISSUE)

- I^2R LOSSES IN THE TRANSMISSION SYSTEM INCREASE WITH DECREASING PF. (LARGER, HEAVIER, MORE # WIRES)

- HIGHER CAPACITY COMPONENTS (TRANSFORMERS, WIRE, ETC) ARE REQUIRED (MORE # + SPACE)

Power-Factor Correction – Why?

TABLE 20.2

Penalties applied to loads based on the overall power factor of the load.

F_p	Penalty
1–0.9	None
0.9–0.85	3%
0.85–0.8	10%
0.8–0.75	20%
0.75–0.7	30%
0.7–0.6	40%
0.6–0.5	50%
0.5–0.3	80%
0.3–0	90%

RG&E

Electric Rates Summary – Effective May 1, 2017
PSC No. 19

Applicable to SC 8

Reactive Charge per Month (rkvah) – All SC8 customers will have a meter to measure the customer's reactive kilovolt ampere hours (rkvah). A customer is billed for the rkvah used that exceeds one-fourth of the metered kwh used. The difference between rkvah and one-fourth of the kwh used, known as the billing rkvah, indicates a low power factor. Power factor is the relationship between the energy actually supplied to the customer's equipment and the energy being effectively used by this equipment. Motors, magnetic lighting ballasts, and other equipment requiring magnetic fields to operate can adversely impact power factor.

https://www.rge.com/MediaLibrary/2/5/Content%20Management/RGE/SuppliersPartners/PDFs%20and%20Docs/RGE%20Electric%20Rate%20Summary.pdf

Power-Factor Correction – Why?

BC Hydro Power smart

Power factor and your bill

Power factor refers to the ability of your electrical system to convert electric current into useful work such as heat, light, and mechanical motion. To use electrical power efficiently your system should draw mostly real power, measured in kilowatts (kW), from our system. If your equipment draws too much reactive power, measured in kilovolt-amperes-reactive (kVAR), it can't perform work as efficiently and limits the capacity of our lines to deliver real power and quality voltage to your facility.

A power factor surcharge is applied to your account when your power factor is below 90%. It is used to recover the cost of supplying reactive power to you, which isn't included in other charges.

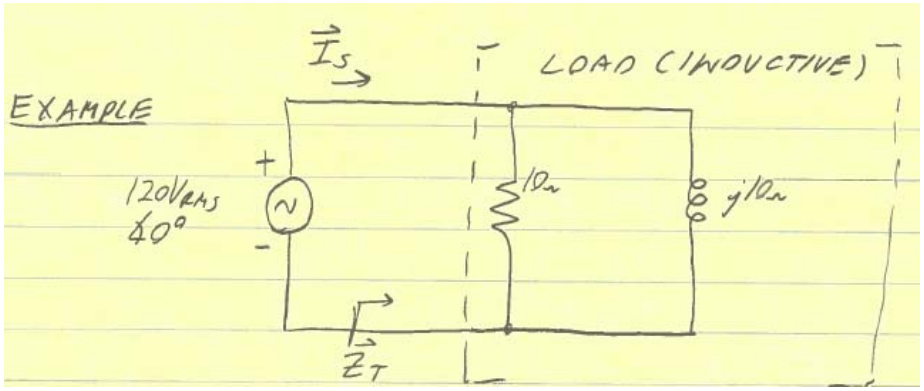
Amount of the surcharge

If your average power factor for the billing period falls below 90%, your bill will be increased by the following percentages, which are applied to the total of all other charges for the same period.

POWER FACTOR		SURCHARGE
100%	but 90% or more	None
90%	but 88% or more	2%
88%	but 85% or more	4%
85%	but 80% or more	9%
80%	but 75% or more	16%
75%	but 70% or more	24%
70%	but 65% or more	34%
65%	but 60% or more	44%
60%	but 55% or more	57%
55%	but 50% or more	72%
50%		80%

https://www.bchydro.com/accounts-billing/rates-energy-use/electricity-rates/power-factor.html

Power-Factor Correction – Example (check the numbers)



Find: Is and the power triangle

Approach:

- Find **ZT**, then **Is**
- Use **S** = **V Is***
- Check: expect a lagging power factor (inductive)

$$\vec{Z}_T = 10\Omega \,//\, j10\Omega = (5 + j5)\Omega$$

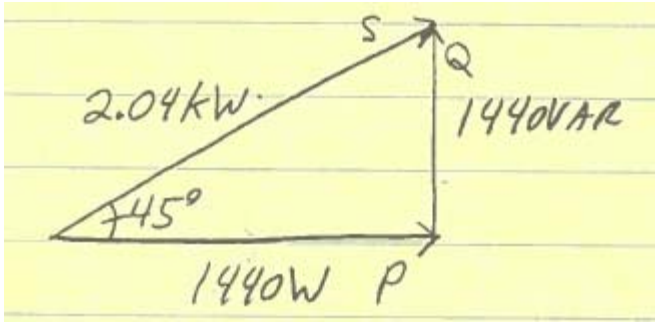
$$\vec{I}_S = \frac{120 V_{RMS} \angle 0^\circ}{(5 + j5)\Omega} = 16.97 A_{RMS} \angle -45^\circ$$

$$\vec{S} = \vec{V}\vec{I}_S^{\,*} = (120 V_{RMS} \angle 0^\circ)(16.97 A_{RMS} \angle 45^\circ)$$

$$= 2{,}036.4 VA \angle 45^\circ$$

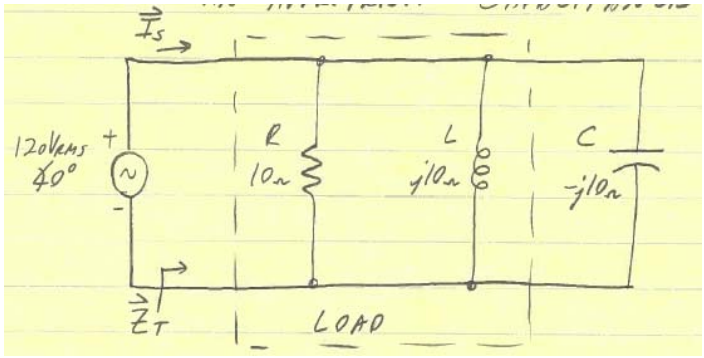
$$= 1{,}440 + j1{,}440$$

P (W) Q (VAR) INDUCTIVE



$$PF = \cos(45^\circ) = 0.707$$ lagging

Power-Factor Correction – Example (check the numbers)



Find: Is and the power triangle (for this power-factor corrected circuit) where we use C to cancel the effect of L)

Approach:

- Find **ZT**, then **Is**
- Use **S** = **V Is***
- Check: expect a unity power factor (resistive)

$$\vec{Z}_T = 10\Omega \,//\, j10\Omega \,//\, -j10\Omega = 10\Omega$$

$$\vec{I}_S = \frac{120 V_{rms} \angle 0^\circ}{10\Omega} = 12 A_{rms} \angle 0^\circ$$

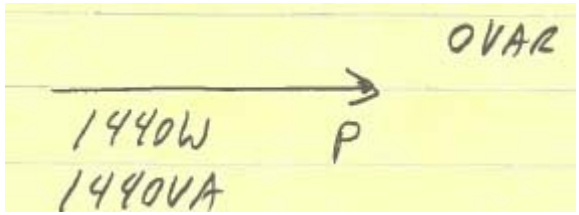
$$\vec{S} = \vec{V}\vec{I}_S^{\,*} = (120 V_{rms} \angle 0^\circ)(12 A_{rms} \angle -0^\circ) =$$

VAR

(1440 + j0) VA

W

Fp = cos(0º) = 1



Notes:

- In both cases the load received the same voltage and current
- In the corrected case, the source current was lower

Power-Factor Correction – PFC Panels

FIG. 20.30
Power-factor correction panel.
(Courtesy of Imsat Maritime, s.a.)

Power-Factor Correction – In Class Problem

THE LOADING OF A FACTORY ON A 1000V, 60Hz SYSTEM INCLUDES:

20kW HEATING ($F_p = 1$)
10kW INDUCTION MOTORS ($F_p = 0.7$ LAGGING)
5kW LIGHTING ($F_p = 0.85$ LAGGING)

(a) ESTABLISH THE POWER TRIANGLE FOR THE TOTAL LOADING ON THE SUPPLY

(b) FIND THE CAPACITOR REQUIRED TO CORRECT THE POWER FACTOR TO $F_p = 1$

(c) FIND $\vec{I}_s$ COMPENSATED & $\vec{I}_s$ UNCOMPENSATED (USE $\vec{S} = \vec{V}\vec{I}^*$)

Approach:

- (a) We know **S1** = 20kW + j0VAR, find **S2** and **S3** using the given Fp info and add to get $\mathbf{S_T}$ and the power triangle
- (b) Use **S** = **V Is*** to find **Ic** and hence **Zc** and finally C
- (c) Use **S** = **V Is*** to find **Is** for each case