# Basic Electrical Technology

[ELE 1051]

***SINGLE PHASE AC CIRCUITS***

# Recap

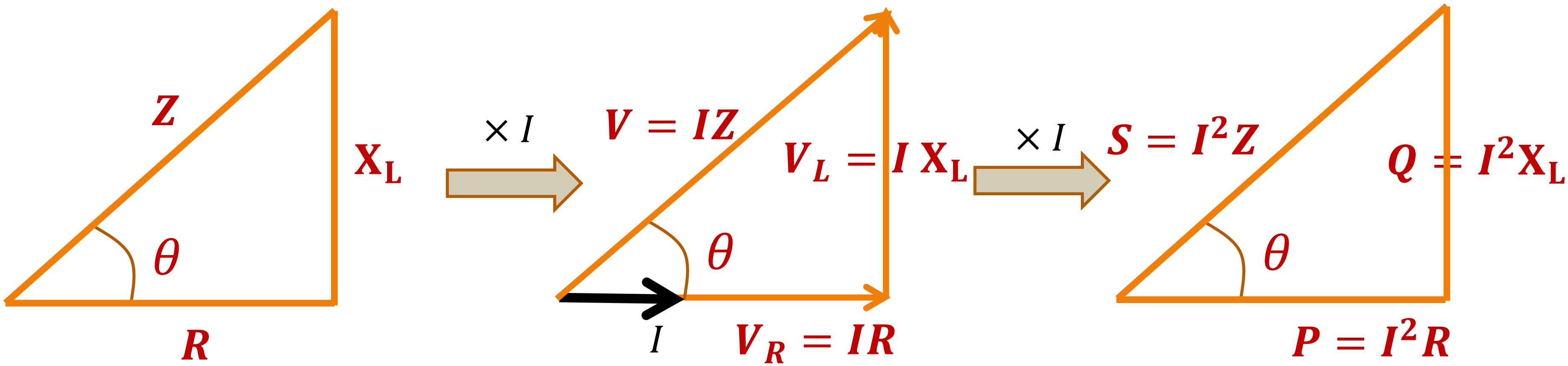
- AC circuit equations and solving
- Tutorial 1

# Topics covered

- Impedance, phasor & power triangles
- Concept of power factor and its significance
- Need for power factor improvement
- Tutorial 2a

# Power associated in RL load

For RL load:




Impedance diagram — Phasor diagram — Power diagram

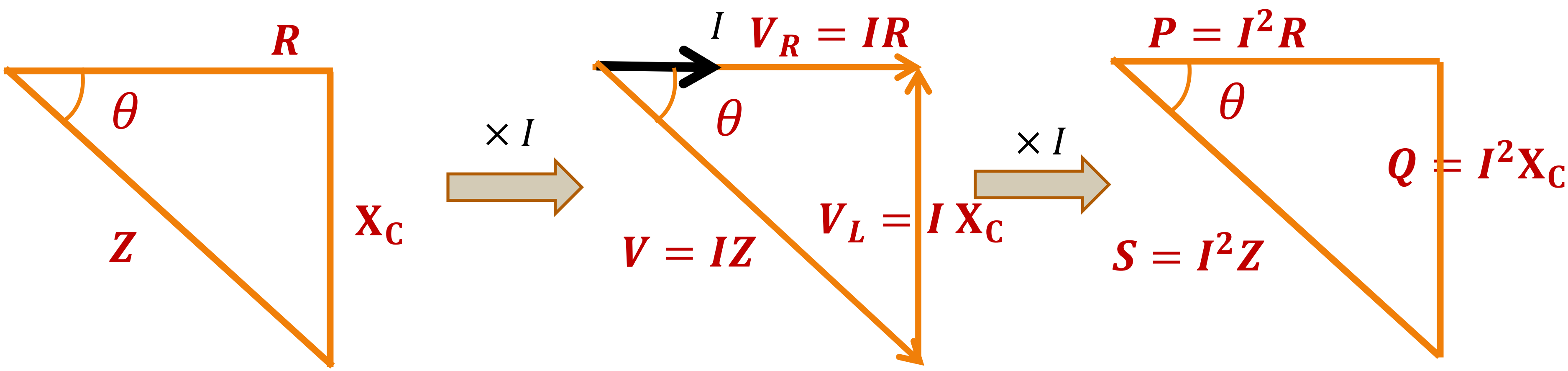
$$S = P + jQ$$

Where,
S = Apparent Power (VA)
P = Active Power (W)
Q = Reactive Power (var)

$$S = |V||I|$$
$$P = VI\cos\emptyset$$
$$Q = VI\sin\emptyset$$

# Power associated in RC load

For RC load:




<u>Impedance diagram</u> <u>Phasor diagram</u> <u>Power diagram</u>

$$S = P - jQ$$

Where,
S = Apparent Power (VA)
P = Active Power (W)
Q = Reactive Power (var)

$$S = |V||I\,|$$

$$P = VI\cos\emptyset$$

$$Q = VI\sin\emptyset$$

# Power in AC circuits

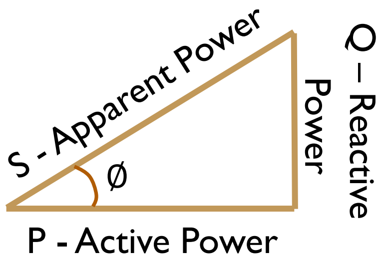
Power in AC circuit can be written as,

$$S = (\bar{V})(\bar{I}^*)$$

**For RL Load**

$$Z = |Z|\angle\emptyset$$
$$if\ \bar{V} = |V|\angle 0°$$
$$\bar{I} = |I|\angle -\emptyset$$
$$I^* = |I|\angle\emptyset$$

$$S = VI(\cos\emptyset + j\sin\emptyset)$$
$$S = P + jQ$$
$$P = V_{rms}I_{rms}\cos\emptyset$$
$$Q = V_{rms}I_{rms}\sin\emptyset$$




**For RC Load**

$$Z = |Z|\angle -\emptyset$$
$$if\ \bar{V} = |V|\angle 0°$$
$$\bar{I} = |I|\angle\emptyset$$
$$I^* = |I|\angle -\emptyset$$

$$S = VI(\cos\emptyset - j\sin\emptyset)$$
$$S = P - jQ$$
$$P = V_{rms}I_{rms}\cos\emptyset$$
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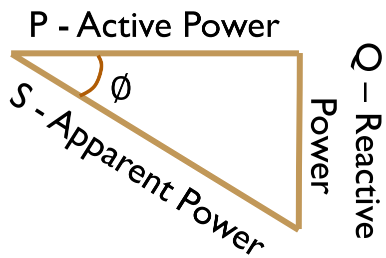
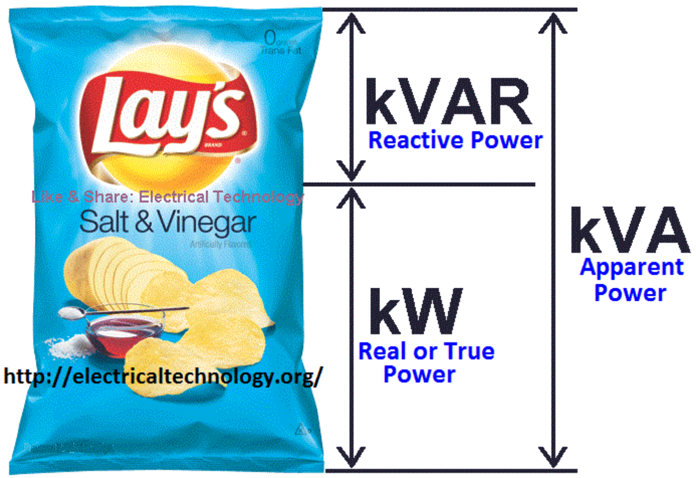
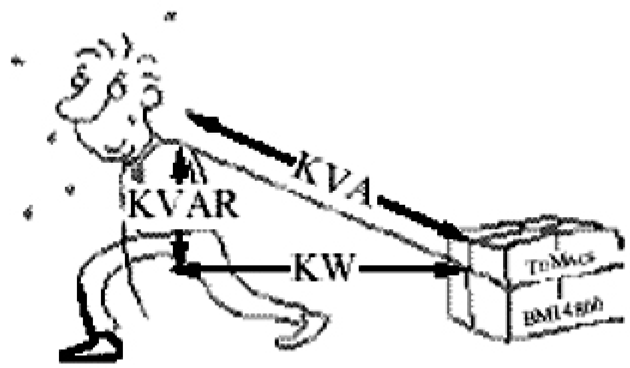



| | | | |
|---|---|---|---|
| *Units:* | *Apparent Power(S)* **VA** | *Active Power(P)* **W** | *Reactive Power(Q)* **var** |

# Complex Power Analogy



# Power Factor

$$\textbf{Power Factor} = \frac{\textbf{Active Power P in watts}}{\textbf{Apparent Power S in voltamperes}}$$

$$\cos\theta = \frac{P}{S} = \frac{P}{VI}$$

- For an impedance Z,

$$\cos\theta = \frac{IR}{V} = \frac{IR}{IZ} = \frac{resistance}{impedance}$$

- Power factor is *lagging* when the *current lags the supply voltage*
- Power factor is *leading* when the *current leads the supply voltage*
- For a resistive load, power factor is Unity

# Disadvantages of Low Power Factor

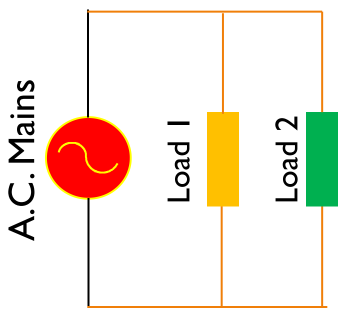
- Under utilisation of power system network
- Increased transmission losses
- Hence bulk consumers are advised to maintain the power factor close to unity by power utilities

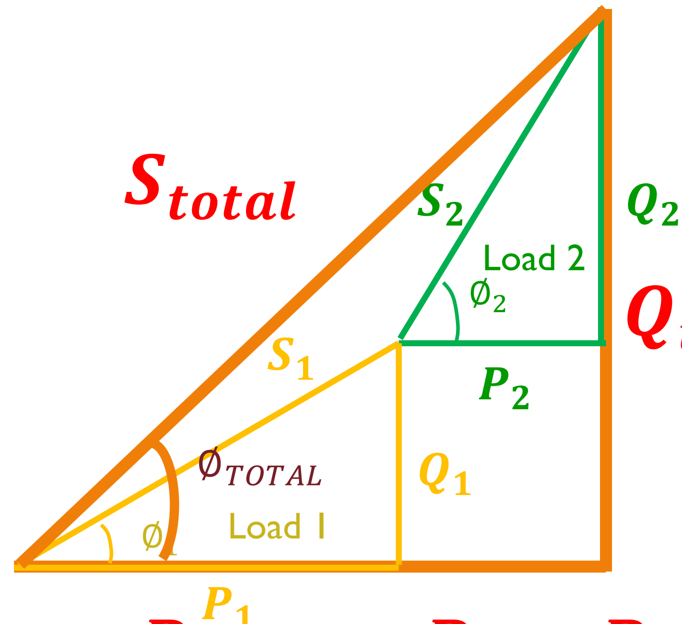
## Remedial Measures

- Reactive power demand of Inductive loads can be compensated with capacitive loads
- It is possible to localise reactive power requirement by connecting parallel capacitors across the load

# Power Triangle

- Practically, loads are in connected parallel
- Majority of the loads are inductive in nature




$$Q_{total} = Q_1 + Q_2$$

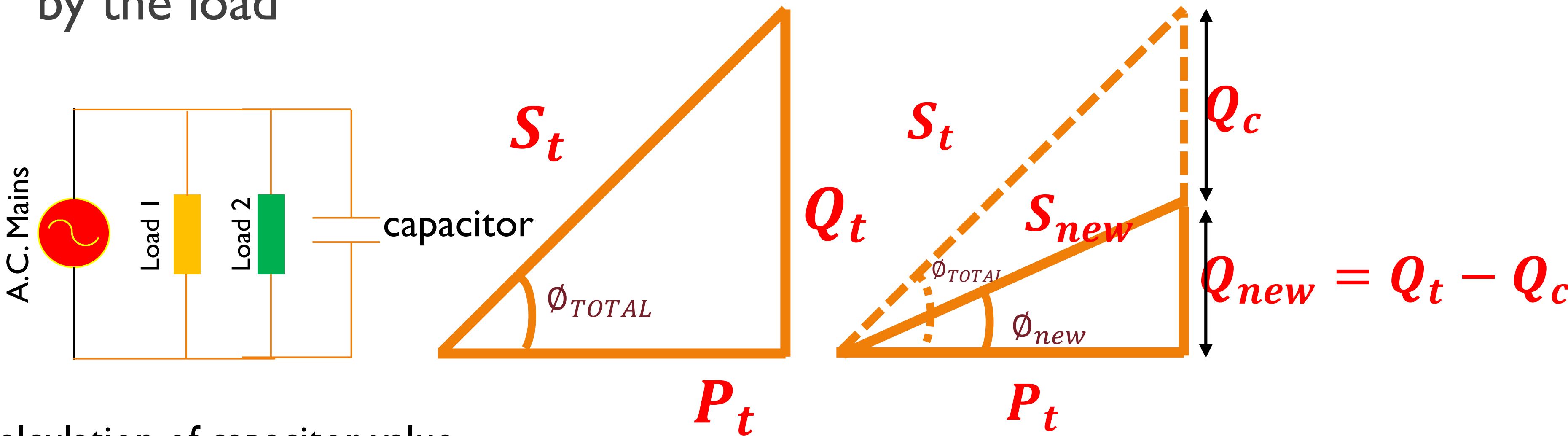
$$S_{total} = P_{total} + jQ_{total}$$

$$P_{total} = P_1 + P_2$$

http://www.kptcl.com/save.htm

# Power Factor Improvement

- Connect capacitor parallel to the load
- Energy stored by the capacitor provides the required reactive power by the load



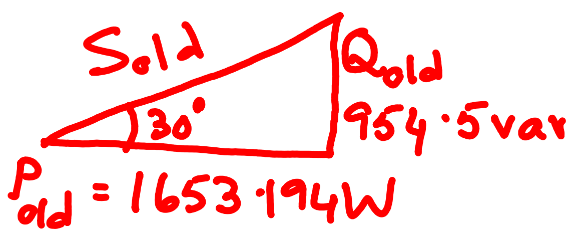

<u>Calculation of capacitor value</u>

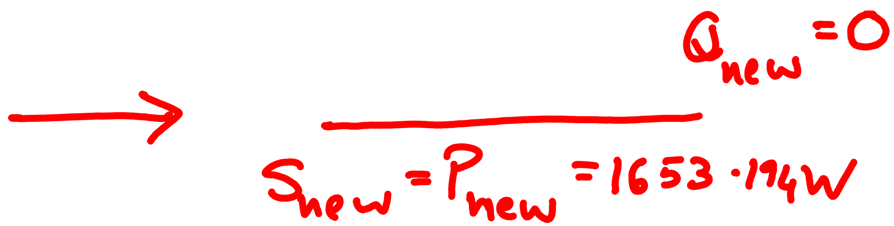
- Calculate $Q_c$ needed to improve power factor to $cos\emptyset_{new}$
- Calculate $X_c = \frac{V^2}{Q_C}$ & $C = \frac{1}{2\pi f X_c}$

# Illustration 1

A single-phase motor takes 8.3 A at a power factor of 0.866 lagging when connected to a 230 V, 50 Hz supply. Capacitance bank is now connected in parallel with the motor to raise the power factor to unity. Determine the capacitance value

**Solution:**




$P_{old} = 230 \times 8.3 \times 0.866$

$Q_{old} = 230 \times 8.3 \times \sin 30$

$Q_C = Q_{old} - Q_{new} = 954.5 \text{ var}$

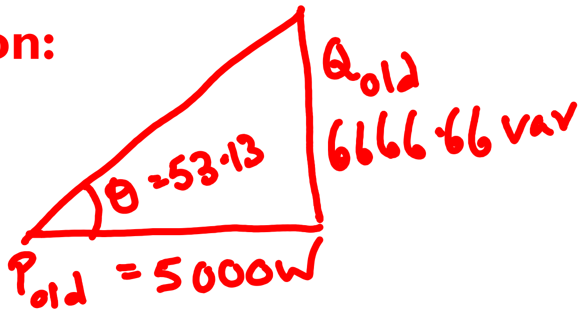
$Q_C = \frac{V^2}{X_C} \Rightarrow X_C = \frac{230^2}{954.5} = 55.4216\ \Omega$

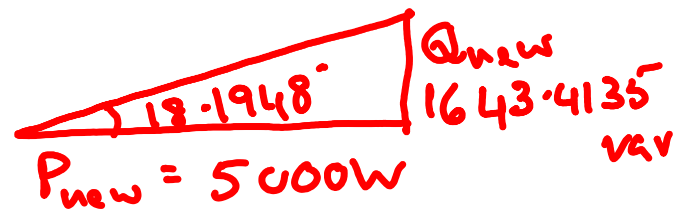
$\Rightarrow C = \frac{1}{2\pi f X_C} = 57.43\ \mu F$

# Illustration 2

A single-phase load of 5 kW operates at a power factor of 0.6 lagging. It is proposed to improve this power factor to 0.95 lagging by connecting a capacitor across the load. Calculate the kvar rating of the capacitor

**Solution:**



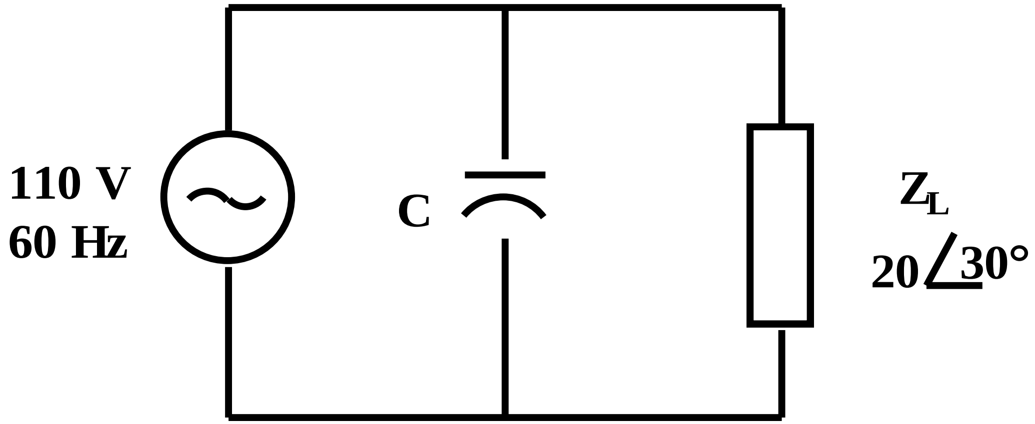

$$\tan 53.13 = \frac{Q_{old}}{5000}$$

$$Q_C = (6.666 - 1.643)k$$

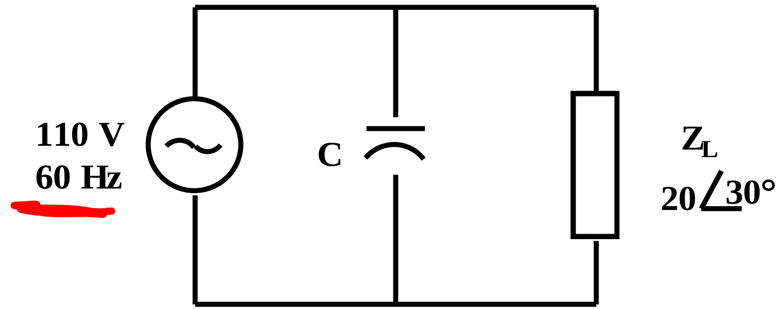
$$Q_C = \underline{5.023 \text{ kvar}}$$

# Exercise 1

In the parallel circuit shown, Find the value of Capacitance C, necessary to correct the power factor to 0.95 lagging



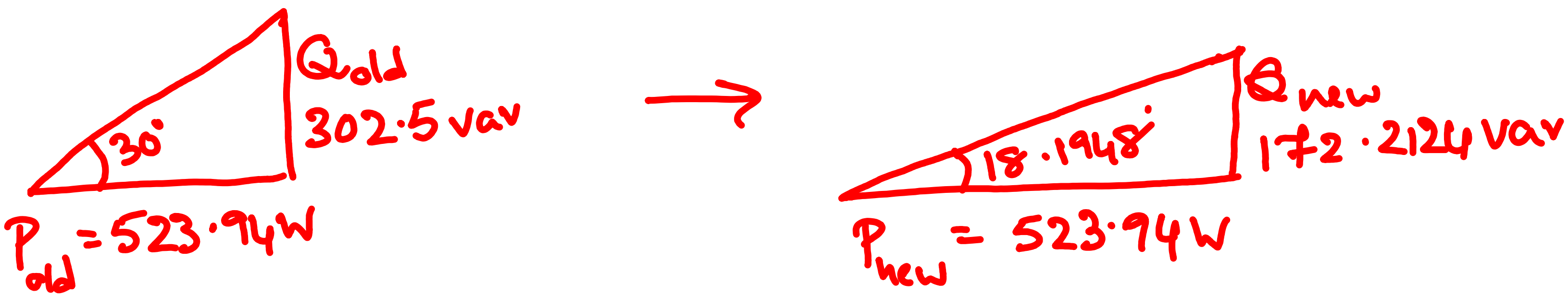
**Solution:**




Find C to improve p.f. to 0.95 lag

$$I = \frac{V}{Z} = \frac{110\angle 0}{20\angle 30} = 5.5\angle -30\ A$$

$$P_{old} = 110 \times 5.5 \times \cos 30 = 523.94\ W$$




$$Q_c = Q_{old} - Q_{new}$$

$$Q_c = 130.2875\ var$$

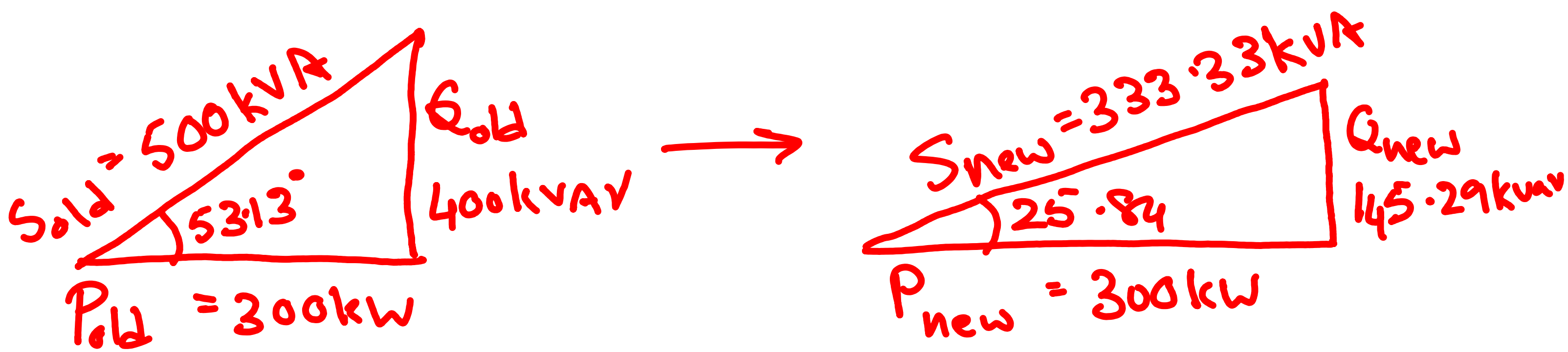
$$X_c = \frac{110^2}{130.2875} = 92.8715\ \Omega$$

$$C = \frac{1}{2\pi \times 60 \times 92.87} = 28.56\ \mu F$$

# Exercise 2

A 500 kVA transformer is at full load with power factor 0.6 lagging. What should be the kVAR rating of the shunt capacitor needed to improve its operating power factor to 0.9 lagging? What will be the percentage loading of the transformer after power factor correction?

**Solution:**




$$Q_c = Q_{old} - Q_{new} = 254.7033 \text{ kvar}.$$

$$\% \text{ loading} = \frac{333.33}{500} \times 100 = \underline{66}.$$

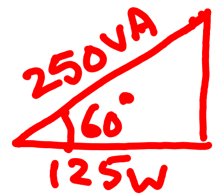
# Exercise 3

Obtain the complete power triangle for three parallel-connected loads:

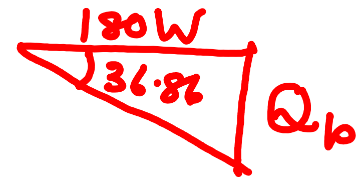
(a) 250VA, 0.5 p.f lagging

(b) 180W ,0.8 p.f leading

(c) 300VA, 100 var (inductive)

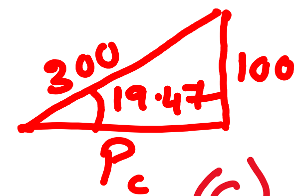



(a)




(b)

$S = P - jQ$




(c)

**Solution:**

$P_a = 0.5 \times 250 = 125W$

$Q_a = \tan 60 \times 125 = 216.50\ var$

$P_c = \sqrt{300^2 - 100^2}$

$= 282.84W$

$Q_c = 100\ var$

$P_b = 180W$

$Q_b = -135\ var$

$P_{total} = P_a + P_b + P_c = 587.84W$

$Q_{total} = Q_a - Q_b + Q_c = 181.50 var$

$S_{total} = P_{total} + jQ_{total} = 615.22 \angle 17.15\ VA$

# Homework 1

An inductive circuit supplied with 250V, 50Hz has an active power of 11.9 KW and apparent power of 17 KVA

a) Find the power factor of the circuit

b) Draw the power triangle

c) Find the value of the capacitance required to improve the p.f. to unity, 0.9 lagging ,0.9 leading

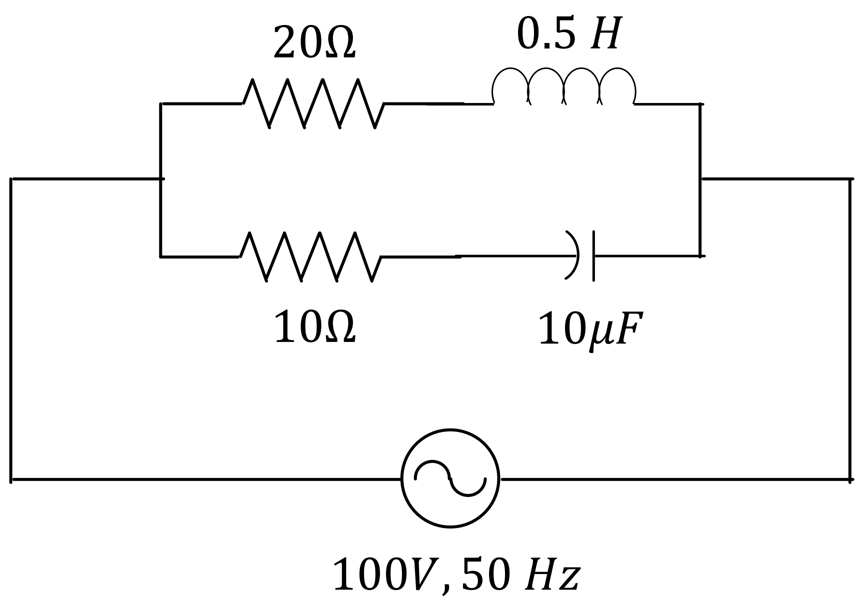
**Ans:**

**a) p.f = 0.7 lag**

**c) C= 618.3 μF,**
**324.9 μF,**
**911.6μF**

# Homework 2

Find the power factor of the circuit shown below. Also, find the value of the capacitor to be connected in series with the circuit to increase the power factor to unity.




**Ans: 0.276 lag, 9.95μF**