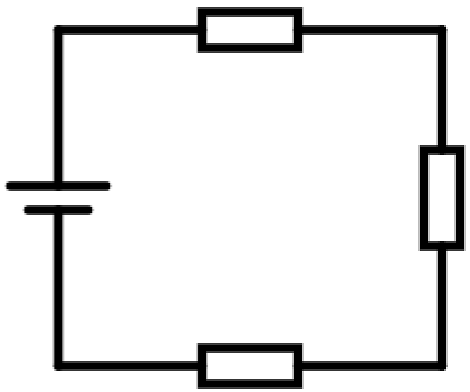
HE1027 Electrical Principals

Power in AC Current

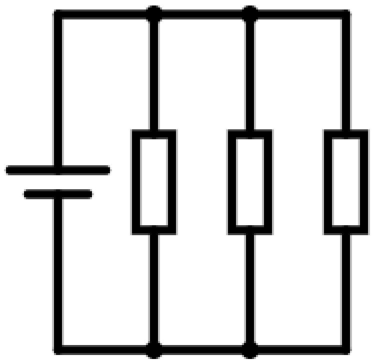
Power in series and parallel



$P_{total}=I_{total}*V_{total}$

$I_{total}=I_1=I_2=I_3$
$V_{total}=V_1+V_2+V_3$

$P_{total}= I_{total}*(V_1+V_2+V_3)$
$P_{total}= I_{total}*V_1+I_{total}*V_2+I_{total}*V_3$
$P_{total}= I_1*V_1+I_2*V_2+I_3*V_3$
$P_{total}=P_1+P_2+P_3$



$P_{total}=I_{total}*V_{total}$

$V_{total}=V_1=V_2=V_3$
$I_{total}=I_1+I_2+I_3$

$P_{total}= (I_1+I_2+I_3)*V_{total}$
$P_{total}= V_{total}*V_1+V_{total}*I_2+V_{total}*I_3$
$P_{total}= V_1*I_1+V_2*I_2+V_3*I_3$
$P_{total}=P_1+P_2+P_3$

Real Power (aktiv effekt)

The actual amount of power being used, or dissipated, in a circuit is called real power

It is measured in watts (symbolized by the capital letter P, as always)

$$P = VI\cos\theta$$

θ=0° for purely resistive

θ=90° for purely inductive

θ=-90° for purely capacitive

Reactive Power (reaktiv effekt)

- Inductors and capacitors do not decrease power
- They cause drops of voltage and draws of current that creates impression that they actually use power
- This “phantom power” is called reactive power
- It is measured in a unit called Volt-Amps-Reactive (VAR)
- The mathematical symbol for reactive power is the capital letter Q

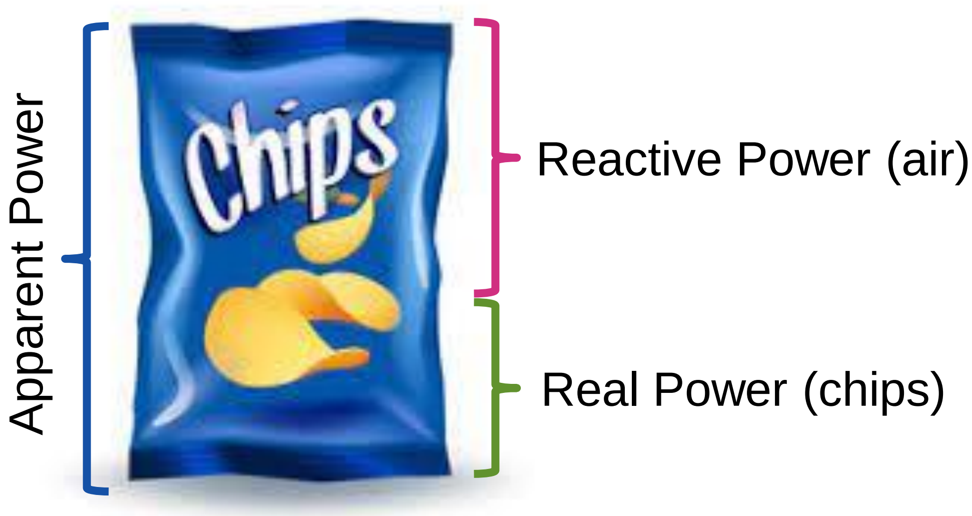
$$Q = VI\sin\theta$$

$$Q = I^2X$$

$$Q = V^2/X$$

Apparent Power (skenbar effekt)

- The combination of real power and reactive power is called apparent power
- It is the product of a circuit's voltage and current, without reference to phase angle
- Apparent power is measured in the unit of Volt-Amps (VA) and is symbolized by the capital letter S



$$S = VI$$

$$S = P/\cos\theta$$

$S = P + Qi$ for inductive load

$S = P - Qi$ for conductive load

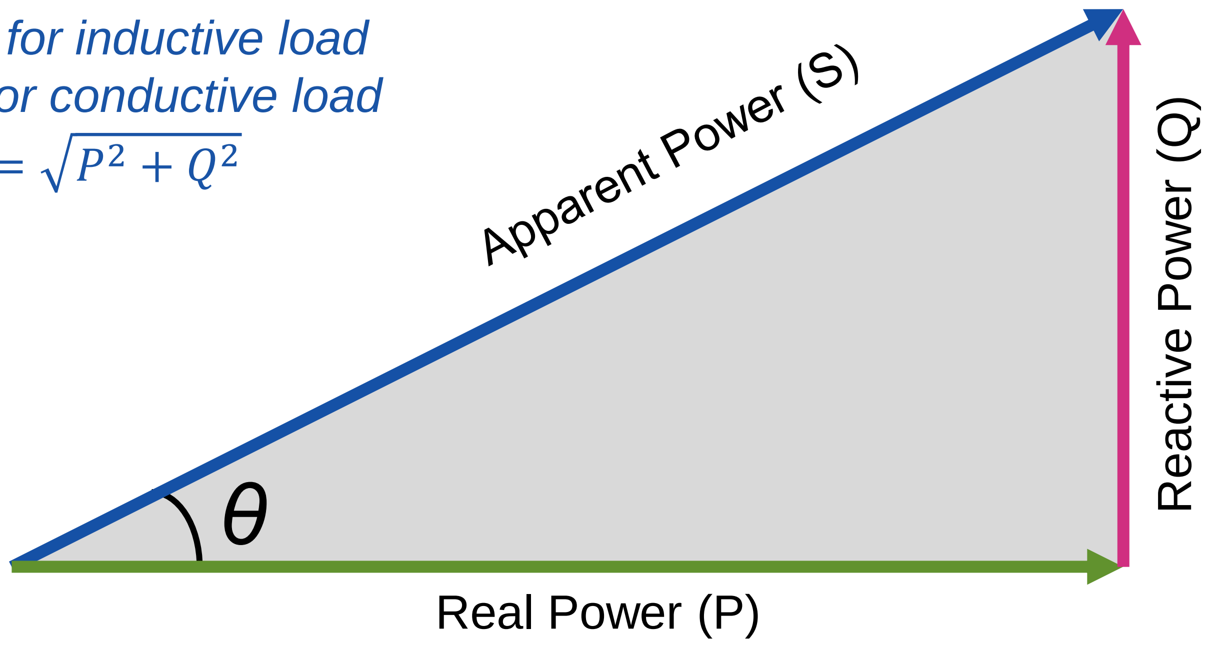
$$S = \sqrt{P^2 + Q^2}$$

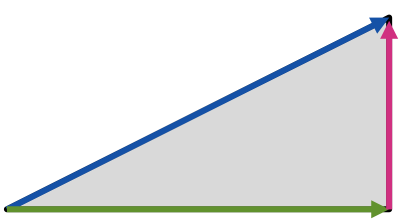
Power Diagram

From previous slide:

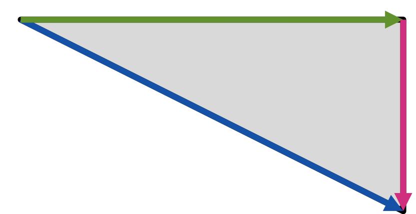
$S=P+Qi$ for inductive load
$S=P-Qi$ for conductive load

$$S = \sqrt{P^2 + Q^2}$$





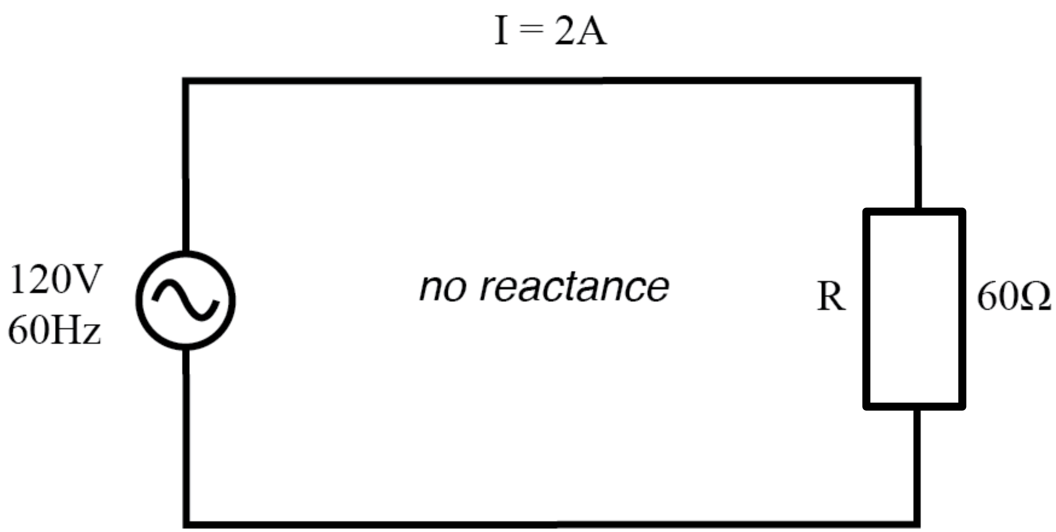
Power diagram for inductive load



Power diagram for capacitive load

Example

Find P, Q and S



Real power P=VIcosθ=120*2*1=240W

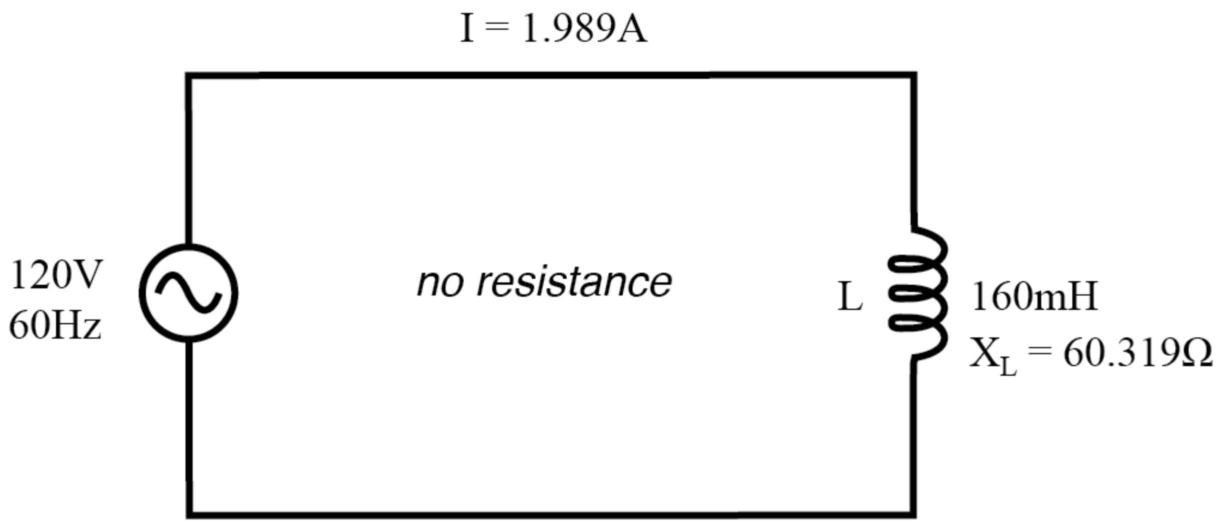
since it is a resistive network cosθ=1 and sinθ=0

Reactive power Q=VIsinθ=120*2*0=0VAR

Apparent power S=240+0i=240VA

Example

Find P, Q and S



Real power $P=VI\cos\theta=120*1.989*0=0W$

Reactive power $Q=VI\sin\theta=120*1.989*1=238.73VAR$

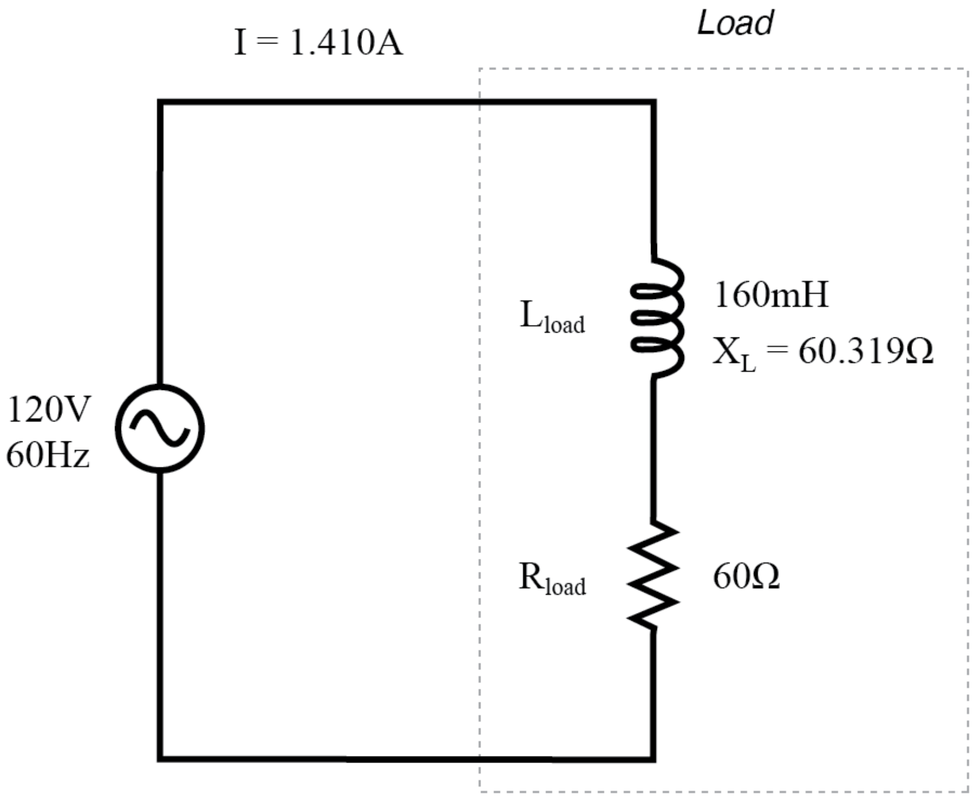
$Q= I^2X=1.989^2*60.319=238.6VAR$

$Q=V^2/X=120^2/60.319=238.73VAR$

Apparent power $S=VI=120*1.989=238.73VA$

Example

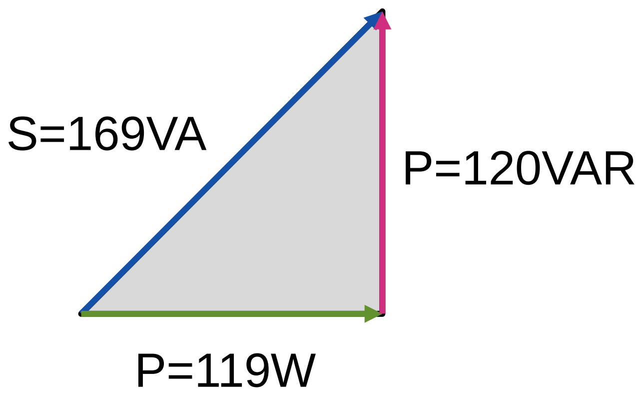
Find P, Q and S



Real power $P=I^2R=119.395W$

Reactive power $Q=I^2X=119.998VAR$

Apparent power $S=119.395+119.998i$



Power Factor

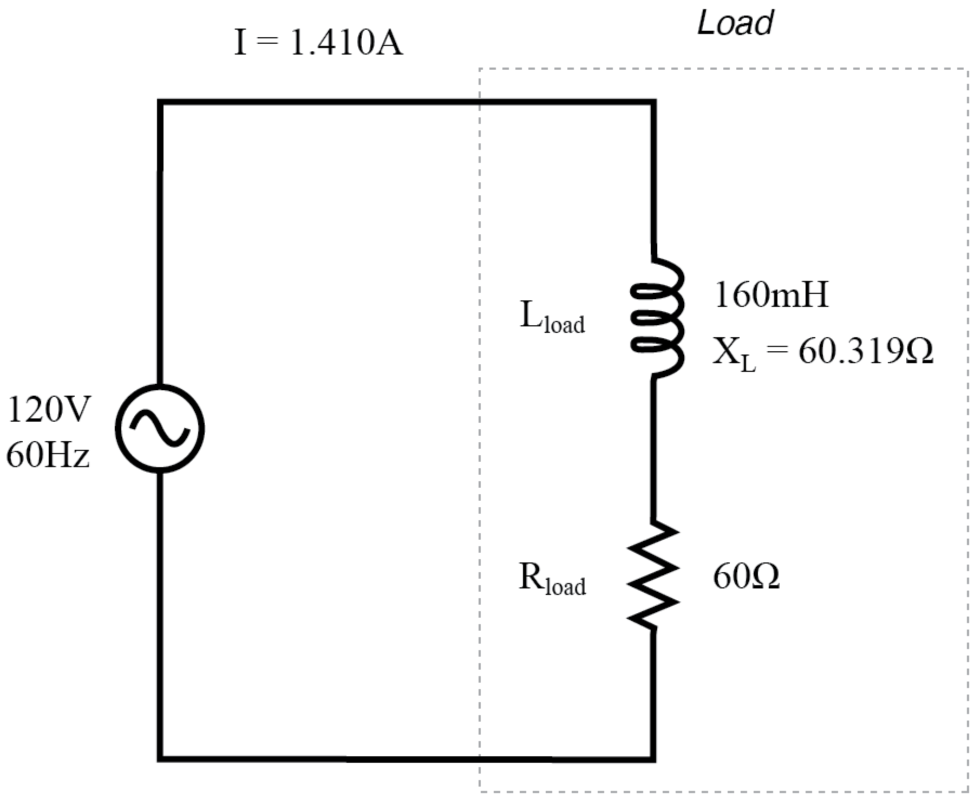
Since $P=VI\cos\theta$ and $S=VI$, $P=S\cos\theta$

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

A ratio of the real power to apparent power ($\cos\theta$) is known as power factor

Example

Find power factor



Real power $P=I^2R=119.395W$

Reactive power $Q=I^2X=119.998VAR$

Apparent power S=119.395-119.998i VA

$$\cos\theta = \frac{P}{S} = \frac{119}{169} = 0.704 = 70.4\%$$

P_{Total}, Q_{Total} and S_{Total}

1. Find the real power and reactive power for each branch of the circuit.

2. The total real power of the system P_{Total} is then a sum of average power delivered to each branch

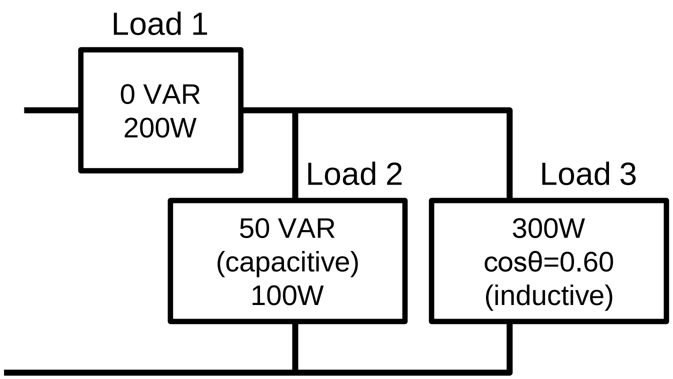
3. The total reactive power Q_{Total} is the difference between the reactive power of the inductive loads and that of the capacitive loads

4. The total apparent power $S_T = \sqrt{P_{Total}^2 + Q_{Total}^2}$

5. The total power factor is $\cos\theta = \frac{P_{Total}}{S_{Total}}$

Example

Find S_{Total} and power factor



1. Find P and Q for each element

$P_1=200W$ and $Q_1=0VAR$

$P_2=100W$ and $Q_2=-50VAR$ (cap)

$P_3=300W$

$\cos\theta=P/S \rightarrow S_3=P_3/\cos\theta_3=300/0.6=500VA$

$Q=VI\sin\theta=S\sin\theta$

$\theta_3=\arccos(0.6)=53.13°$

$Q_3=500*\sin(53.13°)=500*0.8=+400VAR$ (induc)

2. Find real power P_{Total}

$P_{Total}=P_1+P_2+P_3=200+100+300=600W$

3. Find reactive power Q_{Total}

$Q_{Total}=Q_1-\underset{cap}{Q_2}+\underset{induc}{Q_3}=0-50+400=350VAR$ (induc)

4. Find apparent power S_{Total}

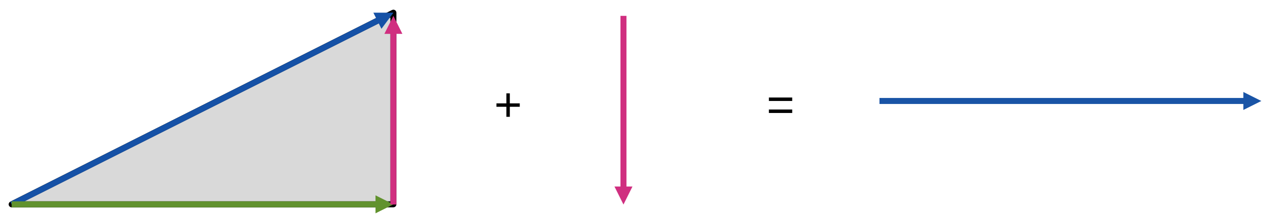
$$S_{Total}=\sqrt{600^2+350^2}=695VA$$

5. Find power factor

$$\cos\theta=\frac{600}{695}=0.86\ \text{(inductive)}$$

Power Factor Correction

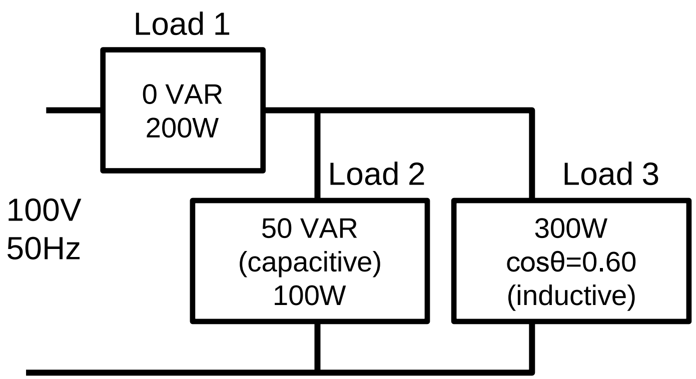
- Reactive power leads to power losses
- To decrease the reactive power, we need to have power factor as close to 1 as possible
- The process of introducing reactive element to bring the power factor closer to 1 is called power factor correction



To correct inductive load we add a capacitor and to improve capacitive load we add inductor

Example

Find a value for an element to increase power factor to 1



P_{Total}=600W
Q_{Total}=350VAR (inductive)
S_{Total}=695VA
$\cos\theta$=0.86 (inductive)

Since loads in total are inductive, we need to add a capacitor to remove all reactive power.

So we need to get away of Q=350VAR

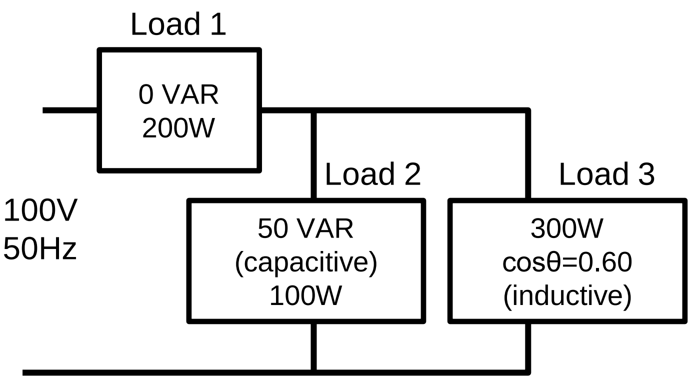
We know that $Q=V^2/X$ or $X_C=V^2/Q$

$X_C=100^2/350=28.57\Omega$

$$C=\frac{1}{2\pi f X_C}=\frac{1}{2\pi\cdot 50\text{Hz}\cdot 28.57\Omega}=1.11\cdot 10^{-4}\text{F}=111\mu\text{F}$$

Example

Find a value for an element to increase power factor to 0.95



P_{Total}=600W
Q_{Total}=350VAR (inductive)
S_{Total}=695VA
$\cos\theta$=0.86 (inductive)

Since loads in total are inductive, we need to add a capacitor

$$\cos\theta' = 0.95 = \frac{P}{S}$$

P stays the same, so new $S' = \frac{P}{0.95} = \frac{600}{0.95} = 631{,}58VA$

$\theta' = \cos^{-1}(0.95) = 18{,}19°$

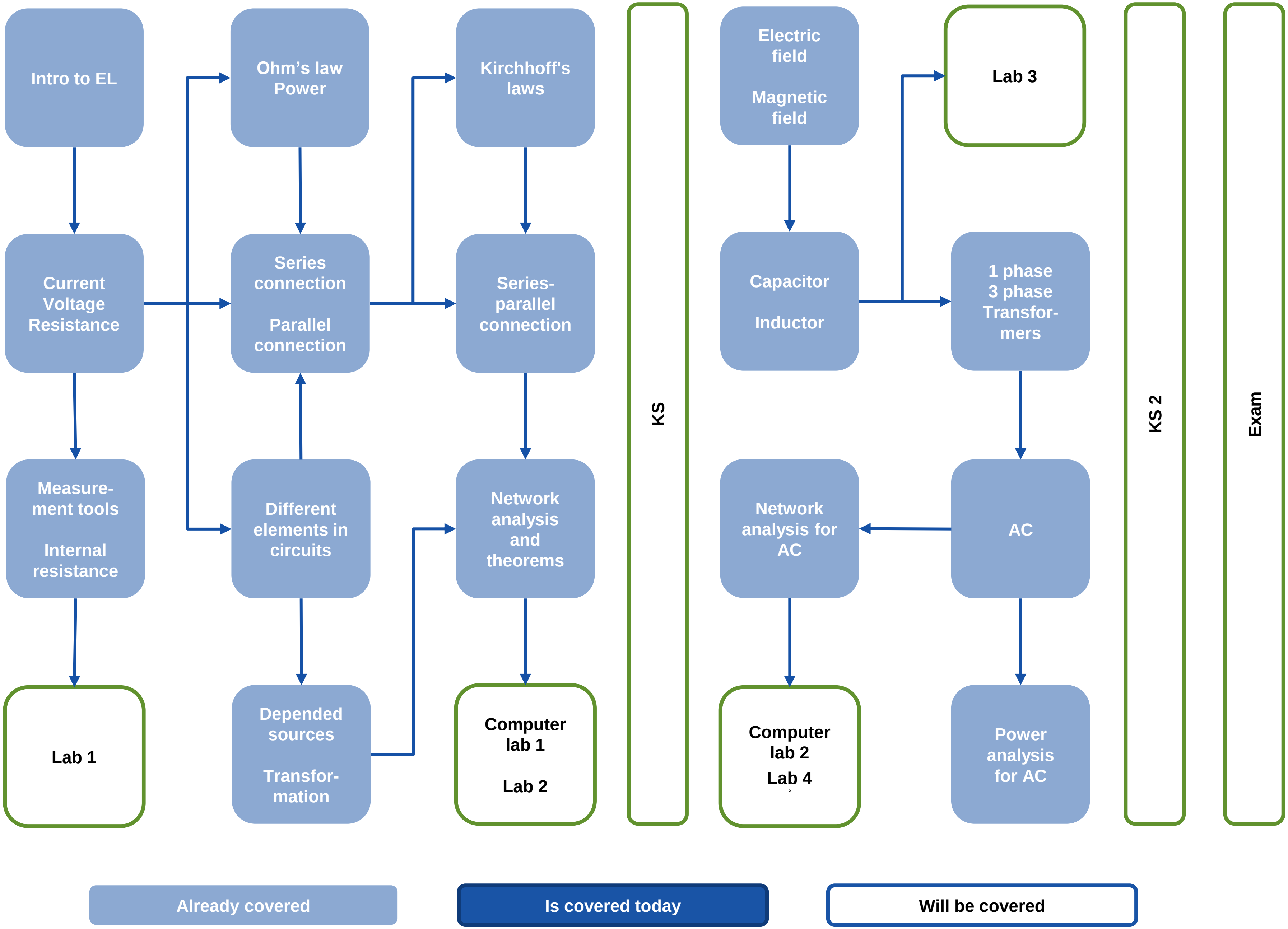
New $Q' = S'\sin(\theta') = 631{,}58 * \sin(18{,}19°) = 631{,}58 * 0.312 = -197.21VAR$

So we need to get away of $\Delta Q = 350 - 197.21 = 152.79VAR$

We know that $Q = V^2/X$ or $X_C = V^2/Q$

$X_C = 100^2/152.79 = 65.45\Omega$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi \cdot 50Hz \cdot 65.45\Omega} = 4.86 \cdot 10^{-5}F = 49\mu F$$



Intro to EL
Ohm's law Power
Kirchhoff's laws
Electric field Magnetic field
Lab 3
Current Voltage Resistance
Series connection Parallel connection
Series-parallel connection
Capacitor Inductor
1 phase 3 phase Transfor-mers
KS
KS 2
Exam
Measure-ment tools Internal resistance
Different elements in circuits
Network analysis and theorems
Network analysis for AC
AC
Lab 1
Depended sources Transfor-mation
Computer lab 1 Lab 2
Computer lab 2 Lab 4
Power analysis for AC
Already covered
Is covered today
Will be covered

Suggested reading

Introductory Circuit Analysis

- Kap 20: **20.1 - 20.9**

*suggestions in bold are more important

Suggested exercises

- Kap 20: 11, 14, 15, 17, 18, 19