Distribution & Utilization of Electrical Power (4340902)

www.vishaldevdhar.org

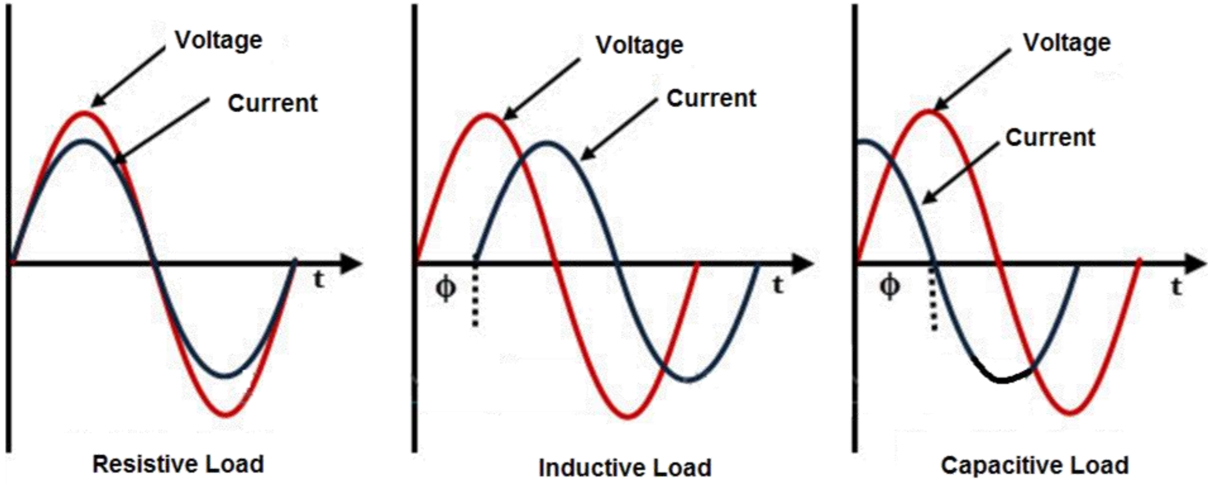
Vishal D Devdhar
Lecturer
Electrical Engineering Department
Government Polytechnic Rajkot

Power Factor Improvement

- What is Power Factor?
- Disadvantages of low Power Factor
- Effect of Low Power Factor on Various Equipments/Installations
- Cause of Low Power Factor
- Advantages of improved Power Factor
- Methods for Power Factor Improvement
- Location of Power Factor correction equipment

What is Power Factor?

- The cosine of angle between voltage and current in an AC circuit is known as Power Factor

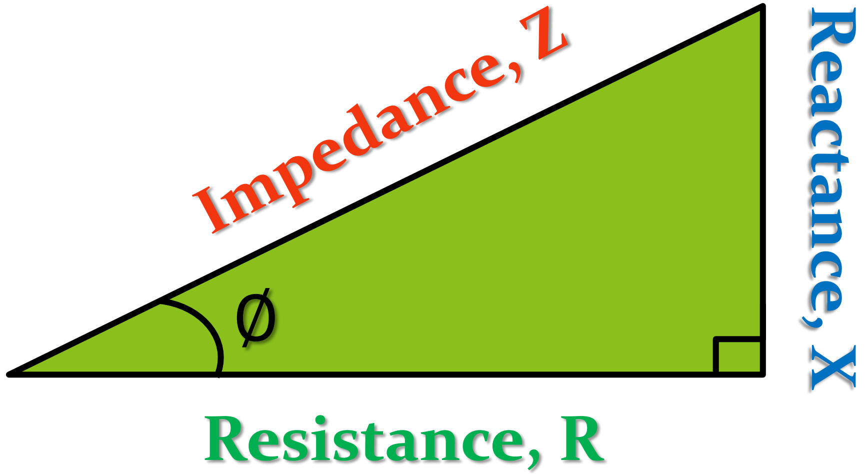


- Power Factor is a measure of how effectively incoming power is used in electrical system

- The ratio of Real (working) power to Apparent (total) power

What is Power Factor?

Impedance Tringle



$$Z^2 = R^2 + jX^2$$

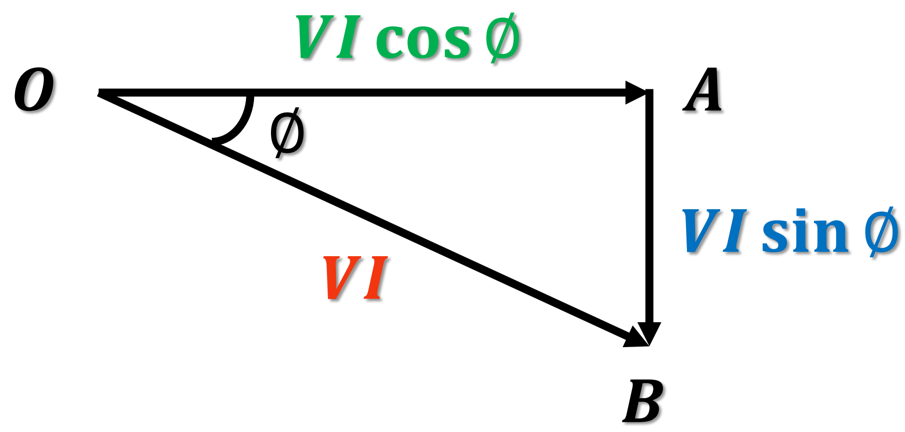
$$\cos\emptyset = \frac{R}{Z}$$

$$\sin\emptyset = \frac{X}{Z}$$

$$\tan\emptyset = \frac{X}{R}$$

What is Power Factor?

- Power Tringle



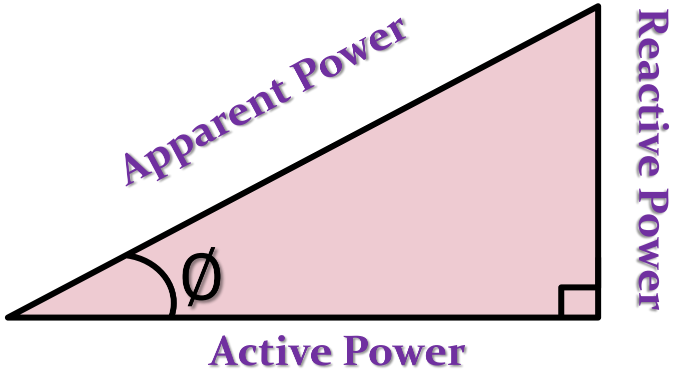
$$OB^2 = OA^2 + AB^2$$

$$(kVA)^2 = (kW)^2 + (kVAR)^2$$

- Active (Real)Power - kW
  - the power that actually powers the equipment and performs useful, productive work
  - $VI\cos\emptyset$
- Reactive Power – kVAR
  - the power required to produce a magnetic field to enable real work to be done
  - $VI\sin\emptyset$
- Apparent Power – kVA
  - vector sum of Real Power (kW) and Reactive Power (kVAR) and is the total power supplied through the power mains
  - VI

What is Power Factor?

- Important Relationships
  - $(Apparent\ Power)^2 = (Active\ Power)^2 + (Reactive\ Power)^2$
  - $(kVA)^2 = (kW)^2 + (kVAR)^2$
  - $\cos \emptyset = \frac{R}{Z}$
  - $\cos \phi = \frac{Active\ Power}{Apparent\ Power} = \frac{kW}{kVA}$
  - $kVAR = kVA\ \sin \emptyset = \frac{kW}{\cos \emptyset} \sin \emptyset = kW \tan \emptyset$



Disadvantages of low Power Factor

- Large kVA Rating of Equipments
- Greater Conductor Size
- More Copper Losses
- Poor Voltage Regulation
- Reduced Handling Capacity of Equipment

$$P = \sqrt{3} V_L I_L \cos \emptyset$$

$$I_L = \frac{P}{\sqrt{3} V_L \cos \emptyset}$$

$$kVA = \frac{kW}{\cos \emptyset}$$

Effect of Low Power Factor on Various Equipments/Installations

- **Transmission & Distribution:**
  - Higher conductor c/s
  - High voltage drop
  - Low efficiency (High Losses)
- **Switchgear:**
  - Higher rating
  - More contact surface
  - Higher busbar c/s

<u>Low Power Factor</u>

i. Increased energy costs
ii. Reduced equipment lifespan
iii. Reduced system capacity

- **Prime Mover:**
  - High rating
  - Low Efficiency
- **Motors:**
  - Overheat
  - Reduced efficiency
  - Lifespan
- **Transformers:**
  - Overloaded
  - Increased heating
  - Shorter lifespan
- **Generators:**
  - Produce less power
- **Lighting:**
  Flicker
  Low efficiency
  Reduced bulb life
- **HVAC systems:**
  - Operate inefficiently,
  - Increased energy costs
  - Poor power quality

Causes of low Power Factor

- Inductive Loads
  - Induction Motors
  - ARC Furnaces
  - Induction Furnaces
  - Electrical Welding
  - Arc Lamps, Discharge Lamps
- Low load periods
- Unbalanced loads
- Long distribution lines
- Harmonics

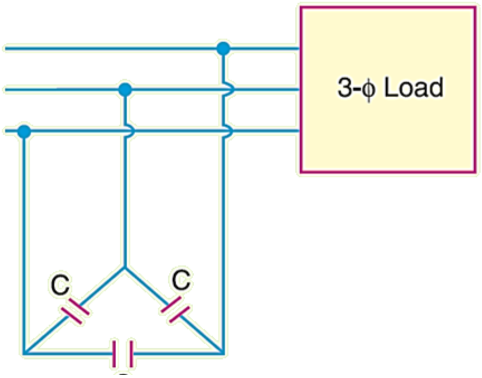
Advantages of improved Power Factor

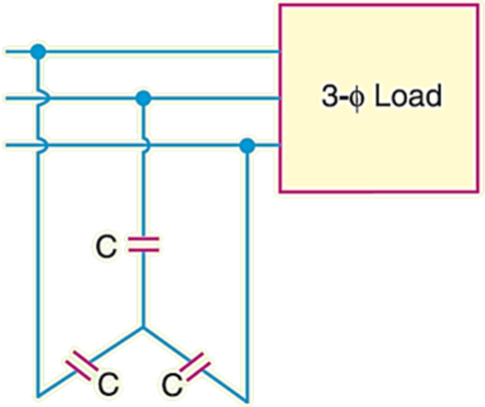
- Reduced energy costs
- Increased capacity
- Longer equipment lifespan
- Improved voltage stability
- Reduced carbon footprint

Methods for Power Factor Improvement

- Capacitor banks
- Synchronous condensers
- Phase Advancer
- Static VAR compensators
- Active power factor correction
- Upgrading equipment
- Operating practices

Capacitor Banks





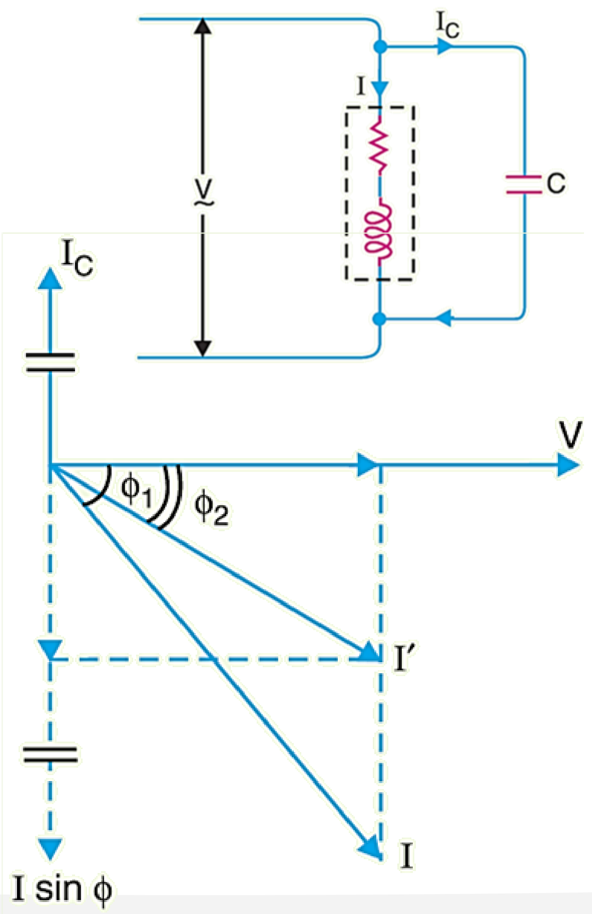
Advantages

- Low losses
- Low maintenance
- Easy installation - no foundation
- Work well in different weather conditions

Disadvantages

- Short service life
- Damaged by voltage variation
- Uneconomical repairing

Capacitor Banks
Calculations for Power Factor Improvement



After power factor correction:

- **Current,**
  - $I' < I$
- **Active Power,**
  - $I\cos\emptyset_1 = I'\cos\emptyset_2$
- **Lagging reactive Component**
  - $I'\sin\emptyset_2 = I\sin\emptyset_1 - I_C$
  - $VI'\sin\emptyset_2 = VI\sin\emptyset_1 - VI_C$
  - $X_C = \frac{V}{I_C} \Rightarrow \frac{1}{\omega C} = \frac{V}{I_C} \Rightarrow \; C = \frac{I_C}{\omega V}$

$\omega = 2\pi f$

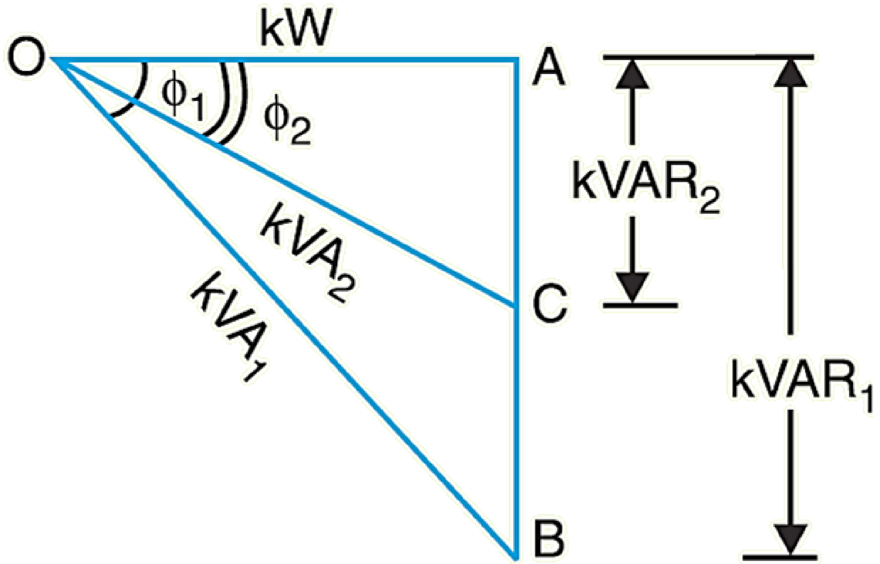
$P = VI\cos\emptyset$

$I = \frac{P}{V\cos\emptyset}$

- $I_C = 2\pi f CV$
- $I_C = I\sin\emptyset$
- $2\pi f CV = I\sin\emptyset$
- $2\pi f CV = I\sqrt{1-\cos^2\emptyset}$
- $C = \frac{I}{2\pi f V}\sqrt{1-\cos^2\emptyset}$
- $C = \frac{P}{2\pi f V^2\cos\emptyset}\sqrt{1-\cos^2\emptyset}$
- $C = \frac{P}{2\pi f V^2}\sqrt{\frac{1}{\cos^2\emptyset} - 1}$

Capacitor Banks

Calculations for Power Factor Improvement



Leading kVAR Supplied by capacitor,

$$BC = AB - AC$$

$$= kVAR_1 - kVAR_2$$

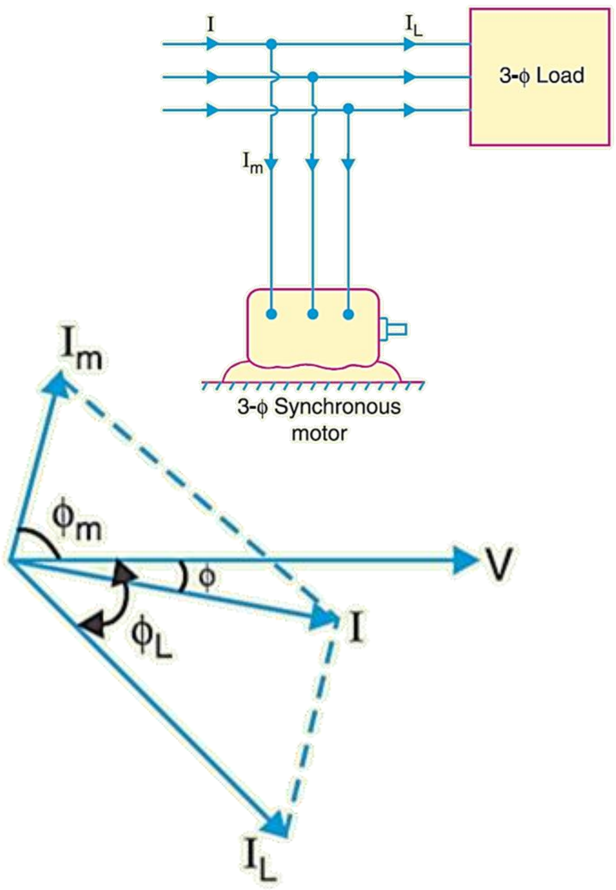
$$= kW(\tan\phi_1 - \tan\phi_2)$$

$$\because \; kVAR = kW \tan\phi$$

Synchronous condensers

A synchronous motor takes a leading current when over-excited and, therefore, behaves as a capacitor.

An over-excited synchronous motor running on no load is known as synchronous condenser.

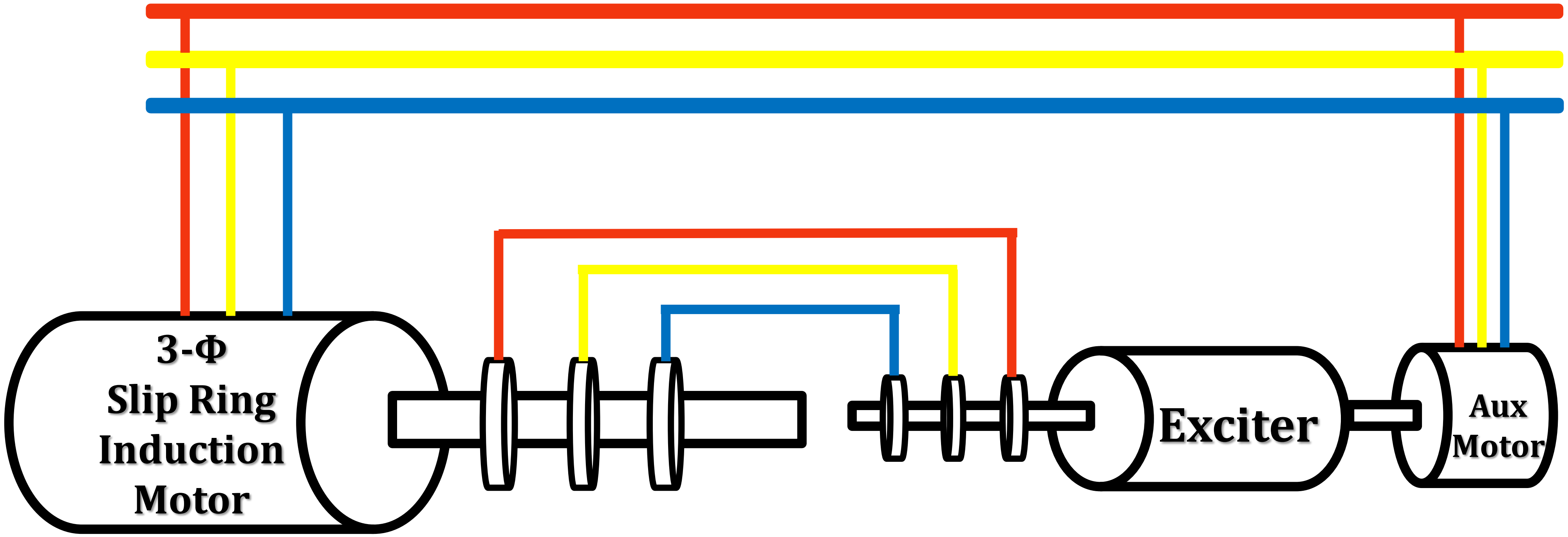


Advantages

- Motor current magnitude can be controlled by excitation
- High thermal stability
- Smooth pf control
- Easy fault removal

Disadvantages

- High losses in Motor
- High maintenance cost
- No self starting
- Produces noise
- Economical above 500kVA rating



Phase Advancer

Advantages

- Lagging kvar drawn by the motor is less
- Conveniently used where the use of synchronous motors is inadmissible

Disadvantages

- Not economical for motors below 200 H.P.

Comparison : Capacitor Banks – Synchronous Condenser

Capacitor Banks

- Low capital cost
- Constant PF
- Complex to vary capacitance
- Low maintenance

Synchronous Condensers

- High capital cost
- PF can be varied smoothly
- By varying excitation PF can be changed
- High maintenance

Location of Power Factor correction equipment

- Power factor correction equipment is typically installed near the electrical load that is causing the low power factor
- In larger industrial facilities, power factor correction equipment may be installed in a centralized location

Thank You