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# Training Module on LT Capacitors

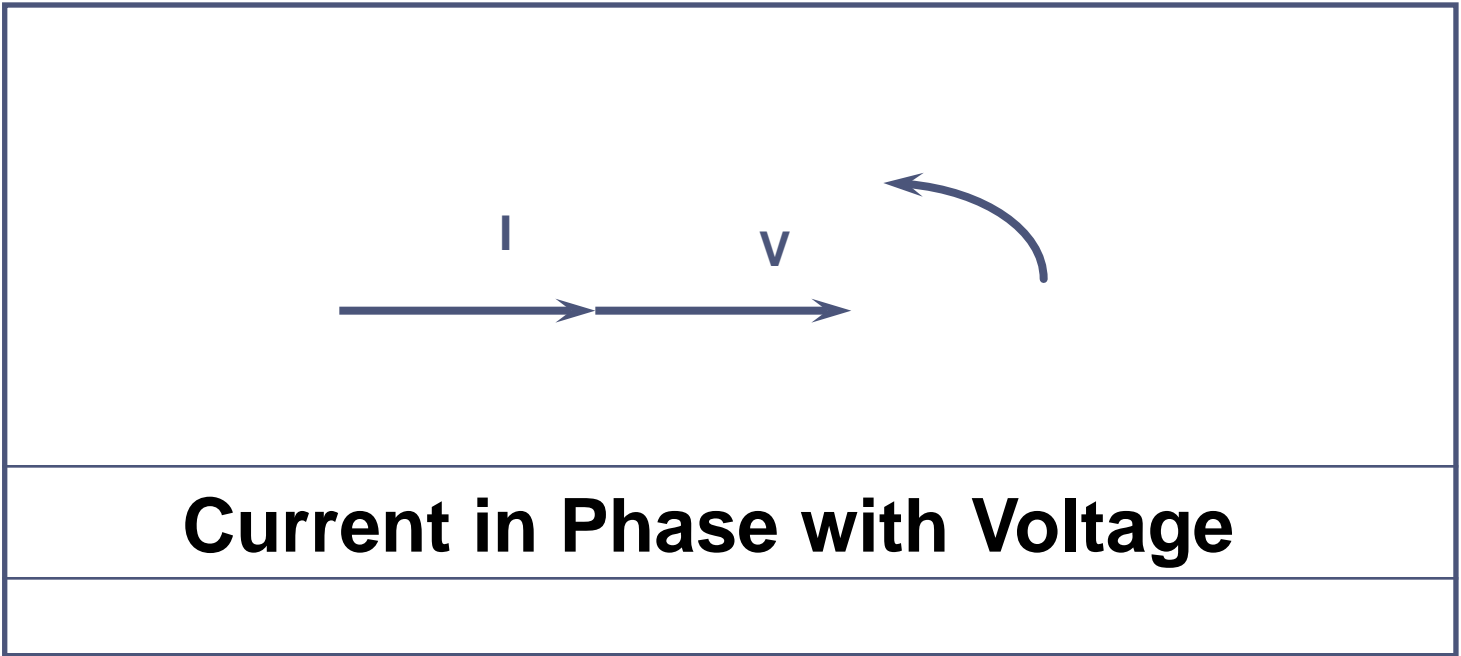


# INTRODUCTION TO REACTIVE POWER MANAGEMENT

# Types of Loads

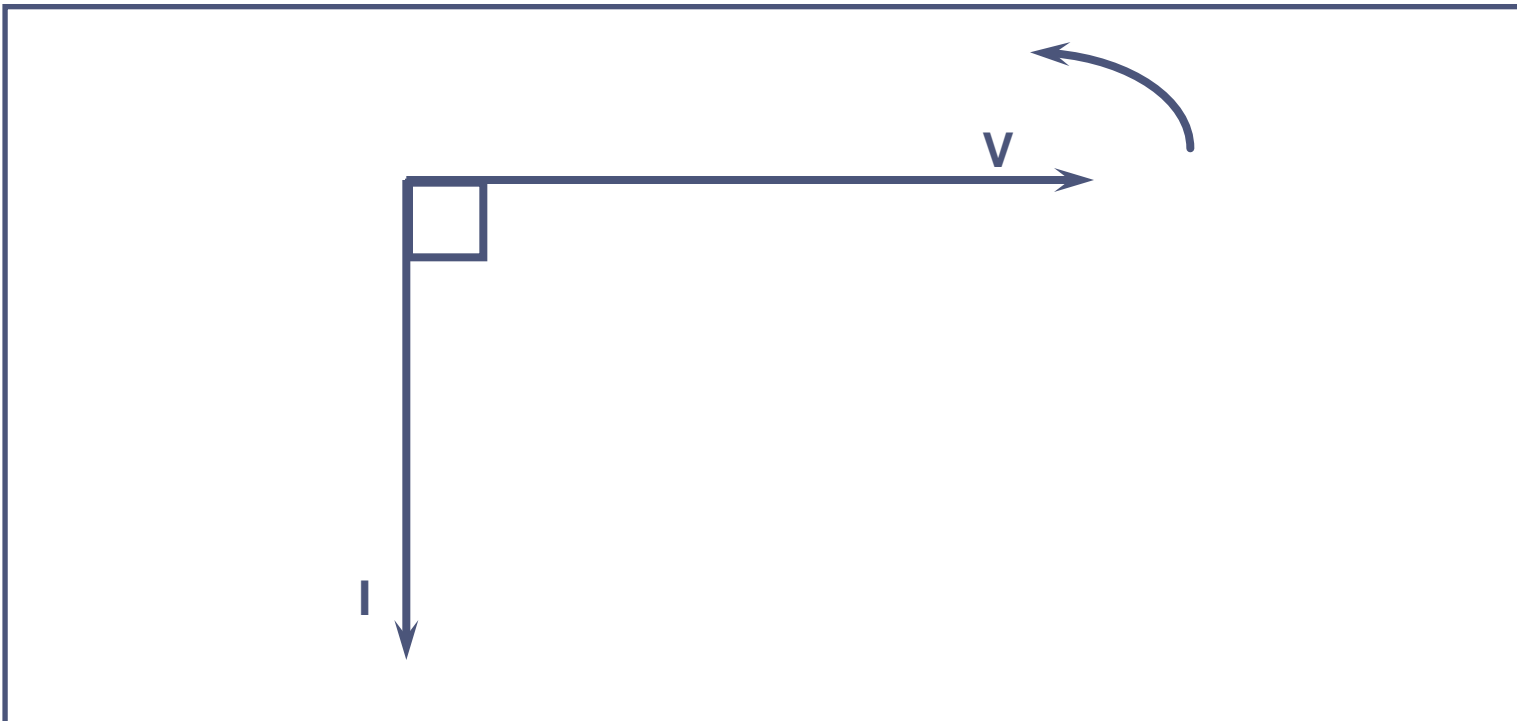
- \* **Resistive**
- \* **Inductive**
- \* **Capacitive**

# Resistive Circuit





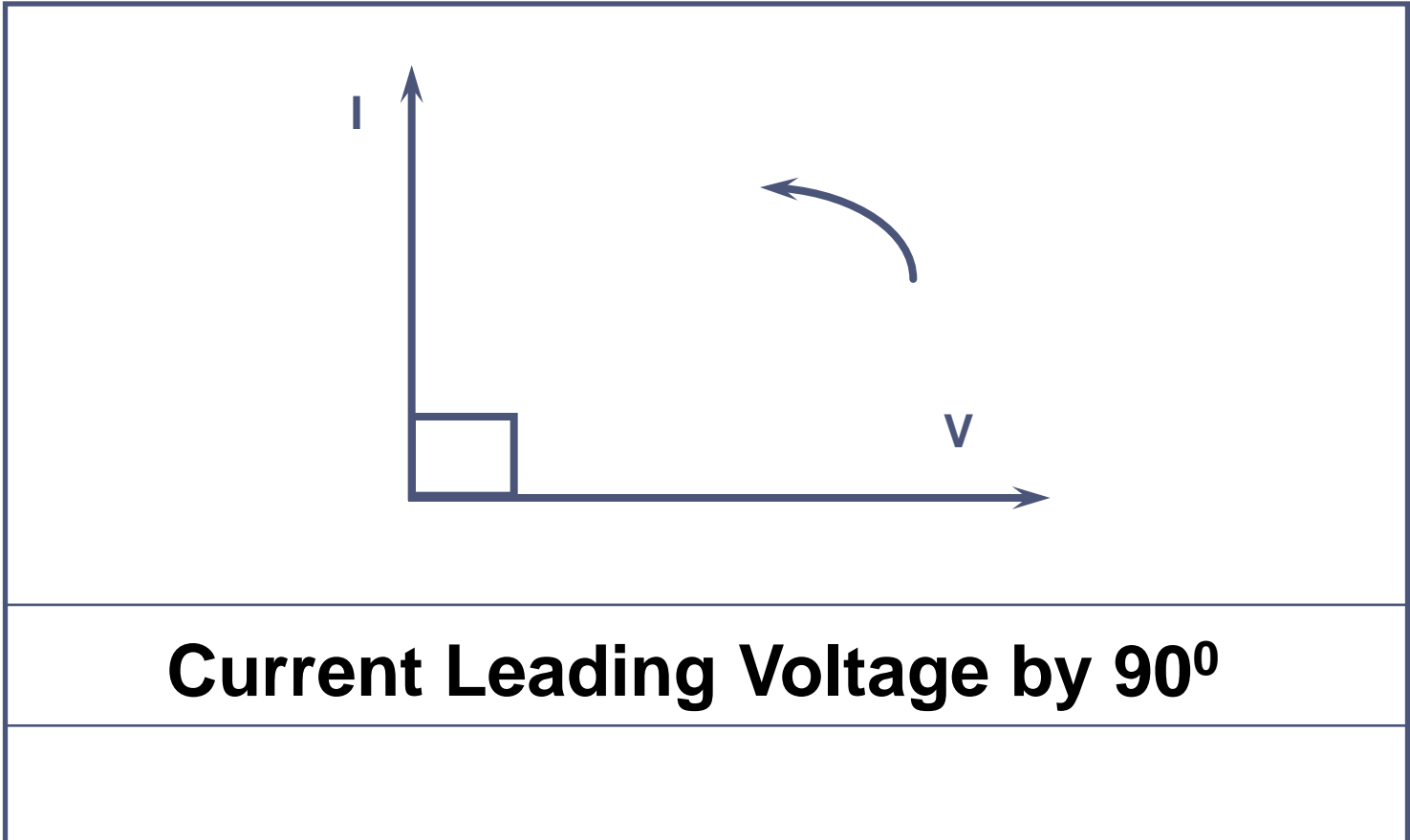
# Inductive Loads



**Current Lagging Voltage by 90°**



# Capacitive Loads



# Power factor correction

## Some fundamental thoughts

- What is Power factor?
- Why power factor is important?
- Why improve power factor?
- What is the power factor of various loads?
- What is the origin of power factor?
- How to improve power factor?

# Definition of Power Factor

- Power Factor =  $\frac{\text{Active Power (kW)}}{\text{Apparent Power (kVA)}}$
- Power Factor can never be greater than 1.00
- Power Factor at best can be equal to 1.00
- Usually P.F is always “Lag” ( Inductive)
- Some times P.F can be “Lead” ( Capacitive)

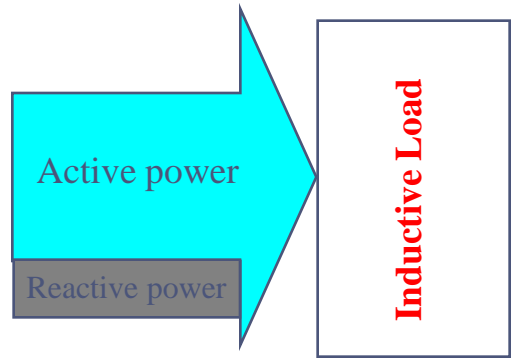
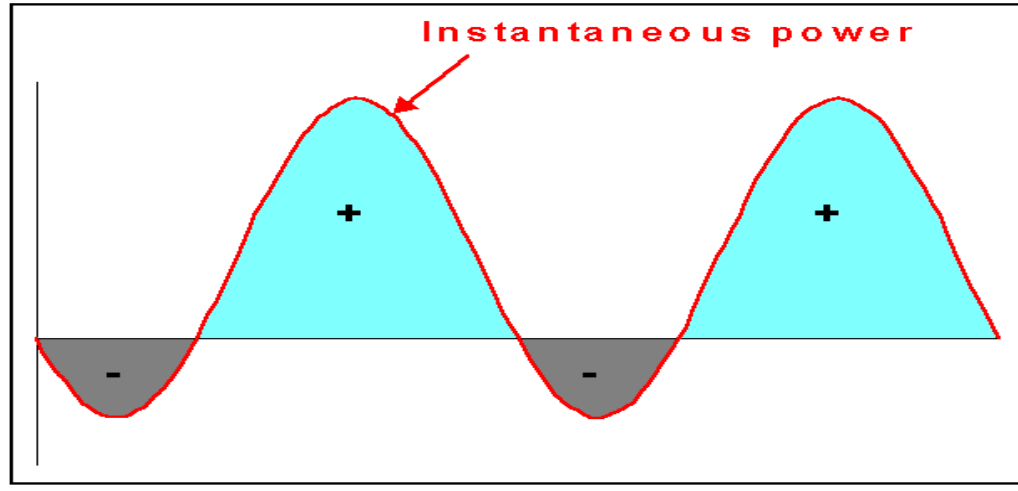
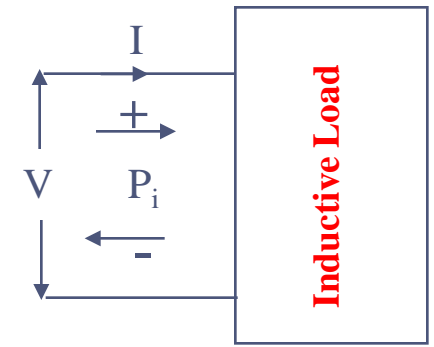
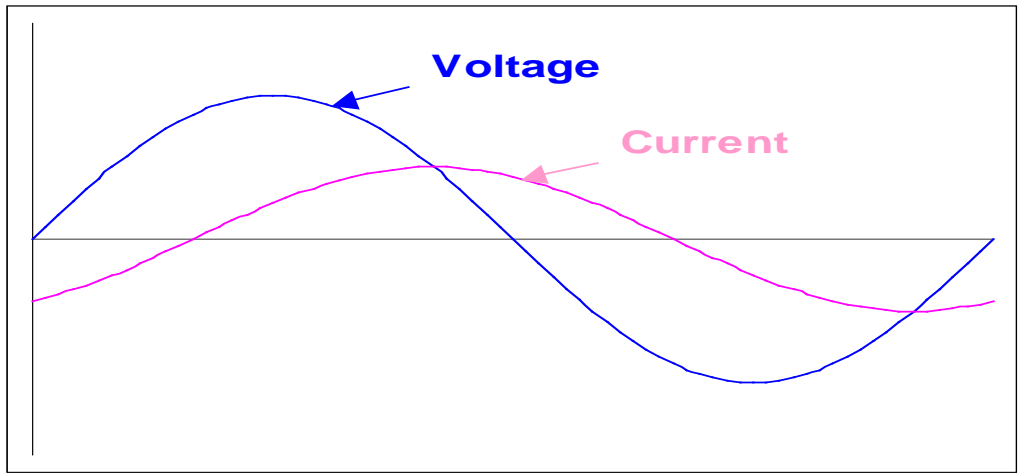
## Origin of Low Power Factor

- Electrical Equipment need Reactive Power
- Inductive loads draw Reactive Power
- Phase difference between current & Voltage reduces “Displacement PF”.
- Reactive Power to maintain magnetic fields in Motors.
- Non-Linear loads reduces “Distortion PF”.
- True PF, being product of displacement and distortion PF is lower than both.

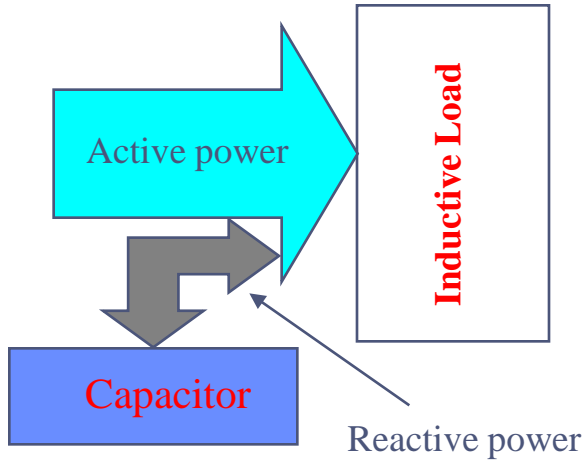
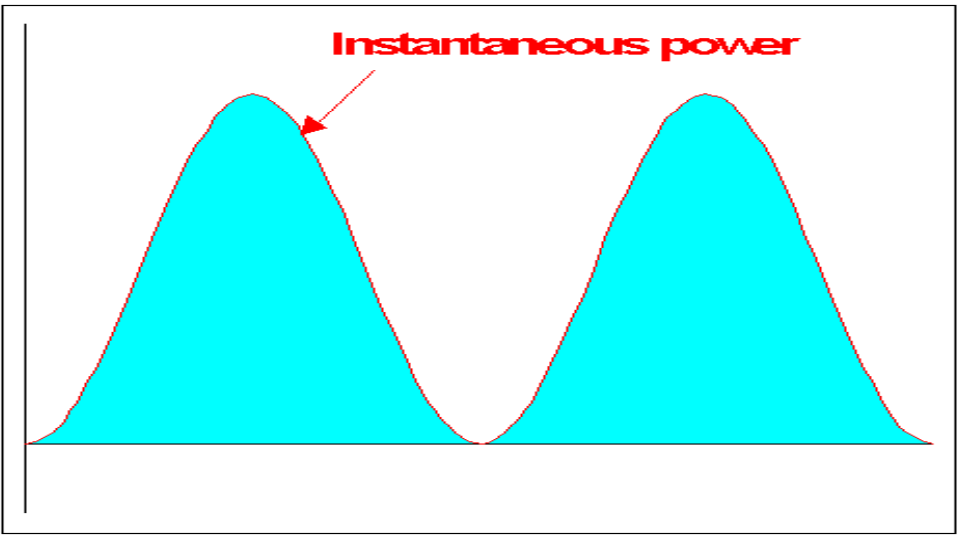
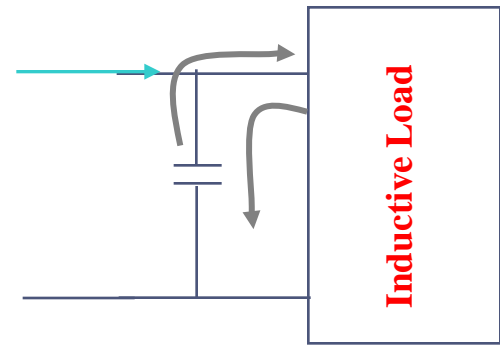
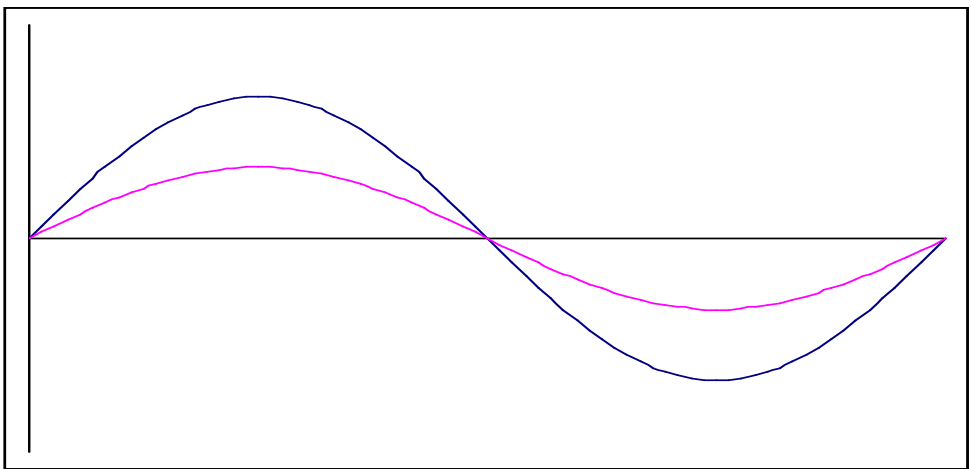
# Power Factor Improvement Concept

- Reactive Power flow analogy
- Power Triangle analogy
- Resonance analogy

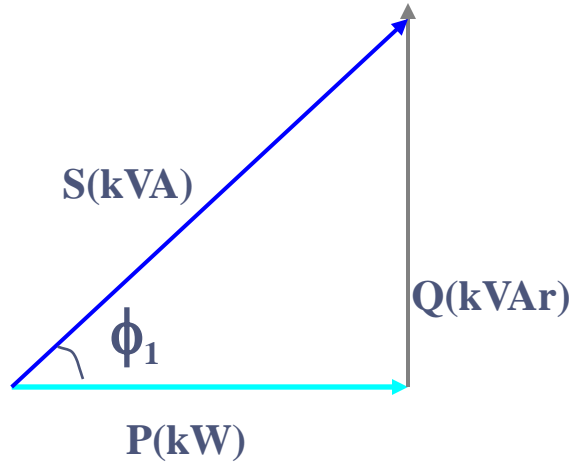
# Reactive Power Flow Analogy



# Reactive Power Flow Analogy



# Power Triangle Analogy

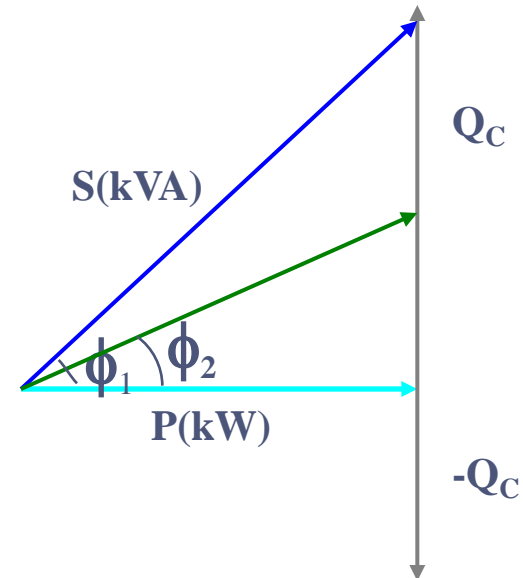


$$kVA = \sqrt{(kW)^2 + (kVAr)^2}$$

$$PF = kW/kVA = \cos \phi_1$$

$$Q = P \cdot \tan \phi_1$$

Uncompensated Load



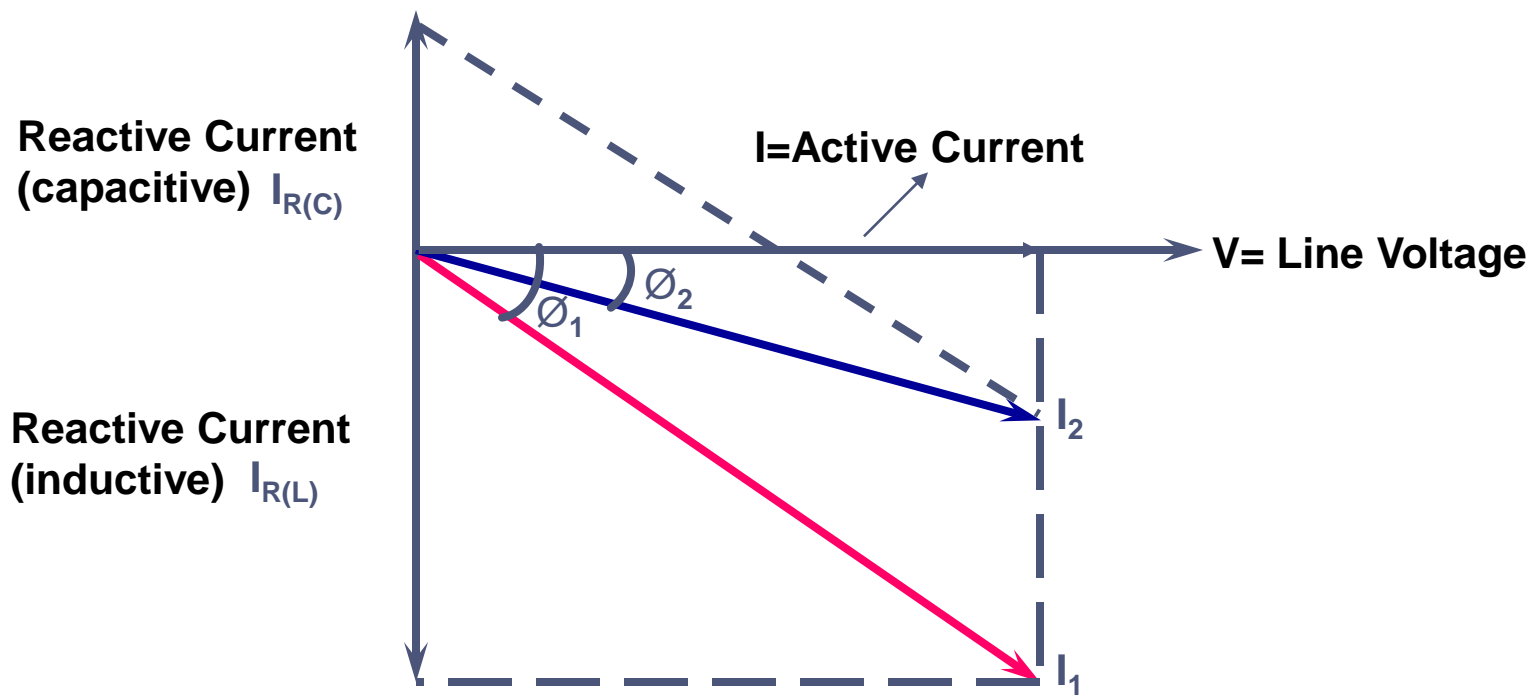
$$Q_C = P (\tan \phi_1 - \tan \phi_2)$$

$\cos \phi_1 =$  Initial Power Factor

$\cos \phi_2 =$  Final Power Factor

Partially compensated Load

# Power Factor Correction



# Types of Power Factors

- “**Displacement PF**” is defined as the cosine of the angle between fundamental voltage and fundamental current of the load.
- Presence of “**harmonics**” increases the RMS current and voltage relative to their respective fundamental values. This increases the kVA of the load.
- The PF taking into account the effect of harmonics, called “**True PF**”, is lower than or at best equal to displacement PF.
- The factor by which the displacement PF is related to true PF is called the “**Distortion PF**”

$$\text{True PF} = \text{Displacement PF} \times \text{Distortion PF}$$

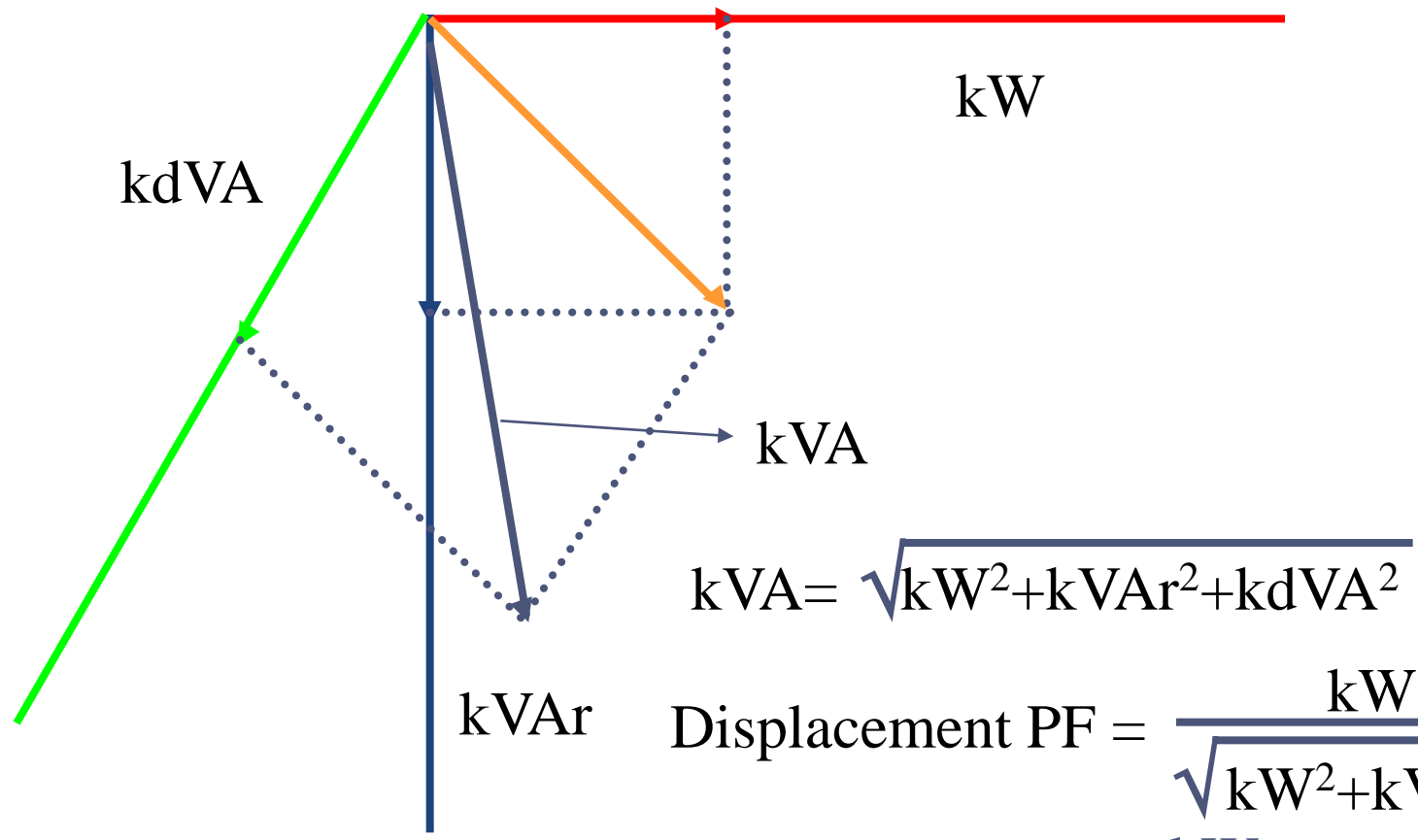
- Capacitors can only improve displacement PF.



# Effect of harmonics on PF

%THD(V)	%THD(I)	Distortion PF
0	0	1.00
1	20	0.98
2	40	0.93
3	60	0.86
4	80	0.78
5	100	0.71

# Three dimensional power triangle



$$kVA = \sqrt{kW^2 + kVAr^2 + kdVA^2}$$

$$\text{Displacement PF} = \frac{kW}{\sqrt{kW^2 + kVAr^2}}$$

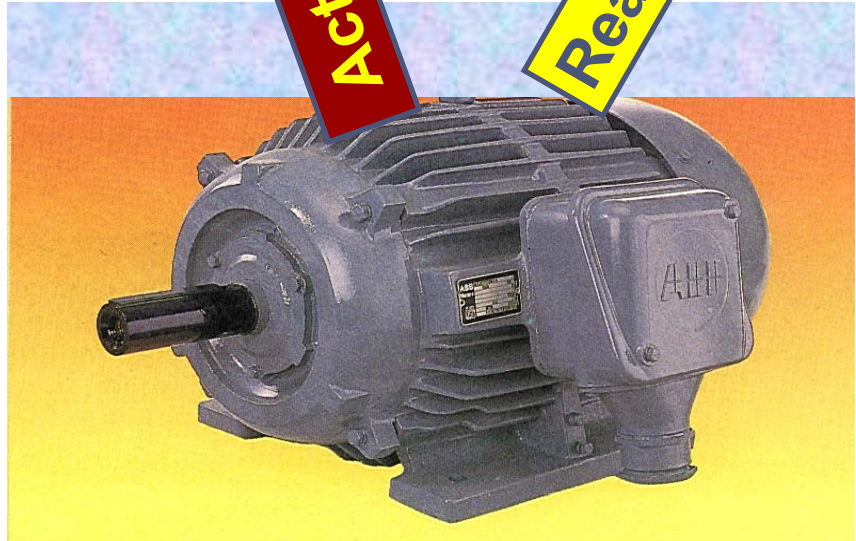
$$\text{True PF} = \frac{kW}{\sqrt{kW^2 + kVAr^2 + kdVA^2}}$$

# Electric Power

Apparent Power  
kVA

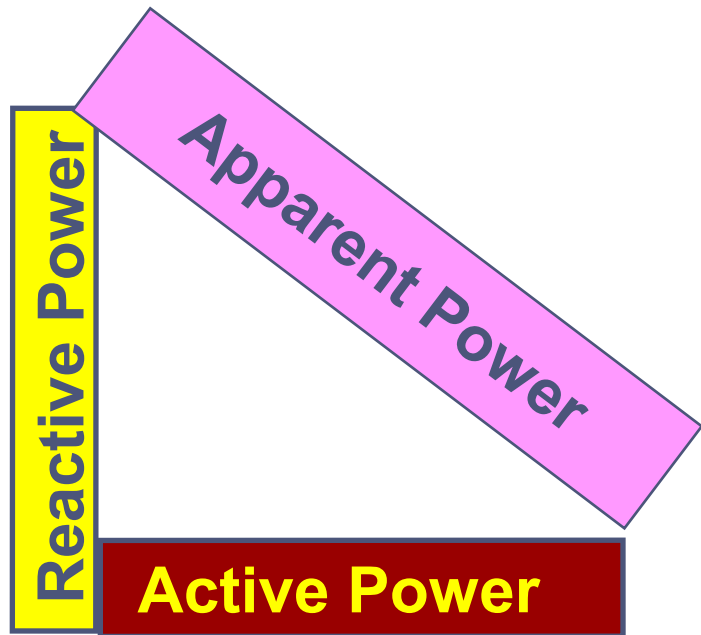
Active Power

Reactive Power





# Power Triangle



A 3D wooden block containing the following equations:

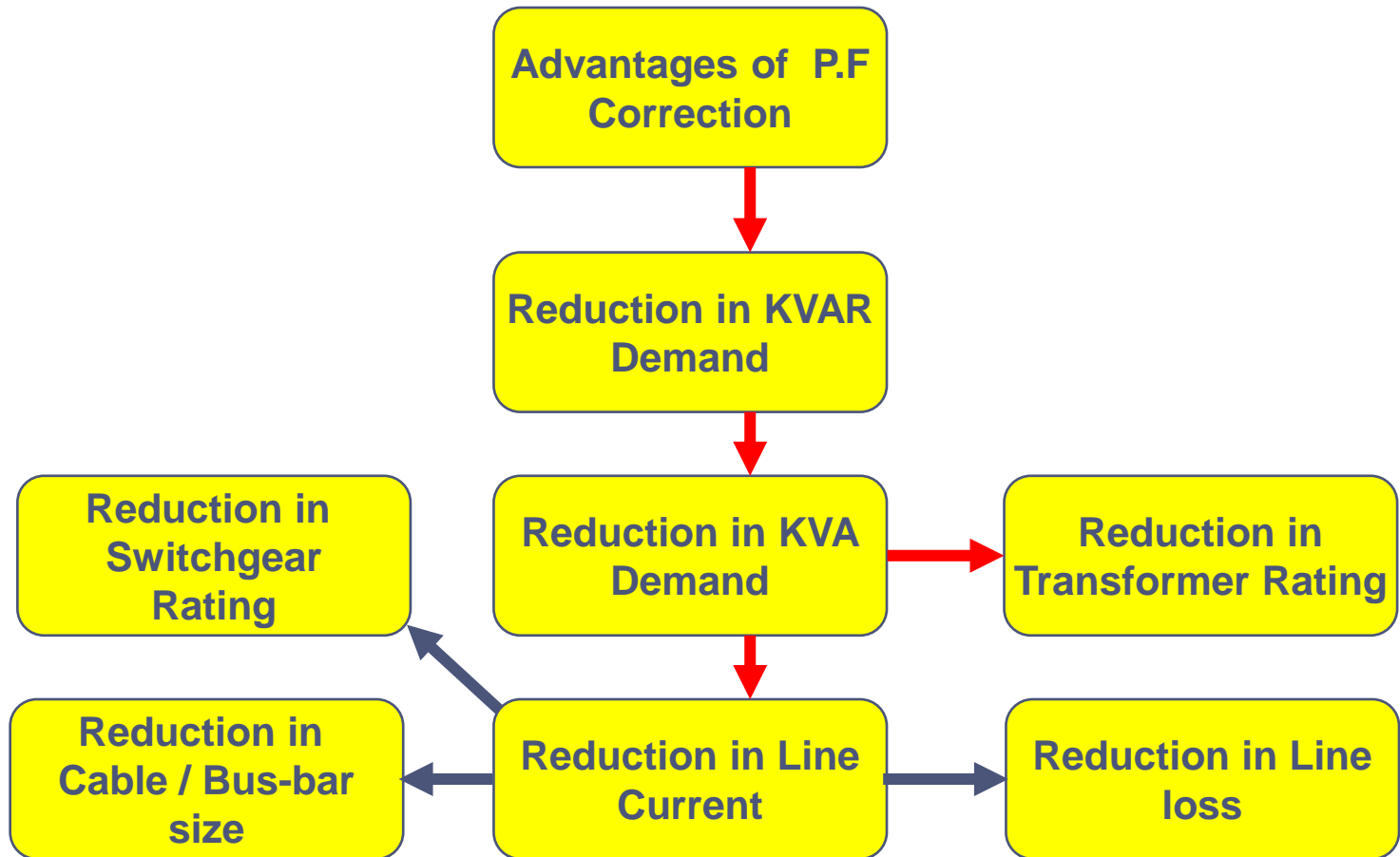
$$kVA = \sqrt{kW^2 + kVAr^2}$$
$$P.F. = \frac{kW}{kVA}$$



# PF of various Industries

<u>Industry</u>	<u>Power Factor</u>
Textiles	0.65/0.75
Chemical	0.75/0.85
Machine shop	0.4 / 0.65
Arc Welding	0.35/ 0.4
Arc Furnaces	0.7 / 0.9
Coreless induction furnaces and heaters	0.15/0.4
Cement plants	0.78/0.8
Garment factories	0.35/0.6
Breweries	0.75/0.8
Steel Plants	0.6 / 0.85
Collieries	0.65/0.85
Brick Works	0.6 / 0.75
Cold Storage	0.7 / 0.8
Foundries	0.5 / 0.7
Plastic moulding plants	0.6 / 0.75
Printing	0.55/0.7
Quarries	0.5 / 0.7
Rolling Mills (i.e. ,Paper, Steel , etc.)	0.3 / 0.75

# Advantage of PF correction



# Inductive Loads

**Induction Motor**  
**0.8 P.F**

**Arc Furnace**  
**0.8 P.F**

**Floursent Lamp**  
**0.5 P.F.**

**Induction Furnace**  
**0.8 P.F**

**Welding Transformer**  
**0.5 P.F.**



# 1. CAPACITOR TYPES & APPLICATION

## A. SH-MPP CAPACITOR

**a. Normal duty** – Rectangular & Cylindrical  
(Resin filled / Resin coated-Dry)

### Application:

- Steady inductive load
- Non linear up to 10%
- For Agriculture duty.

**b. Heavy-duty - Rectangular & Cylindrical**  
(Resin filled / Resin coated-  
Dry/oil/gas)

Application :

- Suitable for fluctuating load
- Non linear up to 20%
- Suitable for APFC Panel
- Harmonic filtering

## B. NSH-LT CAPACITOR

### Application :

- Suitable for fluctuating load
- Non linear up to 20%
- Suitable for APFC Panel & Harmonic filter application

# Selection of Capacitor

- 1. Individual Compensation**
- 2. Group Compensation**
- 3. Central Compensation**

## Where to install Power Factor correction Equipment

### Individual Compensation

- Directly at the Load terminals
- Ex. Motors, Steady loads
- Gives maximum benefit to user
- Not recommended for Drives
- Costly solution



## Where to install Power Factor correction Equipment-3

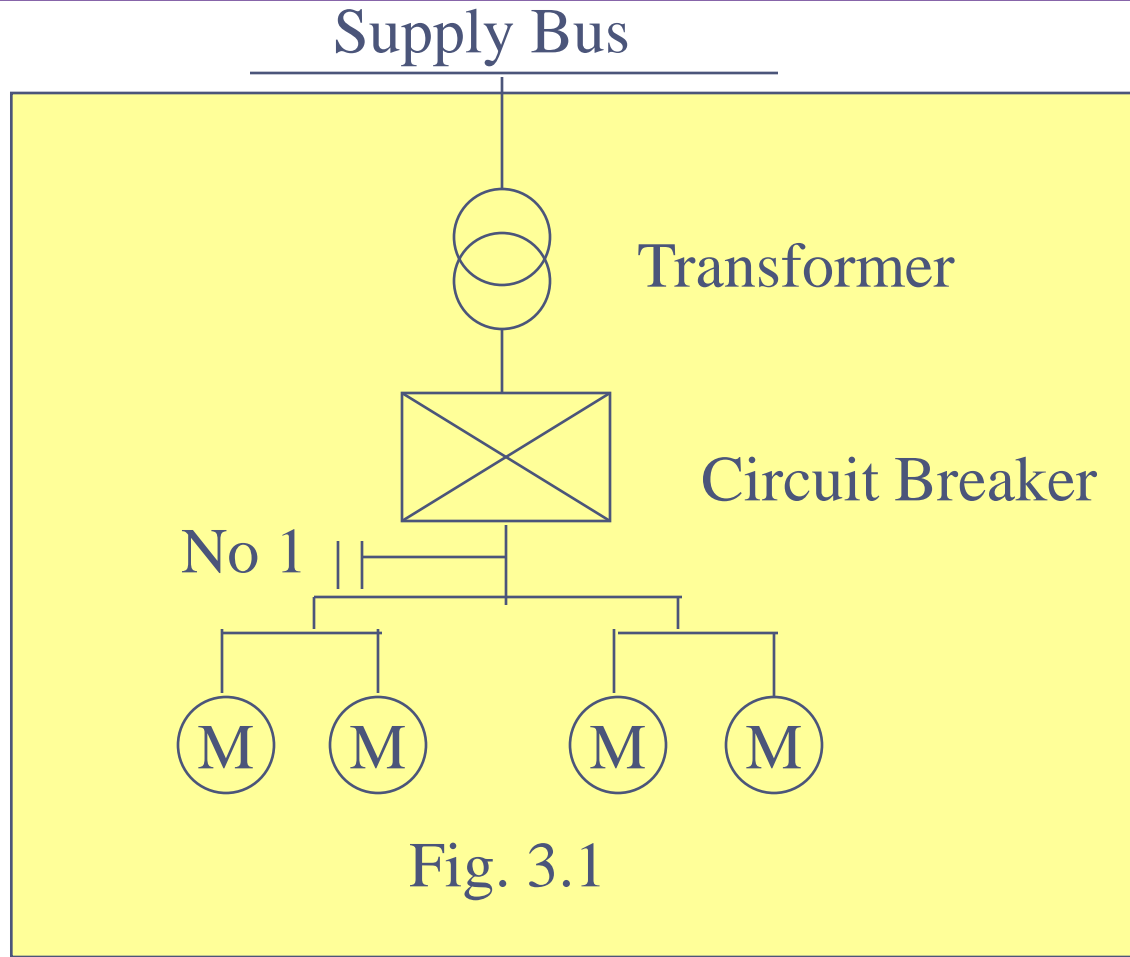
### Central Compensation

- Directly connected at the incomer
- Improves PF at the metering point
- Line losses continue to prevail downstream
- Least beneficial to user
- Extremely easy to maintain

## Central Compensation

Providing compensation at the main incomer of the installation is called central compensation (pos. No. 1).

This is suitable for installations where the loads are few and situated close to the main supply. (Refer Fig. 3.1)



## Central, Group and Individual Compensation

Providing compensation at

- main incomer bus – central compensation. (pos. No 1)
- At power distribution boards – group compensation (pos. No. 2).
- At individual load terminals – individual compensation. (pos. No. 3)

This is suitable for installations consisting of main receiving station, substations, several load feeders and a wide variety of loads. (refer fig 3.3)

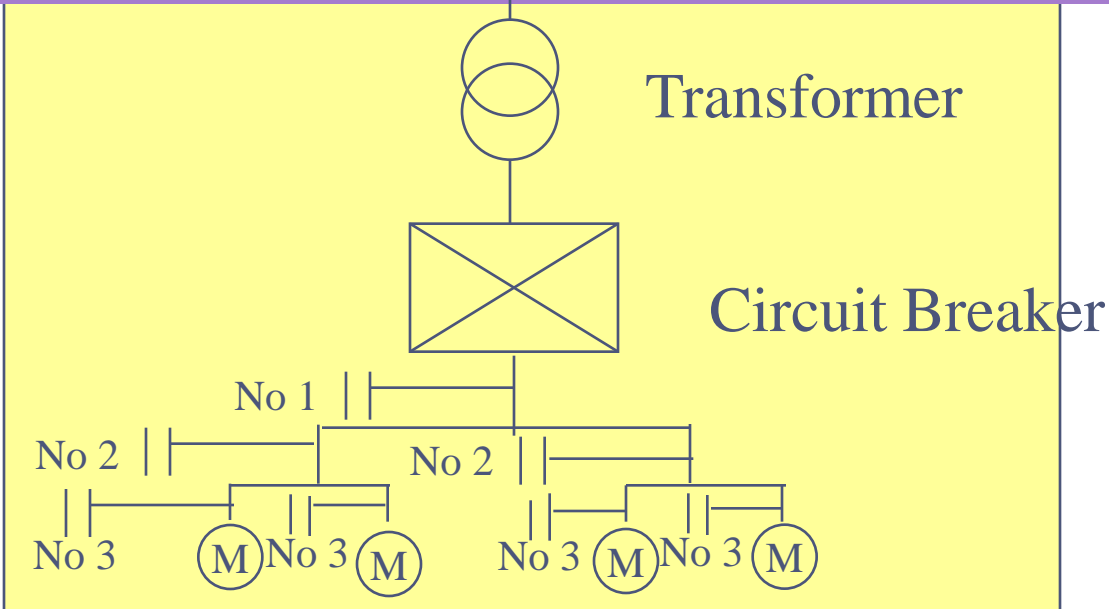


Fig. 3.3



## 2. SELECTION AND SPECIFICATION

**SELECTION** : Selection depends on application

Total Cost = Purchase + Operating cost.

### Calculation of Non-Linear Load:

Example : -

Installed Transformer rating = 1000 KVA

Non – Linear Load = 100 KVA

% Non-Linear load = (Non-Linear load /  
Transformer rating)  
x 100  
= 10%



# REDUCTION IN KVA DEMAND

**LOAD - 900 KW**

**EXISTING P.F. (COS  $\phi_1$ ) - 0.6**

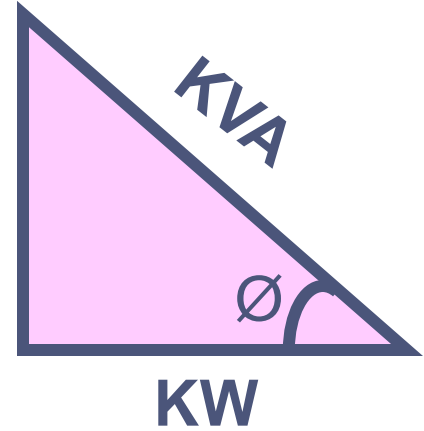
**DESIRED P.F. (COS  $\phi_2$ ) - 0.92**

$$\text{COS } \phi = \frac{\text{kW}}{\text{kVA}}$$

$$\text{KVA} = \frac{\text{kW}}{\text{COS } \phi}$$

$$\text{KVA}_1 = 900 / 0.6 = 1500$$

$$\text{KVA}_2 = 900 / 0.92 = 978$$

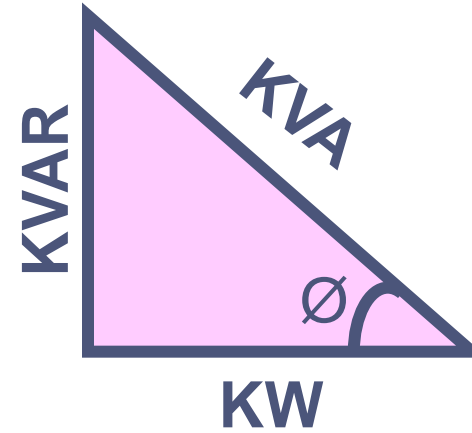


Reduction in KVA  
 $1500 - 978 = 522$

# REDUCTION IN KVAR DEMAND

**KW - 900**  
**KVA<sub>1</sub> - 1500**  
**KVA<sub>2</sub> - 978**

$$kVA = \sqrt{KW^2 + KVAR^2}$$



$$KVAR_1 = \sqrt{KVA_1^2 - KW^2}$$

$$= \sqrt{1500^2 - 900^2} = 1200$$

Reduction in KVAR  
1200 - 382 = 818

$$KVAR_2 = \sqrt{978^2 - 900^2} = 382$$



# REDUCTION IN LINE CURRENT

$$KVA_1 - 1500$$

$$KVA_2 - 978$$

Reduction in Current

$$2087 - 1361 = 726$$

$$\begin{aligned} KVA &= \frac{\sqrt{3} V I}{1000} \\ I &= \frac{KVA \times 1000}{\sqrt{3} \times 415} \\ I_1 &= \frac{1500 \times 1000}{\sqrt{3} \times 415} \\ &= 2087 \text{ Amp} \\ I_2 &= \frac{978 \times 1000}{\sqrt{3} \times 415} \\ &= 1361 \text{ Amp} \end{aligned}$$

## Selection of required kVAr

### Example

Electricity Bill indicates **560kVA** as max recorded demand, kWh = **2345**, and kVAh = **3245**.

$$\begin{aligned}\text{Average Power factor} &= \text{kWh} / \text{kVAh} \text{ (Data from E.B. bill)} \\ &= 2345 / 3245 \\ &= 0.72\end{aligned}$$

Average (Initial) power factor = 0.72 (Data taken from E.B. Bill)

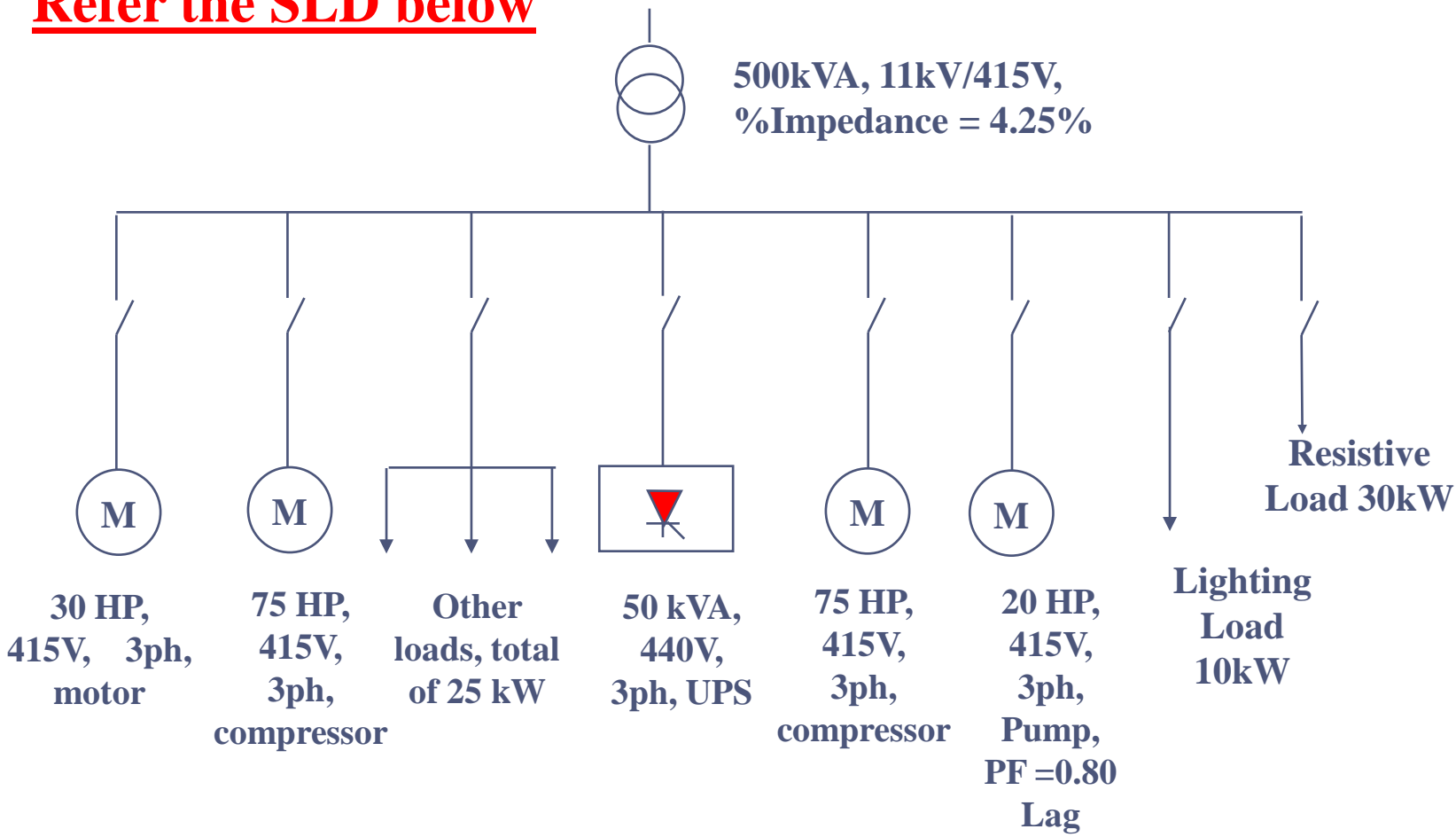
$$\text{Target power factor} = 0.99$$

$$\begin{aligned}\text{KW} &= \text{Recorded max demand (KVA)} \times \text{Average power factor} \\ &= 560\text{kVA} \times 0.72 = 403.2\end{aligned}$$

$$\begin{aligned}\text{Required kVAr} &= 403.2 \text{ kW} \times 0.82 \\ &= 330 \text{ kVAr (Approximate)}\end{aligned}$$

## ESTIMATE kVAR REQUIRED for New Electrical Installations - I

Refer the SLD below





# Methods of Improving Power Factor

## **Fixed Compensation**

- For Steady Loads
- No load compensation of Motors
- No load compensation of Transformers

## **Variable Compensation**

For Varying Loads

# FIXED COMPENSATION

**Selection of capacitor for transformer no-load compensation.**

<b>KVA Rating of the Transformer</b>	<b>KVAr Required for compensation</b>
<b>Upto and including 315 KVA</b>	<b>5% of KVA Transformer Rating</b>
<b>315 to 1000 KVA</b>	<b>6% of KVA Transformer Rating</b>
<b>Above 1000 KVA</b>	<b>8% of KVA Transformer Rating</b>

## **Selection of capacitor for motor compensation.**

- \* While connecting capacitor across the motor terminal, ensure that the capacitor current does not exceed 90% of no-load current of the motor to avoid self-excitation.
- \* Capacitor is a fixed power factor compensation for individual loads on low voltage power transmission lines close to reactive power source enhances the voltage quality levels.
- \* Enhancing power quality – improving the power factor – saves costs and ensures a fast return on investment



# SELECTION FOR LARGE FIXED BANK/APFC/HARMONIC FILTERS

## **Highest system voltage on the capacitors during operation**

- a, Voltage raise at the point of connection of capacitor
- b, Series reactor connection increases capacitor voltage.
- c, Increase system voltage will increase capacitor voltage.

# SELECTION FOR LARGE FIXED BANK/APFC/HARMONIC FILTERS

**Highest ambient temperature around the capacitor  
& not the room temperature**

- a, The proximity effect of other heat generating devices
- b, Highest level of over current – The presence of Harmonic and the Phenomena of resonance .
- c, Switching transient – Switching devices applied
- d, Over loads on capacitor (Fuses do not provide over load protection)

**The KVAR rating of APFC system can be decided depending upon KW of the load,existing PF(Initial) and final PF .**



# Technical Specification of MPP LT Power Capacitors

Standard	IS 13340 – 1993 & IS 13341 – 1992 / IEC 831–1(1996-11) & IEC 831–2(1995-12)
Rated Voltage	415 / 440 V (Other ratings on request)
Over voltage	$U_N$ continuous $U_N + 15\%$ (up to 12 hrs daily) $U_N + 20\%$ (up to 30 mins daily) $U_N + 25\%$ (up to 5 mins daily) $U_N + 30\%$ (up to 1 minute) Any over voltage $> 1.15 U_N$ shall not occur more than 200 times in the Capacitor's life. As per clause 20.1 of IEC

# Technical Specification of MPP LT Power Capacitors

Over current	1.5 I <sub>N</sub> at 1.15 C <sub>N</sub> combined with over voltage & presence of harmonics as per clause 21 of IEC 831
Frequency	50 / 60 Hz
No. of Phases	Single / Three
Capacitance Tolerance	5 % to + 15 %
Test voltage terminal - terminal	1.75 U <sub>N</sub> / 2.15 U <sub>N</sub>
Test voltage terminal – case	3.6 kV A.C
Discharge Device	Discharge resistor
Electrodes	Special vacuum deposited metal alloy with re-inforced edge / Wave cut

# Technical Specification of MPP LT Power Capacitors

Peak Transient Over current	$\leq 200 I_N$
Total losses	$\leq 0.5 \text{ W} / \text{kVAr}$ excluding discharge resistors
Dielectric losses	$\leq 0.2 \text{ W} / \text{kVAr}$
Degree of protection	IP 31
Ambient temperature category	-25 / D (Max 55 °C)
Max. permissible altitude	2000m above mean sea level
Mounting position	Vertical with terminals upwards
Safety features	Self Healing Pressure Sensitive Disconnecter (PSD) or Internal fuse
Container Type	Rectangular / Cylindrical
Dielectric	Bi – axially oriented Polypropylene film
Impregnant	Non PCB, bio – degradable impregnate or resin or gas



## 3. TESTING & QUALITY CONTROL

### SHUNT CAPACITORS OF SELF – HEALING TYPE FOR AC POWER SYSTEMS HAVING RATED VOLTAGE UP TO 1000 V

**CLASSIFICATION OF TEST – AS PER IS 13340 - 1993 &  
13341 - 1992**

- Routine Tests
- Acceptance Tests
- Type Tests
- Special Tests



## 1. Routine tests

These tests are performed on all units manufactured

- 1.1 Visual examination - To ensure workmanship, finish & marking
- 1.2 Sealing test - To ensure no leak of filling liquid materials
- 1.3 Measurement of output and capacitance - To ensure kVAr output of the capacitor units are as per the tolerance specified in the standard
- 1.4 Insulation resistance between terminals and container –  
DC voltage : 500 V Megger test
- 1.5 Capacitor loss tangent measurement - To verify the capacitor losses within manufacturer's limits
- 1.6 AC Voltage test between terminals - AC Voltage:  $1.75 U_N$  for 2 secs.
- 1.7 AC voltage test between terminals and container - AC voltage : 3 kV for 10 secs
- 1.8 Test of discharge devices - Check for discharge time / Resistance value

## Acceptance tests:

These tests are conducted before the customer as per the contract agreement with the purchaser

- Visual examination
- Sealing test
- Measurement of output and capacitance
- Insulation resistance between terminals and container
- Capacitor loss tangent measurement
- Voltage test between terminals
- Ac voltage test between terminals and container
- Test of discharge devices

### **Type tests:**

These tests are carried out to ascertain the design, size, material & construction as per the specified scheme of testing

- Thermal stability test
- Capacitor loss tangent measurement at elevated temperature
- AC Voltage test between terminals and container
- Lightning impulse voltage test between terminals and container
- Short circuit discharge test
- Voltage test between terminals
- Self – healing test

### **Special tests:**

To ensure reliability performance of capacitor for intended application

- Ageing test
- Destruction test



SHUNT CAPACITORS FOR NON-SELFHEALINGTYPE FOR AC  
POWER SYSTEMS HAVING A RATED VOLTAGE UP TO AND  
INCLUDING 1000 V

**CLASSIFICATION OF TESTS – AS PER IS 13585 (part 1) 1994**

1) Routine tests

2) Type tests

**1. Routine tests**

- 1.1 Visual examination
- 1.2 Sealing test
- 1.3 Measurement of output and capacitance
- 1.4 Insulation resistance between terminals and container
- 1.5 Capacitor loss tangent measurement
- 1.6 Voltage test between terminals
- 1.7 Ac voltage test between terminals and container
- 1.8 Test of discharge devices

## 2. Type tests

- 2.1 Thermal stability test
- 2.2 Capacitor loss tangent measurement at elevated temperature
- 2.3 AC Voltage test between terminals and container
- 2.4 Lighting impulse voltage test between terminals and container
- 2.5 Short circuit discharge test
- 2.6 Voltage test between terminals

## INDIAN STANDARDS FOR POWER CAPACITORS

- 1) L T – Self – healing capacitor up to 1000 v - IS 13340 - 1993  
& IS 13341- 1992 / IEC 60831 – 1(1996) & IEC 60831 – 2(1995)**

**Ex – Metallized polypropylene & Metallized Paper**

- 2) L T – non self – healing capacitor up to 1000 v - IS 13585 ( part 1) 1994**

**Ex – Mixed dielectric & all polypropylene**

- 3) H T – Capacitor above 1000 v - IS 13925 ( part 1 ) 1998**

**Ex – Mixed dielectric & all polypropylene**

- 4) L T – Switchgear and control gear assemblies - IS – 8623 ( part 2 ) 1993**

**Ex – A P F C – Panels**

- 5) L T – Motor capacitors - IS – 2993 - 1975**

**Ex – 25.0 $\mu$ fd, 36.0 $\mu$ fd, 50.0 $\mu$ fd, 72.0 $\mu$ fd, 108.0 $\mu$ fd & 144  $\mu$ fd**

# Quality & Reliability

Capacitors used for intended application at site should perform satisfactorily for the period of stipulated time under operating conditions encountered.

To ensure reliable performance, the capacitor during manufacturing process has to be ensured right from materials & components selection & process control at various stages of manufacturing.

Example:

- MPP film – Self-Healing dielectric, low loss & higher temperature resistance base film
- Provision of safe PSD or Internal fuse– Safe disconnection mechanism, no bursting of capacitor during dielectric breakdown of elements
- Higher inrush current capability – Providing proper zinc spray contacts on wound elements
- Low temperature rise on capacitors – Reduce current density internal to capacitor current carrying members



# Installation of Capacitor Banks

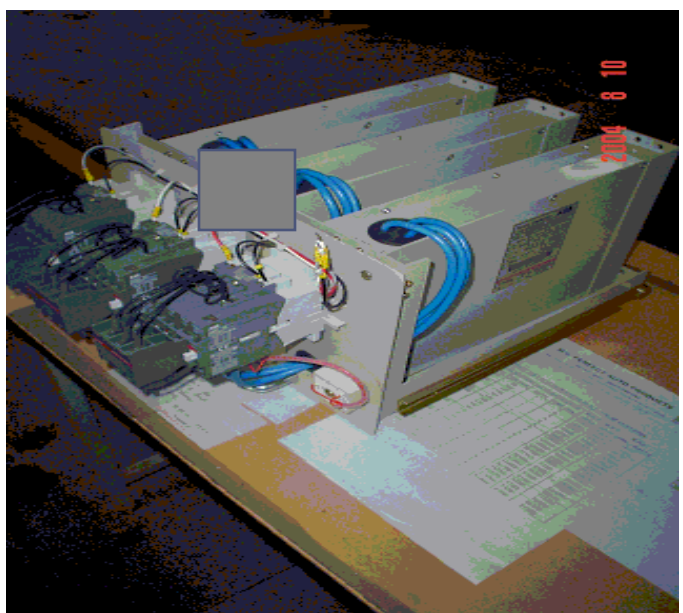
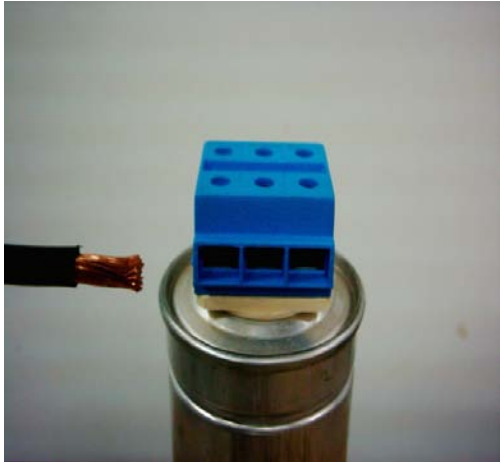
1. It is ~~recommended that capacitor should be installed vertically (liquid filled)~~
2. The banks should be provided cross ventilation, such as louvers.
3. Capacitor mounted in a row should have minimum gap of 30 mm between each unit.
4. Electrical clearance between phase to phase should be 25mm and between phase to earth-19mm
5. Capacitor body should be earthed at both the ends
6. Capacitors are to be installed away from heat generating source with proper cross ventilation or louvers or better design with thermal cooling inside containers and cooling fans for better heat conduction.
7. Use HRC fuse links for short circuit protection/maintenance.
8. Use switch fuse unit for capacitor protection / maintenance
9. Ensure suitable size of lugs to suit the connecting cable for capacitor terminal connection with proper crimping. Improper size of lugs/crimping if used will result in excessive heat generation causing burning of cable insulation/terminal of capacitor connection.

# Installation of APFC Panel

1. The panel should be provided forced cooling fan.
2. Additional cooling should be provided in APFC panels installed with reactors.
3. Electrical clearance between phase to phase should be 25mm and phase to earth 19mm.
4. Maintain a gap of 30mm between capacitor units and 50mm between capacitors and panel enclosure for better air circulation (Cooling).
5. Use inductor coil in series with capacitor (one coil in each of the two lines) or use capacitor duty contactor when capacitors are switched in parallel with other energized capacitor units.
6. Capacitor switching time in the APFC relay should be set to 60 sec, to ensure to discharge of individual capacitor step / unit before reconnection.
7. Panel body should be earthed at both ends.



# Method of Cable connection in to clamptite terminal of capacitor



## Follow the Sequence for connecting cable as in picture (1 to 4)

- a. Cable cross section Min: 2.5 Sq.mm, Max: 16 Sq.mm
- b. Remove Conductor insulation of the cable only 10mm for connection.  
  
(Picture No.1)
- c. Insert conductor fully inside the clamp, no single strand to come out  
  
from the slot. (Picture No.2 & 3)
- d. Use Pneumatic gun to tighten the screw from top of the terminal cover.  
  
(Picture No.4). Keep Pressure 4 to 5 bar, and torque 5Nm

# Commissioning

Check all electrical connection and ensure bolted joints are tightened before commissioning to avoid excessive heating at joints.

1. Check the capacitance value before commissioning RY, YB, BR (If capacitance meter available)
2. Check System voltage.
3. Check harmonic in the installation before commissioning.
4. Check type of load in the installation before commissioning.
5. Check capacitor is drawing current with respect to voltage in all three phases.
6. Capacitor current should not exceed 30% from its rated current with respect to over voltage and harmonic overload.
7. . Capacitor current will not be same as rated, If voltage applied to the capacitor and frequency are lesser / higher than rated voltage and frequency.

# Commissioning

The following formula will give the actual current drawn by a capacitor at a voltage and frequency other than the rated.

$$I_M = \frac{I_N (U_s \times F_s)}{U_N \times F_N}$$

$U_N$  = Capacitor rated voltage

$U_s$  = System voltage

$I_M$  = Measure capacitor current

$I_N$  = Capacitor rated current

$F_N$  = Capacitor rated frequency

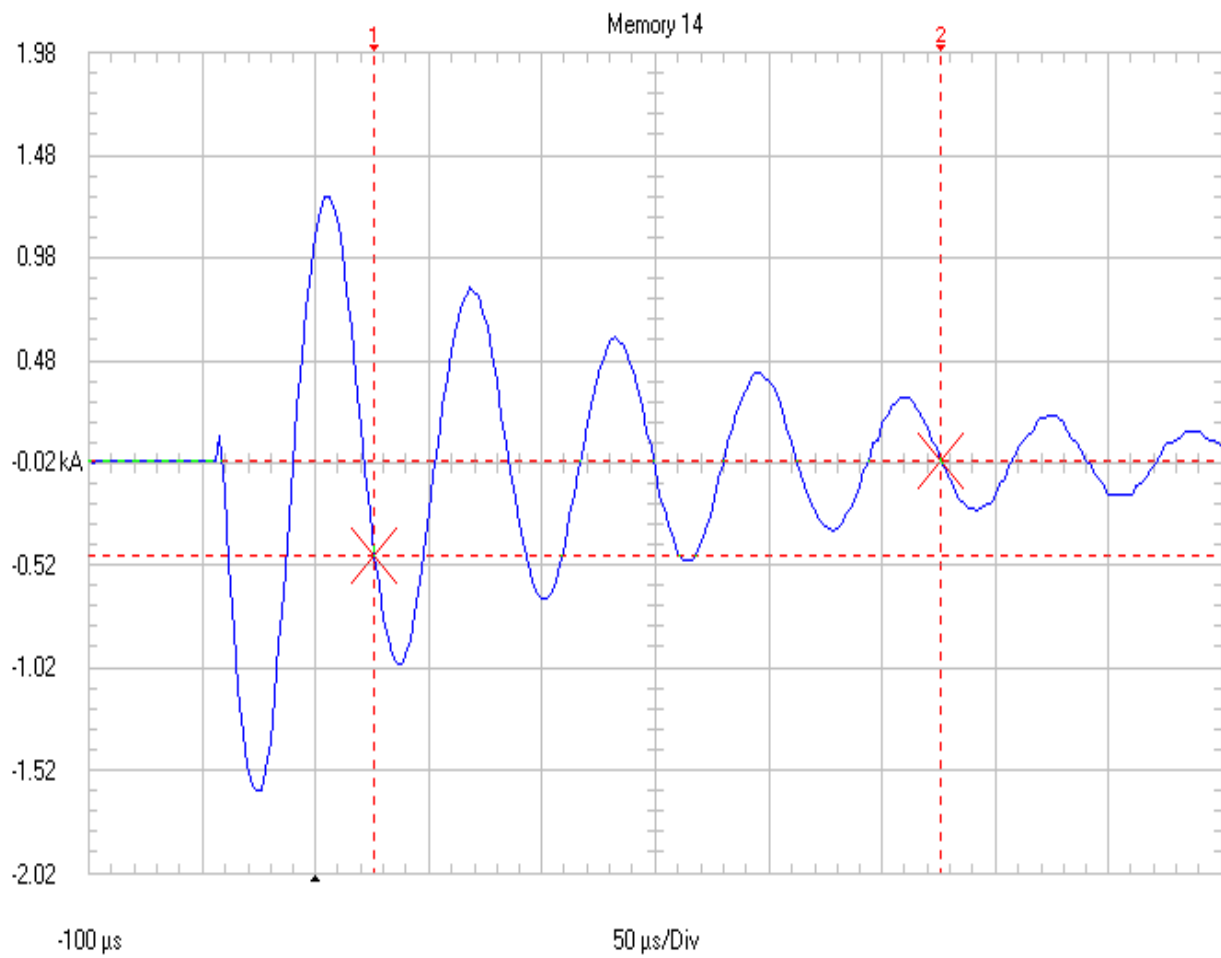
$F_s$  = System Frequency.

9. Check voltage fluctuation in the system during day/night.
10. Capacitor over voltage should not exceed 10% of rated voltage.

# Maintenance

1. Check the tightness of all electrical bolted joints once in 3 months to avoid overheating in the joints and insulation break down.
2. Periodically perform maintenance checks on contactors as per their manufacturer's guidelines to avoid chattering, as this seriously affects the life of capacitors.
3. Supply voltage should not exceed 10% of capacitor rated voltage (as per IS 13340: clause no.6.11)
4. Capacitor current should not exceed 30 % of rated current.
5. Periodically record capacitor current and voltage.
6. Capacitor will be affected by Harmonics imported from grid. Presence of harmonics is detected easily by observing abnormal increase in capacitor current under normal voltages. (Use true RMS instruments only for accurate measurement.)  
Over heating, over stress, shorten the life of capacitor and hence operating condition such as temperature, voltage, current should be strictly controlled.

# Peak current measurement



Datablock	
Name	= Memory 14
Date	= 15/3/04
Time	= 7:06:11 PM
Y Scale	= 500 A/Div
Y At 50%	= -0.02 kA
X Scale	= 50 μs/Div
X At 0%	= -100 μs
X Size	= 250 (512)
Maximum	= 1.28 kA
Minimum	= -1.62 kA

Cursor Values	
X 1:	26 μs
X 2:	276 μs
dX:	250 μs
Y 1:	-0.48 kA
Y 2:	0.00 kA
dY:	0.48 kA

Current waveform of 163.8 micro Farads element at a charging voltage of 880 Volts without additional cable. Peak current 16.2 kA

## CAPACITORS SELECTION - SPECIFICATIONS

THE MAIN FACTORS TO BE CONSIDERED ARE

- System Voltage.
- Type of load linear [inductive] – non linear [harmonics]
- Capacitors connected centrally or individually.
- Internal or external mounting.
- Type of switching- Contactor-SFU-Thyristor.
- Ambient conditions of the locations.
- Specifications- IS13340

## **TESTS PERFORMED ON CAPACITORS AS PER IS 13340**

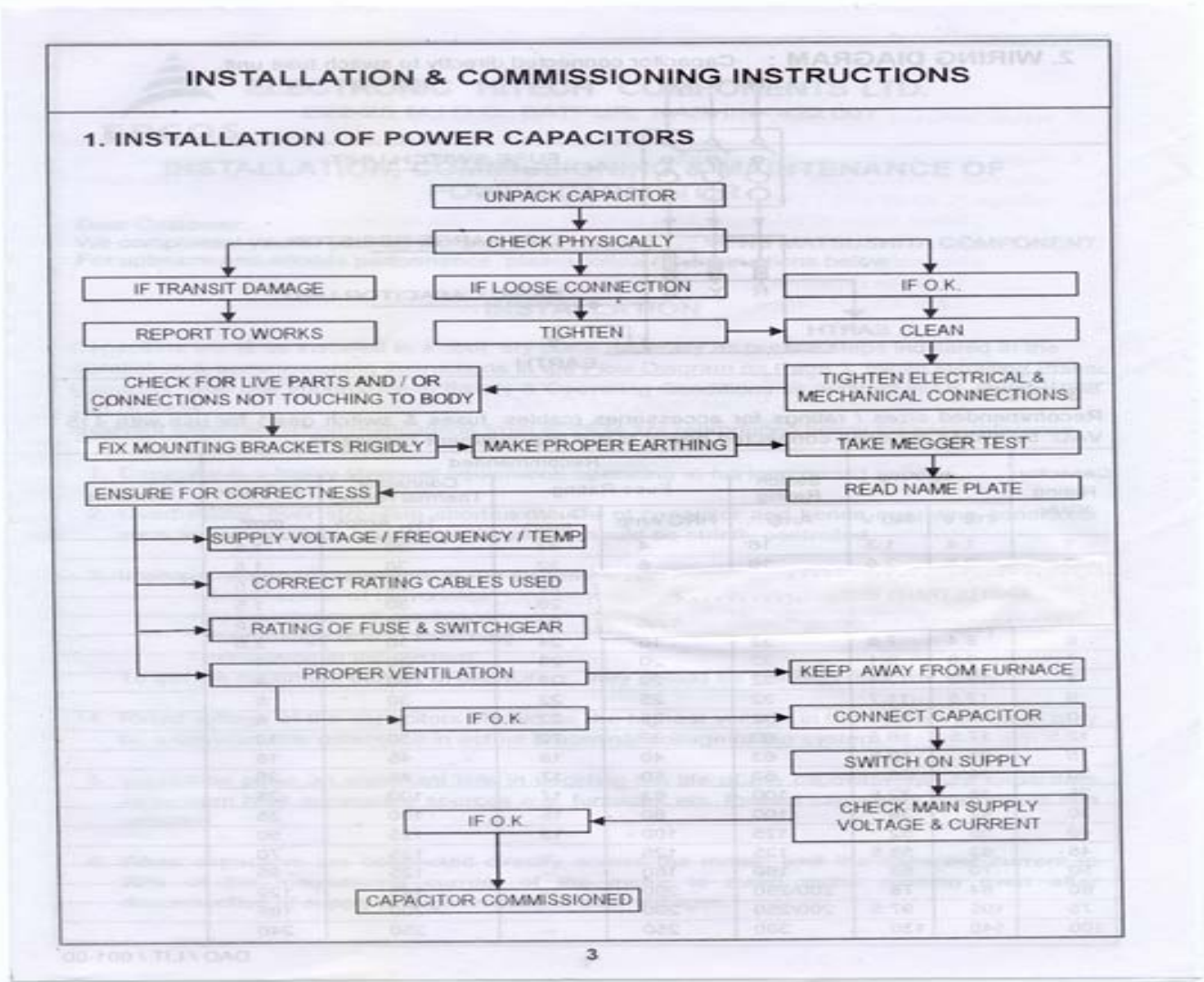
- 1. Visual Examination: Workmanship, Finish & Marking is checked.**
- 2. Sealing Test: Mounting - in a position most likely to reveal leakage.**
- 3. Temperature – 20 deg c above maximum rated temperature.**
- 4. Measurement of capacitance & output: Measurement is done at rated voltage.**
- 5. Frequency - as per choice of manufacturer.**
- 6. Insulation resistance between terminals and capacitor, test Voltage - 500 VDC**
- 7. Insulation resistance so measured shall not be less than 50 meg ohms.**
- 8. Capacitor loss tangent (tan d) measurement:**
- 9. AC voltage test between terminals: Test voltage -  $1.75 U_n$  applied for 2 seconds.**
- 10. AC voltage test between terminals and container: Capacitor is subjected to a voltage of 3 kV applied between terminals (joined together) and the container for 2 seconds.**
- 11. Test for discharge device.**



# Commissioning Guidelines

- **Mount capacitor as per the guidelines of the manufacturer.**
- **Ensure that the operating conditions like temperature, voltage & current are properly maintained.**
- **Always mount the capacitor near utility for maximum benefit of capacitors.**
- **Avoid loose connection of terminals.**
- **Avoid over voltage & over current on capacitor.**
- **Avoid overheating or overstressing of capacitor.**
- **Avoid using underrated switchgears / cables for connection.**
- **Never install the capacitors without series reactors if harmonic level is significant (above 20%).**
- **Never bank the capacitors of different voltage ratings together.**

# Installation & commissioning instruction



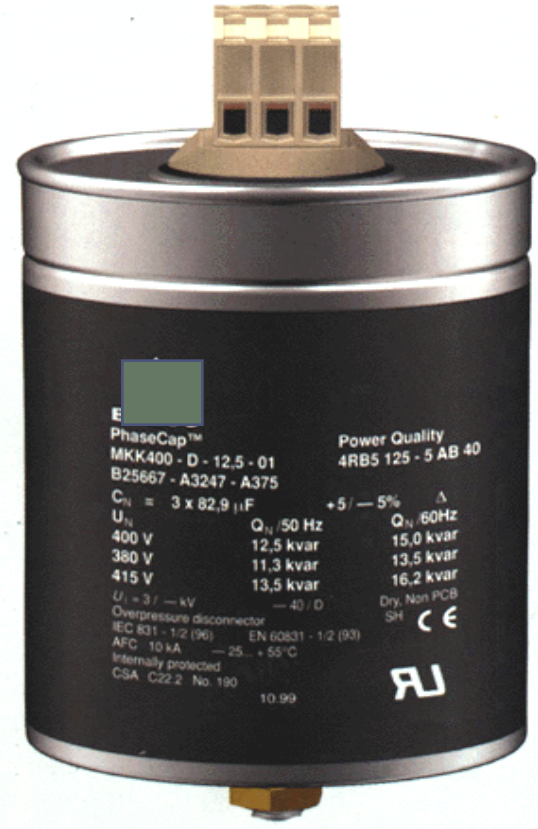
# Life Expectancy of a Capacitor is determined by

- **Voltage specification**
- **Current specification, no harmonic resonance**
- **Damping of inrush current**
- **Less than 5000 switching operations per year**
- **Within temperature class limits**

Keep lowest possible ambient temperature.



**TAMB < 35°C**



**Panel design must take care of this !**

# Switching operations and damping of inrush currents



**Use intelligent controllers with optimised switching sequence.**



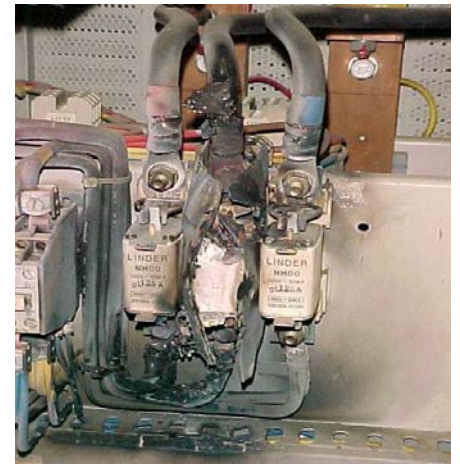
**Use capacitor contactors specially designed to damp inrush currents.**

# PREVENTIVE MAINTENANCE OF CAPACITORS

1. Check current / Voltage drawn by the capacitor bank
2. If any abnormality please go for a detailed analysis.
3. Check if fuses are intact.
4. Is there any frequent replacement of fuses.
5. Check the terminals for loose connection.
6. Check if capacitors are properly ventilated.
7. Evaluate risk of resonance.
8. Check for any leakage of impregnant.



**Problems Caused by Harmonics**



**Problems caused by loose connections**

# Harmonic mitigation & Rapid Compensation



**De-tuned reactors are used in series with capacitor to avoid harmonic amplification**



**Thyristor switch are used for rapid switching of capacitors without causing switching transients for dynamically varying loads like welding, extrusion etc.**

## CAPACITOR FAILURE - CHECK LIST

- **When were the capacitors installed & date of failure detection.**
- **What is the power of bank? [ Kvar ] & power of each stage**
- **Type of switching is used? [ Contactor/SFU/MCCB ] ,**
- **Type of cable used [ Al / Cu ] & its cross section.**
- **What is the condition of capacitor contactors? Any evidence of sparks or carbonization of contacts & on the cable terminals.**
- **Is there some inductor in series with the capacitors (detuned filters, discharge chokes, contactor with series damping resistors)?**

## CAPACITOR FAILURE - CHECK LIST

- **What are the parameters set on APFC relay:  
switching time and sequence of switching the  
stages?**
- **Is it possible to provide a single line diagram.**
- **Are capacitors individually connected or housed in a  
centralized APFC panel.**
- **Are there any loads that generate harmonics, if so  
what are the harmonic levels [ V & I ] in the system.**

**Thank you for  
your attention!**

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