بسم الله الرحمن الرحيم

IN THE NAME OF ALLAH WHO IS MOST BENEFICENT AND MERCIFUL

PRUDENT PRACTICES TO IMPROVE POWER FACTOR AND REDUCE POWER LOSS.

DEFINATIONS

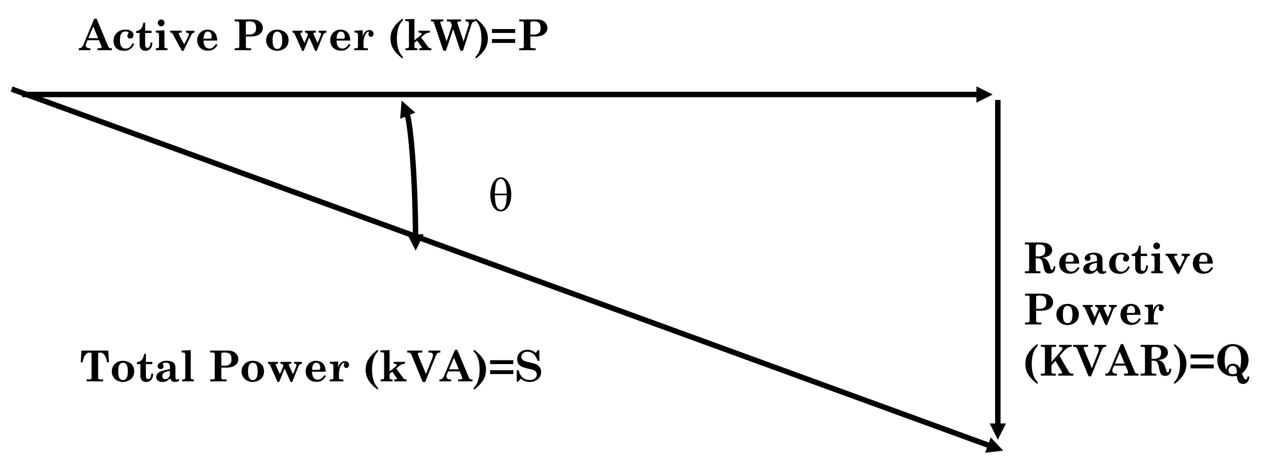
- ***Working /Active Power***: Normally measured in kilowatts (kW). It does the "work" for the system--providing the motion, torque, heat, or whatever else is required.
- ***Reactive Power***: Normally measured in kilovolt-amperes-reactive (kVAR), doesn't do useful "work." It simply sustains the electromagnetic field.
- ***Apparent Power***: Normally measured in kilovolt-amperes (kVA). Working Power and Reactive Power together make up apparent power.

POWER FACTOR

- Power Factor is the ratio between the useful (true) power (kW) to the total (apparent) power (kVA) consumed by an item of a.c. electrical equipment or a complete electrical installation.

- "Power Factor" is an electrical term used to rate the degree of the synchronization of power supply current with the power supply voltage

POWER TRIANGLE



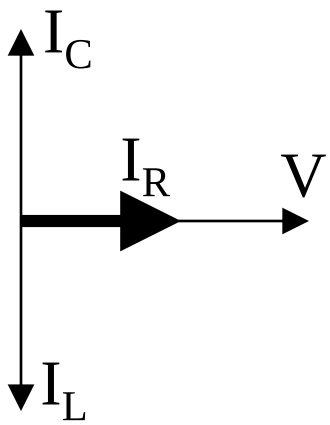
Power Factor = Active (Real) Power / Total Power

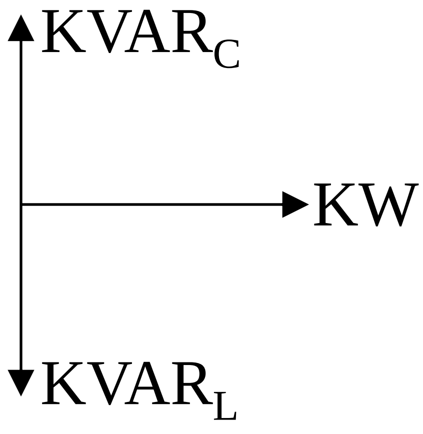
= P (kW) / S (kVA)

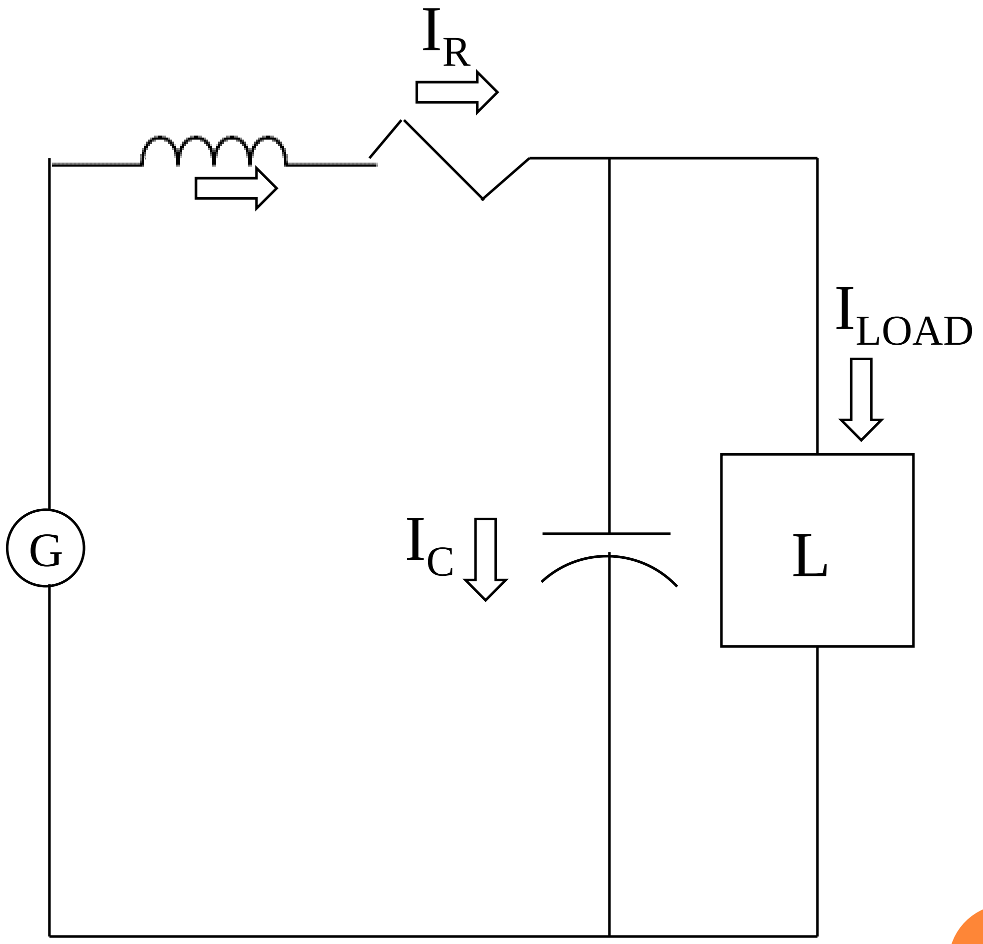
= Cosine (θ)

= DISPLACEMENT POWER FACTOR

LAGGING & LEADING





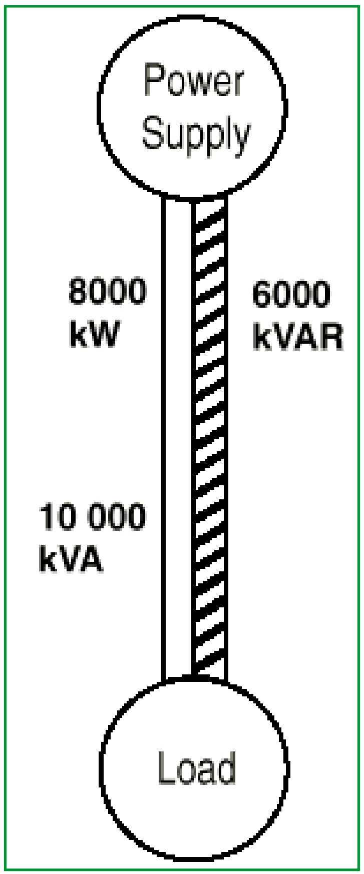


Why Do We Care About Power Factor?

- Low power factor results in:
  - **Poor electrical efficiency**
  - **Higher utility bills**
  - **Lower system capacity**
  - **On the Supply Side, Generation Capacity & Line Losses Increases.**
  - **Higher Load Currents**
  - **Higher I^2R Losses**
  - **For Lower Power factor KVA rating of the equipment has to be more which means equipment has to be larger and expensive**

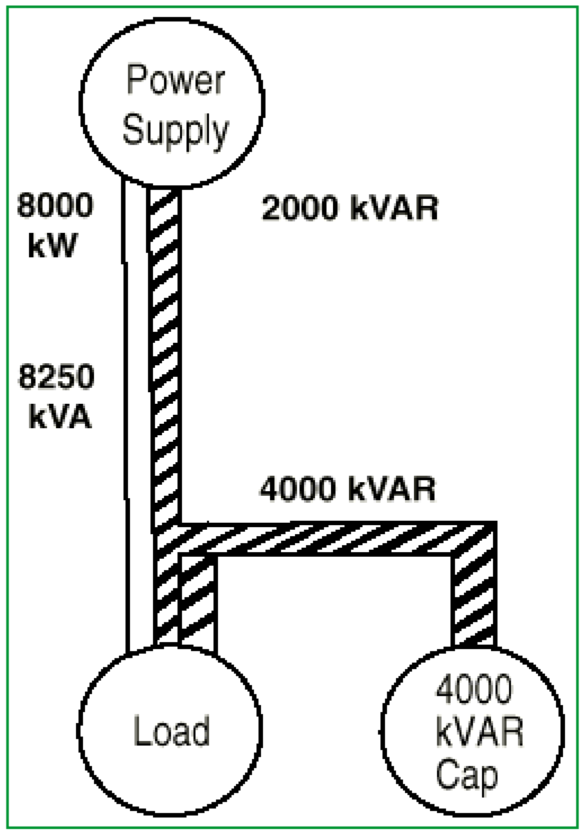
Improved Power Factor Reduces Power Losses.

Before



$$PF = \frac{kW}{kVA} = 80\%$$

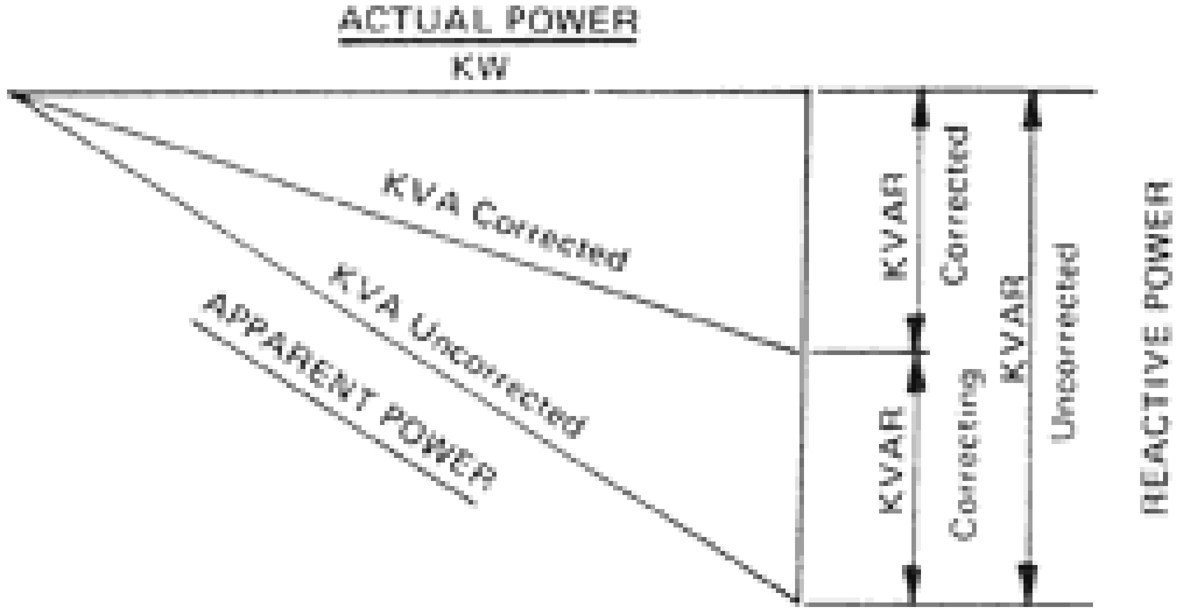
After



$$PF = \frac{kW}{kVA} = 97\%$$

- In this example, demand was reduced to 8250 kVA from 10000 kVA.
- 1750KVA Transformer Capacity Release.
- The power factor was improved from 80% to 97%

Improved Power Factor Reduces Power Losses.



Now with improved power factor to Provide Same Actual Power to the Load Less Apparent Power is Required.

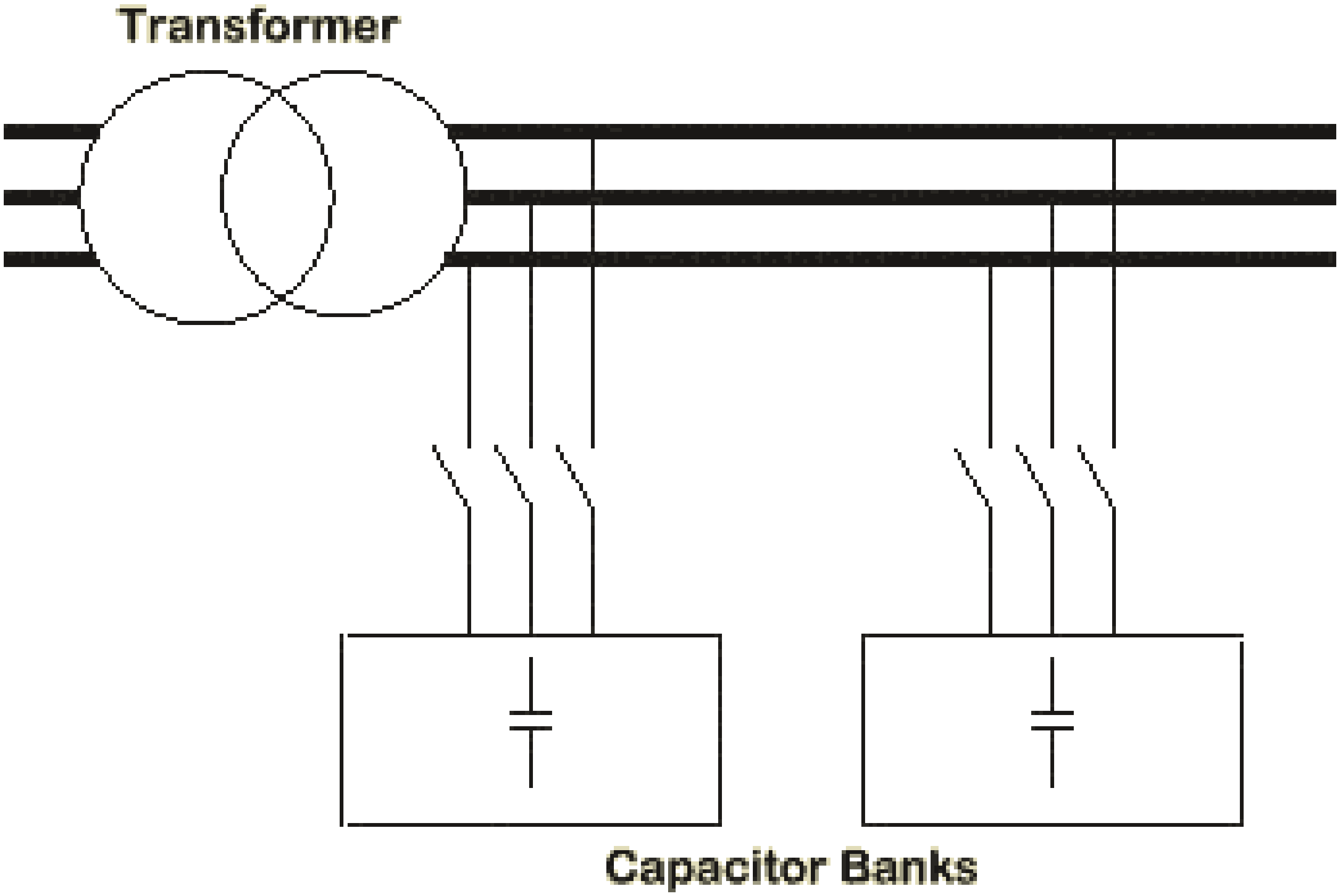
METHODS OF POWER FACTOR CORRECTION/ IMPROVMENT

- **Bulk Correction**
- **Static Power Factor Correction**

BULK CORRECTION

- The Power factor of the total current supplied to the distribution is monitored by a controller which then switches capacitor banks In a fashion to maintain a power factor better than a preset limit. (Typically 0.95)
- Ideally, the power factor should be as close to unity (Power factor of "1") as possible. There is no problem with bulk correction operating at unity.

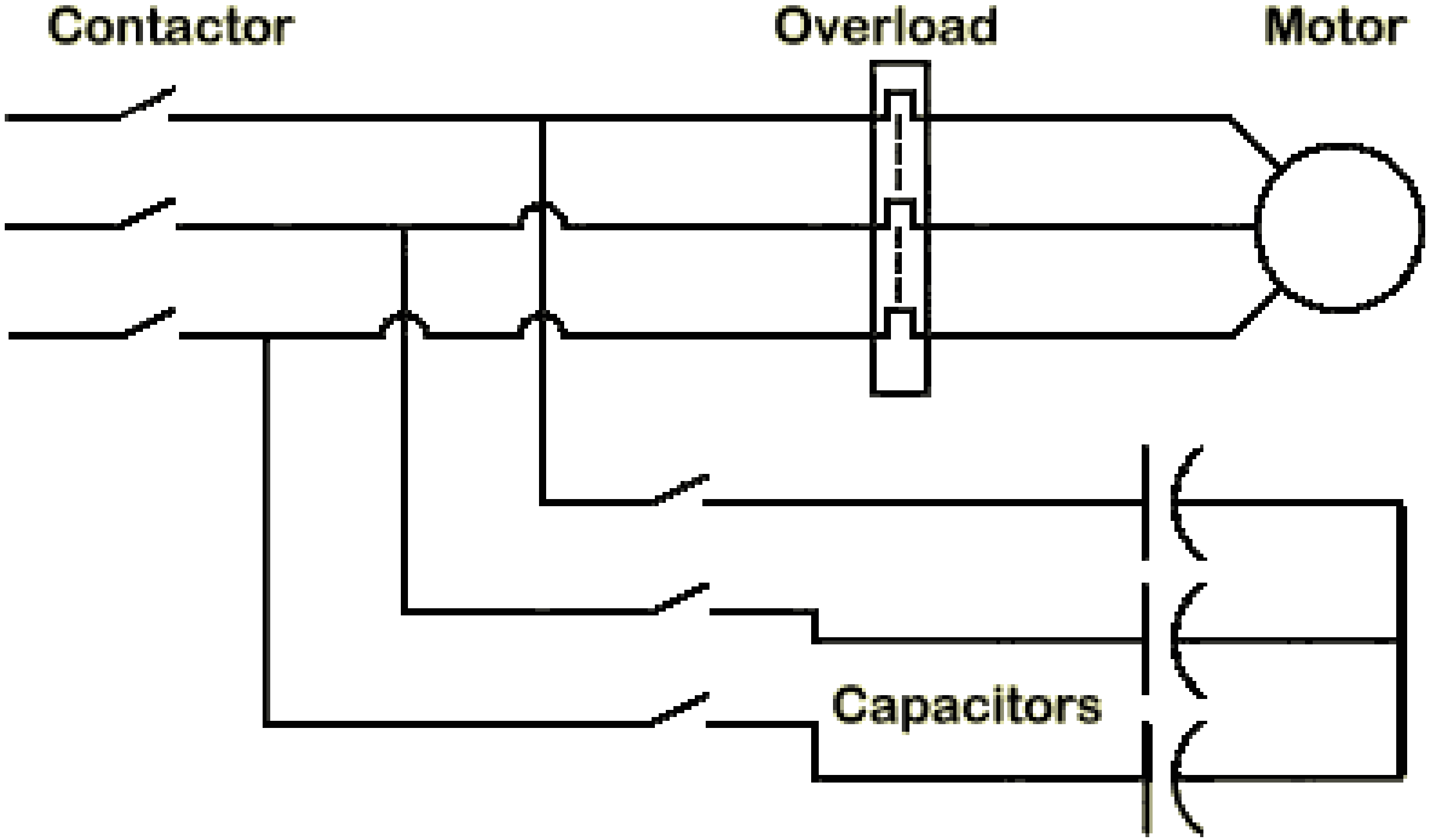
BULK CORRECTION



STATIC CORRECTION

- As a large proportion of the inductive or lagging current on the supply is due to the magnetizing current of induction motors, it is easy to correct each individual motor by connecting the correction capacitors to the motor starters.
- With static correction, it is important that the capacitive current is less than the inductive magnetizing current of the induction motor.

STATIC CORRECTION



PRUDENT METHODS FOR P.F CORRECTION

- Static Var Compensator (SVC)
- Synchronous Condenser

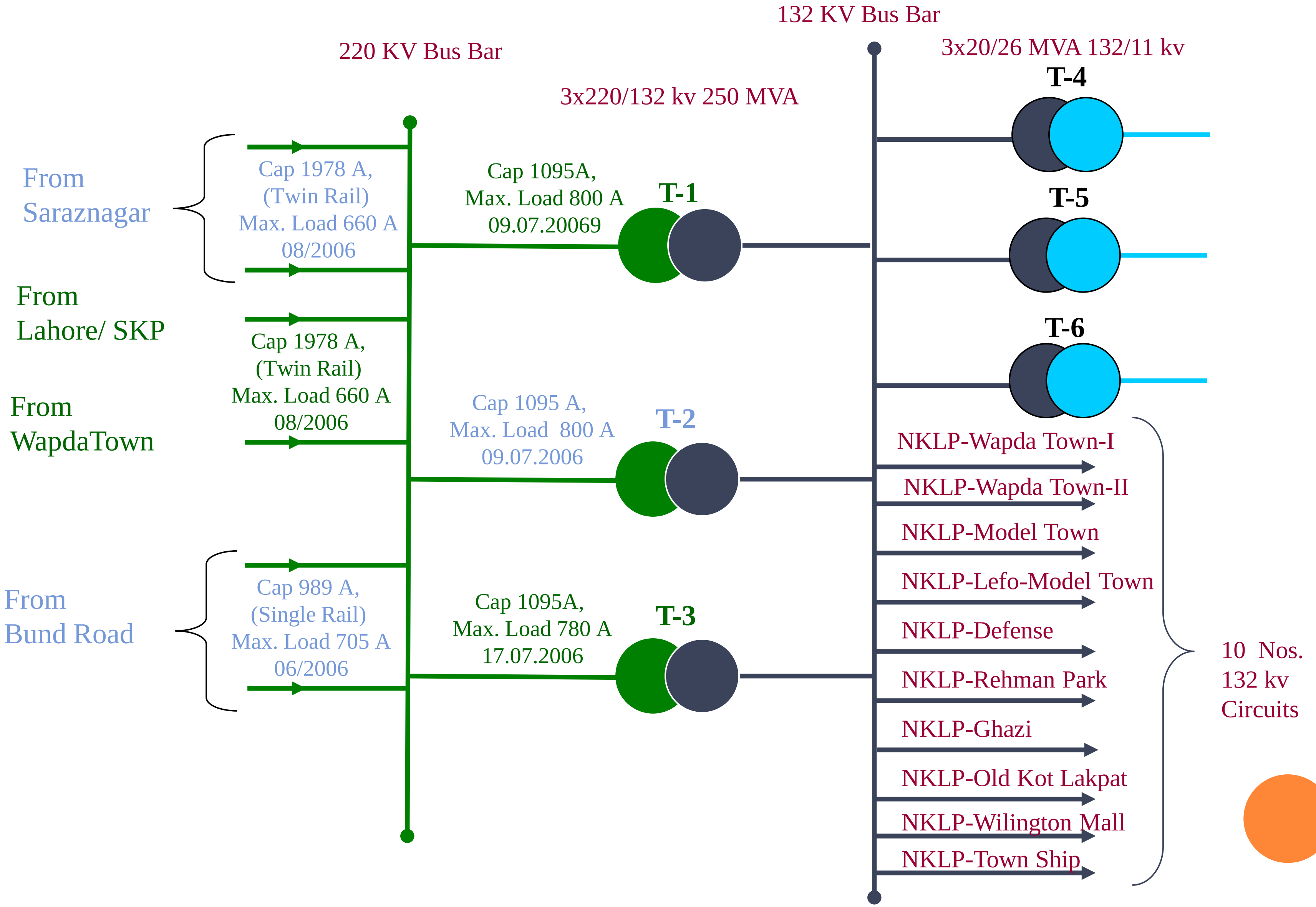
STATIC VAR COMPENSATOR (SVC)

- **The Static VAr Compensator is a thyristor controlled (hence static) device which controls the flow of reactive power in a system by generating or absorbing reactive power.**
- **The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system.**

STATIC VAR COMPENSATOR (SVC)

- When system voltage is low , the SVC generates reactive power (SVC capacitive).
- When system voltage is high ,it absorbs reactive power (SVC inductive).
- Control is achieved by variation of the firing angle of the thyristors.

220 KV GRID STATION NEW KOT LAKHPAT



SYNCHRONOUS CONDENSER

- Synchronous Condenser (sometimes called a synchronous capacitor or synchronous compensator) is a device identical to a synchronous motor, whose shaft is not connected to anything but spins freely.
- Its purpose is not to convert electric power to mechanical power or vice versa, but to adjust conditions on the power network. Its field is controlled by a voltage regulator to either generate or absorb reactive power as needed to adjust the grid's voltage, or to improve power factor. The condenser's installation and operation are identical to large electric motors.

- **Increasing the device's field excitation results in its furnishing Reactive Power (VARS) to the system.**

BENEFITS

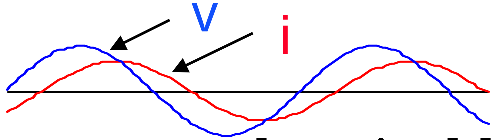
- **Its principal advantage is the ease with which the amount of correction can be adjusted. The Kinetic Energy stored in the rotor of the machine can help stabilize a power system during Short Circuits or rapidly fluctuating loads such as Electric Arc Furnaces.**
- **Eliminate Power Bill Penalties**
- **Automatic Power Factor Correction**
- **Increase System Stability**
- **Mitigate Voltage Transients**
- **Reduced System Losses**
- **Low Maintenance Costs**

Harmonics

- Displacement Power Factor (DPF)
- Total Power Factor/ True P.F
- Effects of Harmonics on Capacitors

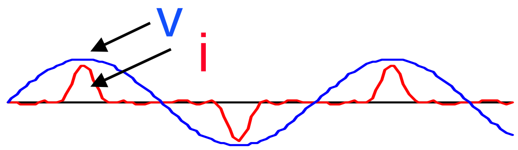
Linear vs Non-Linear

- Until recently, most electrical equipment drew current in a "linear" fashion:



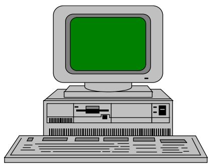
• Current (i) & Voltage (v) are both "Sinusoidal"

- Today, many electrical loads draw current in a "non-linear" fashion:

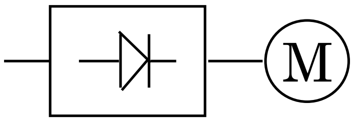


• Current (i) is periodic, but not "sinusoidal"

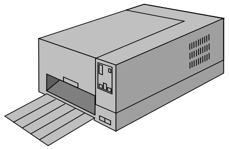
WHAT PRODUCES "NON-LINEAR" CURRENT?



- Computers

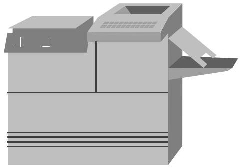


- Variable Frequency Drives

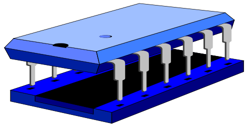


- Fax Machines

- UPS



- Copiers



- **Almost anything electronic**

WHAT PRODUCES “NON-LINEAR” CURRENT?

UPS:

- Highly Inefficient
- Generates Harmonics
- Distorts Power Quality

TOTAL HARMONIC CURRENT DISTORTION (THD) IS SAME AS

Total Demand Distortion (TDD)

$$I_{TDD} = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \cdots}}{I_1} \cdot 100\ \% = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1} \cdot 100\ \%$$

TOTAL OR TRUE POWER FACTOR (TPF)

$$\text{TPF} = (\text{DPF}) \times (\text{Harm Coefficient})$$

$$\text{DPF} = \frac{\text{KW}}{\text{KVA}} = \cos\phi$$

$$\text{Harm Coefficient} = \frac{1}{\sqrt{1 + \text{TDD}^2}}$$

TPF = Total or true power factor

DPF = Displacement power factor

Harm coefficient = Harmonic power factor = Cos δ

TOTAL POWER FACTOR EXAMPLE

- **VFD (Six Pulse)**
- **DPF = .95**
- **TDD = 90% (No Line Reactor)**

Harm coefficient =

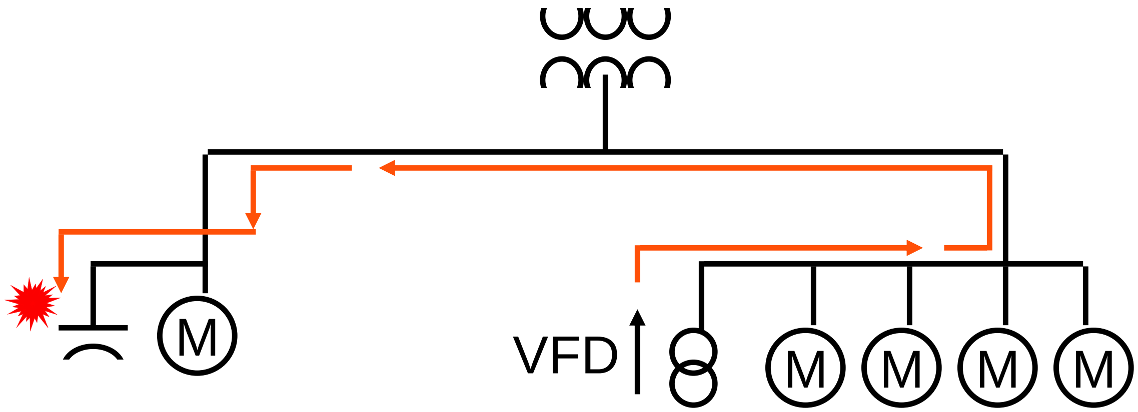
$$\frac{1}{\sqrt{1 + .9^2}} = .7433$$

- **TPF = .95 x .7433 = .7061**

Applying Capacitors:

- **Caps. at Motors or at SWBD / MCC:**

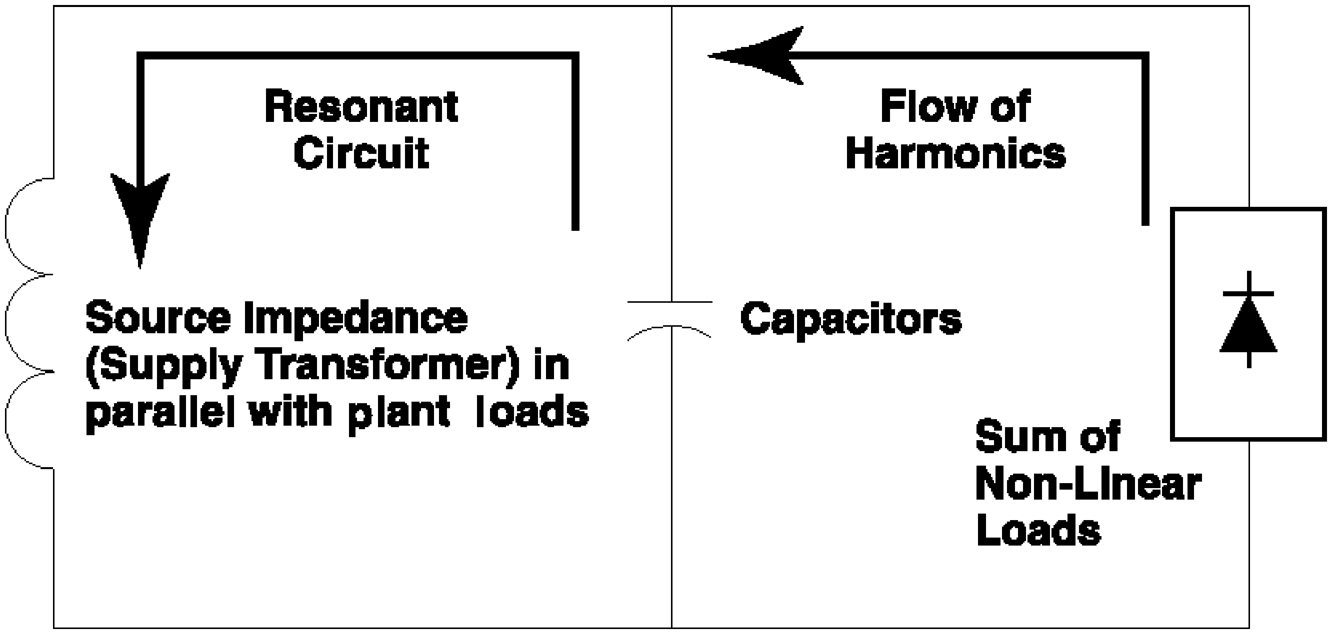
  <u>Disadvantage</u>:
  - **If Drives are present <u>anywhere</u>, the harmonic currents they produce can flow back to the point of <u>lowest impedance</u>: the capacitor!**
  - **This will cause premature failure of the capacitor.**



HOW HARMONICS AFFECT CAPACITORS

- **Capacitors are naturally a low impedance to high frequencies:**
  - **Caps. absorb harmonics**
  - **Caps. do not generate harmonics**
- **As capacitor absorbs harmonics, the capacitor heats up**
  - ***Reduced life expectancy***
- **Voltage harmonics stress the capacitor dielectric**
  - ***Reduced life expectancy***
- ***Parallel combination of capacitors with motor or transformer can cause resonance*** **condition**

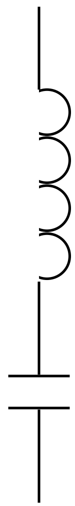
RESONANCE



The installation of standard capacitors can magnify harmonic currents on the network

HOW HARMONICS AFFECT CAPACITORS:

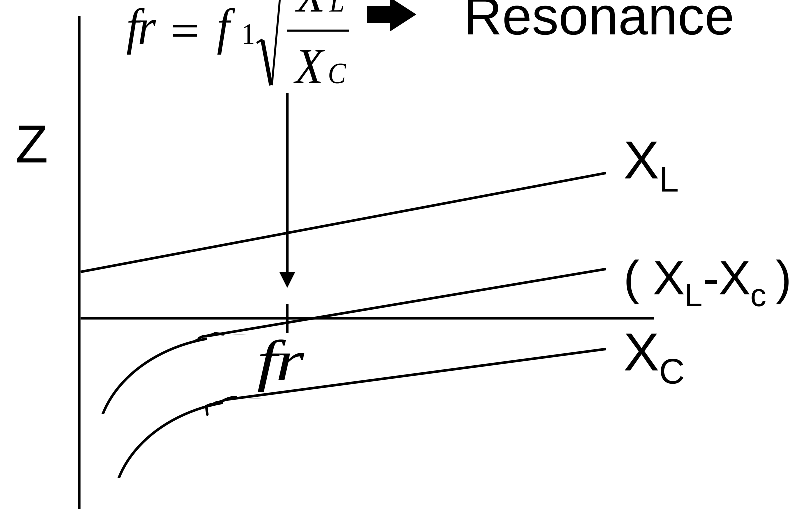
- **Resonance:**



$$X_L = 2\pi fl$$

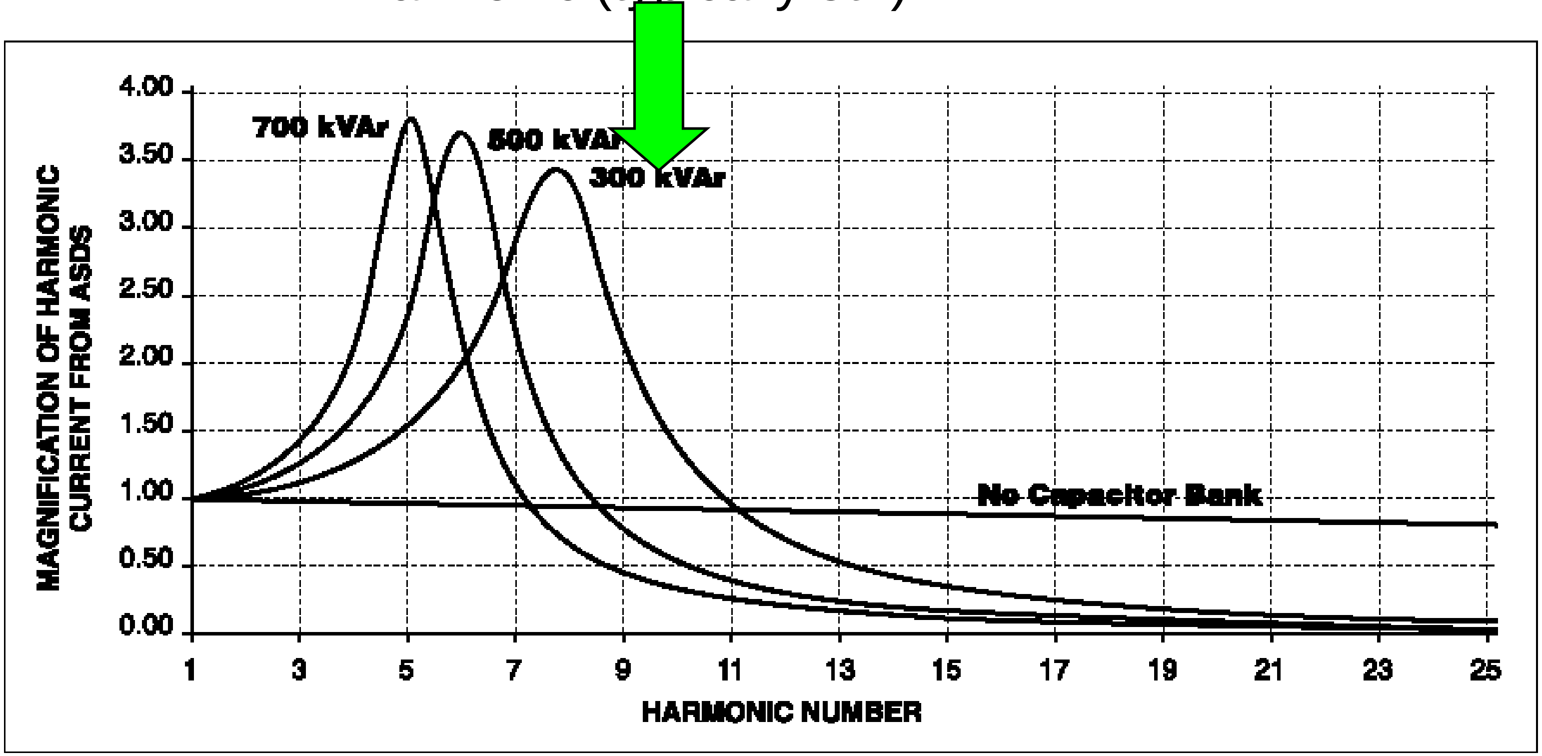
$$X_C = \frac{1}{2\pi fc}$$

$$fr = f_1 \sqrt{\frac{X_L}{X_C}}$$ ➡ Resonance



CAPACITOR RESONANCE

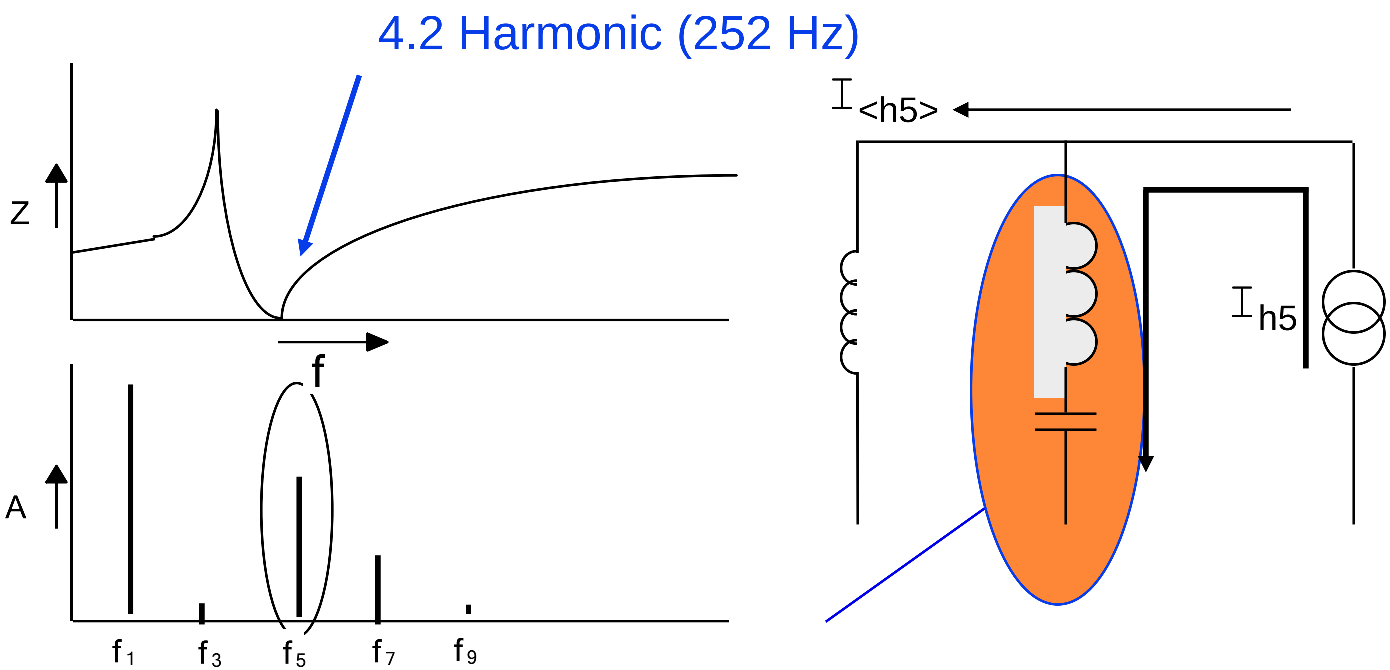
Resonant Point likely to amplify dominant harmonic (typically 5th)



Magnification of Harmonic Current when Standard Capacitor are Added to the Network

POWER FACTOR CORRECTION WITH HARMONICS:

- **De-tuning a network:**
  - "Force" the resonant point away from naturally occurring harmonics



We control the impedance of these two elements

POWER LOSS

POWER SYSTEM

The interconnected facilities of an electrical utility of power system includes generation, transmission, distribution, transformation and productive components necessary to provide service.

POWER LOSS

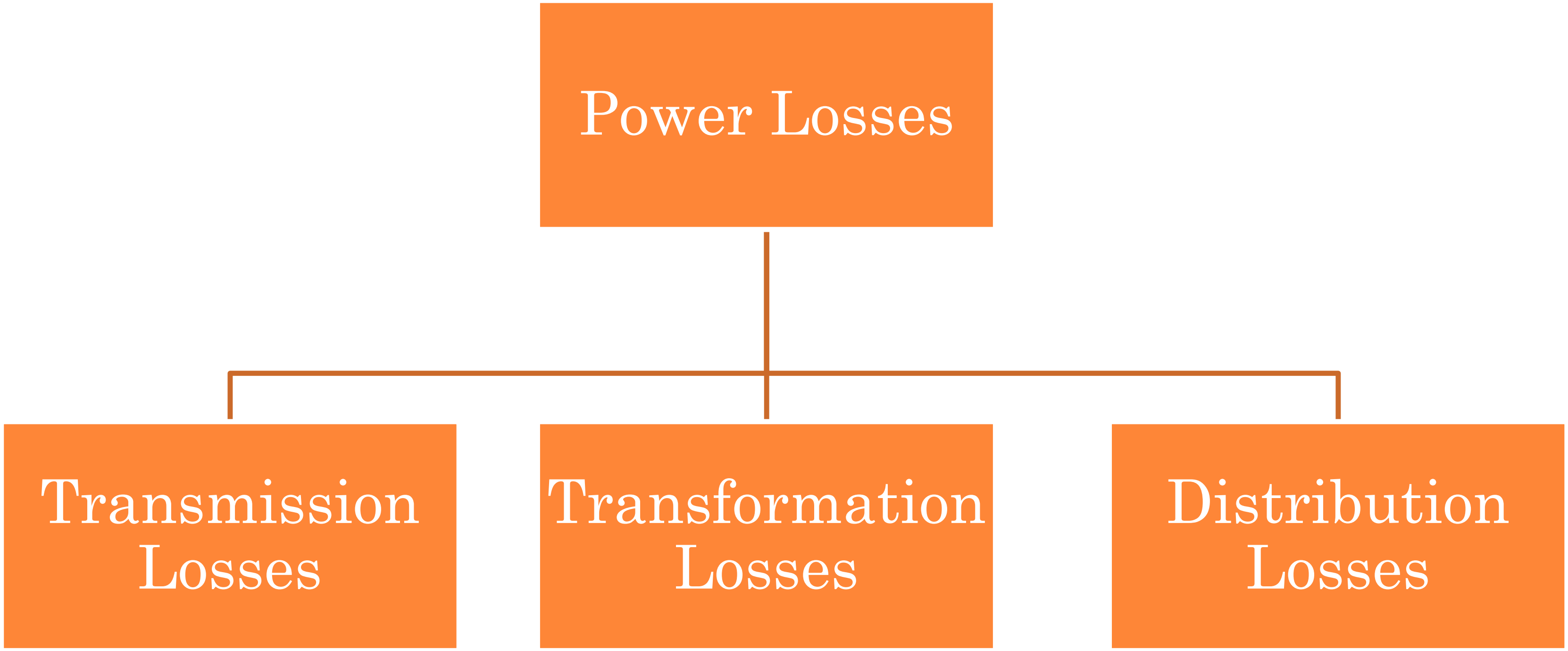
- It is defined as difference between energy generated in power house and billed on the basis of re-consumption by the consumer connected to that particular power system

- Mathematically,

Energy loss =

Energy Generated – Energy Billed

TYPES OF POWER LOSSES



TRANSMISSION LOSSES

- **Electricity is transmitted at High Voltages (132kV or above) to reduce the energy lost in long-distance transmission.**
- **Power is usually transmitted through overhead Transmission lines.**
- **Over head Transmission Lines mostly have technical losses.**

TRANSMISSION LOSSES

- Technical Losses are mostly due to the energy dissipated in the Equipment which is Transmission Lines in this case.
- There are two major sources of loss in high voltage AC transmission lines

- Resistive loss
- corona loss

TRANSMISSION LOSSES

- **Resistive losses**

Although the conductors in a transmission line have extremely low resistivity, they are not perfect. Also AC current tends to flow on the surface of the conductor causing skin effect.

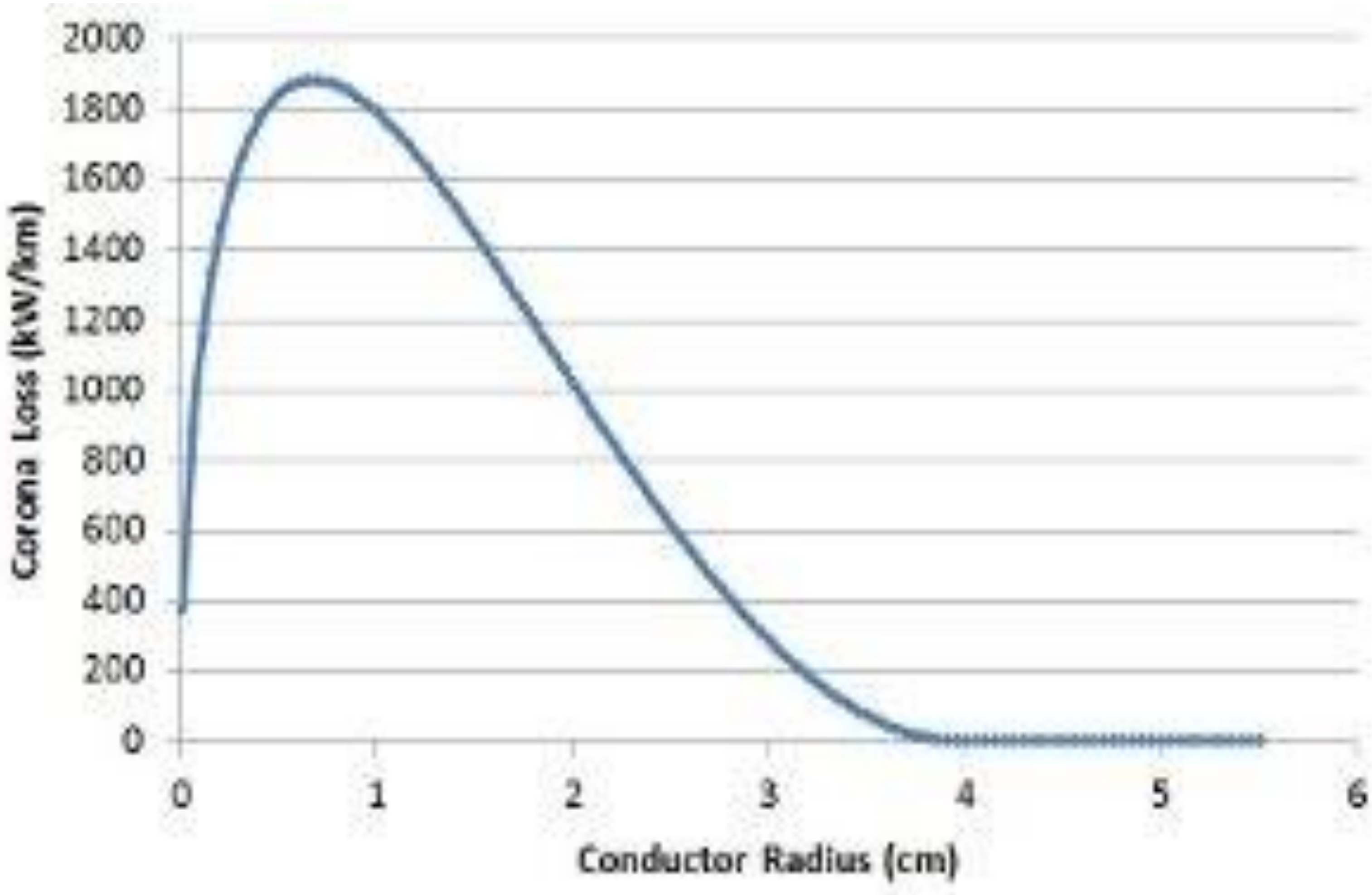
Resistive losses are = I^2R Losses

TRANSMISSION LOSSES

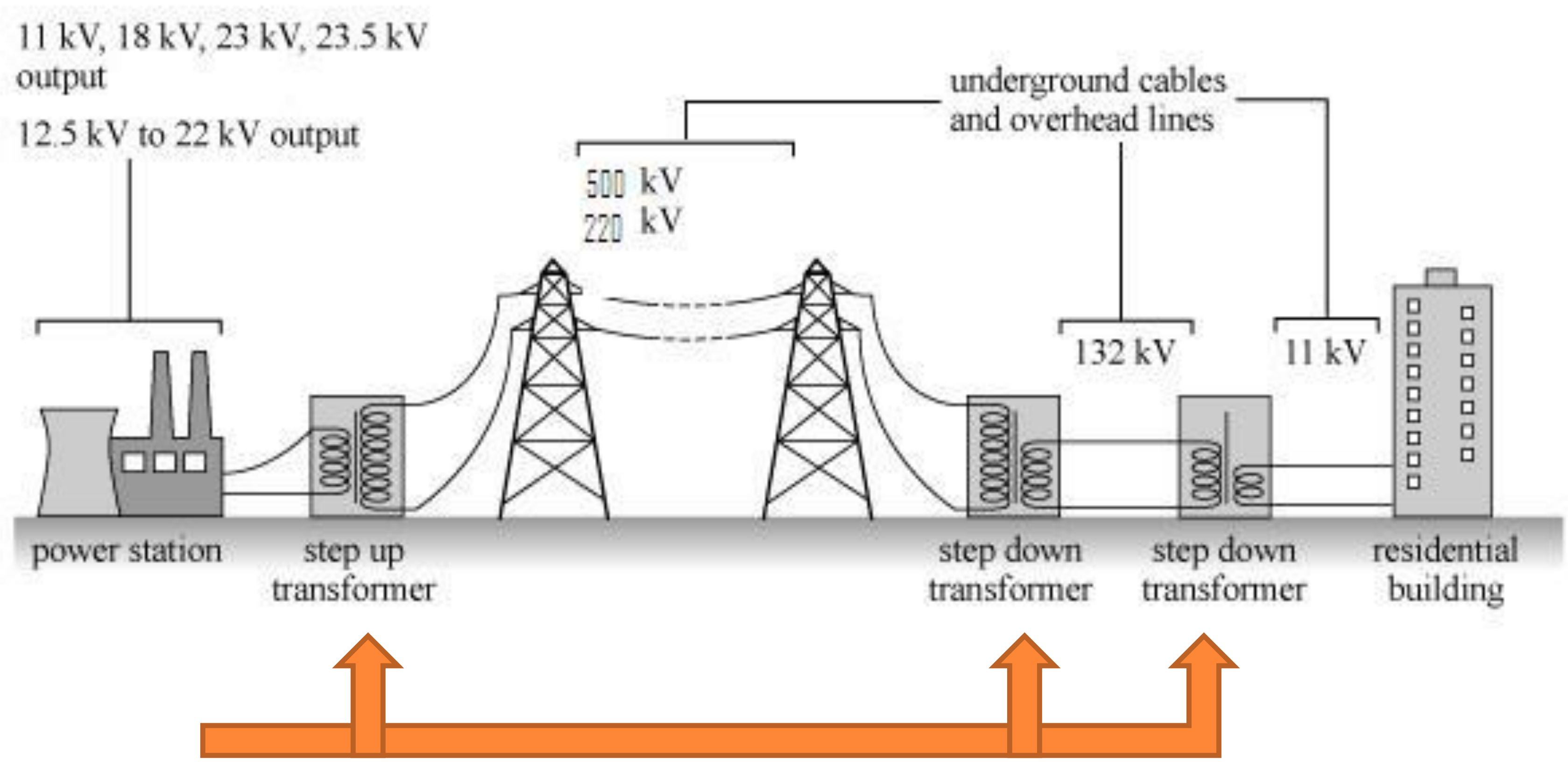
- Corona Losses

Corona Losses are caused by the ionization of air molecules near the transmission line conductors. These coronas do not spark across lines, but rather carry current (hence the loss) in the air along the wire. Corona discharge in transmission lines can lead to hissing/cackling

REDUCING TRANSMISSION LOSSES



TRANSFORMATION LOSSES



CAUSES TRANSFORMATION LOSSES

REDUCING TRANSFORMATION LOSSES

- **Buy low loss transformer**
- **Don’t Go for the initial cost of transformer**
- **Low cost transformer might have higher transformation losses which causes losses for the rest of the operating life.**
- **Don’t operate transformer on overload because losses = I^2R**

Distribution Losses

- **Distribution losses refers to the losses occurring during the process of delivering electrical energy from 11kV feeder to the specific locations like residential homes and industries.**

Types Of Distribution Losses

- Administrative Losses (Theft)
- Technical Losses

Causes of Technical Losses

- Sub standard and under sized conductor
- Low power factor
- Over loading of transformers
- Over loading of conductor and cable
- Lengthy Lines
- Unplanned Substandard System
- Low Frequency
- Substandard Repair of Distribution Transformers.

Remedial Measures

- Re-conductoring
- Bifurcation of feeders
- Adding new grids
- Providing additional transformers
- Balance Loading of transformers
- Adequate preventive maintenance

Administrative Distribution Losses

Administrative losses are caused by lack of administration, financial constraints, theft, defective meter and error in meter reading and in estimating unmetered supply of energy.

Causes of Administrative Losses

- On the part of Organization
- On the part of Customers

On the Part of Organization

- Metering Equipment
  - Sub standard energy meters
  - Defective energy meters
  - Non replacement/ calibration of energy meters
  - Un secured energy meters

Remedial Measures to Control Administrative Losses

- Metering equipment including testing set
- Accurate Meter reading and billing
- Replacing faulty meters.
- Shift to pre-paid card system
- Checking of energy meters

Thank You