Electrical Distribution System

Transformer

- ❖ **Transformer**
  - ❑ **Heart of Electrical Distribution**
- ❖ **Category**
  - ❑ **Power Transformers**
  - ❑ **Distribution Transformers**

Loss in Transformer

- ❖ Efficient Transformer – 1% loss
  - ❑ Substantial at higher ratings
- ❖ Losses contributed by
  - ❑ Core loss – No load loss
  - ❑ Copper Loss – Depends on load

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Transformer Efficiency

- ❖ Transformer efficiency - 98-99%
- ❖ Optimum efficiency occurs at
  - ❑ 50% load
  - ❑ 75% load
  - ❑ 100% load

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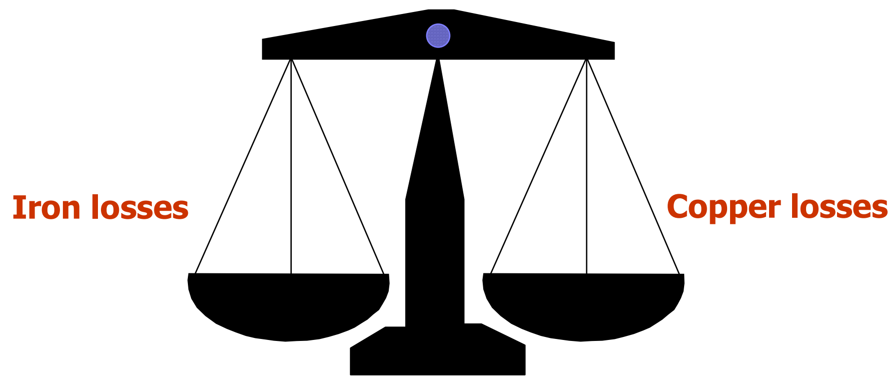
Transformer Efficiency

❖ **Optimum efficiency occurs, where**



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Three Phase Transformer-Typical Loss Chart

KVA Rating	Iron Loss (Watt)	FL copper Loss (W)
500	1030	6860
750	1420	9500
1000	1770	11820
1250	1820	12000
2000	3000	20000

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Types Of Transformers

Distribution Transformer

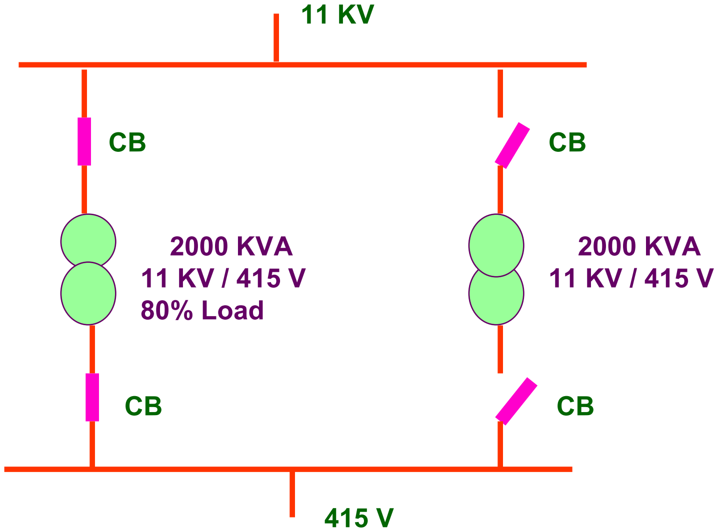
- Normal Efficiency- 98% to 99%
- Iron loss is 10% to 15% of full load copper loss
- Optimum efficiency occurs between 40% to 60% of loading

Types Of Transformers

Power Transformer

- Normal Efficiency- 99% to 99.5%
- Iron losses is 20% to 25% of full load copper losses
- Optimum efficiency occurs between 60% to 80% of loading

Case Study



Case Study

Background

- Capacity of transformer 2000 KVA
- Load on the transformer is 80%
- Iron loss = 3 kW
- F L Copper loss = 20 kW

Operate Both The Transformers In Parallel

Loss calculation

- **One transformer in operation**

  $(3) + 20 \times (0.8)^2 = 15.8$ kW

- **Both transformers are in operation**

  $[(3) + 20 \times (0.4)^2] \times 2 = 12.4$ kW

Annual Savings= Rs 1.1 Lakhs

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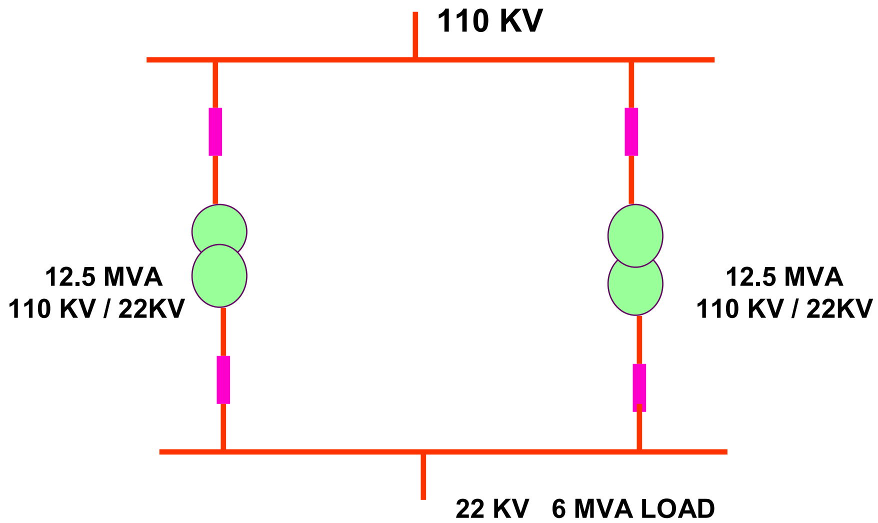
Case Study



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Case Study

Background

- Two Transformers (12.5MVA) are operated parallel
- Actual total effective load is 6 MVA
- % load to the individual transformers is 24%
- Losses
  - Iron loss = 25 kW
  - FL. Copper losses = 72 kW

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Isolate One Transformer In Main Substation

Loss calculation

- Both transformers are in operation

  $[(25) + 72 \times (0.24)^2] \times 2 = 58.2$ kW

- One transformer operation

  $(25) + 72 \times (0.48)^2 = 41.5$ kW

- *Isolated one transformer*

Savings in kW = 16.7 kW

Annual savings = Rs 5.1 Lakhs

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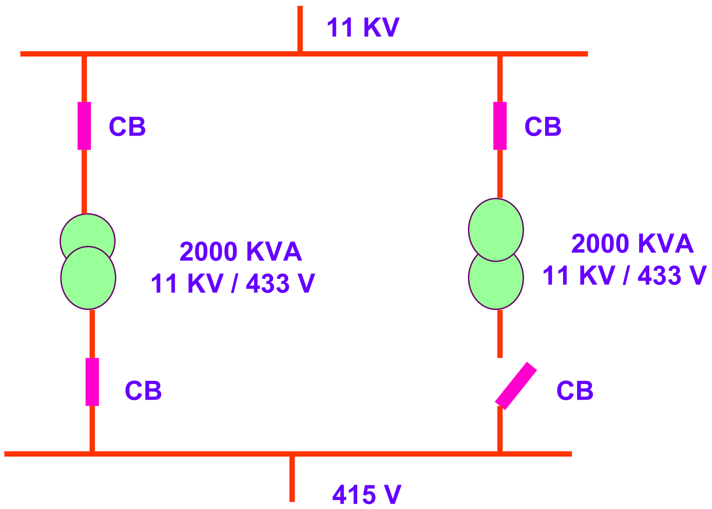
Case Study



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Isolate Primary Of The Idle Transformer

- Idle transformer consumes power for its inherent magnetization losses
- No load loss = 3 kW

Annual Savings = Rs 0.8 Lakhs

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Energy Efficient Amorphous Transformer

- Recommended to install in the project stage
- Made up of amorphous metal core
- 70% reduction in energy loss over iron core transformer

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Comparison of Efficiency

Rating (kVA)	No Load Loss (W)		Efficiency (%)	
	Amorphous	CRGO	Amorphous	CRGO
250	180	570	98.7	98.2
500	250	900	99	98.53
630	200	1000	99.1	98.54
730	365	1250	99.2	98.65
1000	450	1500	99.2	98.68

Cold-Rolled Grain Oriented silicon steel (**CRGO**).

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Selection Of Transformer

- Selection should be based on TOC
- TOC = [Price] + [No load loss x Loss value] + [Load loss x loss value]

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Power Factor

How Poor operating power factor cost money?

- Maximum demand increases for the same load – Increased demand charges
- Draws more current for the same load
- More distribution voltage drop i.e loss in the distribution cable increase
- Copper loss in the transformer increase

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Improve Overall PF and Reduce MD

- Case Study – Cement plant
  - Monthly avg PF maintained at 0.96
  - Sanctioned MD : 7300 kVA
  - Min demand charges : 75% (5475 kVA)
- Recorded monthly MD
  - 6800 kVA
- High demand charges

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Improve Overall PF and Reduce MD

- Action taken
  - Installed additional capacitor banks & APFC to improve PF
- PF improved to 0.995
  - kVA demand reduced by 240 kVA
- Additional benefits
  - Reduced voltage drop in feeders
  - Feeder loss reduction
  - Cushion for capacity expansion

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Improve Overall PF and Reduce MD

Annual Saving	**-**	**Rs 10.3 Lakhs**
Investment	**-**	**Rs 15.0 Lakhs**
Payback period	**-**	**18 Months**

Improving PF of Generator

- **10 MW turbo generator**
  - **Rated PF : 0.8**
  - **Operating PF: 0.9**
- **Generator delivers active power & reactive power**
- **Efficiency of TG depends on operating PF**
  - **Higher the PF, higher is the efficiency**

Improving PF of Generator

- Improving PF from 0.9 to 0.96 resulted in improvement in efficiency
  - Reduced loss due to reduction in current
- Installed additional capacitor banks and reduced excitation of Gen

Annual Savings	:	Rs 14.8 Lakhs
Investment	:	Rs 15.0 Lakhs
Payback	:	13 Months

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PF Compensation methods

- 3 methods
  - Centralised compensation
  - Distributed compensation
  - Mixed compensation

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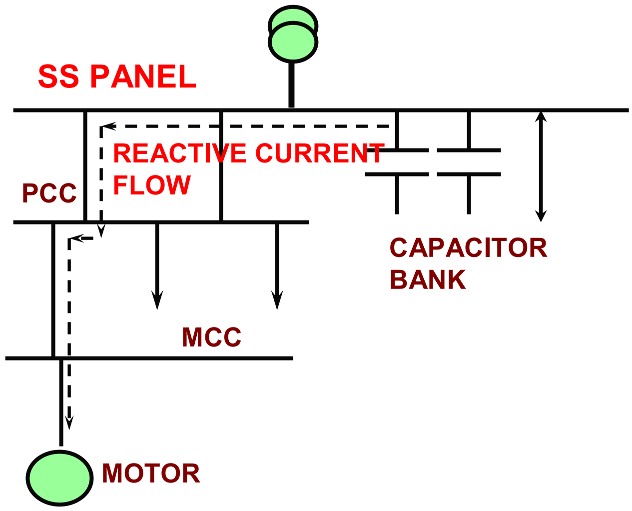
Power Factor Compensation

Centralized compensation



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Power Factor Compensation

❖ **Advantages**
- Easy P.F maintenance
- Capacitor maintenance easy

❖ **Disadvantages**
- More voltage drop in distribution
- Over heating of cable resulting in failure

❖ **Suitable if distance between PCC and MCC is less**

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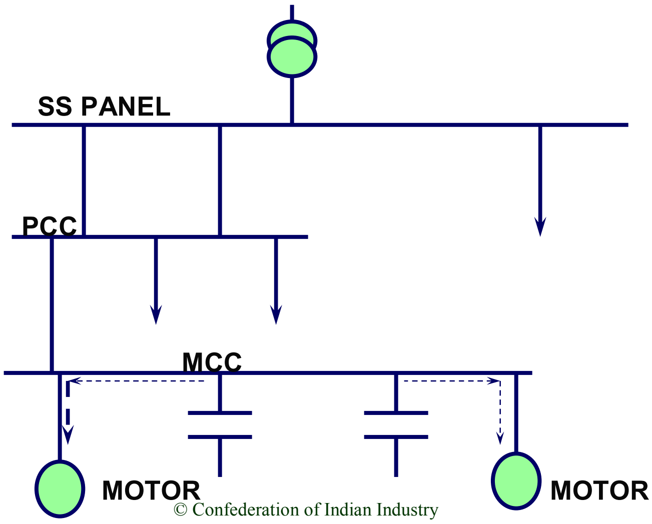
Power Factor Compensation

Distributed Compensation

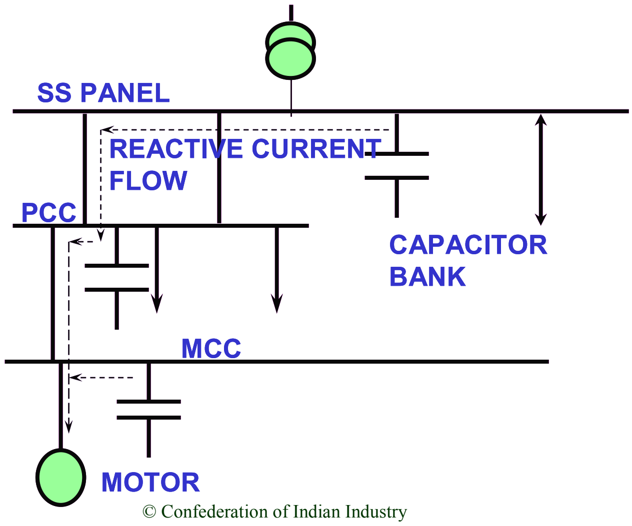


Power Factor Compensation

- **Advantages**
  - Minimum voltage drop
  - Low distribution losses
- **Disadvantages**
  - Maintenance is difficult
- **Applicable where distribution is remote**

Power Factor Compensation

Mixed Compensation



Power Factor Compensation

- **Advantages**
  - **Good P.F control**
  - **Easy maintenance**
  - **Low distribution losses**
- **Common in Continuous Process industry**

Voltage Drop

- Voltage drop is an indication of distribution loss
- Causes of voltage drop
  - Poor power factor
  - Inadequate cable size laid
  - Poor contact surface at
    - Cable Termination
    - Cable joints
    - Contactors/Switches

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Voltage Drop

- In a large complex distribution system, voltage drops are very common
- Acceptable limit in a 3 Ph. System is 4-5 Volts / Phase
- More than 5 V/Phase indicates energy loss in the distribution

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Voltage Drop Measuring Procedure

- Measuring instruments should be calibrated
- Simultaneous measurement of voltage in the feeding and receiving end of the feeder
- Measure P.F & Current
- Note down the cable size

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Case Study-Voltage Drops

- Voltage drop – PCC to MCC

Measurements

- Voltage at PCC = 418 V
- Voltage at MCC = 405 V
- Drop in Voltage = 13 Volts
- Load current = 225 A
- Power factor = 0.6 Lag
- Cable size = 1R x 3C x 300 Sq.mm

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Case Study-Voltage Drops

- Cable loss = 5.1 kW
- Capacitor installed at Load end – 60 kVAr
- Reduction cable loss = 2.5 kW
- Capacitor relocated

Annual savings = 0.76 Lakhs

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Capacitor Selection

- Chart Method
- Formula Method
  - Capacitor required (kVAr)

    $= kW \times \{Tan\ cos^{-1}\Phi_1 - Tan\ cos^{-1}\Phi_2\}$

    Cos Φ1 – Present power factor

  - Cos Φ2 – Desired power factor

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Power factor – Individual compensation

- Motor end compensation
  - Below 15 HP not economical
  - kVAR of capacitor bank – Appx 25% of motor HP
  - Capacitor current Ic at rated voltage < 90% of no-load current of motor
  - Relay setting should be adjusted after connecting capacitor bank (Current drops after PF improvement)

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Power Factor Compensation

- Power factor near to 1 is always recommended
- Avoid leading power factor
- Same current for 0.8 lag or 0.8 lead

Equipment	Rated kW	Amp	kW	PF
Packer-2 D/C fan	30	58.0	32.0	-0.77
Packer-3 D/C fan	30	52.0	31.5	0.85

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Power Capacitors

- Capacitor banks install to improve power factor
- Allowable power loss = 3-5 W/kVAR

Reasons for failure

- Ageing
- Input voltage and frequency fluctuation
- Harmonics present in the system
- Temperature around the bank
- Poor quality capacitors use in the construction

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Replace Faulty Capacitor Banks

- Power measurement taken with digital power meter

Indication:

- Power consumption above the permissible level
- Temperature on the body is above ambient temperature

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