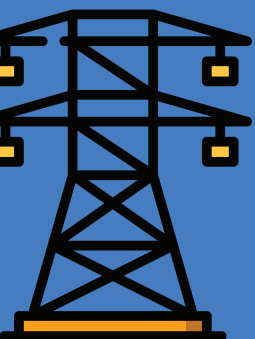


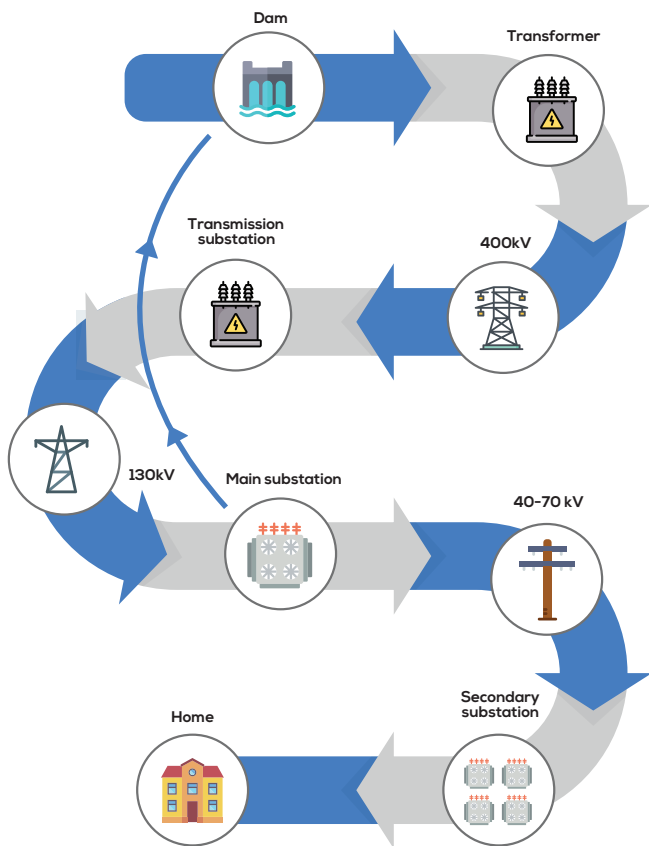
# GEF - UNIDO - BEE PROJECT

on

“Promoting EE/RE in selected MSME Clusters in India”

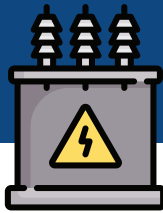


## ELECTRICAL SYSTEMS

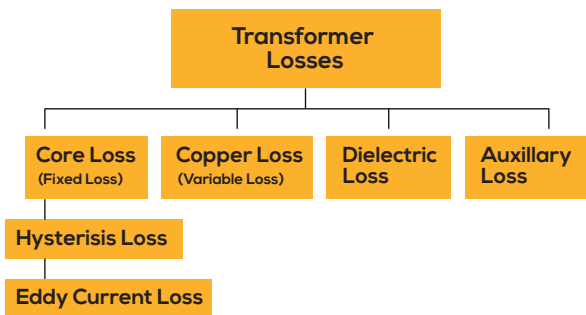


Confederation of Indian Industry

# Transformers



- Transformers are classified as power transformers and distribution transformers. Power transformers are used in transmission network of higher voltages, used for step-up and step down application (400 kV, 220 kV, 110 kV, 66 kV, 33kV)
- Distribution transformers are used for lower voltage distribution networks, which distributes the supply to the end users (11kV, 6.6 kV, 3.3 kV, 440V)



- The maximum efficiency of the transformer occurs at a condition when constant loss is equal to variable loss. For distribution transformers, the core loss is 15 to 20% of full load copper loss. Hence, the maximum efficiency of the distribution transformers occurs at a loading between 40 – 60%.

## Transformer Loss Estimation

$$\text{Find the percentage loading of the transformer} = \frac{\sqrt{3} \times \text{Voltage in kV} \times \text{current} \times 100}{\text{Rated kVA of transformer}}$$

Find out the no-load and full load copper loss of the transformer from the test certificate

$$\text{Transformer loss} = \frac{\text{No-load loss}}{[(\% \text{loading}/100)^2 \times \text{Full load copper loss}]}$$

The core loss and the full load copper loss for transformers are specified in the transformer test certificate.

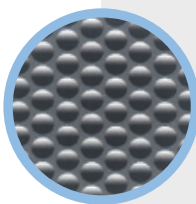
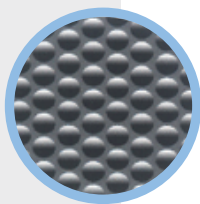
TYPICAL LOSS CHART		
KVA Rating	Iron Loss (Watt)	FL copper Loss (W)
500	1030	6860
750	1420	9500
1000	1770	11820
1250	1820	12000
2000	3000	20000

## Energy Efficient transformer

- Core of the transformer is made of amorphous material
- Electrical resistivity of amorphous material is 2-3 times higher than silicon steel
- 70-80 % less core losses than normal transformers under linear loads
  - More savings under non linear loads

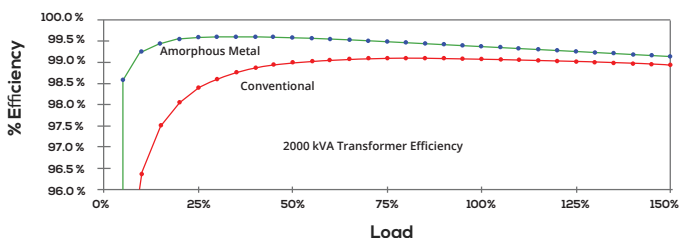
Crystalline structures have hard directions for magnetization

Requires grain orientation processing for best properties



In Amorphous random Arrangement of atoms offers High electrical resistance for eddy current.

Easy to magnetize and Demagnetize



OLD Transformer



Efficiency  
**94%**



NEW Transformer



Efficiency  
**99%**

Annual Saving - Rs 4.50 Lakhs  
 Investment - Rs 12 Lakhs  
 Payback - 32 motnhs



# Maintenance of Transformer



## Maintenance Schedule (Hourly)

- Ambient Temperature
- Winding Temperature
- Oil Temperature
- Loading in kVA, Amperes
- Voltage Level ( HV /LV)



## Maintenance Schedule (Daily)

- Oil Level in Transformer
  - Bushings
  - OLTC
  - Conservator
- Condition of Breather
- Cooling fan status

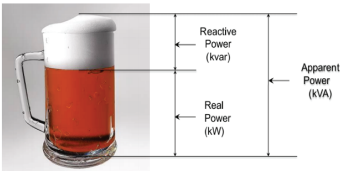


## Maintenance Schedule (Yearly)

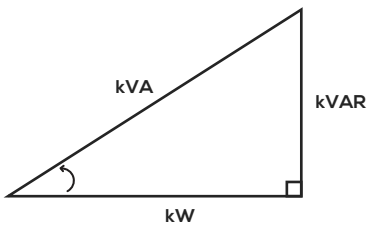
- Oil Dielectric Strength (>40 kV)
  - BDV
  - Water Content
  - DGA Test (Dissolved Gas Analysis)
- OLTC Operation checking
- Condition of Bushings
- Dehydration of Oil

# Power Factor

$$\text{Power factor} = \frac{\text{kW}}{\text{kVA}} = \frac{\text{kW}}{\text{kW} + \text{kVAR}} = \frac{\text{Beer}}{\text{Beer} + \text{Foam}}$$



Power factor is the ratio of working power to apparent power. It measures how effectively electrical power is being used. A high power factor signals efficient utilization of electrical power, while a low power factor indicates poor utilization of electrical power. It is therefore necessary to reduce and manage the flow of reactive power to achieve higher efficiency of the electrical system. The easiest method of reducing and managing reactive power is by power factor improvement through power capacitors.



$$\cos \theta = \frac{\text{kW}}{\text{kVA}} = \text{PF}$$

cos $\theta$	=	Power Factor
kW	=	Active Power
kVAR	=	Reactive Power
kVA	=	Apparent Power
	=	$\sqrt{\text{kW}^2 + \text{kVAR}^2}$

## Benefits

- Reduction in demand charges
- Elimination of power factor penalties
- Reduction in current drawn
- Reduced transformer, switchgear and cable losses
- Improved voltage regulation
- Increased life of switchgear/cables due to reduced operating temperatures

## Estimation of capacitor rating



### Estimation of Capacitor Rating

The estimation of KVAR required for compensation to achieve desired power factor is generally done depending on the type of loads to be compensated.

$$\text{kVAR required} = \text{kW}(\tan \theta_1 - \tan \theta_2)$$

$$\theta_1 = \cos^{-1}(\text{PF}_1)$$

$$\theta_2 = \cos^{-1}(\text{PF}_2)$$

**PF1 and PF2** are initial and final power factors respectively.

**kW** – Maximum operating load of plant

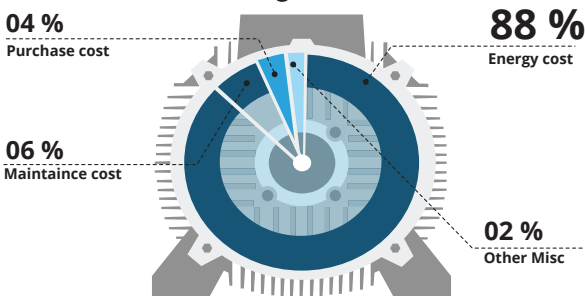
# Capacitor KVAR for AC Induction Motors (Individual Compensation)

Motor Rating (HP)	Capacitor rating (kVar) for motor speed					
	3000	1500	1000	750	600	500
5	2	2	2	3	3	3
7.5	2	2	3	3	4	4
10	3	3	4	5	5	6
15	3	4	5	7	7	7
20	5	6	7	8	9	10
25	6	7	8	9	9	12
30	7	8	9	10	10	15
40	9	10	12	15	16	20
50	10	12	15	18	20	22
60	12	14	15	20	22	25
75	15	16	20	22	25	30
100	20	22	25	26	32	35
125	25	26	30	32	35	40
150	30	32	35	40	45	50
200	40	45	45	50	55	60
250	45	50	50	60	65	70

## Note

- Uneconomical to improve power factor by individual compensation for motor ratings below 15 hp
- For motor ratings above 250 hp the capacitor kVAR rating would be about 25% of the motor rating in hp.
- In all cases it should be ensured that the capacitor current at rated voltage is always less than 90% of the no load current of the motor.

## Lifetime cost of running a motor

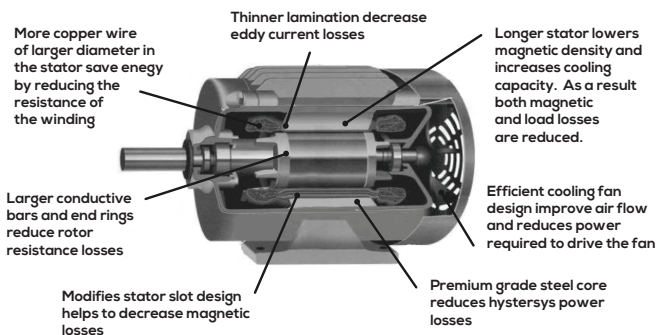


Energy cost of running the motor is 22 times its purchase price. So savings in energy cost are 22 times more effective than savings in the purchase price of the motor.

# Energy Efficient Motors

Energy Efficient Motors are designed with low operating losses. The efficiency of Energy Efficient motors is high when compared to conventional AC induction motors, as they are manufactured with high quality and low loss materials. The efficiency of Energy Efficient motors available in the market range from 75% to 96%, depending on the size.

## EE Motor Features



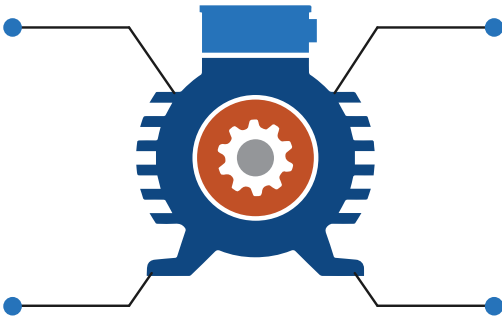
## MOTOR EFFICIENCY CLASS

Rated output power (kW)	Number of poles					
	IE2 efficiency level <sup>1</sup>			IE3 efficiency level <sup>2</sup>		
	2 poles	4 poles	6 poles	2 poles	4 poles	6 poles
0.75	77.4	79.6	75.9	80.7	82.5	78.9
1.1	79.6	81.4	78.1	82.7	84.1	81.0
1.5	81.3	82.8	79.8	84.2	85.3	82.5
2.2	83.2	84.3	81.8	85.9	86.7	84.3
3.0	84.6	85.5	83.3	87.1	87.7	85.6
4.0	85.8	86.6	84.6	88.1	88.6	86.8
5.5	87.0	87.7	86.0	89.2	89.6	88.0
7.5	88.1	88.7	87.2	90.1	90.4	89.1
11.0	89.4	89.8	88.7	91.2	91.4	90.3
15.0	90.3	90.6	89.7	91.9	92.1	91.2
18.5	90.9	91.2	90.4	92.4	92.6	91.7
22.0	91.3	91.6	90.9	92.7	93.0	92.2
30.0	92.0	92.3	91.7	93.3	93.6	92.9
37.0	92.5	92.7	92.2	93.7	93.9	93.3
45.0	92.9	93.1	92.7	94.0	94.2	93.7
55.0	93.2	93.5	93.1	94.3	94.6	94.1
75.0	93.8	94.0	93.7	94.7	95.0	94.6
90.0	94.1	94.2	94.0	95.0	95.2	94.9
110.0	94.3	94.5	94.3	95.2	95.4	95.1
132.0	94.6	94.7	94.6	95.4	95.6	95.4
160.0	94.8	94.9	94.8	95.6	95.8	95.6
200 - 375	95.0	95.1	95.0	95.8	96.0	95.8

# Motor Rewinding

The reduction in efficiency depends on the type of burnt-out in the motor and the quality of re-winder. Generally the drop in efficiency varies from 0.5% to 1% for every rewind.

The efficiency of the motor is reduced whenever the motor is rewind.

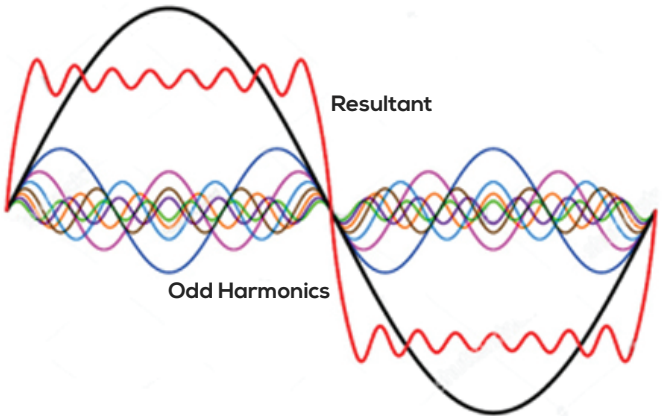


When the old motors are rewind for more than 5 times, it can be replaced with new energy efficient motor.

The overall efficiency improvement considering reduced efficiency of old rewind motor and improvement in energy efficient motor can be up to 10-12%.

# Harmonics

Fundamental



Harmonics are a distortion of the normal electrical current waveform, generally transmitted by nonlinear loads. The non-linear load is one which draws non-sinusoidal or pulsating current when subjected to sinusoidal voltage. Some of the non linear loads.

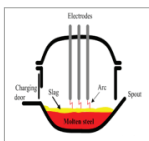
## Non Linear Loads



Variable Speed AC & DC Drives



Welding Sets



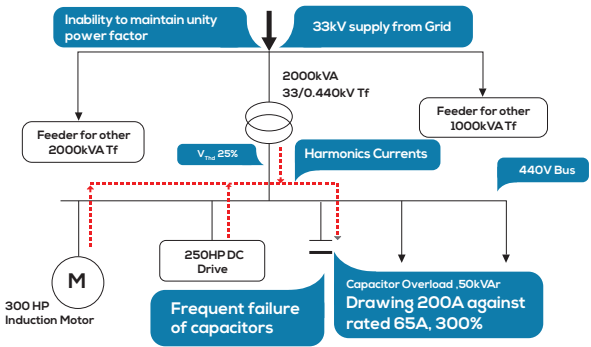
Arc Furnace



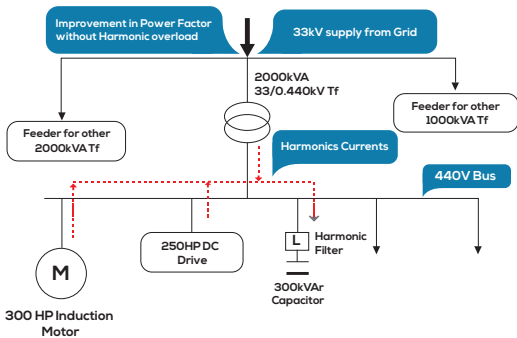
LED Lights



# System with Harmonics



# System without Harmonics



## Effect of Harmonics:

Harmonics have varied effects on equipments and devices, causing malfunctioning or even total failure depending on the extent of harmonic pollution. The effects of harmonics can be broadly classified as instantaneous effects and long term effects.

## Voltage Harmonics

- > Malfunctioning/ageing of sensitive electronic equipment.
- > Increase in core losses in motors
- > Increased EMI generation in the power system
- > Increased torque ripple in drive motors directly operated from the utility supply

## Current Harmonics

- > Additional Losses in wires & cables  
Extra heating/noise of Transformers
- > Nuisance tripping of circuit breaker & Protective Relays
- > Failure of Capacitors
- > Failure of the neutral conductor in the supply transformer due to unbalanced single phase non-linear loads

# EE OPPORTUNITIES IN ELECTRICAL SYSTEM

- Change of electrical connection from delta to star for lightly loaded motors
- This can be applied when the load is permanently less than 40% Install automatic power factor controller and maintain high PF
- Distribute load on transformer network in an optimum manner
- Distribute the load on transformer such that loading is 40% to 60% to operate the transformer at maximum efficiency
- For distribution transformer maximum efficiency occurs at 40% to 60% of load
- Optimise the operating voltage by tap setting or installing servo stabilizer
- Use VFD for low/partial loads
- Power consumption is proportional to cube of speed.
- This can be applied for varying centrifugal loads
- Install maximum demand controller to optimize maximum demand
- Replace rewind motor with energy efficient motors
- As a thumb rule motor rewind for more than 5 times can be replaced with energy efficient motors
- Replace V-belts with synthetic flat belts /Cog 'V' belts
- Wedge in and Wedge out losses can be avoided
- Replacement of belt pulley system with Direct driven BLDC motor for AHUs
- Direct drive configurations have a reported efficiency margin of around 80 percent, compared to the belt drive system of around 60 percent.
- Installation of BLDC fans
- BLDC fans consumes only 1/3 electricity compared to ordinary fans in the market.
- Installation of light pipes
- Light collector-collects the sunlight and reflective system delivers high illuminance

# About Project

## Promoting Energy Efficiency & Renewable Energy in Selected MSME Clusters in India

To develop and promote a market environment for introducing energy efficiency and enhanced use of renewable energy technologies in process applications in the selected energy-intensive MSME clusters under GEF UNIDO BEE. The main objective of the project is to increase the capacity building of suppliers of EE/RE product and service providers

### Disclaimer

CII has made every effort to ensure the accuracy of information presented in this manual. However, neither CII nor any of its employees can be held responsible for any financial consequences arising out of the use of information provided herein. However in case of any discrepancy, error etc , same may please be brought to the notice of CII for appropriate corrections.

### Contact Details



**Mr. Niranjan Rao Deevela**  
UNIDO

✉ [n.deevela@unido.org](mailto:n.deevela@unido.org)

☎ +91 9560003730



**Mr. P. V. Kiran Ananth**  
CII

✉ [kiran.ananth@cii.in](mailto:kiran.ananth@cii.in)

☎ +91 40 44185152