

**ELECTRICAL POWER SYSTEMS - CEM
REFRESHER TRAINING**

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FOR ENERGY MANAGEMENT AND EFFICIENCY PROFESSIONALS



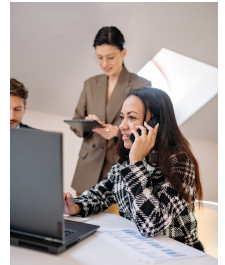


**TRANSFORMERS
FOR ENERGY PROFESSIONALS**

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ENERGY SPECIALIST CURRICULUM



WHAT SHOULD YOU LEARN



Introduction to Transformers

Types of Transformers

Transformer Losses and Efficiency

Voltage Fluctuation Control

System Distribution Losses



TRANSFORMERS

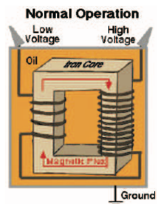
A transformer can accept energy at one voltage and deliver it at another voltage. This permits electrical energy to be generated at relatively low voltages and transmitted at high voltages and low currents, thus reducing line losses and voltage drop (see Figure 1.1).



Transformers consist of two or more coils that are electrically insulated, but magnetically linked. The primary coil is connected to the power source and the secondary coil connects to the load.

TRANSFORMERS

The turn's ratio is the ratio between the number of turns on the secondary to the turns on the primary (See Figure 1.2).



The secondary voltage is equal to the primary voltage times the turn's ratio. Ampere turns are calculated by multiplying the current in the coil times the number of turns. Primary ampere turns are equal to secondary ampere turns. Voltage regulation of a transformer is the percent increase in voltage from full load to no load.

Figure 1.11
Transformer Coil

TYPES OF TRANSFORMERS

Transformers are classified as two categories: power transformers and distribution transformers.

Power transformers are used in transmission network of higher voltages, deployed for step-up and step down transformer application (400 kV, 200 kV, 110 kV, 66 kV, 33kV)

Distribution transformers are used for lower voltage distribution networks as a means to end user connectivity. (11kV, 6.6 kV, 3.3 kV, 440V, 230V)

RATING OF TRANSFORMER

Rating of the transformer is calculated based on the connected load and applying the diversity factor on the connected load, applicable to the particular industry and arrive at the kVA rating of the Transformer. Diversity factor is defined as the ratio of overall maximum demand of the plant to the sum of individual maximum demand of various equipment.

Diversity factor varies from industry to industry and depends on various factors such as individual loads, load factor and future expansion needs of the plant. Diversity factor will always be less than one.



LOCATION OF TRANSFORMER

Location of the transformer is very important as far as distribution loss is concerned. Transformer receives HT voltage from the grid and steps it down to the required voltage. Transformers should be placed close to the load centre, considering other features like optimisation needs for centralised control, operational flexibility etc. This will bring down the distribution loss in cables.



TRANSFORMER LOSSES AND EFFICIENCY

The efficiency varies anywhere between 96 to 99 percent. The efficiency of the transformers not only depends on the design, but also, on the effective operating load. Transformer losses consist of two parts: No-load loss and Load loss

❑ No-load loss (also called core loss) is the power consumed to sustain the magnetic field in the transformer's steel core. Core loss occurs whenever the transformer is energized; core loss does not vary with load. Core losses are caused by two factors: hysteresis and eddy current losses. Hysteresis loss is that energy lost by reversing the magnetic field in the core as the magnetizing AC rises and falls and reverses direction. Eddy current loss is a result of induced currents circulating in the core.



TRANSFORMER LOSSES AND EFFICIENCY +

❑ Load loss (also called copper loss) is associated with full-load current flow in the transformer windings. Copper loss is power lost in the primary and secondary windings of a transformer due to the ohmic resistance of the windings. Copper loss varies with the square of the load current. ($P = I^2R$).

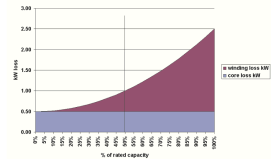


Figure 1.12 Transformer loss vs % Load

❑ Transformer losses as a percentage of load is given in the Figure 1.3.

❑ For a given transformer, the manufacturer can supply values for no-load loss, $P_{NO-LOAD}$, and load loss, P_{LOAD} . The total transformer loss, P_{TOTAL} , at any load level can then be calculated from:

TRANSFORMER LOSSES AND EFFICIENCY +

$$P_{TOTAL} = P_{NO-LOAD} + (\% \text{ Load}/100)^2 \times P_{LOAD}$$

Where transformer loading is known, the actual transformers loss at given load can be computed as:

$$= \text{No load loss} + \left(\frac{\text{kVA Load}}{\text{Rated kVA}} \right)^2 \times (\text{full load loss})$$

VOLTAGE FLUCTUATION CONTROL

❑ A control of voltage in a transformer is important due to frequent changes in supply voltage level. Whenever the supply voltage is less than the optimal value, there is a chance of nuisance tripping of voltage sensitive devices. The voltage regulation in transformers is done by altering the voltage transformation ratio with the help of tapping.

❑ There are two methods of tap changing facility available: Off circuit tap changer and On-load tap changer.

❑ Off-circuit tap changer It is a device fitted in the transformer, which is used to vary the voltage transformation ratio. Here the voltage levels can be varied only after isolating the primary voltage of the transformer.

PARALLEL OPERATION OF TRANSFORMERS

✓ The design of Power Control Centre (PCC) and Motor Control Centre (MCC) of any new plant should have the provision of operating two or more transformers in parallel. Additional switch gears and bus couplers should be provided at design stage.

✓ Whenever two transformers are operating in parallel, both should be technically identical in all aspects and more importantly should have the same impedance level. This will minimise the circulating current between transformers.

✓ Where the load is fluctuating in nature, it is preferable to have more than one transformer running in parallel, so that the load can be optimised by sharing the load between transformers. The transformers can be operated close to the maximum efficiency range by this operation. 1. Electrical System



SYSTEM DISTRIBUTION LOSSES

✓ In an electrical system often the constant no load losses and the variable load losses are to be assessed alongside, over long reference duration, towards energy loss estimation.

✓ Identifying and calculating the sum of the individual contributing loss components is a challenging one, requiring extensive experience and knowledge of all the factors impacting the operating efficiencies of each of these components.



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