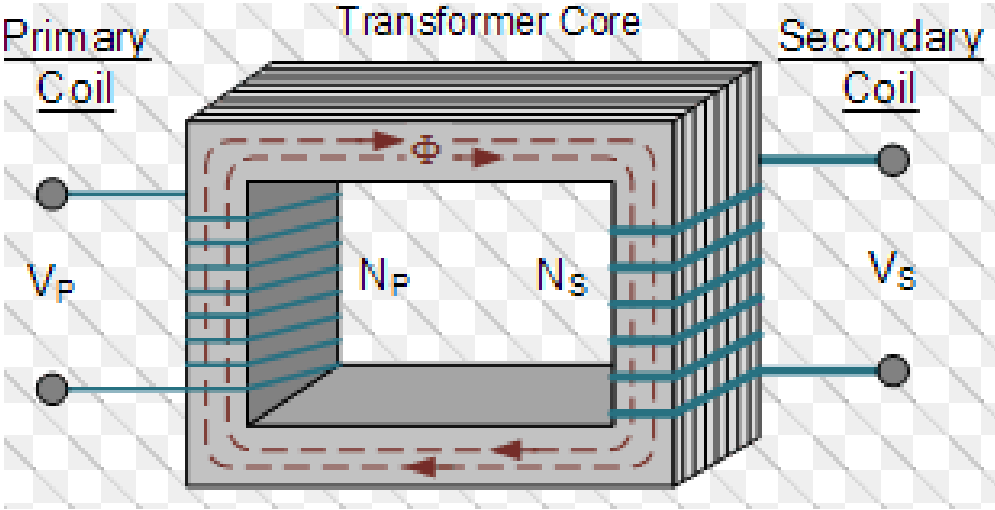
Transformers - Construction

Transformer Construction

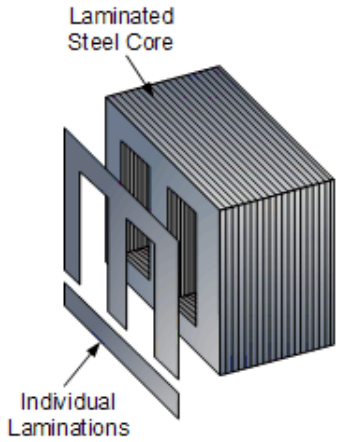
Main elements of a transformer

1. **Two Windings – Primary and Secondary**

2. **Laminated Core**



Transformer Construction - Core



- Constructed from laminations of Silicon steel assembled together to provide continuous magnetic path

  Silicon Steel – minimize hysteresis loss.

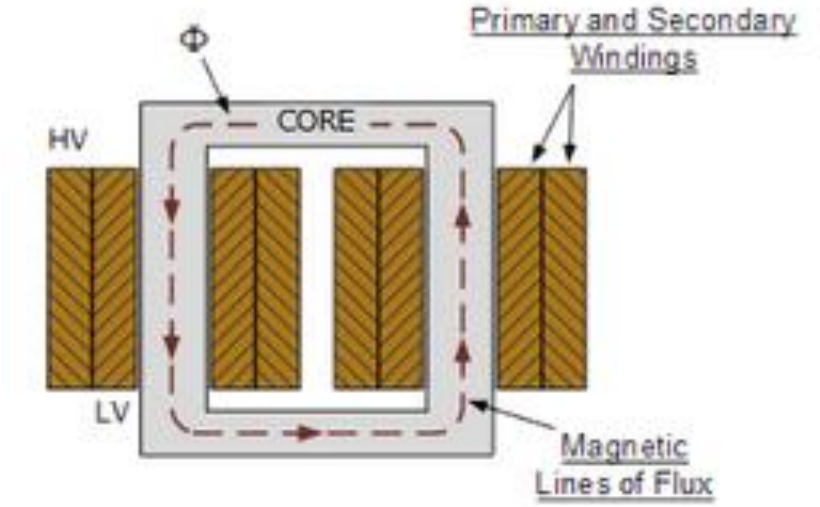
  Laminations – minimize eddy current loss
- Laminations are insulated from each other by a light coat of varnish or by an oxide layer on the surface.
- Thickness of laminations varies for 0.35 mm to 0.5 mm for a frequency of 50 Hz.

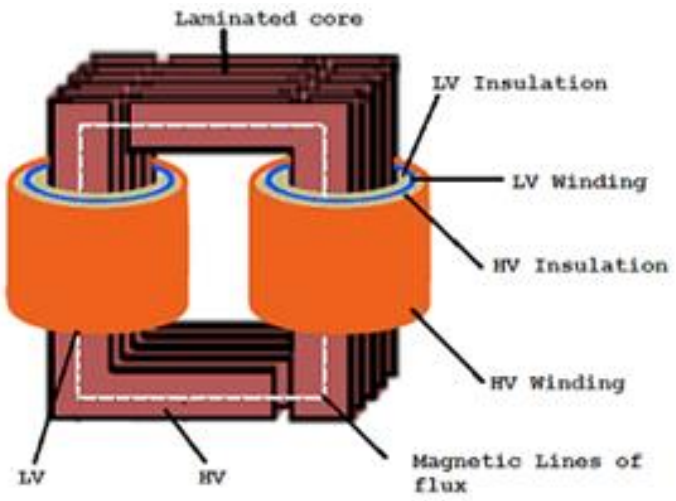
Classification

- Classification according to **core construction** and **the manner in which primary and secondary are placed around it**.

    1. Core type transformer
    2. Shell type transformer

Core Type Transformer - Construction

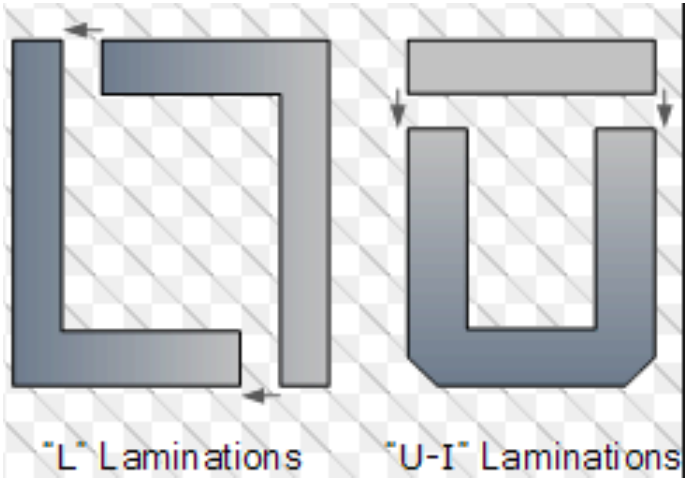




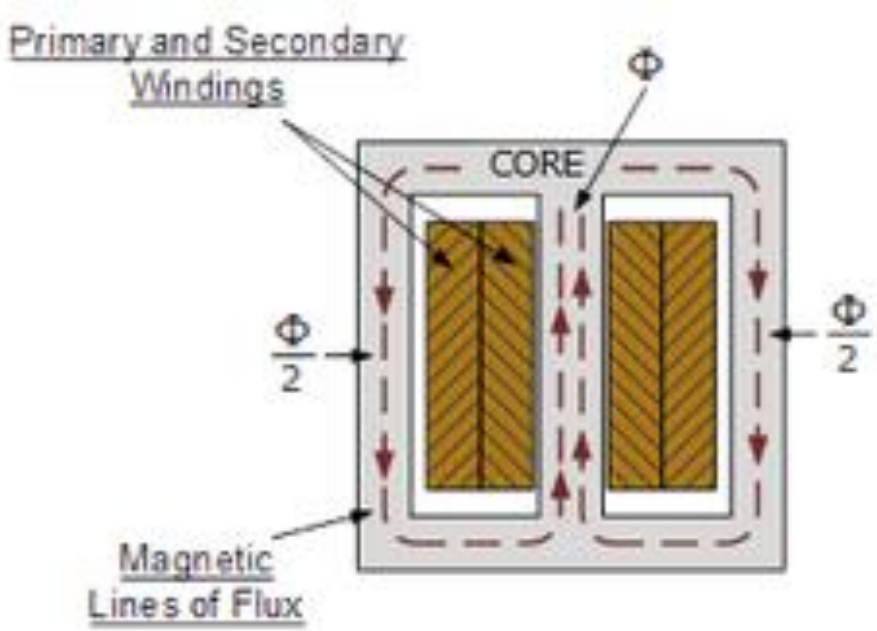
- Half of primary winding and secondary winding are placed around each limb.
- This ensures **tight coupling** between two windings. Consequently **leakage flux is considerably reduced**.
- Insulation is present between core and inner winding and between windings. To reduce insulation, low voltage winding is usually placed nearer the core.

Core Type Transformer - Construction

- Laminations are cut in the form of **L shaped strips**.
- Alternate layers are stacked differently and continuous joints are eliminated to **minimize reluctance** of magnetic path.



Shell Type Transformer - Construction



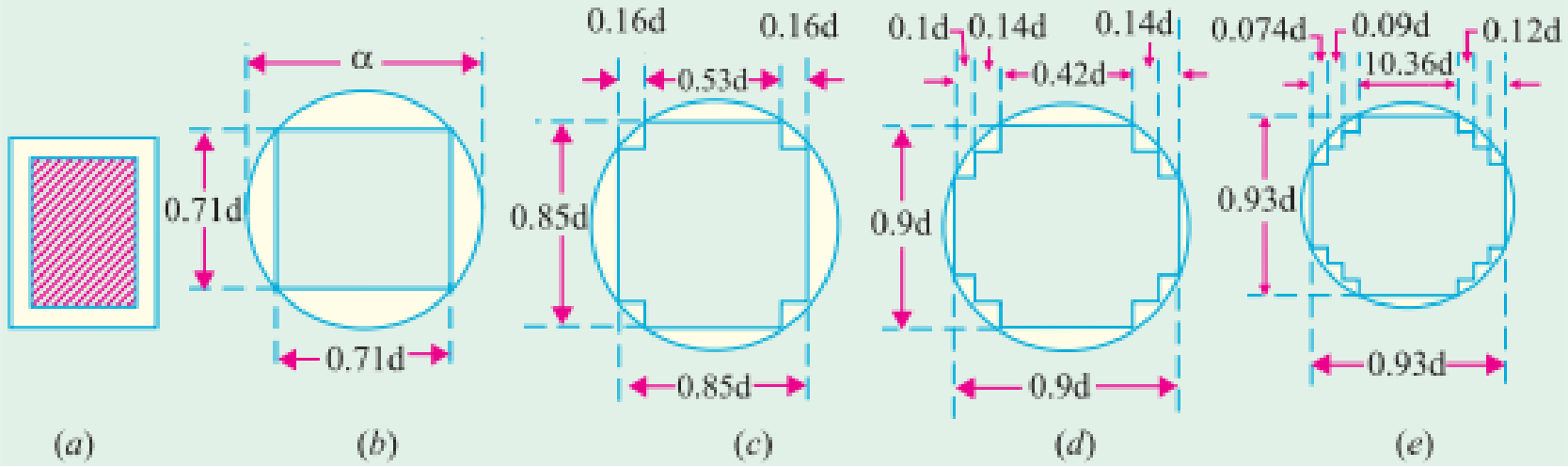
- Both primary winding and secondary winding are placed around central limb.
- Central limb carries whole flux, whereas the side limbs carry half the flux. Therefore size of central limb is double that of outer limbs.

Shell Type Transformer - Construction

- Laminations are cut in the form of **E and I shaped strips**.
- Alternate layers are stacked differently and continuous joints are eliminated to **minimize reluctance** of magnetic path.

Stepped Core Construction

- Coils will be in the form of circular cylinders.
- A considerable amount of useful space is wasted in square core construction, which can be avoided by stepped core construction.



Cooling of Transformers

- Heat is produced in transformer by

  - iron losses in core

  - copper losses in windings

- To prevent temperature rise, this heat is removed by cooling.

Transformer Size	Type of Cooling	Description
Small	Natural Air Cooling	Heat produced is carried away by surrounding air.
Medium	Oil Cooling	Placed in tanks filled with oil Heat produced is carried away by oil to surface of the tank. Oil provides better insulation to windings.
Large	Oil Cooling	Oil moves through radiators where heat is released to surrounding air

Why transformer rated in KVA ?

- **Rating in kW = kVA rating x load pf**

  Load pf depends on load. KW rating is different for different loads. So transformer rating is given in kVA.

- Temperature rise resulting from losses is a determining factor in the rating of machine.

  Pc – depends on current

  Pi – depends on Bm which depends on voltage

  Total losses depend on volt ampere product only not on phase angle between V & I. So transformer is rated in kVA.

Power Transformer and Distribution Transformer

Power Transformer

- Used in generating stations.
- Usually arranged in parallel, so that they can be put into operation during load hours and disconnected during light load hours.
- They are designed to have maximum efficiency at full load

Distribution Transformer

- Used for stepping down voltage and kept near consumer premises.
- They are continuously in the circuit whether they are carrying any load or not.
- They are designed to have maximum all day efficiency

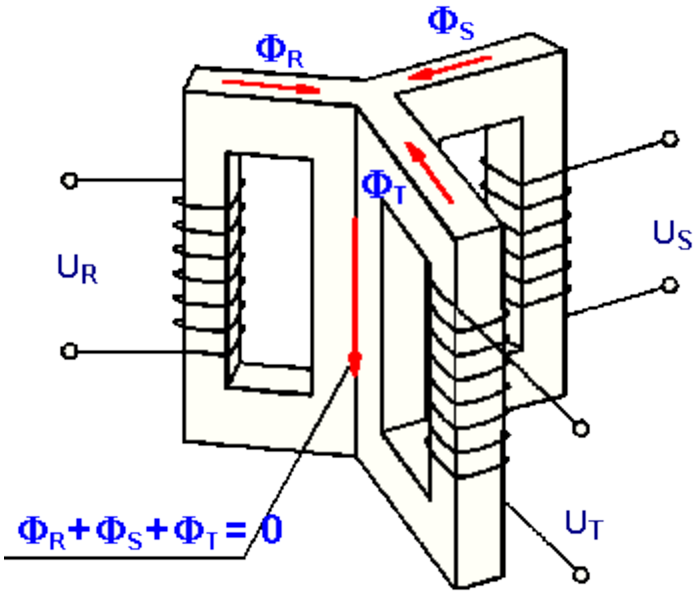
$$\text{all day efficiency} = \frac{\text{kWh output in 24 hours}}{\text{kWh input in 24 hours}}$$

Three Phase Transformers

- Generation of electric power is **three phase** in nature. Transmission is carried out at high voltages. Before transmission, it is required to step up voltage. At distribution substation voltage must be stepped down.

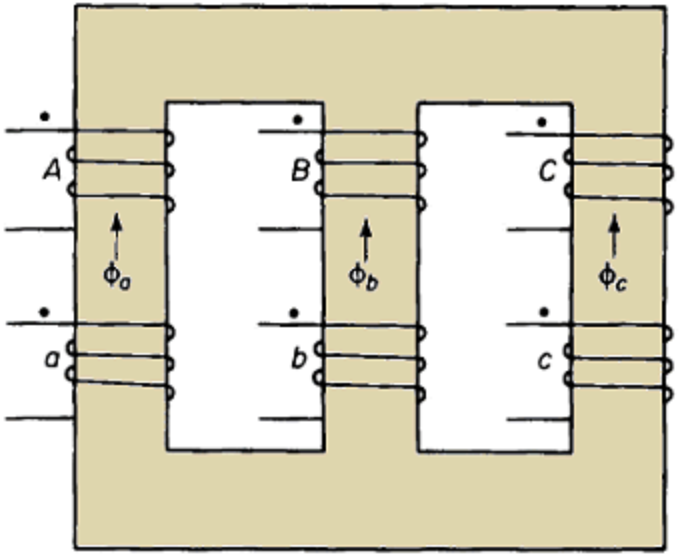
- Hence three phase transformers are required to step up and step down voltages in various stages of a power system.

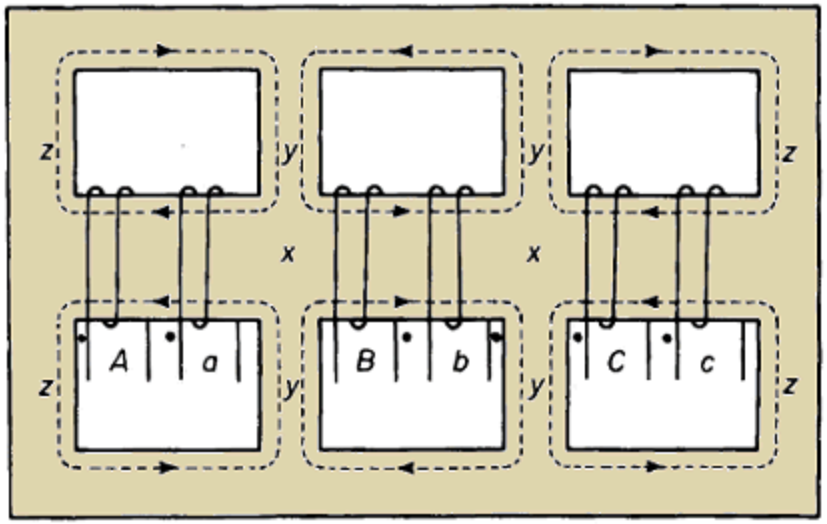
Principle of Operation – Faradays Law



- Three cores are 120^0 apart.
- Primary windings are connected to three phase supply and carry currents I_R, I_Y and I_B producing fluxes ϕ_R, ϕ_Y and ϕ_B in individual cores.
- **Centre leg carries sum of three fluxes = 0**
- If centre leg is removed it doesn't make any difference in working condition of transformer.

Construction





Core Type

- Consists of three legs and two yokes.
- Each limb carries primary and secondary windings

Shell Type

- Three phases are more independent because each phase has an individual magnetic circuit

Three Phase Transformer - Connections

- Primary and secondary of three phase transformers can be independently connected either in **star or delta**. Thus there are **four possible connections**,

1. Delta – Delta Connection
2. Delta – Star Connection
3. Star – Star Connection
4. Star – Delta Connection