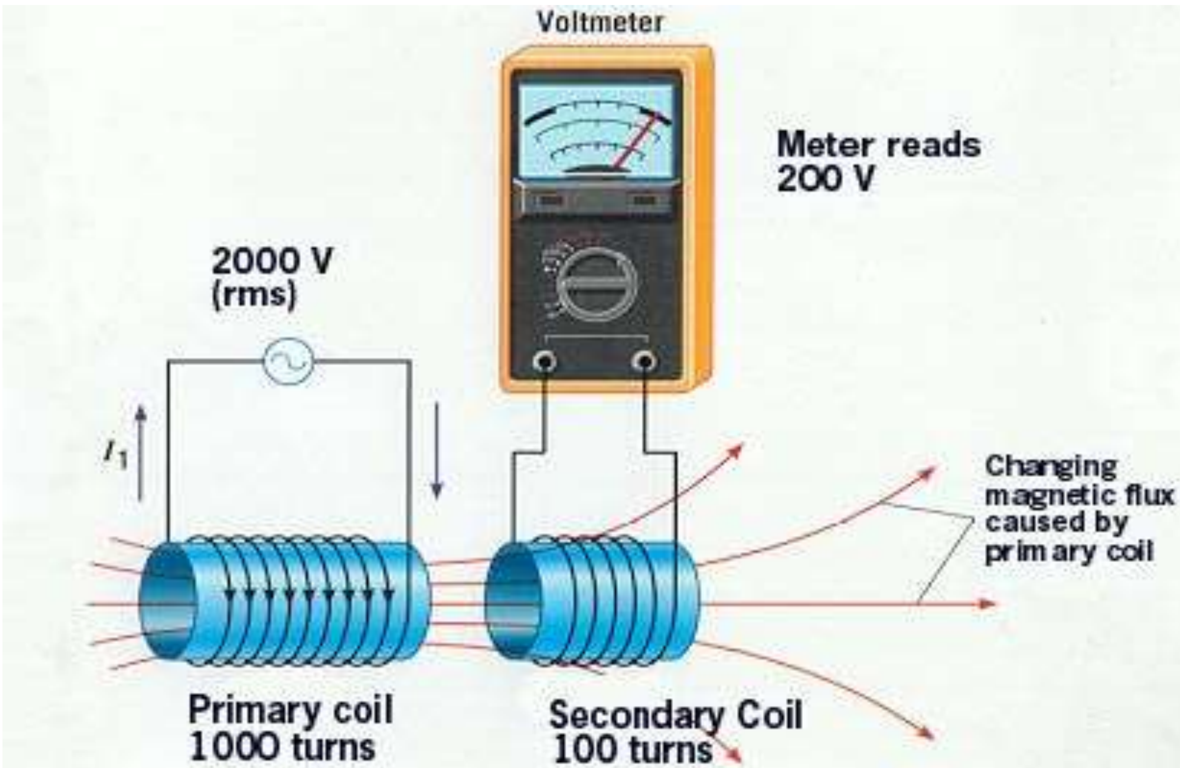
Transformer

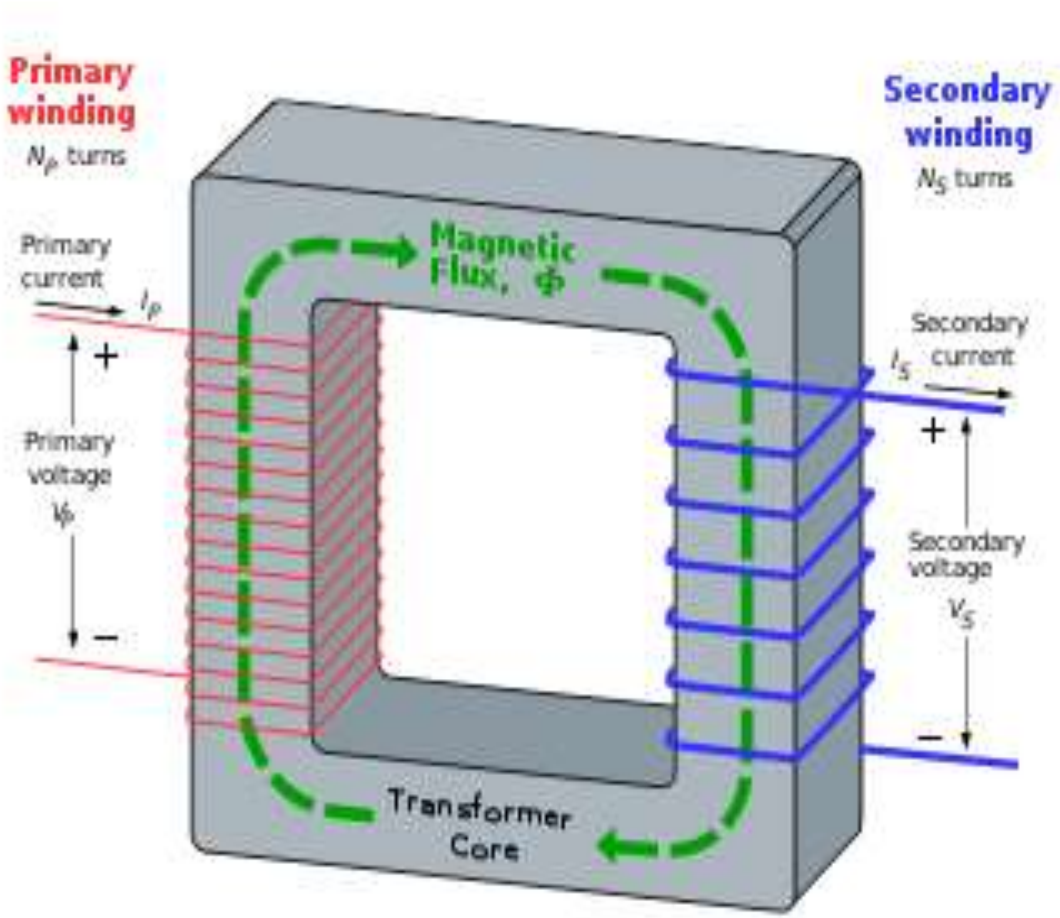
Basic principles

The transformer is based on the principles

- electric current can produce magneticfield(electromagnetism),
- changing magnetic field within a coil of wire induces a voltage across the ends of the coil (electromagnetic induction).
- Changing the current in the primary coil changes the magnetic flux that is developed.
- The changing magnetic flux induces a voltage in the secondary coil.

Mutual induction




Primary winding
N_P turns
Secondary winding
N_S turns
Primary current
I_P
Magnetic Flux, Φ
Secondary current
I_S
Primary voltage
V_P
Secondary voltage
V_S
Transformer Core

- A **transformer** is a device that transfers electrical energy from one circuit to another through inductively coupled conductors—the transformer's coils.
- A varying current in the *primary* winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic field through the *secondary* winding.
- This varying magnetic field induces a varying electromotive force (EMF), or "voltage", in the secondary winding. This effect is called mutual induction.
- If a load is connected to the secondary, an electric current will flow in the secondary winding and electrical energy will be transferred from the primary circuit through the transformer to the load

EMF Equation

- flux $\phi = \phi_{max} Sin(wt)$

Emf induced in the primary winding=N1 $d\phi/dt$

Emf induced in the secondary winding=N2 $d\phi/dt$

E1max=N1*W*ϕmax

E1rms=4.44 f N1 ϕmax

Similarly E2rms=4.44 f N2 ϕmax

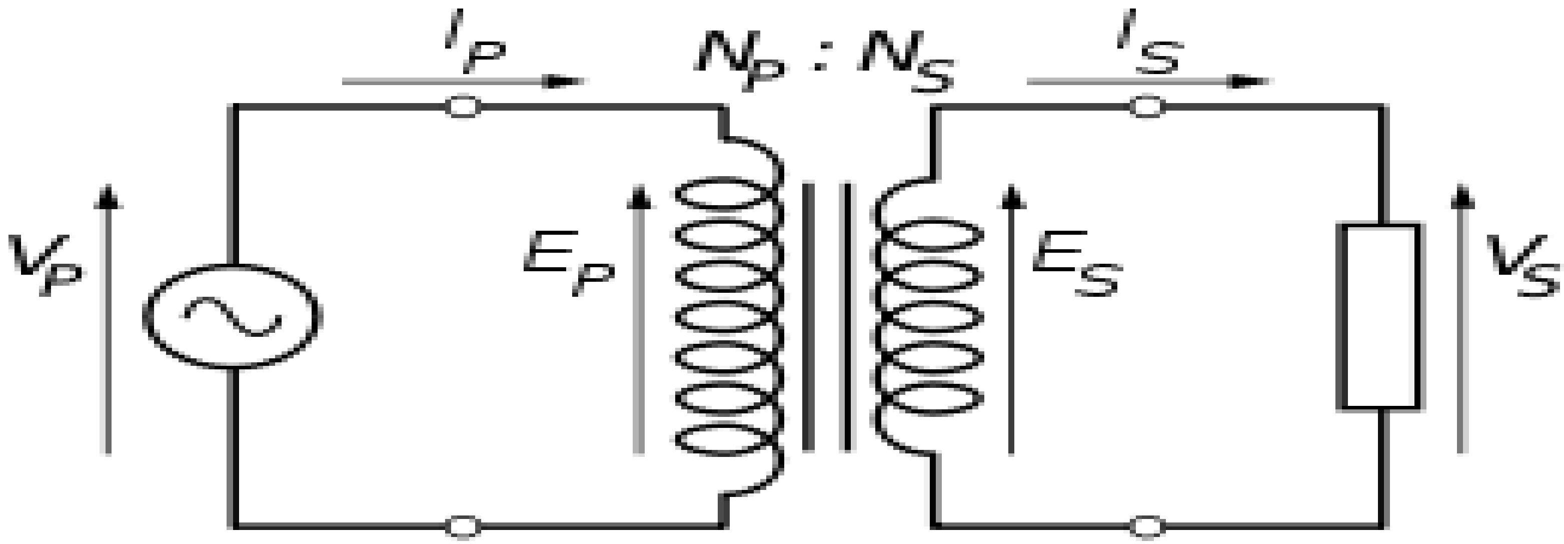
E2/E1=N2/N1=turns ratio of the transformer

- In an ideal transformer

the induced voltage in the secondary winding (V_s) is in proportion to the primary voltage (V_p), and is given by the ratio of the number of turns in the secondary (N_s) to the number of turns in the primary (N_p) as follows:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

Ideal power equation



$$\frac{V_P}{V_S} = \frac{I_S}{I_P} = \frac{N_P}{N_S}$$

The ideal transformer as a circuit element

✓ If the secondary coil is attached to a load that allows current to flow, electrical power is transmitted from the primary circuit to the secondary circuit.

$$P_{\mathrm{incoming}} = I_{\mathrm{p}}V_{\mathrm{p}} = P_{\mathrm{outgoing}} = I_{\mathrm{s}}V_{\mathrm{s}},$$

$$\frac{V_{\mathrm{s}}}{V_{\mathrm{p}}} = \frac{N_{\mathrm{s}}}{N_{\mathrm{p}}} = \frac{I_{\mathrm{p}}}{I_{\mathrm{s}}}.$$

Classification

Transformers can be considered a class of electric machine with no moving parts; as such they are described as *static* electric machines.

They can be classified in many different ways

- ***By power capacity*** **: from a fraction of a volt-ampere (VA) to over a thousand MVA**
- ***By frequency range*** **: power-, audio-, or radio frequency**
- ***By purpose*** **: distribution, rectifier, arc furnace, amplifier output**
- ***By voltage class*** **: from a few volts to hundreds of kilovolts**
- ***By cooling type*** **: air-cooled, oil-filled, fan-cooled, or water-cooled**
- ***By application*** **: such as power supply, impedance matching, output voltage and current stabilizer, or circuit isolation**
- ***By winding turns ratio*** **: step-up, step-down, isolating with equal or near-equal ratio, variable, multiple windings**

Construction

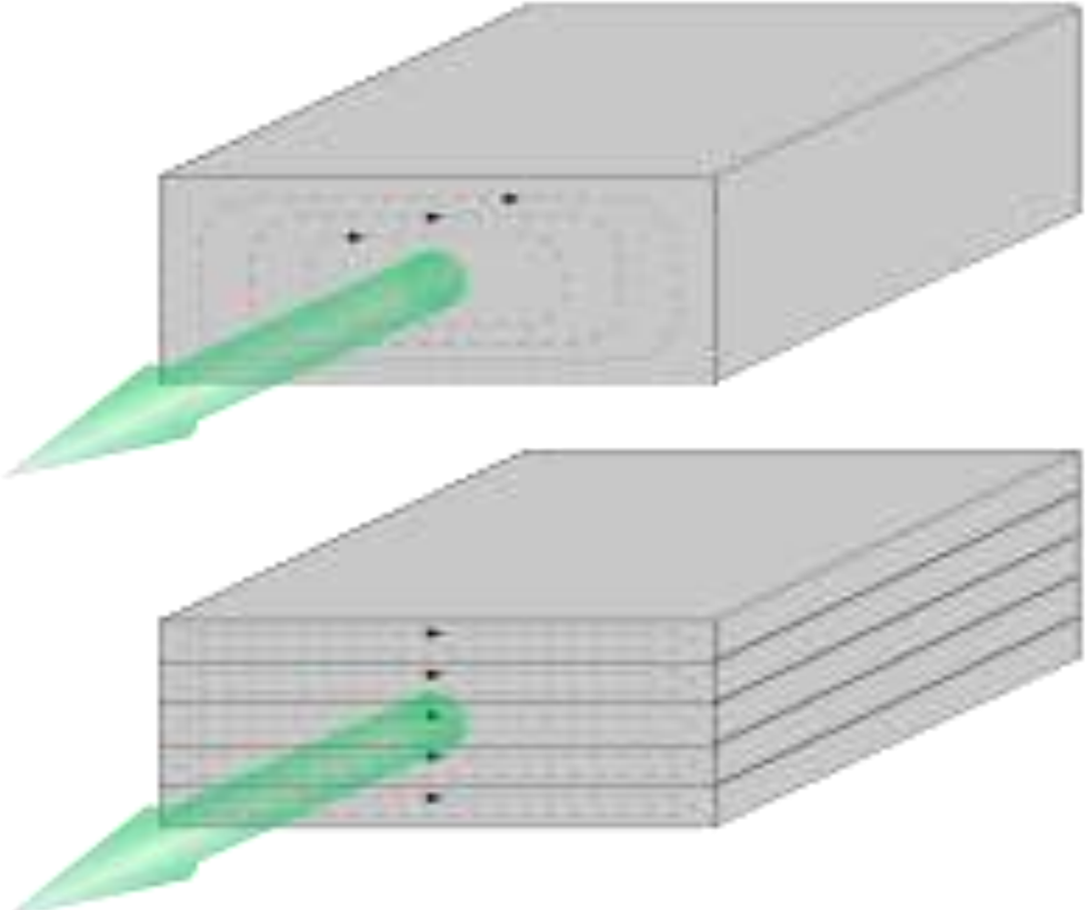
Laminated steel core transformer showing edge of laminations at top of photo

Power or audio frequency transformers typically have cores made of high <u>permeability</u> <u>silicon steel</u>

- **core by stacking layers of thin steel laminations**

- **The effect of laminations is to reduce eddy current losses**

Laminating the core greatly reduces eddy-current losses



Solid cores

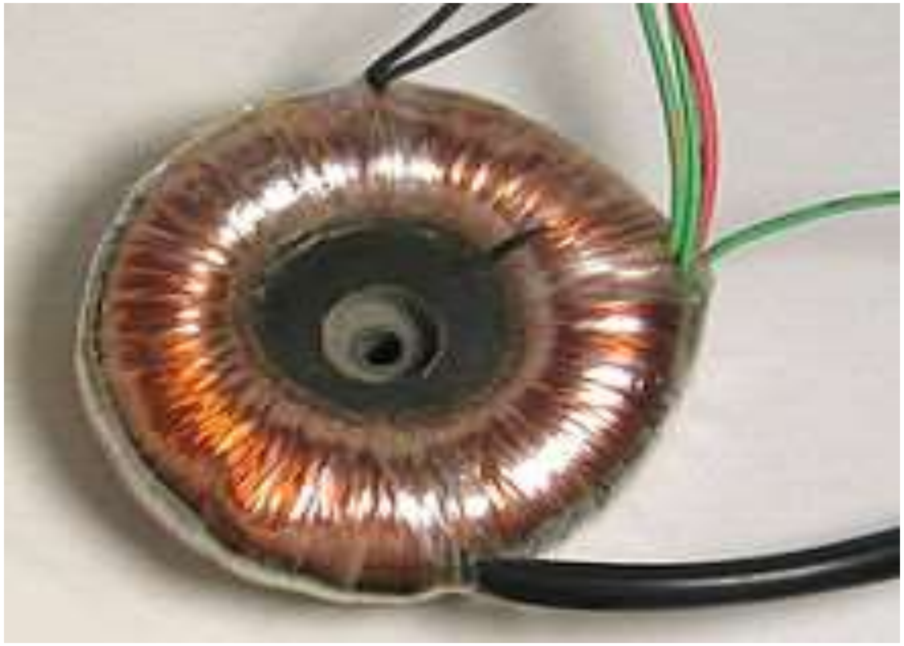
Materials having high magnetic permeability with high bulk electrical resistivity.

- For frequencies extending beyond the VHF band, cores made from non-conductive magnetic ceramic materials called ferrites.

Toroidal cores

- Toroidal transformers are built around a ring-shaped core, which, depending on operating frequency
- It is made from a long strip of silicon steel or permalloy wound into a coil, powdered iron, or ferrite

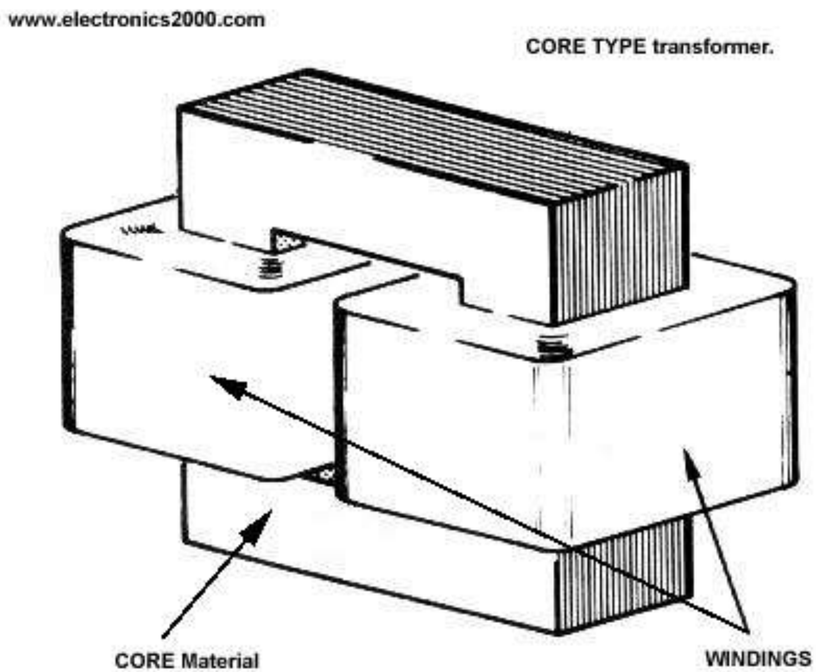
Toroidal cores

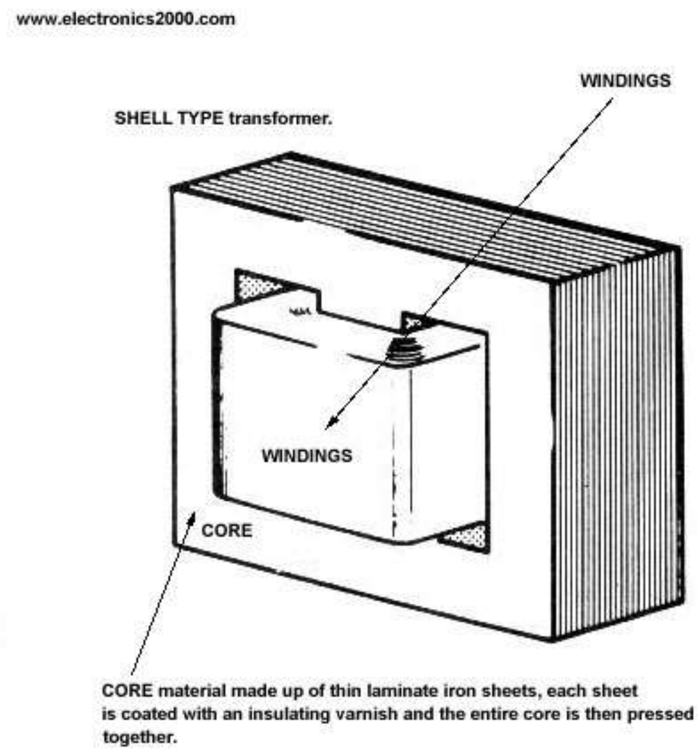


Air Core

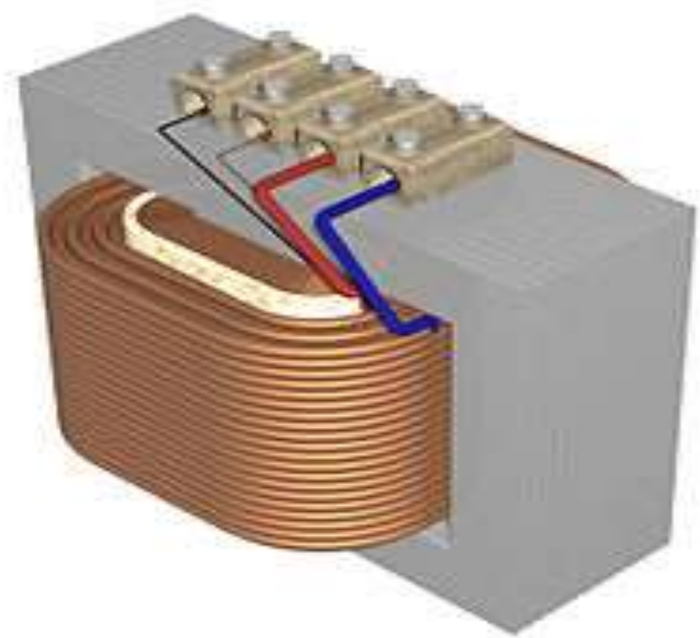
An air-core transformer eliminates loss due to hysteresis

CORE TYPE & SHELL TYPE

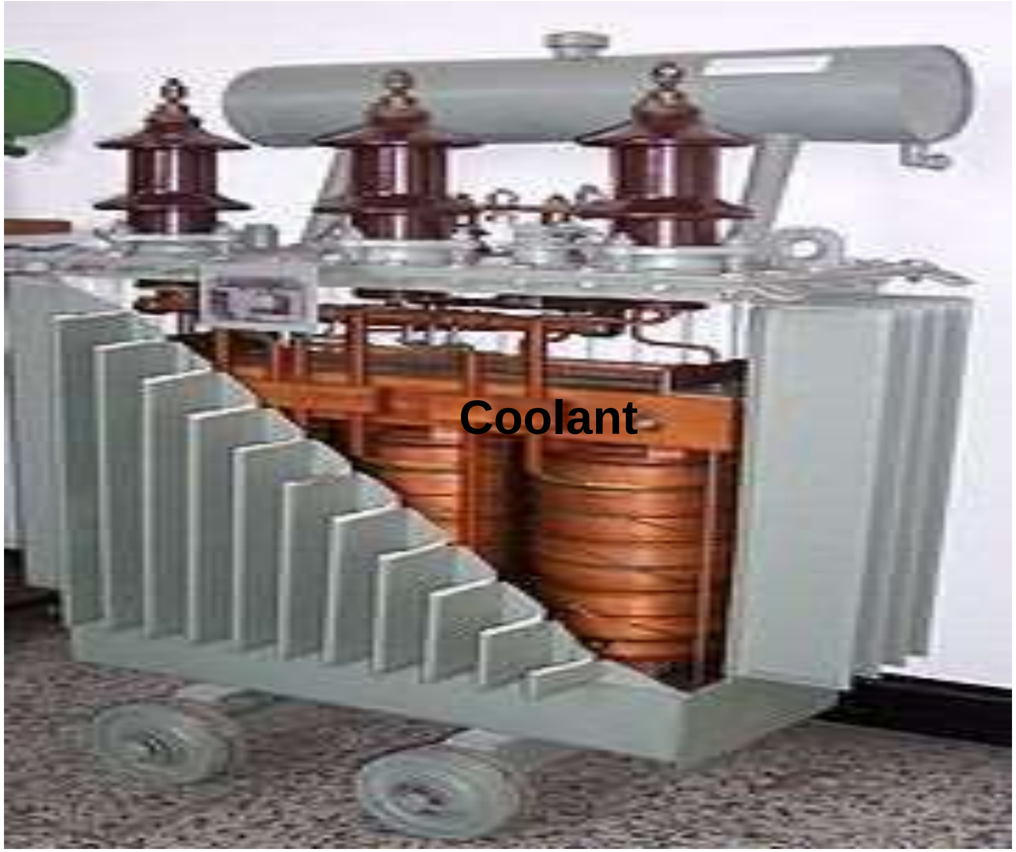




Windings& core



Coolant



Cut-away view of three-phase oil-cooled transformer. The oil reservoir is visible at the top. Radiative fans aid the dissipation of heat.

- Power transformers rated up to several hundred kVA can be adequately cooled by natural convective air-cooling.

- The oil is a highly refined mineral oil that remains stable at transformer operating temperature.

- The oil-filled tank often has radiators through which the oil circulates by natural convection

- Some large transformers employ forced circulation of the oil by electric pumps, aided by external fans or water-cooled heat exchangers

- Oil-filled transformers may be equipped with Buchholz relays, which detect gas evolved during internal arcing and rapidly de-energize the transformer to avert catastrophic failure

- Larger transformers may have heavy bolted terminals, bus bars or high-voltage insulated bushings made of polymers or porcelain.

Thank You