Basic Electrical Technology

Instructor

Jahedul Islam

Lecturer, EEE, DIU

Transformer

Physical image of Transformer

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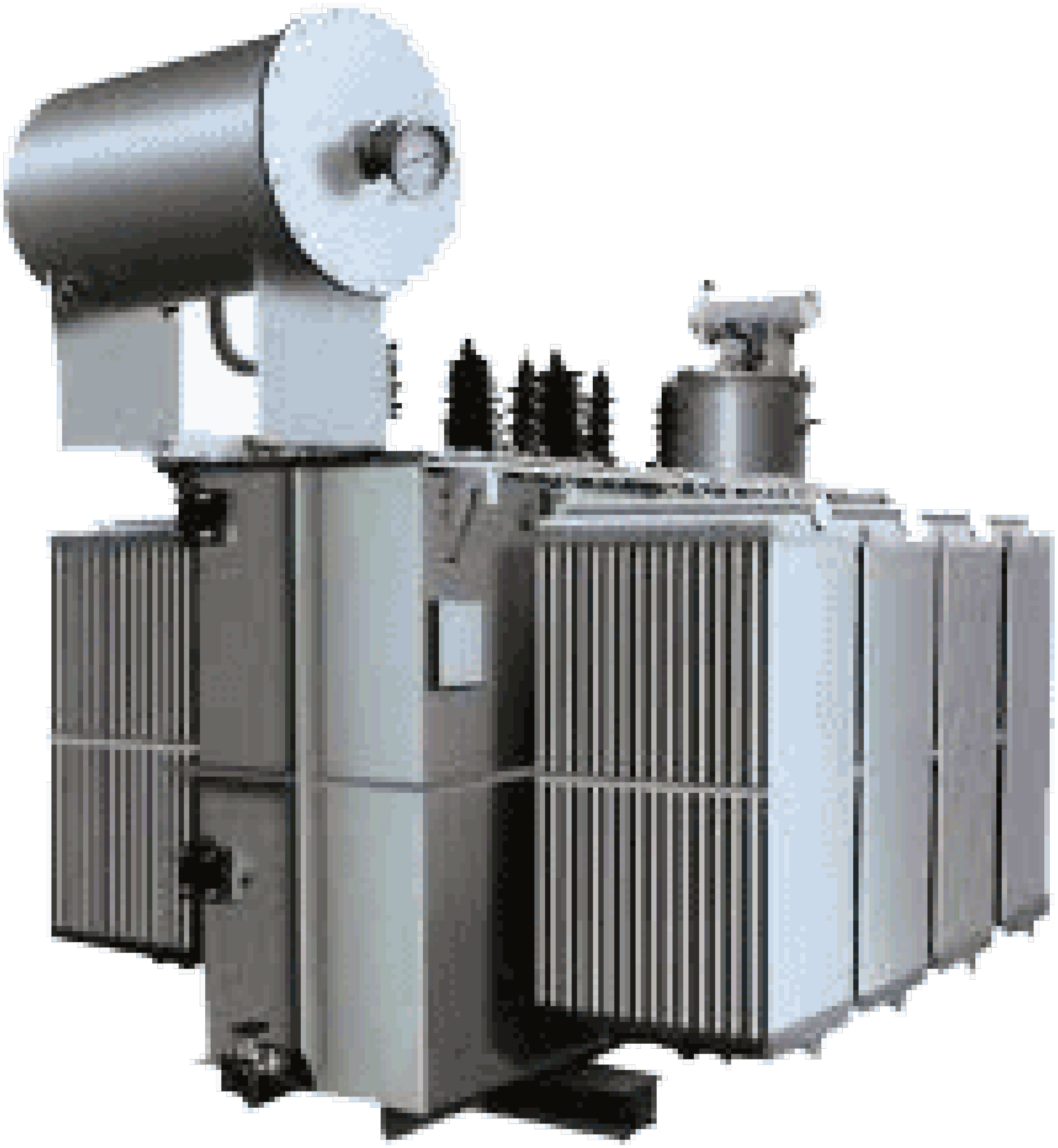
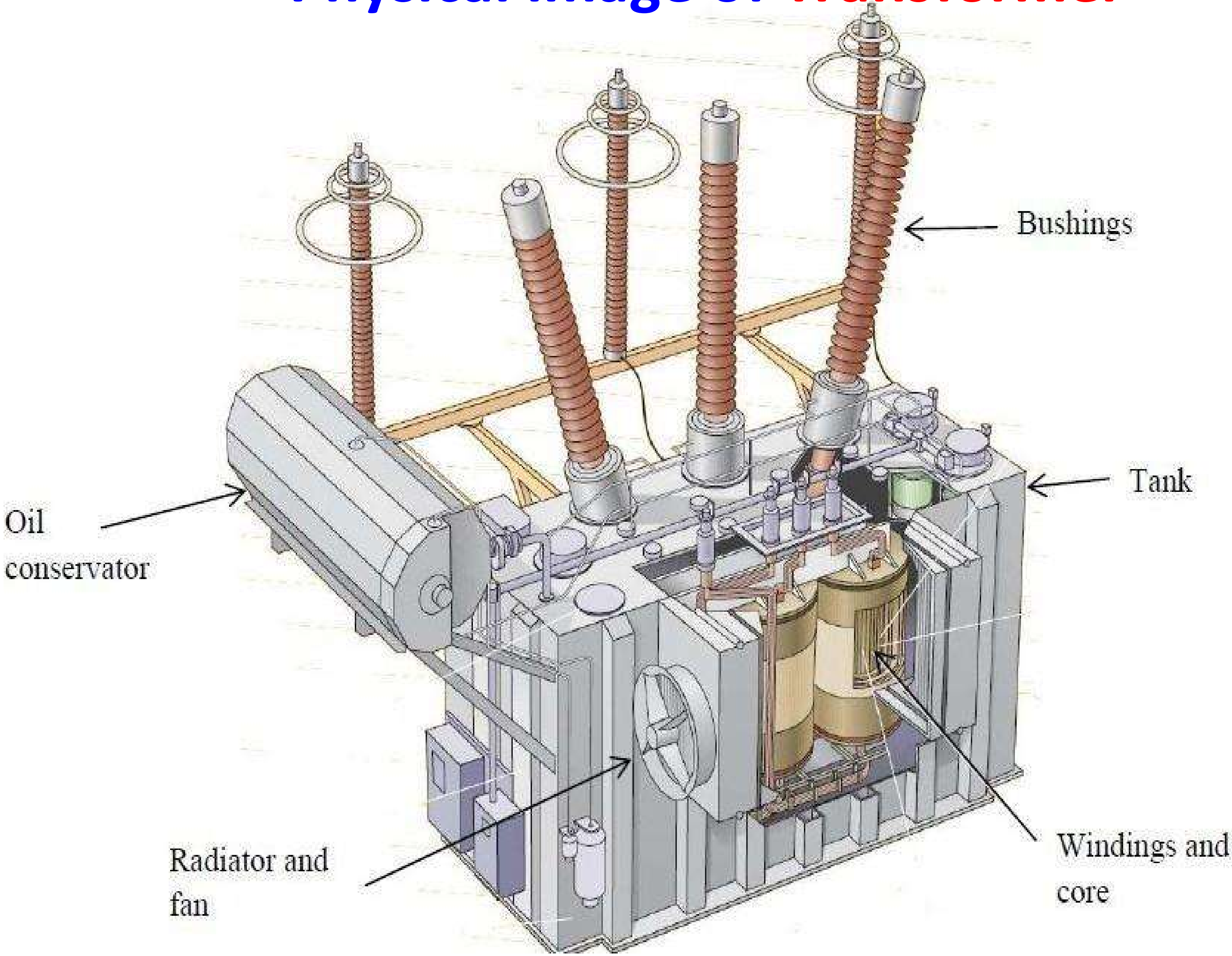
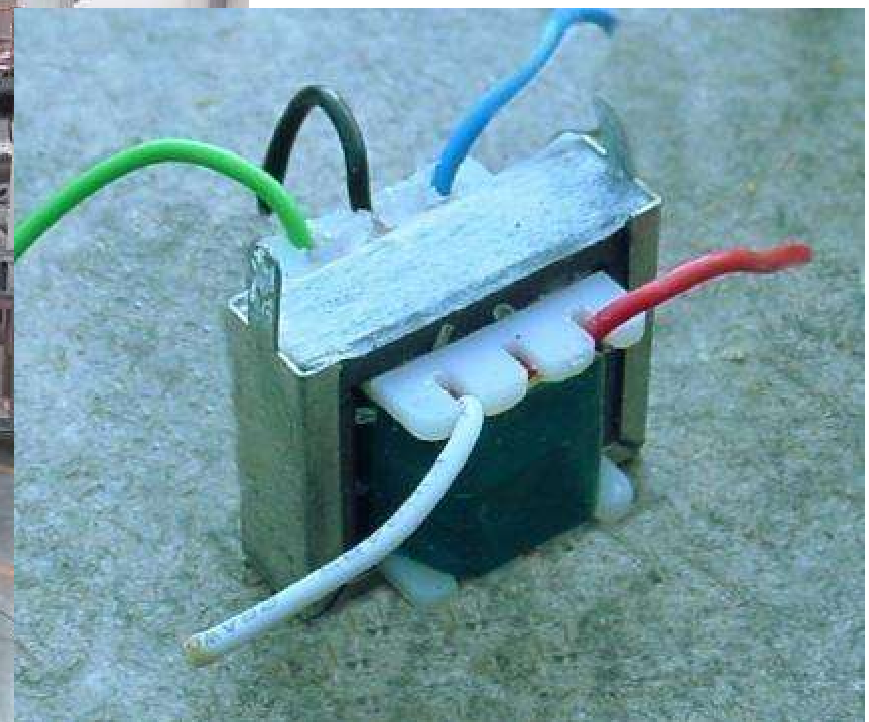


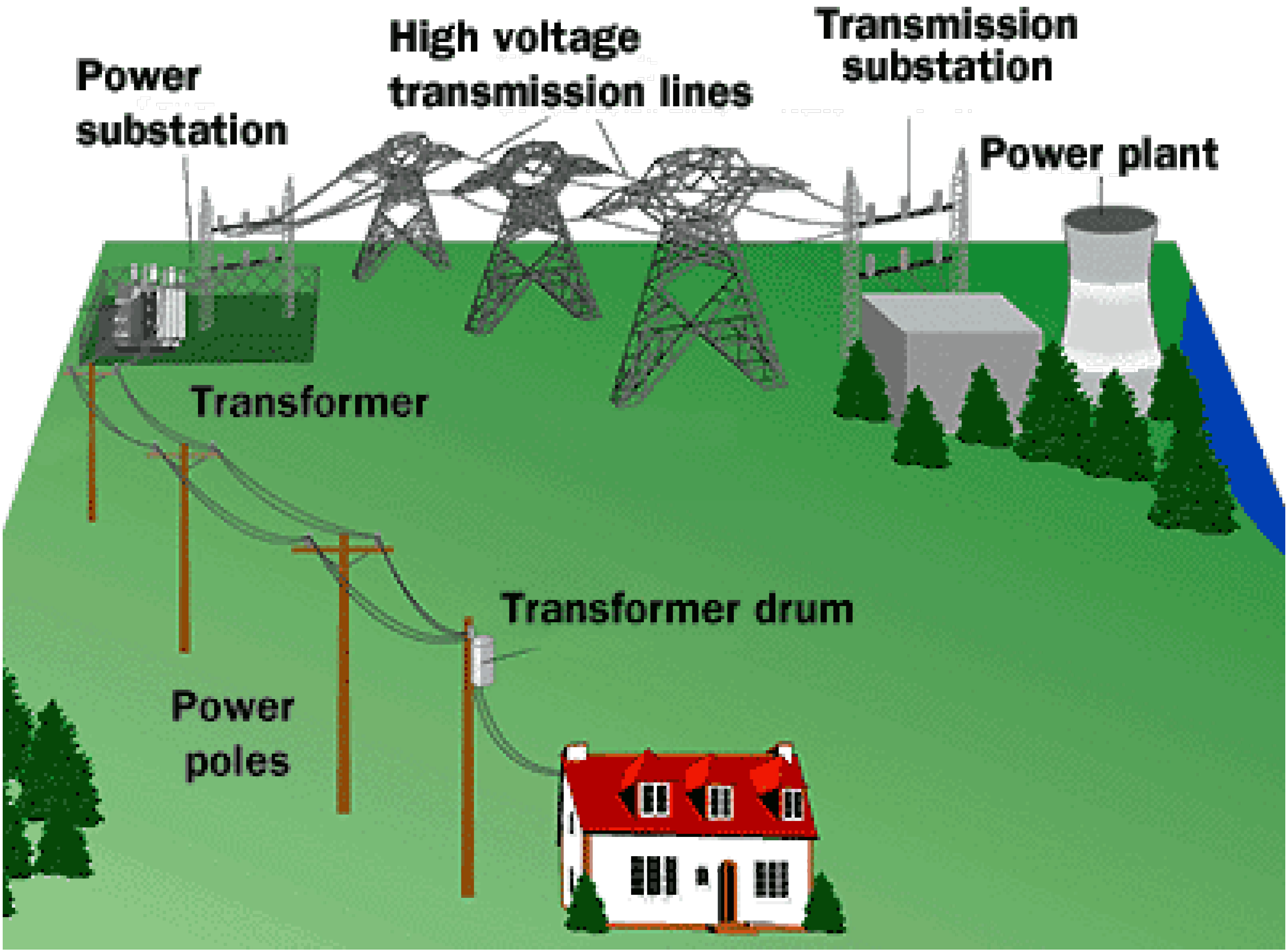
Physical image of Transformer



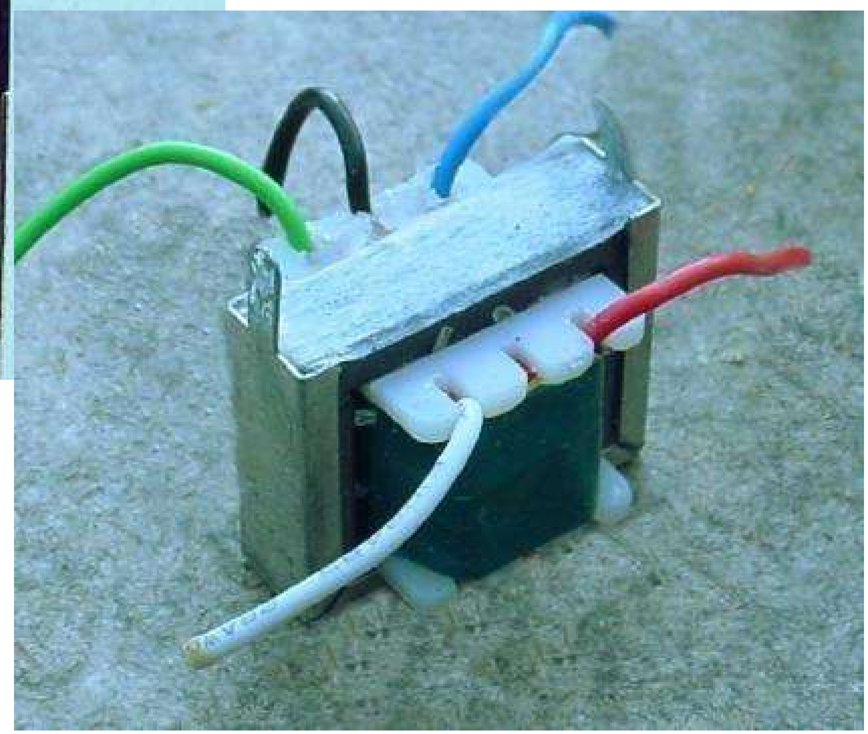
Physical image of Transformer



Application of Transformer

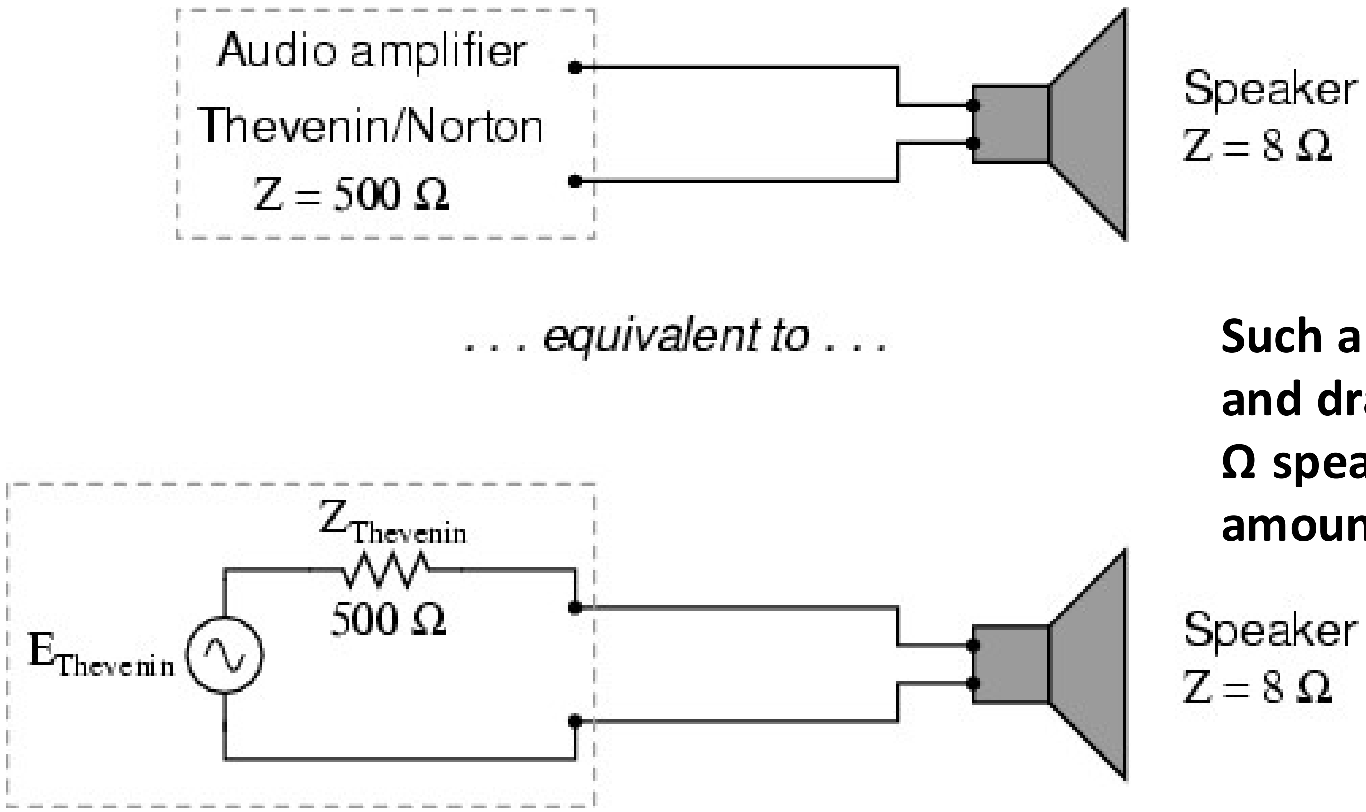


Application of Transformer



Printed circuit board mounted audio impedance matching transformer, top right.

Application of Transformer



If 500 Ω = 500 Ω maximum power

Such a load drop higher voltage and draw less current than an 8 Ω speaker dissipating the same amount of power

Amplifier with impedance of 500 Ω drives 8 Ω at much less than maximum power.

Application of Transformer

$$\text{Voltage transformation ratio} = \frac{N_{\text{secondary}}}{N_{\text{primary}}}$$

$$\text{Current transformation ratio} = \frac{N_{\text{primary}}}{N_{\text{secondary}}}$$

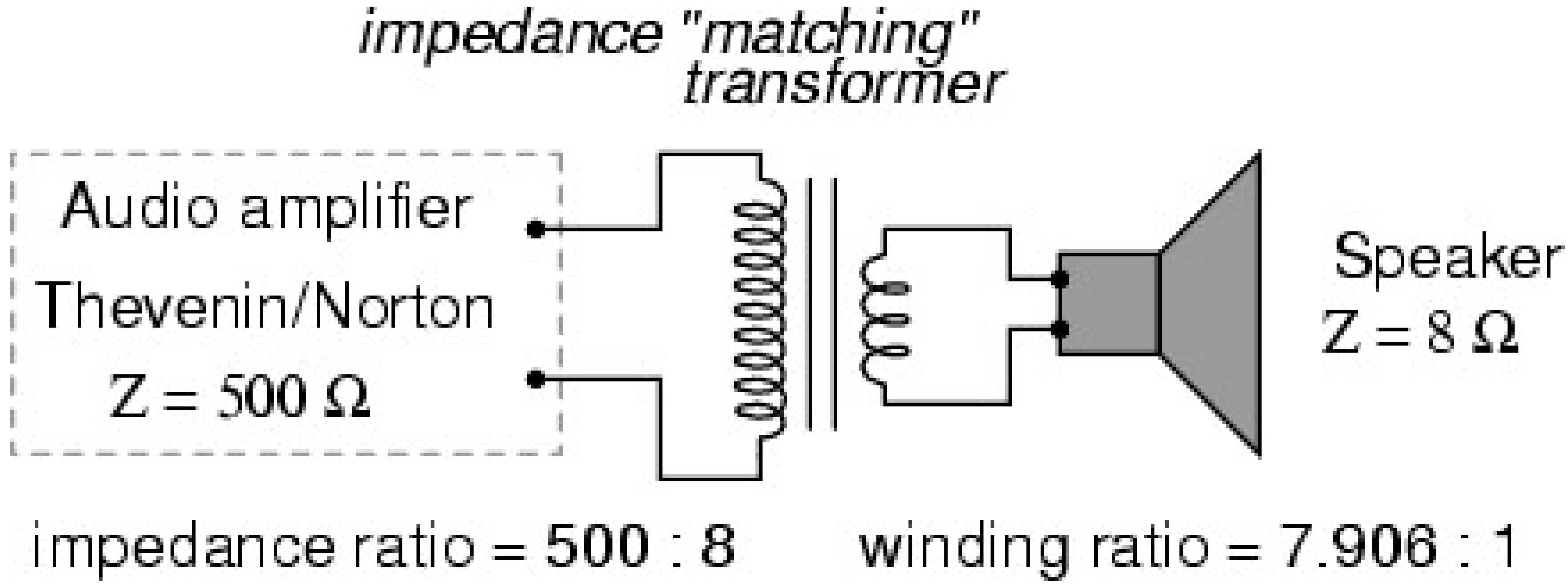
$$\text{Impedance transformation ratio} = \left(\frac{N_{\text{secondary}}}{N_{\text{primary}}}\right)^2$$

$$\text{Inductance ratio} = \left(\frac{N_{\text{secondary}}}{N_{\text{primary}}}\right)^2$$

Where,

N = number of turns in winding

Application of Transformer



Principle of Transformer

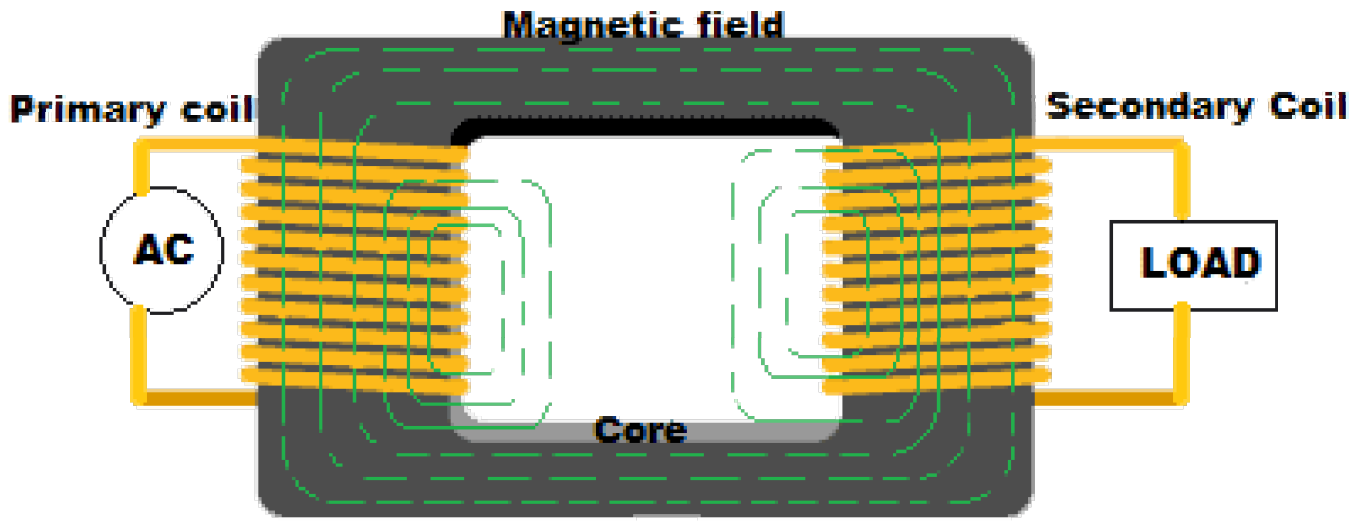
- **The word Transformer refers to transfer something from one place to other**

A Transformer is a static or stationary piece of apparatus by means of which electric power in one circuit is transformed into electric power of the same frequency in another circuit

Although transformers have no moving parts, they are essential to electromechanical energy conversion. They make it possible to increase or decrease the voltage so that power can be transmitted at a voltage level that results in low costs, and can be distributed and used safely

Constructional Parts of a Transformer

Main parts of a transformer :



A typical transformer is constructed with three basic parts

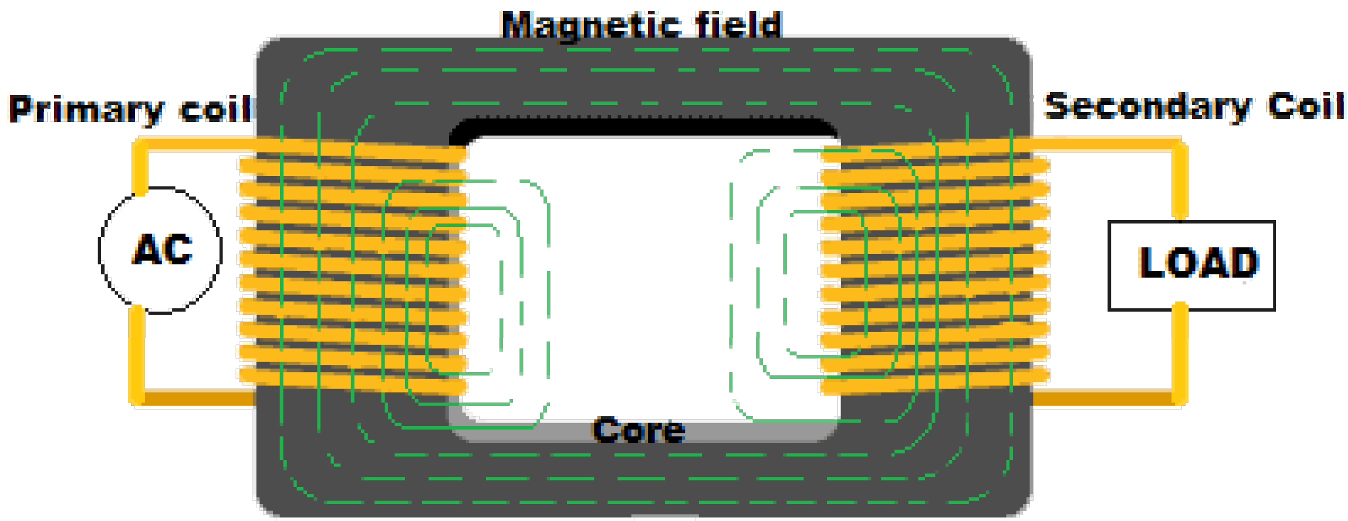
(i) primary winding (ii) secondary winding and a (iii) magnetic core

Constructional Parts of a Transformer

Primary winding: This is a simple coil which is wound by copper wires. This winding generates the required magnetic flux whenever a active AC source is connected across it. It is a closed coil, so whenever an AC voltage is applied across it, current starts flowing. And this flow of current leads to develop an alternating magnetic field surrounding the coil. This winding is used to develop the main magnetic field into the transformer. As the flux generation and creation of magnetic field is initiated from here, so this winding is termed as the primary winding. The primary winding is the input section of a transformer

Core: Core gives the strong mechanical support for the windings as well as serves the necessary path for the magnetic fluxes. Core is generally made up with soft iron or laminated silicon steel. When the magnetic fluxes are generated in the primary winding, it confines them and after that those fluxes are passing through the core. Both primary and secondary windings are connected with a common core. As this magnetic core offers a low reluctance path for the generated magnetic fluxes, so most of the fluxes will go through the core. So they are guided to the secondary winding through the magnetic core.

Constructional Parts of a Transformer



Secondary winding: This is also a copper winding similar to the primary, but the number of turns are different. The generated magnetic fluxes will link this secondary winding by mutual induction method after passing through the magnetic core. Output of a transformer is always taken from the secondary winding terminal that is the load is always connected with this terminal

Working Principle of Transformer

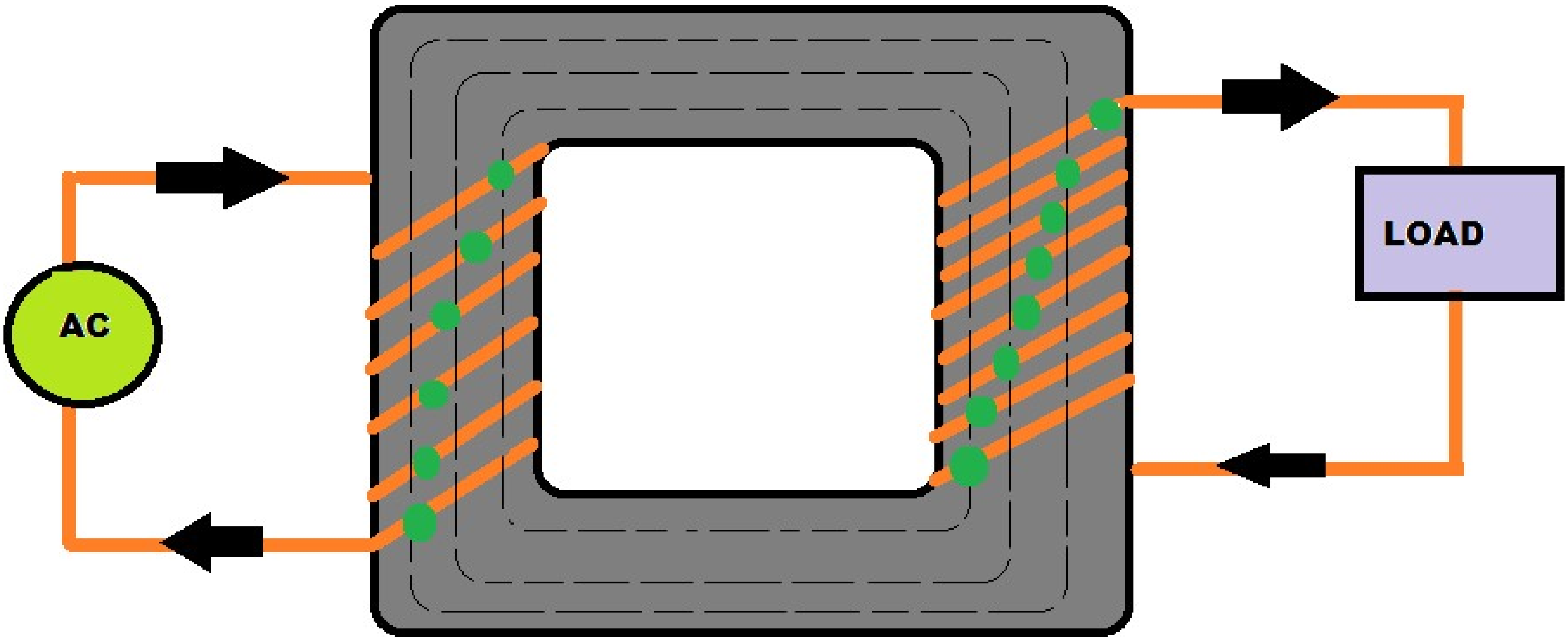
Whenever a closed conductor is placed into a varying magnetic field, a potential difference is developed across the terminals of the conductor

Faradey's law:

This law states that, if a closed conductor is subjected to a varying magnetic field, then the induced emf in the conductor is equal to the rate of change of flux linkages of that magnetic field.

The induced voltage e = – Ndϕ / dt volt

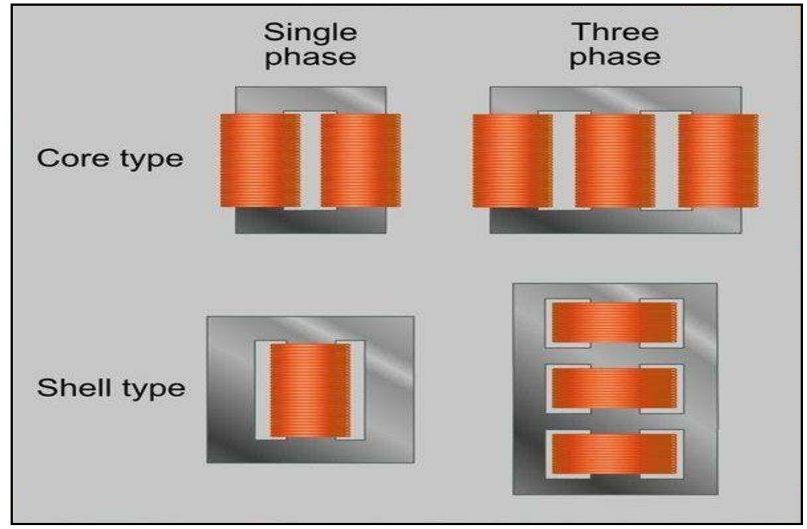
Working Principle of Transformer



Types of Transformer

According to the core construction:

(a) Core type
(b) Shell type
(c) Berry type



According to the voltage ratio :

(a) Step Up transformer
(b) Step down transformer

According to the phase:

(a) Single Phase Transformer
(b) Three Phase Transformer

Types of Transformer

According to the method of cooling:

(a) Self Cooled

(b) Air forced cooled

(c) Oil cooled

(d) forced oil cooled

According to the frequency groups:

(a) Power frequency transformers.

(b) Audio frequency transformers.

(c) Radio frequency transformers.

Types of Transformer

There are many other types of transformers are present according to the specific applications.

Distribution Transformer: Distribution transformers are used in distribution network to step down the voltage level for feeding the local consumers.

Power Transformer: Power transformers are used at each end of transmission line in generating stations and substations for stepping up or down the voltage level.

Current transformer: This transformer is used for the measurement of electric current.

Potential transformer: These type of transformers are used to step down the voltage to low value which can be fed to relay for protection purpose.

Instrument transformers: Current transformers and potential transformer both are called the instrument transformer because their main fuction is to transform high currents and voltages to a standardized low and easily measurable values.

Auto transformer : It is a single winding transformer and a common winding is used as both primary and secondary winding.

32.6. E.M.F. Equation of a Transformer

Let N_1 = No. of turns in primary

N_2 = No. of turns in secondary

Φ_m = Maximum flux in core in webers

$= B_m \times A$

f = Frequency of a.c. input in Hz

As shown in Fig. 32.14, flux increases from its zero value to maximum value Φ_m in one quarter of the cycle *i.e.* in 1/4 f second.

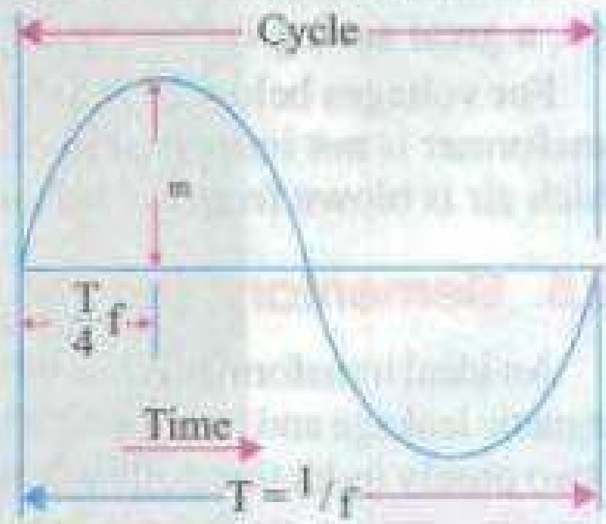


Fig. 32.14

$\therefore$ Average rate of change of flux $= \dfrac{\Phi_m}{1/4f}$

$= 4 f \Phi_m$ Wb/s or volt

Now, rate of change of flux per turn means induced e.m.f. in volts.

$\therefore$ Average e.m.f./turn $= 4 f \Phi_m$ volt

If flux Φ varies *sinusoidally*, then r.m.s. value of induced e.m.f. is obtained by multiplying the average value with form factor.

$$\text{Form factor} = \frac{\text{r.m.s. value}}{\text{average value}} = 1.11$$

$\therefore$ r.m.s. value of e.m.f./turn $= 1.11 \times 4 f \Phi_m = 4.44 f \Phi_m$ volt

Now, r.m.s. value of the induced e.m.f. in the whole of primary winding

= (induced e.m.f/turn) × No. of primary turns

$$E_1 = 4.44 f N_1 \Phi_m = 4.44 f N_1 B_m A \quad \text{...(i)}$$

Similarly, r.m.s. value of the e.m.f. induced in secondary is,

$$E_2 = 4.44 f N_2 \Phi_m = 4.44 f N_2 B_m A \qquad ...(ii)$$

It is seen from (*i*) and (*ii*) that $E_1/N_1 = E_2/N_2 = 4.44 f \Phi_m$. It means that e.m.f./turn is the *same* in both the primary and secondary windings.

In an ideal transformer on no-load, $V_1 = E_1$ and $E_2 = V_2$ where V_2 is the terminal voltage (Fig. 32.15).

32.7 Voltage Transformation Ratio (K)

From equations (*i*) and (*ii*), we get

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

This constant K is known as voltage transformation ratio.

(*i*) If $N_2 > N_1$ *i.e.* $K > 1$, then transformer is called *step-up* transformer.

(*ii*) If $N_2 < N_1$ *i.e.* $K < 1$, then transformer is known as *step-down* transformer.

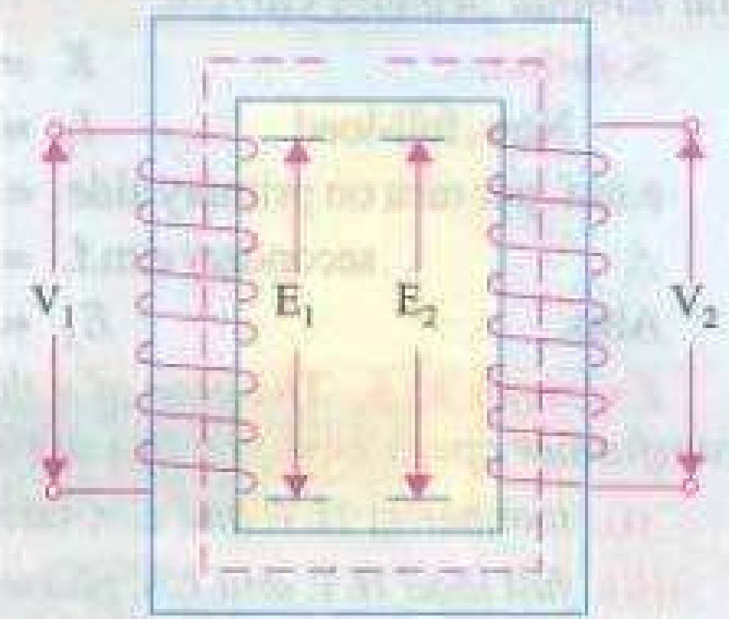


Fig. 32.15

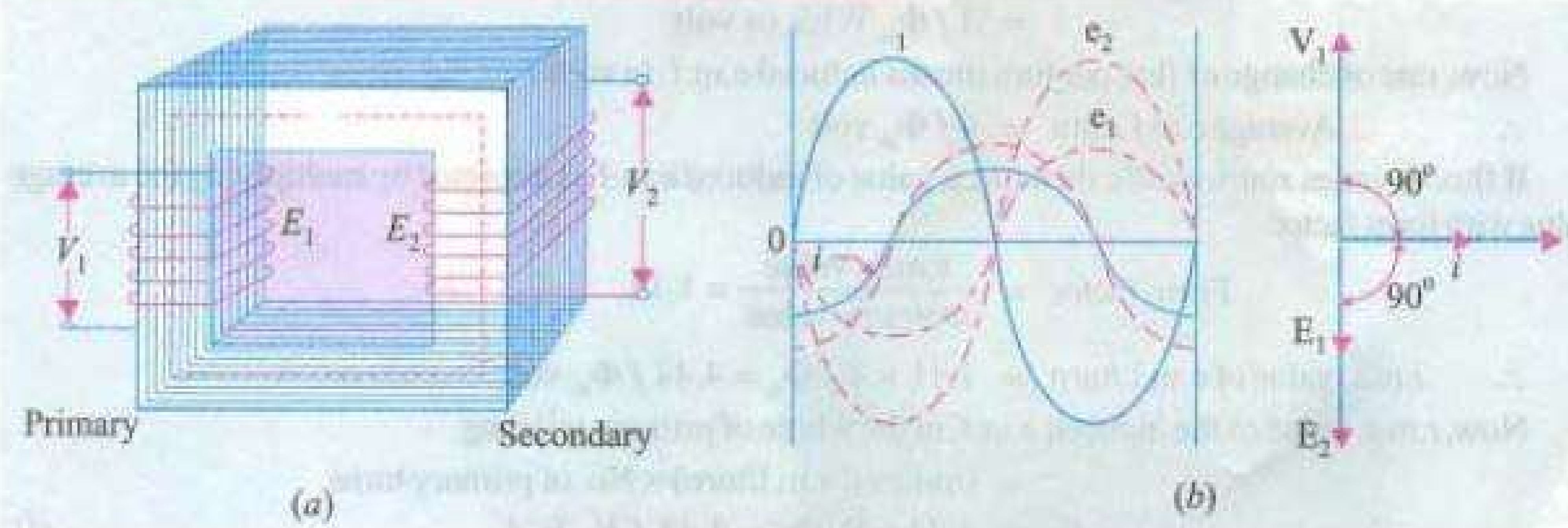
Again, for an *ideal* transformer, input VA = output VA.

$$V_1 I_1 = V_2 I_2 \text{ or } \frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{1}{K}$$

Hence, currents are in the inverse ratio of the (voltage) transformation ratio.

32.5. Elementary Theory of an Ideal Transformer

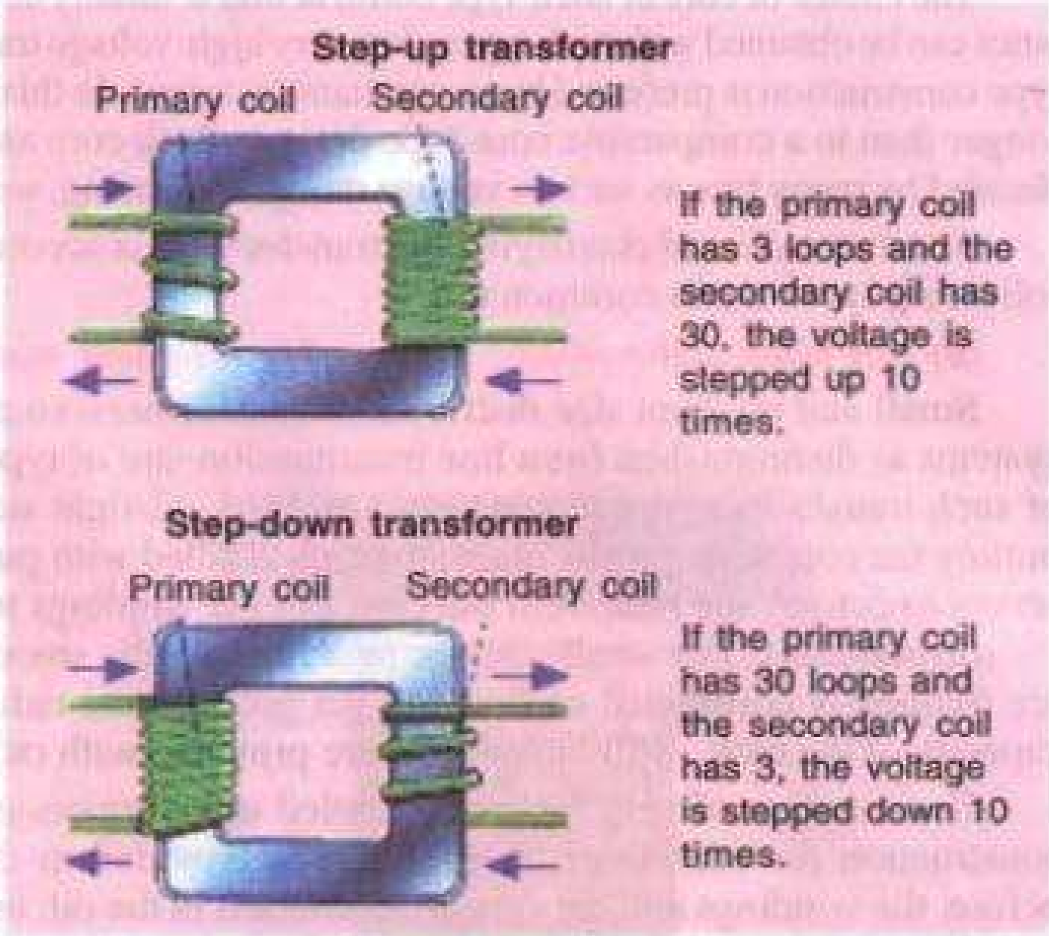
An ideal transformer is one which has no losses *i.e.* its windings have no ohmic resistance, there is no magnetic leakage and hence which has no I^2R and core losses. In other words, an ideal transformer consists of two purely inductive coils wound on a loss-free core. It may, however, be noted ***that it is impossible to realize such a transformer in practice, yet for convenience, we will start with such a transformer and step by step approach an actual transformer***



Consider an ideal transformer [Fig. 32.13 (*a*)] whose secondary is open and whose primary is connected to sinusoidal alternating voltage V_1. This potential difference causes an alternating current to flow in the primary. Since the primary coil is purely inductive and there is no output (secondary being open) the primary draws the magnetising current I_μ only. The function of this current is merely to magnetise the core, it is small in magnitude and lags V_1 by 90°. This alternating current I_μ produces an alternating flux ϕ which is, at all times, proportional to the current (assuming permeability of the magnetic circuit to be constant) and, hence, is in phase with it. This changing flux is linked both with the primary and the secondary windings. Therefore, it produces self-induced e.m.f. in the primary. This *self-induced* e.m.f. E_1 is, at every instant, equal to and in opposition to V_1. It is also known as counter e.m.f. or back e.m.f. of the primary.

Similarly, there is produced in the secondary an induced e.m.f. E_2 which is known as *mutually* induced e.m.f. This e.m.f. is antiphase with V_1 and its magnitude is proportional to the rate of change of flux and the number of secondary turns.

The instantaneous values of applied voltage, induced e.m.fs, flux and magnetising current are shown by sinusoidal waves in Fig. 32.13 (*b*). Fig. 32.13 (*c*) shows the vectorial representation of the effective values of the above quantities.



Step-up transformer

Regulation of Transformer

The voltage regulation of the transformer is the percentage change in the output voltage from no-load to full-load.

The voltage regulation can be defined in two ways - Regulation Down and Regulation up.

Regulation down: This is defined as " the change in terminal voltage when a load current at any power factor is applied, expressed as a fraction of the no-load terminal voltage

$$Regulation = \frac{|V_{nl}| - |V_l|}{|V_{nl}|}$$

Regulation up: Here again the regulation is expressed as the ratio of the change in the terminal voltage when a load at a given power factor is thrown off, and the on load voltage

$$Regulation = \frac{|V_{nl}| - |V_l|}{|V_l|}$$

THREE PHASE TRANSFORMERS

Almost all major generation & Distribution Systems in the world are three phase ac systems
Three phase transformers play an important role in these systems

3 phase transformers can be constructed from

(a) 3 single phase transformers

(b) 2 single phase transformers

(c) using a common core for three phase windings

Three Phase Transformers

Can be formed as:

- 3 single phase transformers connected together
  - Star/Delta winding arrangements
  - Easy to replace failed units
- Common core device
  - Lighter and cheaper than 3 individual units
  - 6 rather than 12 external connections
  - Whole transformer must be replaced if single winding fails
- For both cases analysis procedure identical!

3 phase Transformer connections

By connecting three single phase transformers

1. **Star- Star connection**
2. **Delta- Delta connection**
3. **Star – Delta connection**
4. **Delta – Star connection**

Parallel operation of transformers

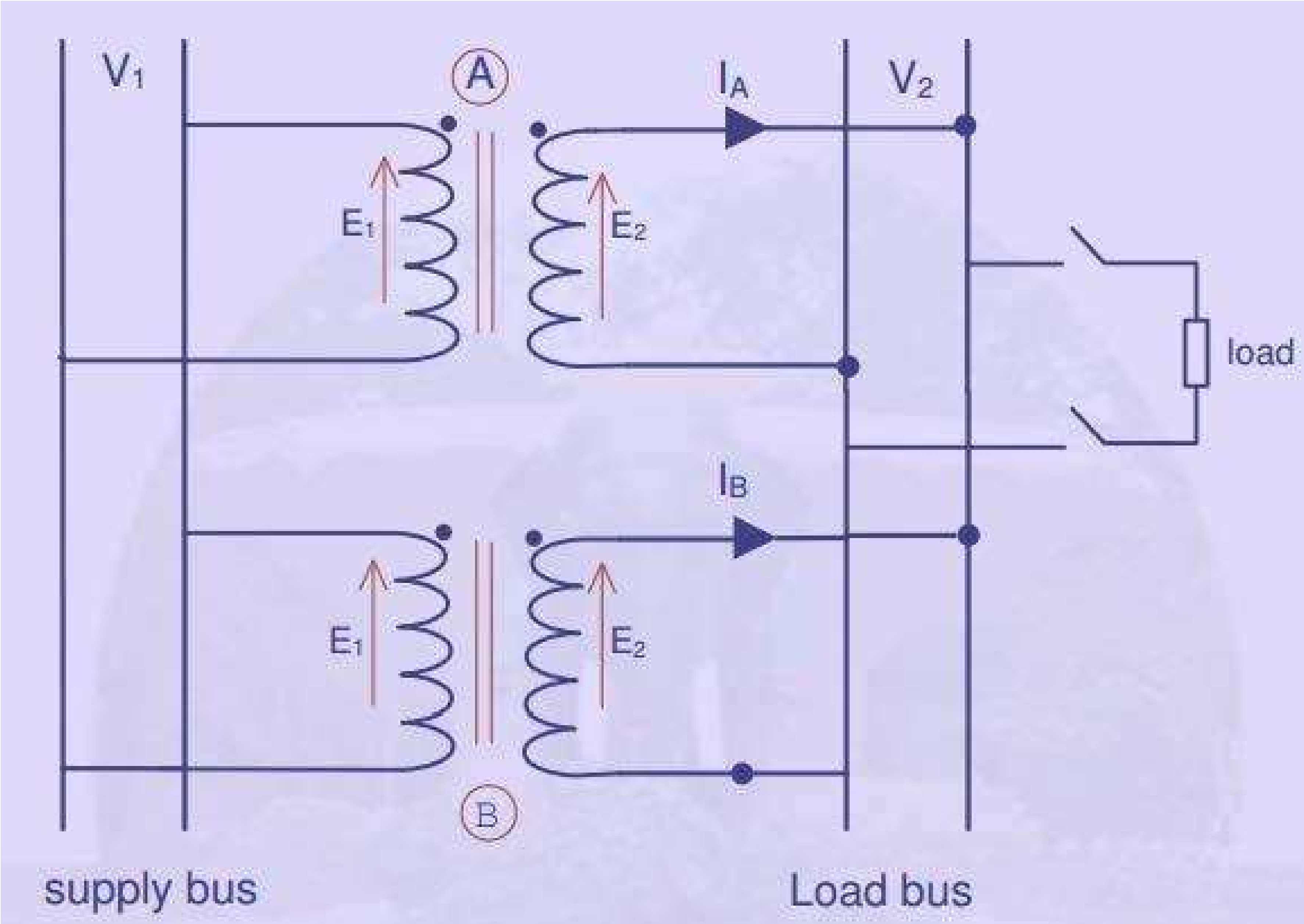
1. Non-availability of a single large transformer to meet the total load requirement.

2. The power demand might have increased over a time necessitating augmentation of the capacity. More transformers connected in parallel will then be pressed into service.

3. To ensure improved reliability. Even if one of the transformers gets into a fault or is taken out for maintenance/repair the load can continued to be serviced.

4. To reduce the spare capacity. If many smaller size transformers are used one machine can be used as spare. If only one large machine is feeding the load, a spare of similar rating has to be available. The problem of spares becomes more acute with fewer machines in service at a location.

5. When transportation problems limit installation of large transformers at site, it may be easier to transport smaller ones to site and work them in parallel.


V1
A
IA
V2
E1
E2
load
IB
E1
E2
B
supply bus
Load bus

Conditions for Parallel operation

1. Primary windings of the transformers should be suitable for the supply system voltage and frequency.
2. The transformers should be properly connected with regard to polarity.
3. The voltage ratings of both primaries and secondaries should be identical. In other words, the transformers should have the same turn ratio *i.e.* transformation ratio.
4. The percentage impedances should be equal in magnitude and have the same X/R ratio in order to avoid circulating currents and operation at different power factors.
5. With transformers having different kVA ratings, the equivalent impedances should be inversely proportional to the individual kVA rating if circulating currents are to be avoided.

(1) is easily comprehended   (2) is absolutely essential