# BASIC ELECTRICAL ENGINEERING

## Module 4
## Scope and Safety measures

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# Topics to be Discussed

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|---|
| Electrical Energy Scenario in India. |
| Single Phase Transformer: Principle and Application. |
| Principle and application of 3-ph and 1-ph Induction Motor. |
| Power ratings of air conditioners, PCs, laptops, printers, refrigerator, washing machine, different lamps, electricity tariff, calculation of electricity bill for domestic consumers. |
| Personal safety measures: Electric Shock, Earthing and its types, Safety Precautions to avoid shock. |
| Working principle of Fuse and Miniature circuit breaker (MCB), Residual Current Circuit Breaker (RCCB) |

Next

# ELECTRICAL ENERGY SCENARIO IN INDIA

- India is the world's third largest producer and third largest consumer of electricity.
- The national electric grid in India has an installed capacity of 408.31 GW as of 31 October 2022.
- Renewable power plants, which also include large hydroelectric plants, constitute 37% of India's total installed capacity. During the fiscal year (FY) 2019-20, the gross electricity generated by utilities in India was 1,383.5 TWh and the total electricity generation (utilities and non utilities) in the country was 1,598 TWh.
- The gross electricity consumption in FY2019 was 1,208 kWh per capita.
- In FY2015, electric energy consumption in agriculture was recorded as being the highest (17.89%) worldwide.
- The per capita electricity consumption is low compared to most other countries despite India having a low electricity tariff.

# ELECTRICAL ENERGY SCENARIO IN INDIA

- **Electricity generation (utility sector) by source in India in FY 2021-2022**

- Coal: 1,078,444 GWh (72.7%)
- Large Hydro: 151,695 GWh (10.2%)
- Small Hydro: 10,463 GWh (0.7%)
- Wind Power: 68,640 GWh (4.6%)
- Solar Power: 73,483 GWh (5.0%)
- Biomass & other RE: 18,324 GWh (1.2%)
- Nuclear: 47,019 GWh (3.2%)
- Gas: 36,143 GWh (2.4%)
- Diesel: 115 GWh (0.0%)

# CLASSIFICATION OF SOURCES OF ENERGY

- Renewable and Nonrenewable source of energy
- Conventional and Nonconventional Source of energy
- Commercial and Non-commercial energy
- Primary and secondary source of energy

# Transformer

- A transformer is a static piece of equipment used either for raising or lowering the voltage of an a.c. supply with a corresponding decrease or increase in current.
- It essentially consists of two windings, the primary and secondary, wound on a common laminated magnetic core.
- The winding connected to the a.c. source is called primary winding (or primary) and the one connected to load is called secondary winding (or secondary).
- The alternating voltage V1 whose magnitude is to be changed is applied to the primary. Depending upon the number of turns of the primary (N1) and secondary (N2), an alternating e.m.f. E2 is induced in the secondary. This induced e.m.f. E2 in the secondary causes a secondary current I2. Consequently, terminal voltage V2 will appear across the load. If V2 > V1, it is called a step up-transformer. On the other hand, if V2 < V1, it is called a step-down transformer.

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## Working

When an alternating voltage $V_1$ is applied to the primary, an alternating flux $\phi$ is set up in the core. This alternating flux links both the windings and induces e.m.f.s $E_1$ and $E_2$ in them according to Faraday's laws of electromagnetic induction. The e.m.f. $E_1$ is termed as primary e.m.f. and e.m.f. $E_2$ is termed as secondary e.m.f.

Clearly, $$E_1 = -N_1 \frac{d\phi}{dt}$$

and $$E_2 = -N_2 \frac{d\phi}{dt}$$

$$\therefore \quad \frac{E_2}{E_1} = \frac{N_2}{N_1}$$

Note that magnitudes of $E_2$ and $E_1$ depend upon the number of turns on the secondary and primary respectively. If $N_2 > N_1$, then $E_2 > E_1$ (or $V_2 > V_1$) and we get a step-up transformer. On the other hand, if $N_2 < N_1$, then $E_2 < E_1$ (or $V_2 < V_1$) and we get a step-down transformer. If load is connected across the secondary winding, the secondary e.m.f. $E_2$ will cause a current $I_2$ to flow through the load. Thus, a transformer enables us to transfer a.c. power from one circuit to another with a change in voltage level.

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The following points may be noted carefully:

(i) The transformer action is based on the laws of electromagnetic induction.

(ii) There is no electrical connection between the primary and secondary. The a.c. power is transferred from primary to secondary through magnetic flux.

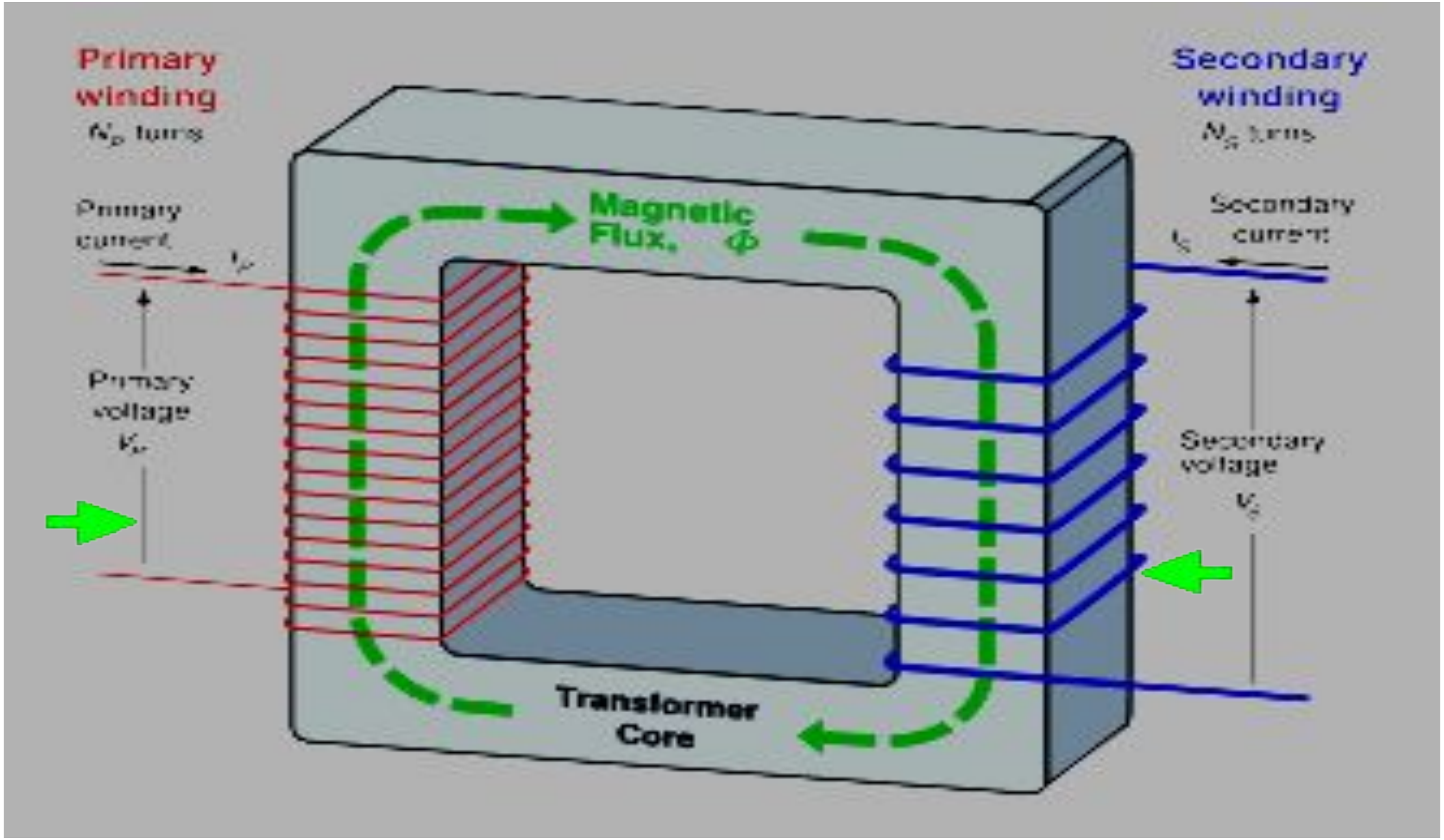
(iii) There is no change in frequency i.e., output power has the same frequency as the input power.

(iv) The losses that occur in a transformer are:

  (a) core losses—eddy current and hysteresis losses

  (b) copper losses—in the resistance of the windings

In practice, these losses are very small so that output power is nearly equal to the input primary power. In other words, a transformer has very high efficiency.



Primary winding
$N_p$ turns
Primary current
$I_p$
Primary voltage
$V_p$
Magnetic Flux, $\Phi$
Transformer Core
Secondary winding
$N_s$ turns
Secondary current
$I_s$
Secondary voltage
$V_s$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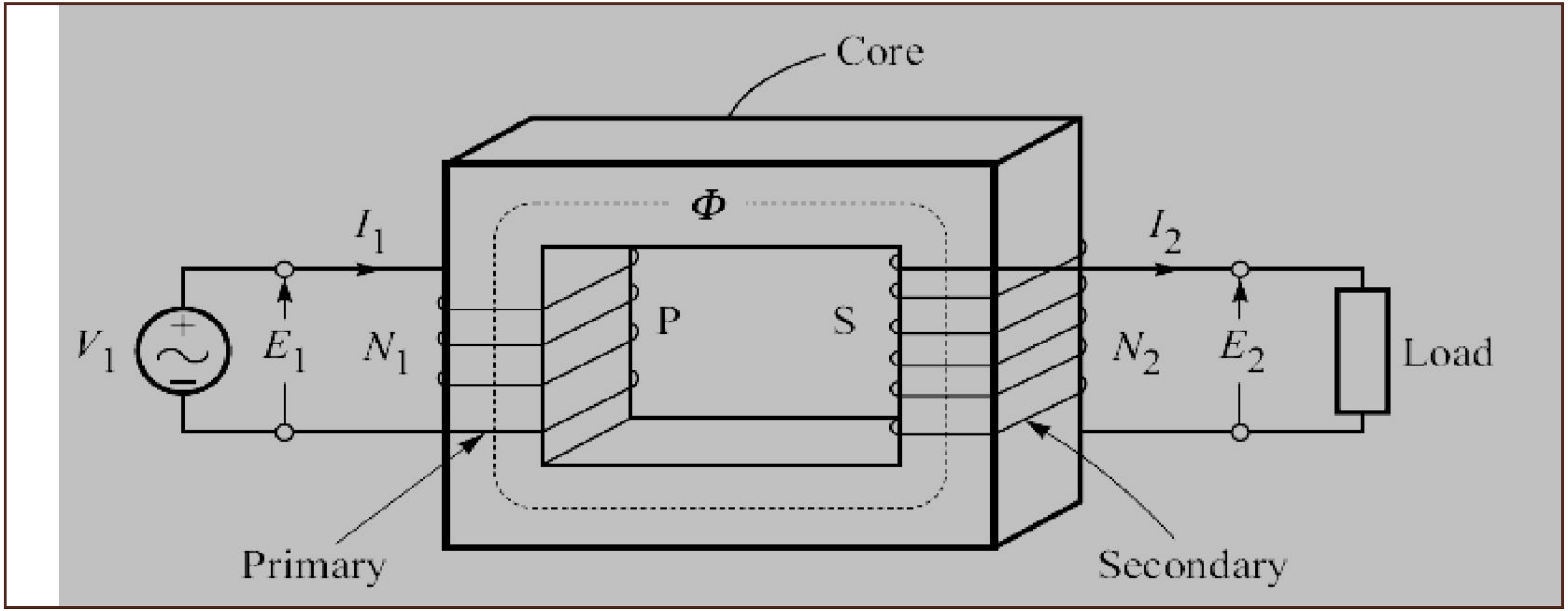


(*a*) Construction.

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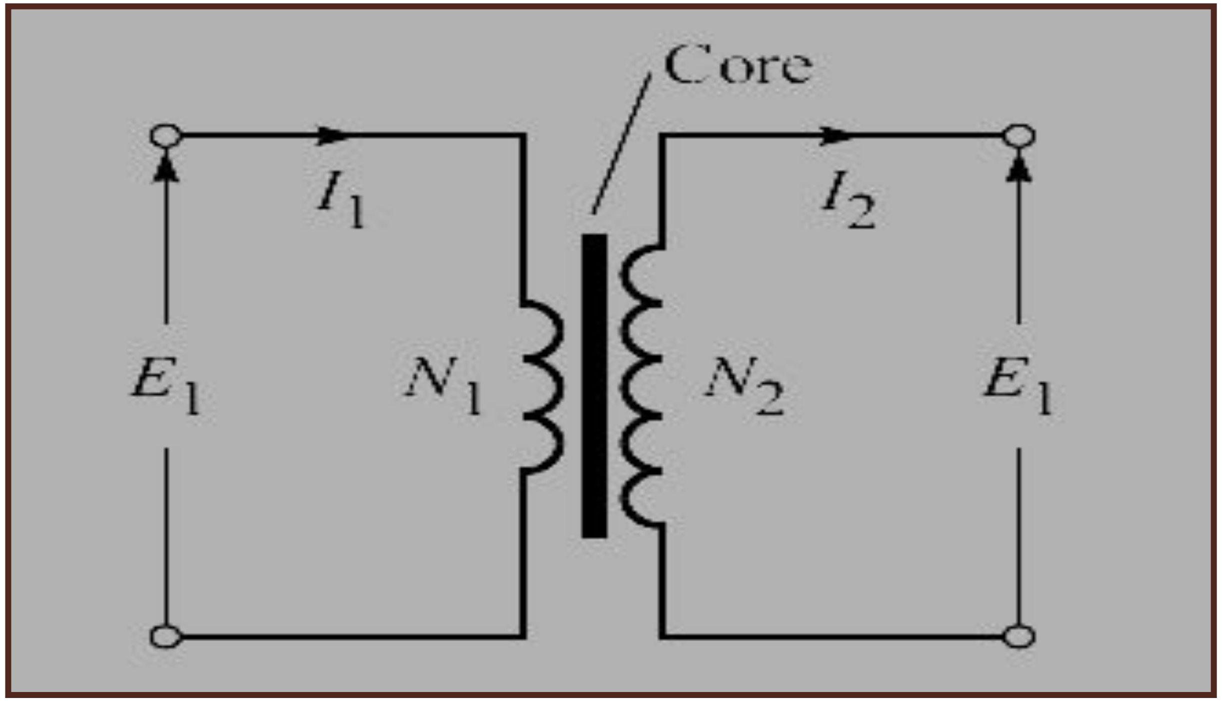


(*b*) Symbol.

- $N_1$ : Number of turns in the Primary
- $N_2$ : Number of turns in the Secondary
- $E_1$ : EMF Induced in the Primary
- $E_2$ : EMF Induced in the Secondary

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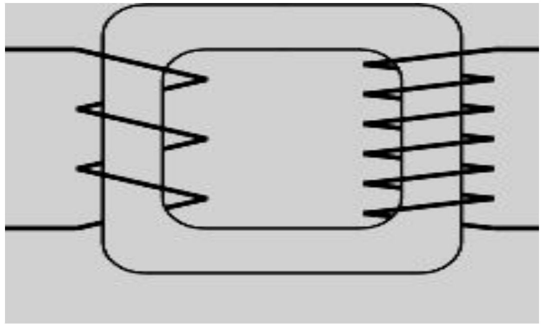
# Step-Up and Step-Down Transformer

If $N_1 < N_2$ ⟹ $E_1 < E_2$ ⟹ Step up



If $N_1 > N_2$ ⟹ $E_1 > E_2$ ⟹ Step down

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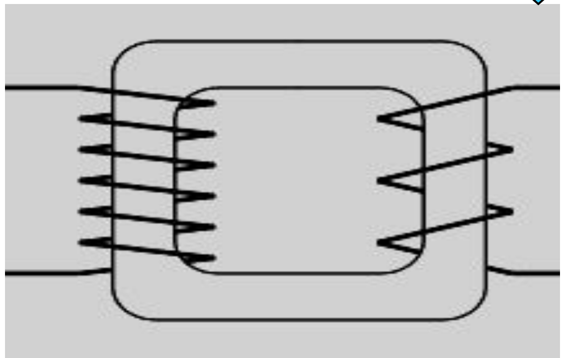

The transformation ratio,

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

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# EMF Equation

Due to the sinusoidally varying voltage $V_1$ applied to the primary voltage, the flux set up in the core,

$$\Phi = \Phi_{\mathrm{m}} \sin \omega t = \Phi_{\mathrm{m}} \sin 2\pi ft$$

The resulting induced emf in a winding of $N$ turns,

$$e = -N \frac{d\Phi}{dt} = -N \frac{d}{dt}(\Phi_{\mathrm{m}} \sin \omega t)$$

$$= -N\omega\Phi_{\mathrm{m}} \cos \omega t = \omega N \Phi_{\mathrm{m}} \sin(\omega t - \pi / 2)$$

Thus, the peak value of the induced emf, $E_m = \omega N \Phi m$.

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Therefore, the rms value of the induced emf *E*,

$$E = \frac{E_{\mathrm{m}}}{\sqrt{2}} = \frac{\omega N \Phi_{\mathrm{m}}}{\sqrt{2}} = \frac{2\pi f N \Phi_{\mathrm{m}}}{\sqrt{2}} = 4.44 f N \Phi_{\mathrm{m}}$$

or $$\boxed{E = 4.44 f N \Phi_{\mathrm{m}}}$$

This equation, known as **emf equation** of transformer.

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# Induction Motors

- Most motors that we see around are induction motors.
- Induction motors
  - are more rugged,
  - need less maintenance,
  - are less expensive.
  - are highly efficient.

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## 8.1 Three-Phase Induction Motor

Like any electric motor, a 3-phase induction motor has a stator and a rotor. The stator carries a 3-phase winding (called stator winding) while the rotor carries a short-circuited winding (called rotor winding). Only the stator winding is fed from 3-phase supply. The rotor winding derives its voltage and power from the externally energized stator winding through electromagnetic induction and hence the name. The induction motor may be considered to be a transformer with a rotating secondary and it can, therefore, be described as a "transformer-type" a.c. machine in which electrical energy is converted into mechanical energy.



### Advantages

(i) It has simple and rugged construction.
(ii) It is relatively cheap.
(iii) It requires little maintenance.
(iv) It has high efficiency and reasonably good power factor.
(v) It has self starting torque.

### Disadvantages

(i) It is essentially a constant speed motor and its speed cannot be changed easily.
(ii) Its starting torque is inferior to d.c. shunt motor.

# Working Principle of 3-Phase Induction motor

Consider a portion of 3-phase induction motor as shown in Fig. (8.13). The operation of the motor can be explained as under:

(i) When 3-phase stator winding is energized from a 3-phase supply, a rotating magnetic field is set up which rotates round the stator at synchronous speed $N_s$ (= 120 f/P).

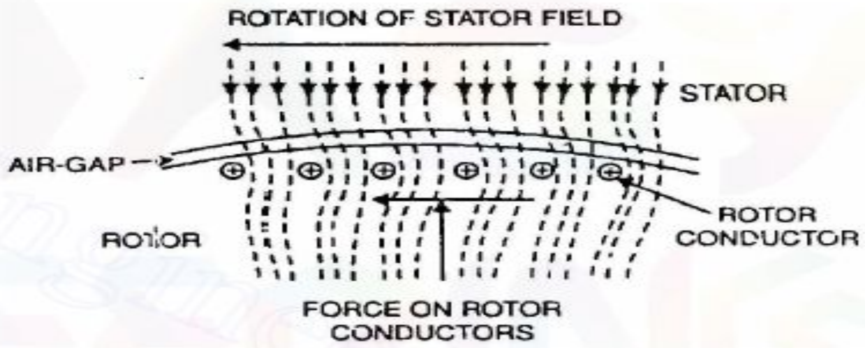

**Fig.(1-)**

(ii) The rotating field passes through the air gap and cuts the rotor conductors, which as yet, are stationary. Due to the relative speed between the rotating flux and the stationary rotor, e.m.f.s are induced in the rotor conductors. Since the rotor circuit is short-circuited, currents start flowing in the rotor conductors.

(iii) The current-carrying rotor conductors are placed in the magnetic field produced by the stator. Consequently, mechanical force acts on the rotor conductors. The sum of the mechanical forces on all the rotor conductors produces a torque which tends to move the rotor in the same direction as the rotating field.

(iv) The fact that rotor is urged to follow the stator field (i.e., rotor moves in the direction of stator field) can be explained by Lenz's law. According to this law, the direction of rotor currents will be such that they tend to oppose the cause producing them. Now, the cause producing the rotor currents is the relative speed between the rotating field and the stationary rotor conductors. Hence to reduce this relative speed, the rotor starts running in the same direction as that of stator field and tries to catch it.

# Single Phase Induction Motors

A single phase induction motor is very similar to a 3-phase squirrel cage induction motor. It has (i) a squirrel-cage rotor identical to a 3-phase motor and (ii) a single-phase winding on the stator.

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# Single Phase Induction Motor Working Principle

Unlike a 3-phase induction motor, a single-phase induction motor is not self-starting but requires some starting means. The single-phase stator winding produces a magnetic field that pulsates in strength in a sinusoidal manner. The field polarity reverses after each half cycle but the field does not rotate. Consequently, the alternating flux cannot produce rotation in a stationary squirrel-cage rotor. However, if the rotor of a single-phase motor is rotated in one direction by some mechanical means, it will continue to run in the direction of rotation. As a matter of fact, the rotor quickly accelerates until it reaches a speed slightly below the synchronous speed. Once the motor is running at this speed, it will continue to rotate even though single-phase current is flowing through the stator winding. This method of starting is generally not convenient for large motors. Nor can it be employed fur a motor located at some inaccessible spot.

# Single Phase Induction Motor Working Principle

Fig. (9.1) shows single-phase induction motor having a squirrel cage rotor and a single-phase distributed stator winding. Such a motor inherently docs not develop any starting torque and, therefore, will not start to rotate if the stator winding is connected to single-phase a.c. supply. However, if the rotor is started by auxiliary means, the motor will quickly attain me final speed. This strange behaviour of single-phase induction motor can be explained on the basis of double-field revolving theory.

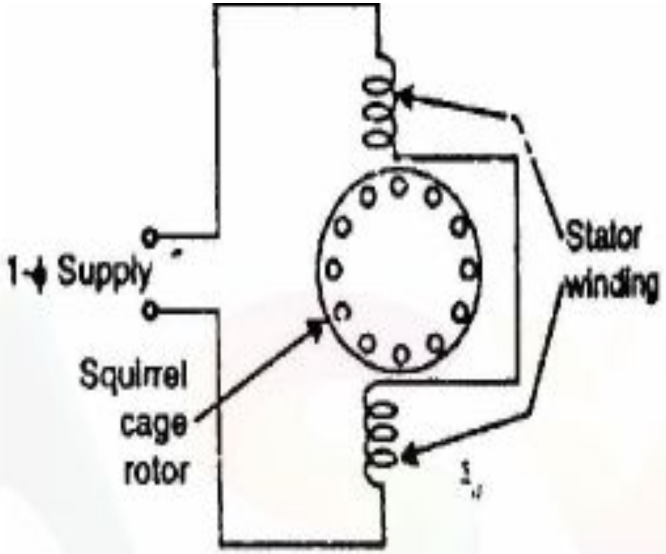


Fig.(9.1)

# Applications of Induction Motors

- Three-phase induction motors are used for high power and industrial applications such as
  - lifts, cranes, pumps, exhaust fans, lathes etc.,
- Single-phase induction motors find use in domestic electric appliances such as
  - fans, refrigerators, washing machines, pumps, hair-driers, etc.

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# Rating of Different Electrical Equipment

## Topics to be Discussed

- Power ratings of air conditioners, PCs, laptops, printers, refrigerator, washing machine, different lamps.

- Electricity tariff.

- Calculation of electricity bill for domestic consumers.

# Power Consumption of Typical home appliances in watt

| .SL NO | ELECTRICAL APPLIANCES | POWER WATTAGE |
|---|---|---|
| 1 | Fan | 80 |
| 2 | LED Light Bulb | 25 |
| 3 | AC – Air Conditioner | 900 |
| 4 | Refrigerator | 250 |
| 5 | Electric Heater | 2000 |
| 6 | Water Heater | 4000 |
| 7 | Hair Dryer | 1500 |
| 8 | Clothes Dryer | 3000 |
| 9 | Clothes Iron | 1400 |
| 10 | Dishwasher | 1300 |
| 11 | Electric Kettle | 1700 |
| 12 | Toaster Oven | 1100 |
| 13 | Microwave Oven | 1000 |
| 14 | Desktop Computer | 150 |
| 15 | Laptop Computer | 100 |
| 16 | TV – Television | 120 |
| 17 | Stereo Receiver | 300 |
| 18 | Vacuum Cleaner | 1200 |
| 19 | Washing Machine | 1500 |
| 20 | Coffee Machine | 1000 |
| 21 | Blender | 500 |
| 22 | Water Pump | 800 |
| 23 | Sewing Machine | 100 |

# Electricity Tariff

- The amount of money frame by the supplier for the supply of electrical energy to various types of consumers in known as an electricity tariff.
- In other words, the tariff is the methods of charging a consumer for consuming electric power. The tariff covers the total cost of producing and supplying electric energy plus a reasonable cost.
- The actual tariffs that the customer pay depends on the consumption of the electricity. The consumer bill varies according to their requirements. The industrial consumers pay more tariffs because they use more power for long times than the domestic consumers. The electricity tariffs depends on the following factors
- Type of load
- Time at which load is required.
- The power factor of the load.
- The amount of energy used.

# Calculation of Electricity bill for domestic consumers

**E = P*(t/1000)**; where E = energy measured in Joules or kilowatt-hours (kWh), P = power units in watts, and t = time over which the power or energy was consumed.

Electrical Energy=KW*Hour

1 KWh=1Unit

**Electric Utility Bill Calculation**

**Calculation of Electric Energy Consumption**

The following formula is used for electrical energy consumption.

**E = P x t in watt hour (Wh)**

**E = (P x t) ÷ 1000 in watt hour (kWh)**

**Consumed Energy = Energy Used in Watts x Time in Hours**

Where:

E = Electrical Energy (Consumed in kWh)

P = Power in Watts

t = Time in hours per day

# Calculation of Electricity bill for domestic consumers

**Example:**

Suppose, a consumer consumes 1000 watts load per hour daily for one month. Calculate The Total Energy bill of the consumer if per unit rate is 9 [Take 1 month = 30 Days.

**Solution:**

1 Unit = 1kWh.

So the Total kWh = 1000 Watts x 24 Hrs x 30 Days = 720000 … Watts / hour.

We want to convert it into electric units, Where 1 Unit = 1kWh.

So the total consumed units by user: = 720000 / 1000 … (k = kilo =1000).

**Total Consumed Units = 720.**

The cost of per unit electricity is 9.

Therefore, the total Cost of Electricity Bill = 720 units x 9 = 6480/-

# Personal safety measures: Electric Shock and Safety Precautions to avoid shock.

- Power equipment should be plugged into wall receptacles with power switches in the off position.
- Electrical equipment should be unplugged by grasping the plug and pulling. Never pull or jerk the cord to unplug the equipment.
- Frayed, cracked or exposed wiring on equipment cords must be corrected. Also check for defective cord clamps at locations where the power cord enters the equipment or the attachment plug.
- Cheater plugs, extension cords with junction box receptacle ends or other jury-rigged equipment should not be used.
- Temporary or permanent storage of materials must not be allowed within 3 feet of an electrical panel or electrical equipment.
- Any electrical equipment causing shocks or which has high leakage potential must be tagged with a “DANGER— DO NOT USE” label or equivalent.

# Earthing and its types

**EARTHING**

Earthing or grounding means connecting the non-current carrying metallic parts of electrical appliances or the neutral of a supply system to the earth. The connection to earth may be through a conductor or other circuit elements.

Earthing can be divided into neutral earthing and equipment earthing. Neutral earthing deals with the earthing of system neutral to ensure system security and protection. Equipment earthing deals with earthing of non-current carrying parts of the equipment to ensure safety of personnel and protection against lightning.

# Earthing and its types

The various types of earthing are the following:

a. Earthing through the water mains
b. Strip or wire earthing
c. Rod earthing
d. Pipe earthing
e. Plate earthing

Using water mains for earthing is not normally advised since it requires an iron water pipe, which ensure electrical continuity. Wire or strip earthing is employed in rocky soils. Rod winding though cheap is suitable for sandy soils. Common methods for earthing are pipe and plate methods.

# Earthing and its types

Earthing is required for following reasons:

a. To ensure that the potential, with respect to the earth, of any current carrying conductor does not rise above its designed insulation level.
b. To avoid shocks to a living body.
c. To provide safety to operating and maintenance personnel.
d. To avoid fire hazards due to earth leakage current.

Relevant specifications are the following:

a. The minimum distance of the earthing electrode from the building whose installation is being earthed shall be 1.5m.
b. The ECC(Earth Continuity Conductor) should not be less than $2.9mm^2$ or half of the installation conductor size.
c. The earth resistance should be sufficiently low to allow adequate flow of earth leakage current to operate the protective relays or blow out the fuse.

# COMPONENTS OF LT SWITCHGEAR

- **Switch Fuse Unit(SFU)**

- There is no separate switch and fuse unit. There is only the fuse unit which itself acts as a switch.
- When we operate it the fuse unit will close the input and output of the breaker. SFU has been used to trip the circuit, particularly for high capacity tripping.

# COMPONENTS OF LT SWITCHGEAR

- **Miniature Circuit Breaker (MCB)**
- A miniature circuit breaker (MCB) automatically switches off electrical circuit during an abnormal condition of the network means in overload condition as well as faulty condition.
- Nowadays we use an MCB in low voltage electrical network instead of a fuse.
- Handling an MCB is electrically safer than a fuse.
- Quick restoration of supply is not possible in case of a fuse as because fuses must be rewirable or replaced for restoring the supply. Restoration is easily possible by just switching it ON.

# COMPONENTS OF LT SWITCHGEAR

## Residual Current Circuit Breaker (RCCB)

- A Residual Current Circuit Breaker (RCCB) is an important safety measure when it comes to protection of electrical circuits. It is a current sensing device, which can automatically measure and disconnect the circuit whenever a fault occurs in the connected circuit or the current exceeds the rated sensitivity.

- Aimed at protecting an individual from the risk of electric shocks as well as electrocution and fires, RCCB is particularly helpful in instances of sudden earth fault. The presence of RCCB ensures that in such cases, the circuit will trip immediately and the person is thus protected from an electric shock.

# COMPONENTS OF LT SWITCHGEAR

## Principle Behind Residual Current Circuit Breaker (RCCB)

- RCCB works on the principle of Kirchhoff's law, which states that the incoming current must be equal to the outgoing current in a circuit.
- RCCB thus compares the difference in current values between live and neutral wires. Ideally, the current flowing to the circuit from the live wire should be the same as that flowing through the neutral wire. In case of a fault, the current from the neutral wire is reduced, the differential between the two known as Residual Current. On spotting a Residual Current, the RCCB is triggered to trip off the circuit.
- A test circuit included with the Residual Current device ensures that the reliability of RCCB is tested. When the test button is pushed, the current starts to flow through the test circuit.
- As it creates an imbalance on the neutral coil of the device, the RCCB trips and supply is disconnected thereby checking RCCB's reliability.