Mr.Arup Kumar Majee, Principal
Jnan Chandra Ghosh Polytechnic

11/04/2020

Chapter 1

Electrical Machines

1.1 Classification of Electrical Machines

Electrical machines can be broadly classified as:

- Static machine: Transformer: This is a static device which consists of two windings interlinked by a common magnetic circuit for the purpose of transferring electrical energy between them.
- Rotating machines: This type of electrical machines comprises of a stationary part called *stator* and a rotating part called *rotor*.
  Rotating machines may be classified in following ways:

Based on Energy Conversion

- Generators: This rotating machine converts mechanical energy into electrical energy.
- Motors: This rotating machine converts mechanical energy into electrical energy.

Based on Supply System

- DC Machines: This rotating machine operates on DC form of electrical energy.
  - Series connected Machines: In this type of rotating DC machines, field winding and armature winding are connected in series.
  - Shunt connected Machines: In this type of rotating DC machines field winding and armature winding are connected in parallel.
  - Compound Machines: In this type of rotating DC machines two field windings are present. One is connected in series and another is connected in parallel with the armature winding.
- AC Machines: This rotating machine operates on AC form of electrical energy. AC machines may further be classified as:
  - Synchronous Machines: In this type of rotating AC machines, magnetic field and the rotor rotates at the same speed called synchronous speed.
  - Asynchronous Machines: In this type of rotating AC machines, magnetic field and the rotor do not rotate at the same speed i.e. synchronous speed. They are popularly known as induction machines. Depending on the rotor structure they are further classified as:
    - Squirrel cage rotor induction machine: In this type of induction machine, the rotor does not carry a conventional winding, it has copper bars shorted by end-rings forming a squirrel cage like shape.
      This motor is quite simple but rugged and possesses high overload capacity. It has a nearly constant speed and poor starting torque.
    - Slip-ring induction machine: In this type of induction machine, both the stator and rotor carry windings. It is also known as wound rotor induction machine.

  AC machines may further be classified as:
  - Three phase Machines: This type of rotating AC machines operates on three phase power supply.
  - Single phase Machines: This type of rotating AC machines operates on single phase power supply.

Special motors

There are some other motors which are frequently used in our daily life. For example: AC series motor, universal motor, repulsion motor, linear induction motor, servo motor, stepper motor etc.

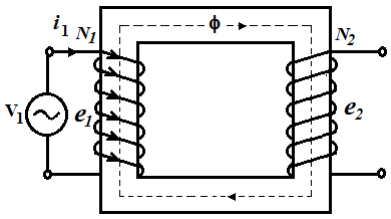
1.2 Transformer

Transformer is an AC static device working on the Faraday's laws of electromagnetic induction and used to step-up or step- down the voltage level. Frequently used transformers are either single phase or three phase. A single-phase transformer comprises of two or more windings magnetically coupled through a common magnetic circuit. One of two windings of a single phase transformer is connected to the AC supply is called the primary winding and the other one which supplies the load is called the secondary winding.

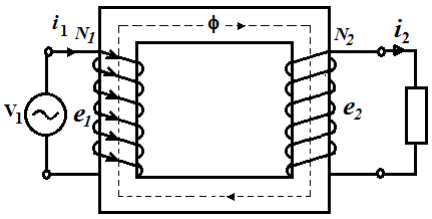
Working principle of transformer: The basic principles on which a transformer works are the Faraday's laws of electromagnetic induction. A single phase transformer consists of two coils electrically isolated but magnetically coupled. They are wound on the same magnetic core. The coil which is connected to an a.c. supply is called the primary winding and the other is called secondary winding. When a.c. supply V_1 is switched on, an alternating current i_1 flows into the primary winding, establishing an alternating flux ϕ in the core which also links the secondary winding. Thus, emfs e_1 and e_2 are induced both in primary and secondary winding having number of turns N_1 and N_2 respectively.

$$e_1 = -N_1 \frac{d\phi}{dt}$$
$$e_2 = -N_2 \frac{d\phi}{dt}$$
$$\frac{e_1}{e_2} = \frac{E_1}{E_2} = \frac{N_1}{N_2}$$

where E_1 and E_2 are rms values of induced emfs in primary and secondary winding respectively.



(a) No Load



(b) On load

If a load is connected in the secondary, e_2 will drive a current i_2 through the load. Thus the electrical power is getting transferred from the primary side to secondary side through mutual induction.

Applications of transformer: Transformers are often used to step up and step down the supply voltage and provide electrical isolations.

1. They are used at power stations to step up the generated voltage to transmission level. They are called **power transformers**.
2. They are used at customer end to step down the transmission level voltage to distribution level. These are called **distribution transformers**.
3. They are used in DC supplies, UPS, SMPS etc. to step down the supply voltage and provide electrical isolation.
4. When the voltage or current level is too high to measure, potential transformer or current transformers are used to step down them to measurable level. These are called **instrumentation transformers**.

Autotransformer

This is a special transformer having single winding. This is popularly known as VARIAC, variable AC supply. Stepping up and down is possible using this type of transformer but no electrical isolation may be obtained. Because of their lesser cost, smaller size and lighter weight, they are often used in laboratories to obtain a variable AC supply from a fixed AC supply.

1.3 Generators

This rotating electrical machine converts mechanical energy into electrical energy working on the basis of Faraday's Laws of Electromagnetic induction. The direction of generated voltage can be determined by Flemming's right hand rule. Depending on the generated output they are classified into DC generators and AC generators.

1.3.1 DC generators

1.3.2 AC generators

AC generators or alternators are further classified into

Synchronous generators:

They are used in all conventional power stations i.e. thermal and hydel. Depending on the rotor structure they are further classified into

Non-salient pole synchronous generators: They have rotors of smaller diameter and longer length and run at a very high speed (1500r.p.m. or 3000r.p.m.). They are used in thermal power stations.

Salient pole synchronous generators: They have rotors of larger diameter and shorter length and run at a low speed (250r.p.m. or 500r.p.m.). They are used in hydro-power stations.

Asynchronous (or induction) generators:

These are commonly used in harnessing wind power. They suffer from one major disadvantage. Reactive power has to be supplied to them.

1.4 Motors

This rotating electrical machine converts electrical energy into mechanical energy working on the basis of Faraday's Laws of Electromagnetic induction. The direction of rotation can be determined by Flemming's left hand rule.

1.4.1 DC motors

1.4.2 AC motors

Synchronous motors

Asynchronous motors (Induction motors)

1.5 Field of Applications

DC series motors have high starting torque and variable speed, they are used for heavy duty applications such as electric locomotives, steel rolling mills, hoists, lifts and cranes.

DC shunt motor is used for driving constant speed line shafts, lathes, vacuum cleaners, wood-working machines, laundry washing machines, elevators, conveyors, grinders and small printing presses etc.

Cumulative compound motor is a varying speed motor with high starting torque and is used for driving compressors, variable head centrifugal pumps, rotary presses, circular saws, shearing machines, elevators and continuous conveyors etc.

Because its speed remains constant under varying loads, 3-phase synchronous motor is used for driving continuously operating equipment at constant speed such as ammonia and air compressors, motor generator sets, continuous rolling mills, paper and cement industries.

Squirrel cage induction motor is used for low and medium power drives where speed control is not required as for water pumps, tube wells, lathes, drills, grinders, polishers, wood planers, fans, blowers, laundry washing machines and compressors etc.

Single Phase Series Motor possesses high starting torque and its speed can be controlled over a wide range. It is generally used for driving small domestic appliances like refrigerators and vacuum cleaners etc.

Repulsion motor is commonly used for drives which require large starting torque and adjustable but constant speed as in coil winding machines. Capacitor-start induction-run motor has fairly constant speed and moderately high starting torque. It is generally used for compressors, refrigerators and small portable hoists.

Capacitor Start And Run Motor has better power factor and higher efficiency. Hence, capacitor-start-and-run motors are commonly used for drives requiring quiet operations.

- A d.c. generator works on the principle of **Fleming's Right hand rule** whereas a d.c. motor works on the principle of **Fleming's Left hand rule**.
- A d.c. generator converts mechanical energy into electrical energy whereas d.c. motor converts electrical energy into mechanical energy.

DC generator	
It converts mechanical power into d.c. electric power.	It co
It requires commutators and brushes to convert induced a.c. armature current into d.c.	No conversion i
Presence of commutators and brushes leads to frequent maintenance problem and reduced life.	Absence of commutators

Characteristic	DC motor	AC motor
Supply system	DC	AC

- In a d.c. generator, armature voltage or generated voltage is greater than the terminal voltage whereas in a d.c. motor, armature voltage or back emf is less than the terminal voltage.