

Evaluation (English):

A "closed book" examination.

You cannot have in your possession or use: books, notes or paper.

The time allocated for the examination is 2 hours.

Only calculator will be permitted

L'épreuve surveillée est (en anglais) , sans document et avec calculatrice et d'une durée de 2 heures.

Electrotechnics – HEI 3

Electrotechnical courses Part 2

contents

Fundamentals of electrical machines..

DC machines

Synchronous machines..

Induction machines .

Selecting Electric Motors..

Power Electronic Systems .

Electric drives .

CHAPTER ONE

Learning outcomes

- State the principle by which machines convert mechanical energy to electrical energy.
- Discuss the operating differences between different types of generators and motors.
- Understand the principle of dc generator and dc motors.

Advantages of Using Electrical Motors

- Economical Operation: can work continuously
- Efficient: efficiency ranges from 65 to 95 percent
- Long Life: 20 to 30 years with proper care
- Ease of Operation: special skills not required
- Safe: if properly used
- Quiet Operation: when properly applied and installed
- Automation: can be automatically and remotely controlled
- Adaptable: light, compact, easily moved
- Available: standard bases, sizes, wiring equipment, etc.

Basic principles of operation of electrical machines

Two related physical principles underline the operation of generators and motors.

1. The first is the principle of electromagnetic induction discovered by Michael Faraday

If a conductor is moved through a magnetic field, a current is set up or induced in the conductor

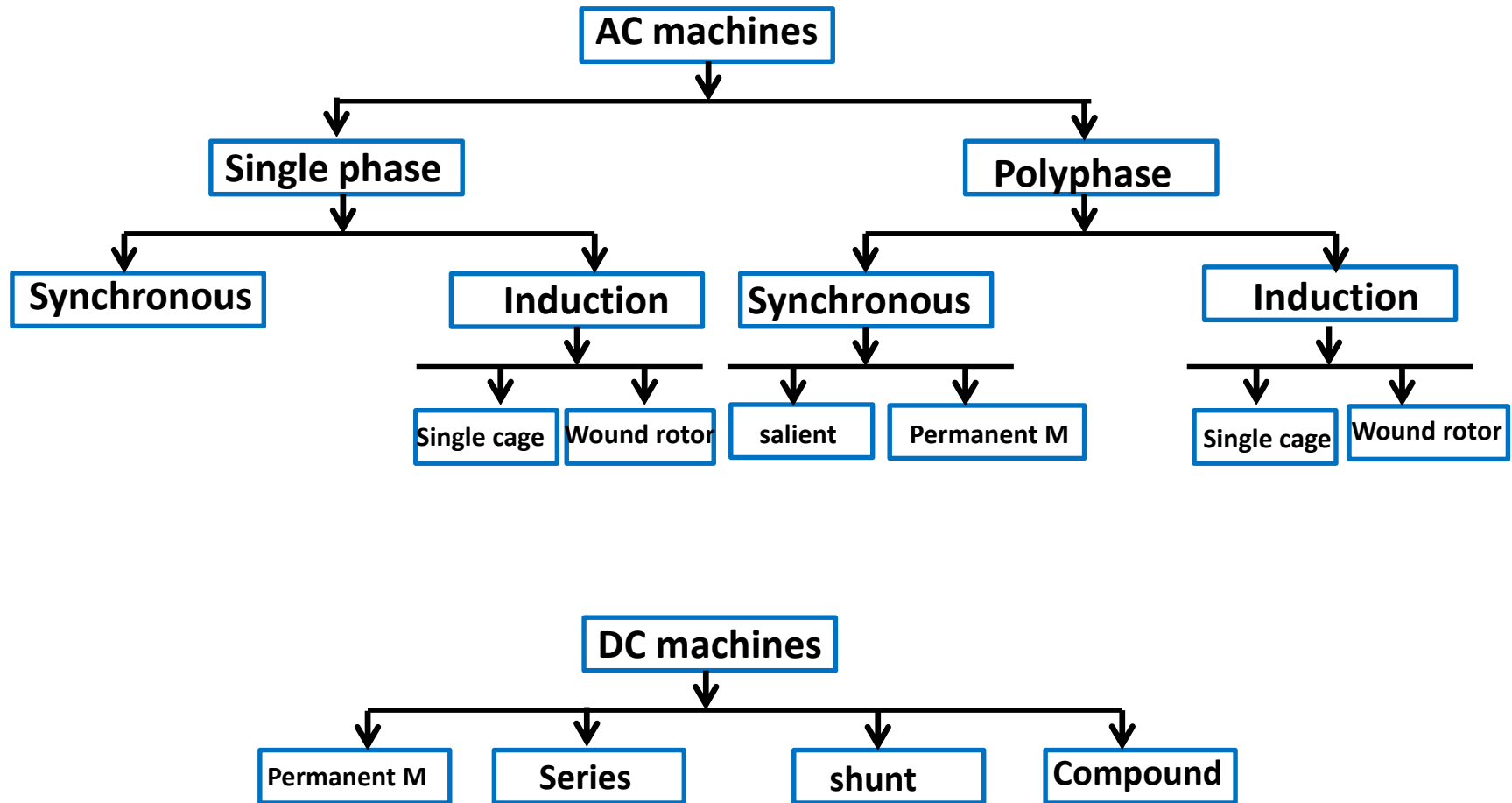


2. The converse of this principle of the electromagnetic reaction, first discovered by André' Ampere.

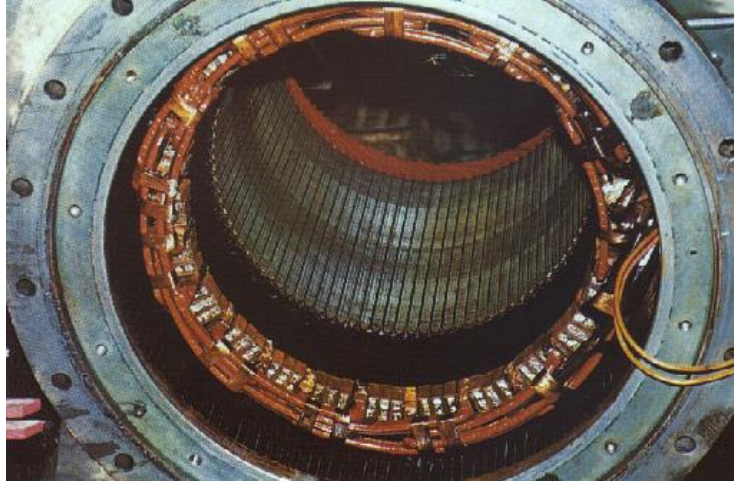
If a current is passed through a conductor located in a magnetic field, the field exerts a mechanical force on it.



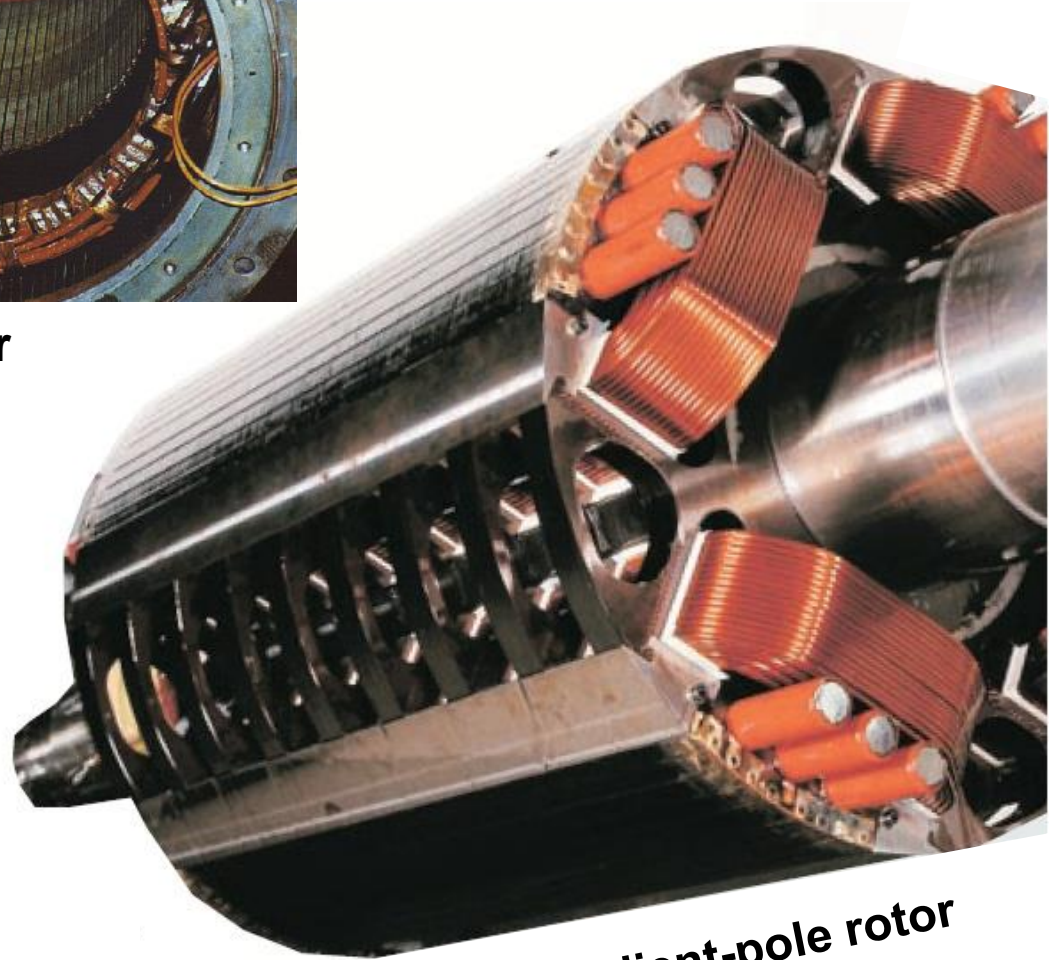
Classification of electrical machines



CONSTRUCTION

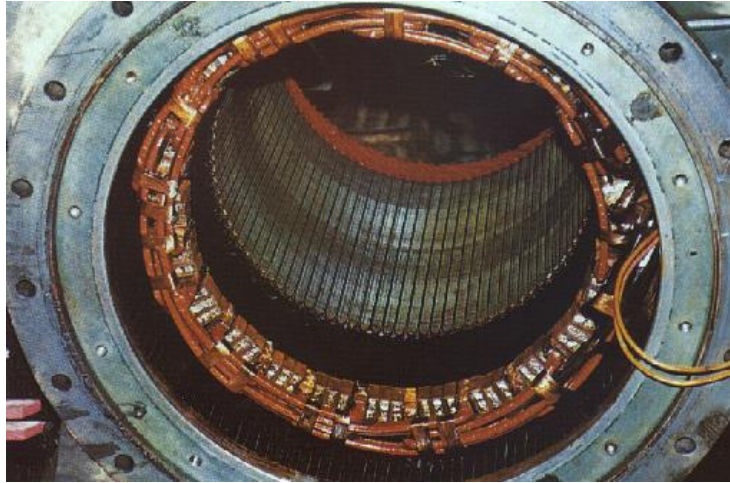


▪ Stator

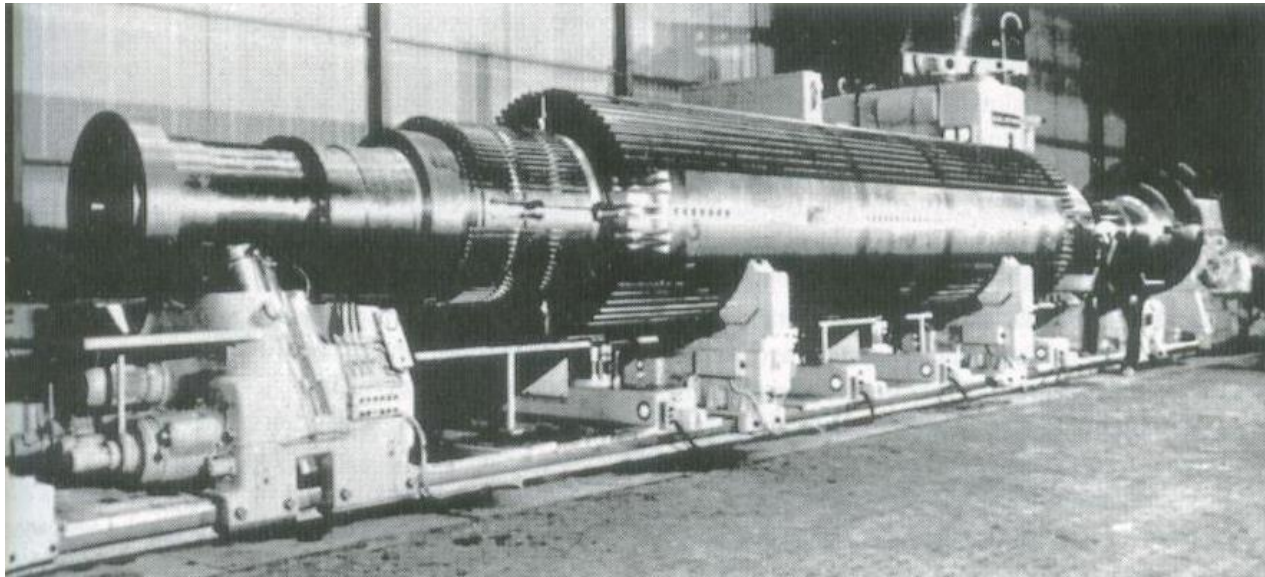


▪ Salient-pole rotor

Cylindrical-Rotor Synchronous Generator



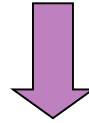
■ Stator



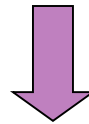
■ Cylindrical rotor

Operation Principle

The rotor of the generator is driven by a prime-mover



A dc current is flowing in the rotor winding which produces a rotating magnetic field within the machine



The rotating magnetic field induces a three-phase voltage in the stator winding of the generator

Production of induced force on a wire.

A current carrying conductor present in a uniform magnetic field of flux density B , would produce a force to the conductor/wire

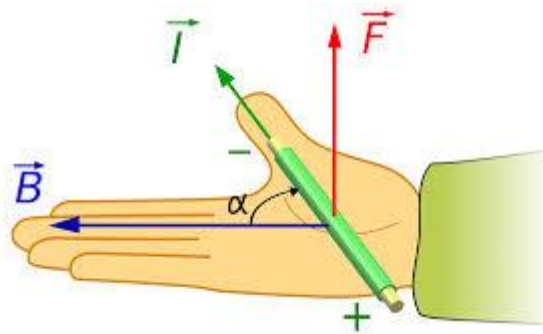
$$F = i \times (l \times B)$$

i – Represents the current flow in the conductor

l – Length of wire, with direction of l defined to be in the direction of current flow.

B – Magnetic field density

Right-hand rule for determining the direction magnetic-field component of the Lorentz force

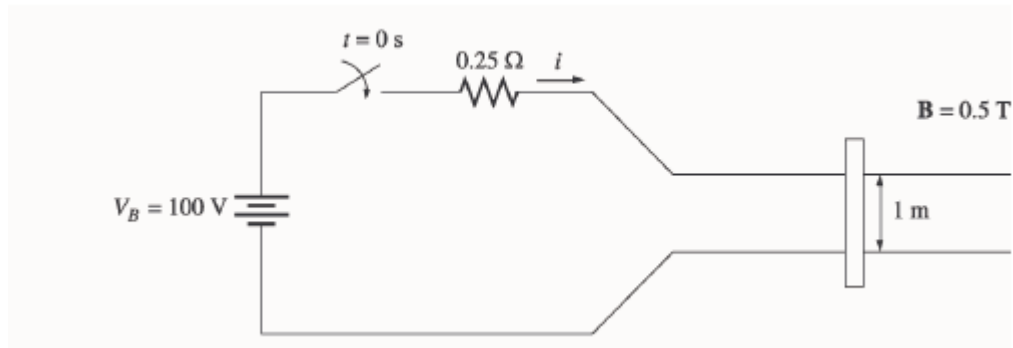


The linear DC motor

The DC linear machine is a fairly simple device

It can be used as a motor or a generator,

Diagram of circuit



How it works?

- The DC source supplies a voltage to produce current through the wires in the circuit.
- The resistor helps to reduce the voltage from the source, so that the circuit is more stable and doesn't overheat.
- The track or the bar that is in the magnetic field is the object or load that moves down the pair of conducting wires.
- The force induced is caused by electrical current perpendicular to the magnetic field.
- The direction, in which the bar moves, is dependent on which direction the magnetic field is and the current direction.

Equations

Force on a wire in a magnetic field: $F = i.(l \times B)$

Voltage induced on the wire: $e_{ind} = (v \times B).l$

Kirchhoff's voltage law yields: $V_B = e_{ind} + Ri$

Newton's law: $F = ma$

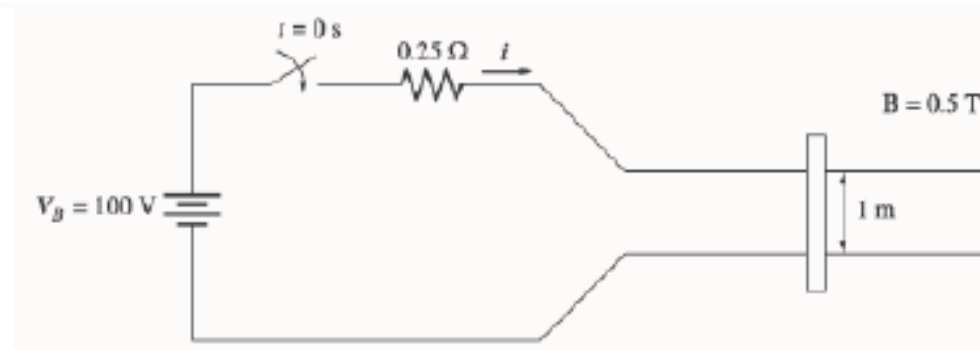
The speed of the bar moving $v_s = \frac{e_{ind}}{B.l}$

Exercise 1. A linear machine has a magnetic flux density of 0.5 T directed into the page, a resistance of 0.25Ω , a bar length $l = 1.0 \text{ m}$, and a battery voltage of 100 V.

(a) What is the initial force on the bar at starting? What is the initial current flow?

(b) What is the no-load steady-state speed of the bar?

(c) If the bar is loaded with a force of 25 N opposite to the direction of motion, what is the new steady state speed? What is the efficiency of the machine under these circumstances?



Solution

(a) The current in the bar at starting is

At $t = 0 \text{ sec} \rightarrow v_s = 0 \rightarrow e_{ind} = 0$. Therefore $V_B = RI_{start}$

$$I_{start} = \frac{V_B}{R} = \frac{100}{0,25} = 400 A$$

Therefore, the force on the bar at starting is:

$$F_{start} = I_{start}(l \times B) = 400 \times (1 \times 0,5) = 200 Nm, \text{ to the right}$$

(b) The no-load steady-state speed of this bar can be found from the equation

$$I_0 \cong 0 \rightarrow RI_0 \ll e_{ind} \rightarrow V_B \cong e_{ind} \quad V_B = e_{ind} = v_s \times B \times l \rightarrow v_s = \frac{V_B}{B \times l} = \frac{100}{0.5 \times 1} = 200 \text{ m/sec}$$

(c) With a load of 25 N opposite to the direction of motion, the steady-state current flow in the bar will be given by:

$$I_L > I_0$$

$$F_{app} = F_{ind} = I_L \times l \times B \rightarrow I_L = \frac{F_{app}}{l \times B} = \frac{25}{1 \times 0.5} = 50 \text{ A}$$

The induced voltage in the bar will be:

$$e_{ind} = V_B - RI = 100 - 0.25 \times 50 = 87.5 \text{ V}$$

And the velocity of the bar will be:

$$v_s = \frac{e_{ind}}{B \times l} = \frac{87.5}{0.5 \times 1} = 175 \text{ m/sec}$$

The input power to the linear machine under these conditions is:

$$P_{in} = \bar{V}_B \times I = 100 \times 50 = 5000 \text{ W}$$

The output power from the linear under these conditions is:

$$P_{out} = e_B \times I = 87.5 \times 50 = 4375 \text{ W}$$

Therefore, the efficiency of the machine under these conditions is:

$$\eta = \frac{P_{out}}{P_{in}} \times 100 \qquad \eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{4375}{5000} \times 100 = 87,5\%$$

Angular position, θ

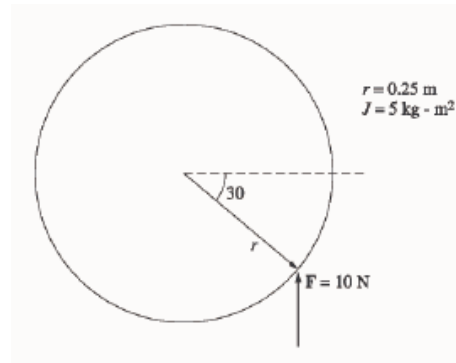
Angular speed, Ω $\Omega = \frac{d\theta}{dt} (\text{rad / sec})$

Torque, T (Nm) $T_{\text{ind}} = r \times F \times \sin \theta$

Work, W $W = \int T \times d\theta$ $W = T \times \theta$

Power, P $P = \frac{dW}{dt} = \frac{d(T\theta)}{dt} = T \frac{d(\theta)}{dt} = T \times \Omega$

Exercise 2 A force of 10 N is applied to a cylinder, as shown in Figure 3. What are the magnitude and direction of the torque produced on the cylinder?



SOLUTION: The magnitude and the direction of the torque on this cylinder is:

$$T_{ind} = r \times F \times \sin \theta = (0,25m) \times (10N) \times \sin 120^\circ = 2,16Nm$$

The triangle is a 30-60-90, so the θ needed for the calculation will be $180^\circ - 60^\circ = 120^\circ$

Review

Q1. What are the three basic types of ac motors?

R1. Universal motors, synchronous, induction

Q2. Universal motors are generally used to operate what type of equipment?

R2. To power small appliances

Q3. Why we call universal motors?

R3. They operate on either ac or dc.

Q4. What determines the number of field poles required to establish a rotating magnetic field in a multiphase motor stator?

R4. The number of phases in the applied voltage

Q5. What is the angular displacement between field poles in a two-phase motor stator?

R5. 90°

Q6. What is the major difference between a two-phase and a three-phase stator?

R6. Number and location of field poles

Q7. What requirement is the synchronous motor specifically designed to meet?

R7. Constant speed required by some loads

The End