CHAPTER FIVE

Selecting Electric Motors

Learning Outcomes:

Discuss the basic types of electric motors and their differences

Identify and describe the different types of motor enclosures.

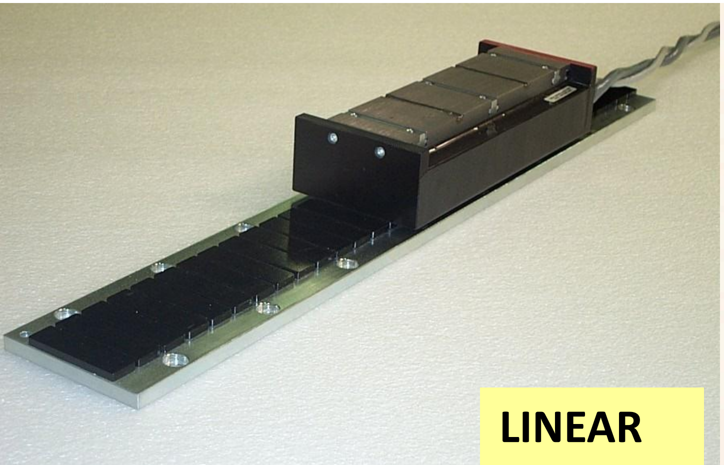
Describe the proper maintenance and care principles for electric motors.

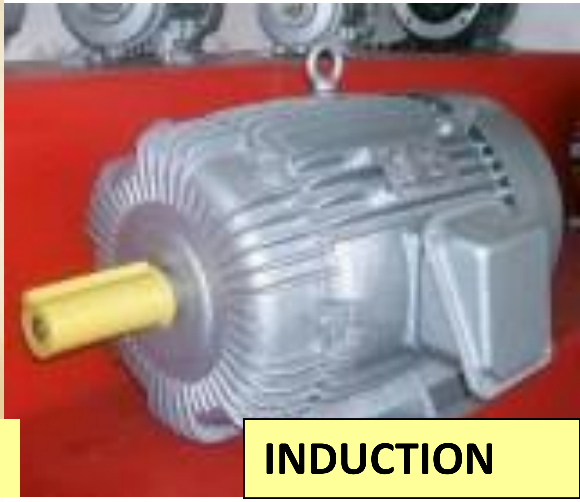
The Purpose of this chapter is to:

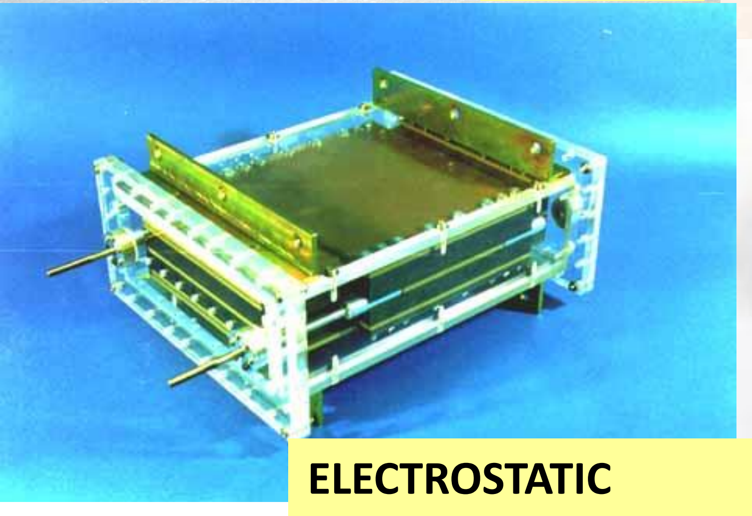
- Show what types of motors are available
- Give brief descriptions of how these motors work and when they are used
- Identify design parameters to consider when selecting a motor

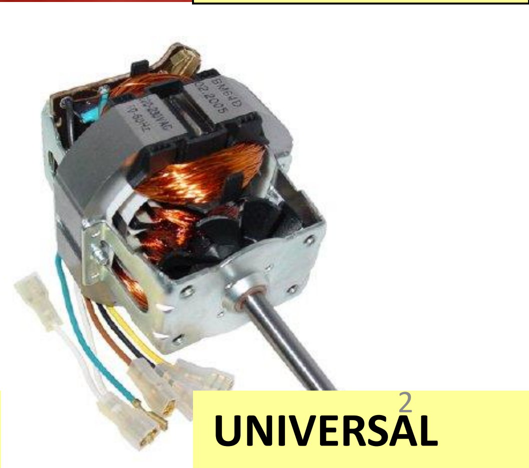
Motors

- Motors convert electrical energy to mechanical energy
- Motors make things move





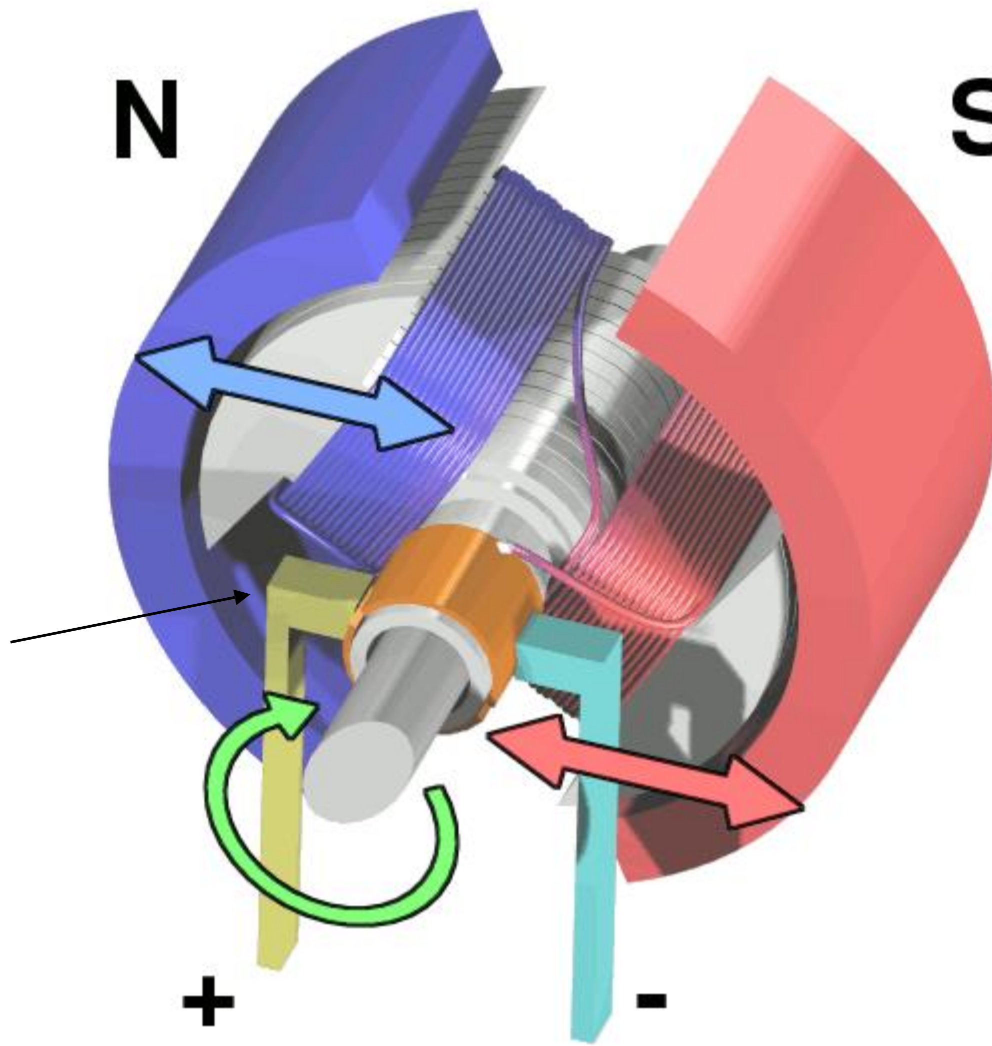




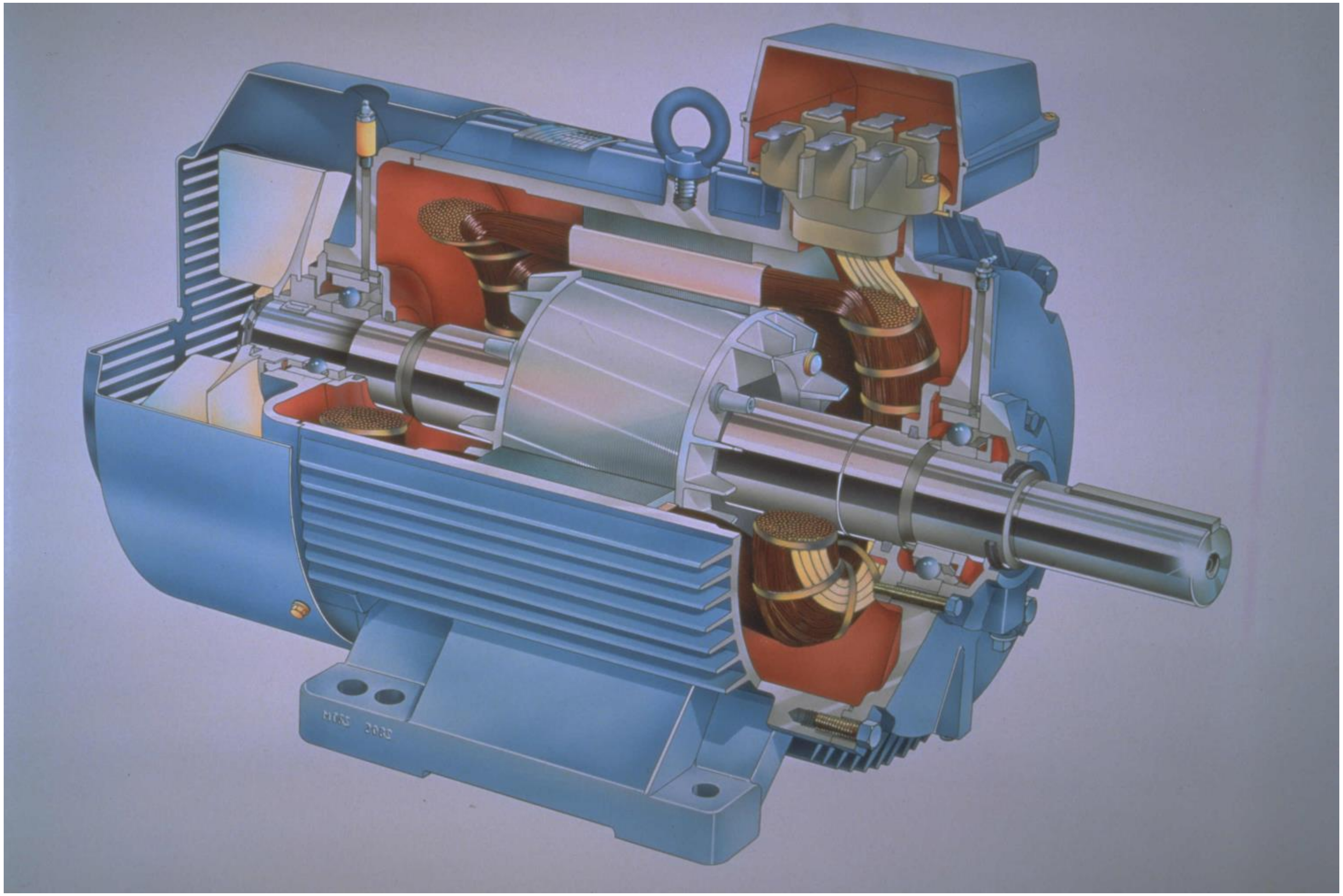
What are the basic types of electric motors and how are they different?

How a DC Motor Works

Brushes



Induction Motors

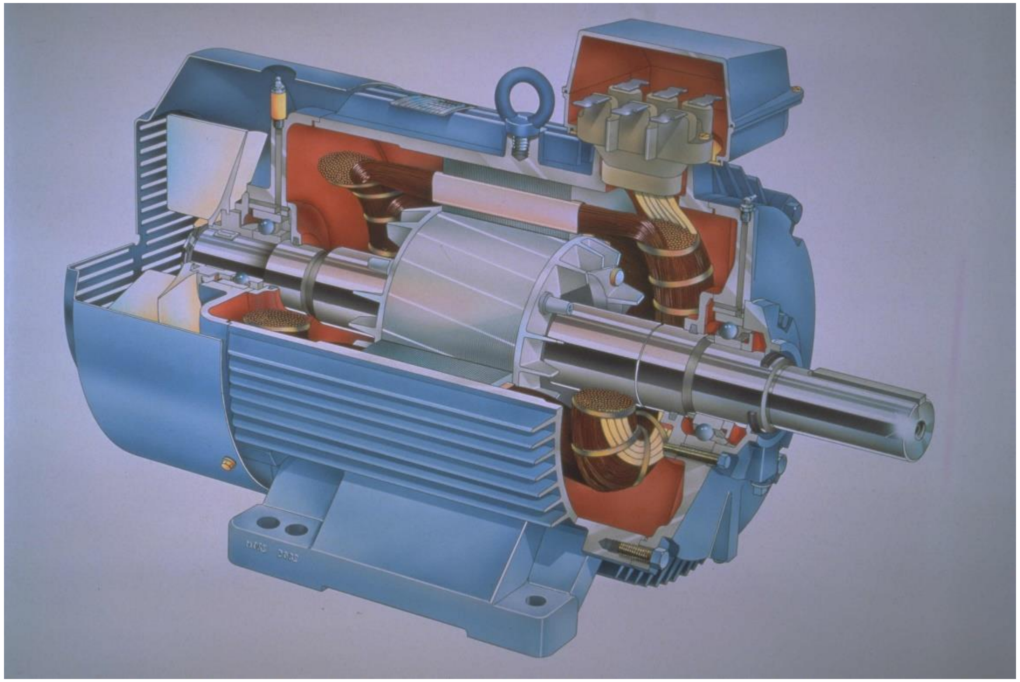


Universal Motors

1. Universal or Series Motor

- Special purpose motor
- Usually a part of portable appliances or tools
- Can be operated on AC or DC
- Designed for intermittent use, variable speed, and may be reversible
- Has a high starting torque & a high starting current

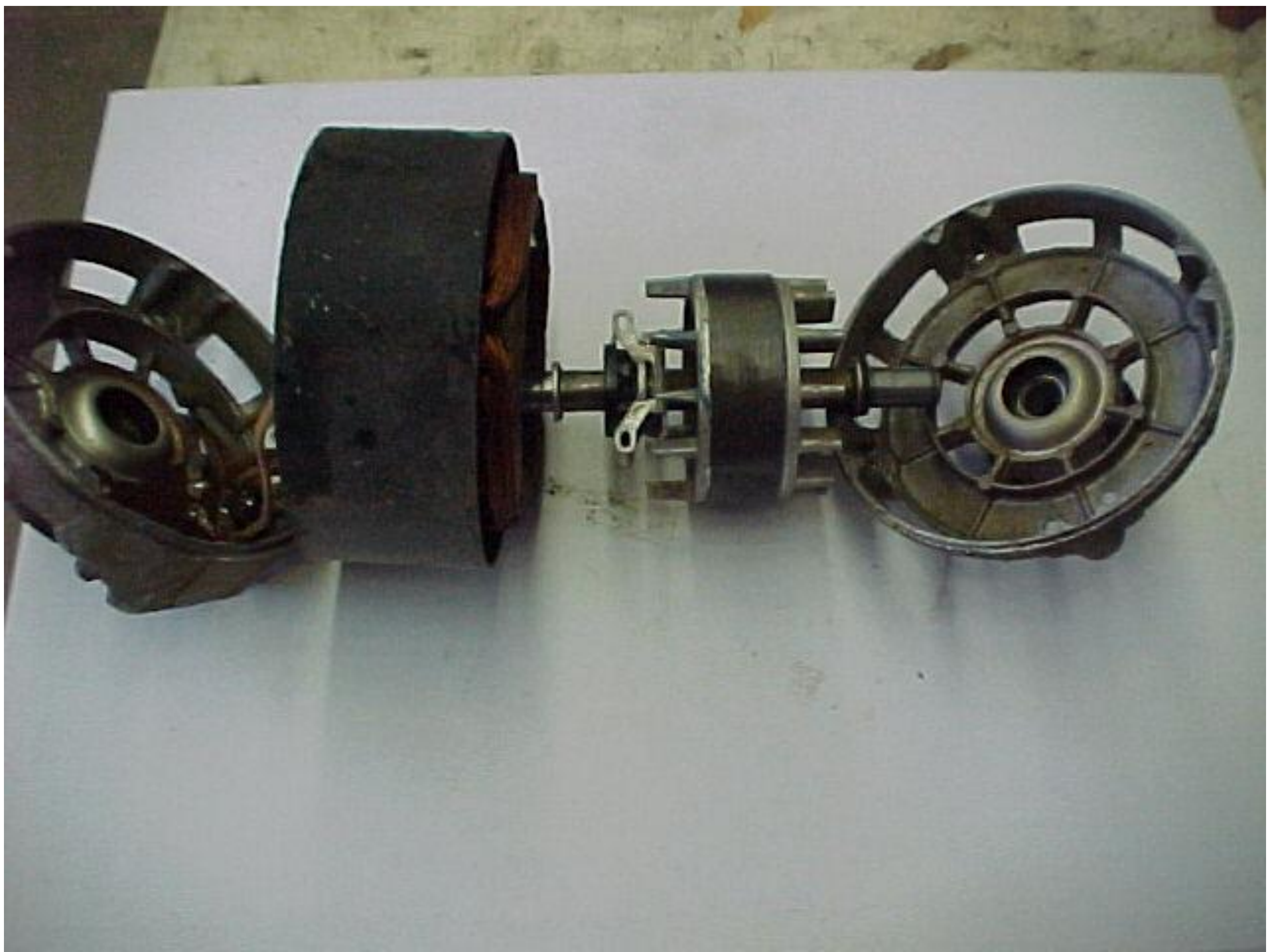
Three-phase motors



3. Three-Phase Motor

- Operated only on three-phase AC
- Medium to high starting torque
- Low-, normal-, or high-starting current requirement
- Designed for self-starting applications
- Has no starting-winding
- Constant-speed motor
- Commonly used in industry
- Less expensive to purchase & operate than single-phase motors
- Last longer, fewer parts & fewer reliability problems

What are the basic parts of an electric motor?



The rotor

- There are two types of rotors:

1. A squirrel-cage rotor

2. A wound-rotor

The Stator

Other Parts

- The end shields house the bearings for the rotor

What are proper maintenance and care principles for electric motors?

Motor Protection and Maintenance

Overload Protection

- Motor size too small for job
- Improper wiring and low voltage
- Improper installation
- Improper lubrication
- Entry of foreign materials into motor

Protection:

- Proper fusing of motor circuit
- Built-in protection in motor
- Manual reset switch control
- Special motor starter (current-limiting starter)

Proper Installation

- Minimum amount of vibration
- Proper alignment

Preventive Maintenance

- Check condition of bearings
- Check working path of motor and driven machine

Safety Precautions for Removing & Disassembling a Motor

- **ALWAYS** disconnect motor's electrical power source before making any adjustments
- Discharge capacitor to prevent electrical shock
- Beware of moving parts.
- Necessary electrical repairs should be made by a qualified electrician.
- Remove and replace any safety guards

Trouble-shooting:

When trouble-shooting an electric motor:

- Be sure motor is receiving correct voltage and frequency
- Check terminals to be sure correct voltage is getting to motor terminals
- Check for proper condition of all fuses and/or protective devices, especially reset button
- Check and secure all connections made on motor terminal plate
- Measure amperage draw of motor while operating and compare the reading with the percent of rated load figure on nameplate

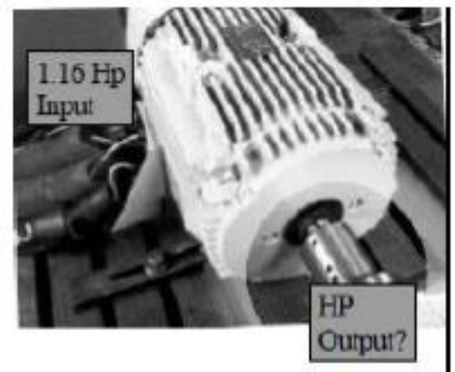
- Both starting and running amperage draw can be checked with a clip-on or clamp-type ammeter.
- Each conductor must be tested separately.
- Wear appropriate Personal Protective Equipment (PPE) when trouble-shooting motor problems

Exercise1

Is a 1 Hp 1-phase motor driving a fan overloaded?

$$P_{out} = 1HP = 746W$$

- We measured Input
  - – Voltage = 123 volts
  - – Current = 9 amps
  - – p.f. = 78%
  - – 75% efficient



- If the motor is 75% efficient, is it overloaded?

Solution

Electric power Input

$$P_{in} = VI\cos\varphi$$

$$P_{in} = 123 \times 9 \times 0{,}78 = 863{,}5W$$

$$\eta = \frac{P_{out}}{P_{in}} \rightarrow P_{out} = \eta \times P_{in} = 0{,}75 \times 863{,}5 = 647{,}6W$$

- The motor is **NOT** overloaded

Exercise2

- Is this 10 Hp, 3-phase motor overloaded?

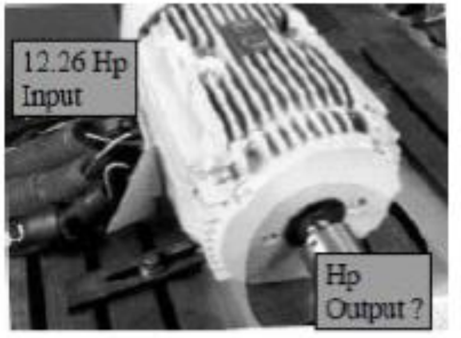
– Voltages = 458 volts

– Currents = 14.0 amps

– P.f. = 82%

– 90% efficient

$$P_{out} = 10HP = 7460W$$



- If the motor is 90% efficient, is it overloaded?

Solution

Electric power Input

$$P_{in} = \sqrt{3}UI\cos\varphi$$

$$P_{in} = \sqrt{3} \times 458 \times 14 \times 0{,}82 = 9106{,}84W$$

$$\eta = \frac{P_{out}}{P_{in}} \rightarrow P_{out} = \eta \times P_{in} = 0{,}9 \times 9106{,}84 = 8196{,}15W$$

- The motor IS **overloaded**!

MOTOR NAMEPLATE INFORMATION

- Manufacturer's Name, Model, & Serial #
- Motor Type
- Enclosure Type
- Insulation Class
- **Power rating**
- R.P.M.
- Dutv Rating
- Phase
- Rated Voltage(s)

Frequency

- Current (Amperage) Rating
- Power Factor
- Connection Diagram
- Ambient Temperature
- Temperature Rise
- Thermal Protection
- Efficiency

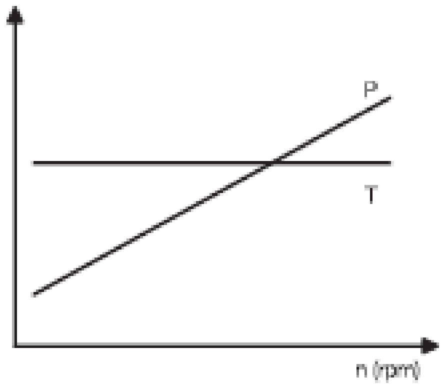
Energy Efficiency Opportunities

1. Use energy efficient motors
2. Reduce under-loading (and avoid over-sized motors)
3. Size to variable load
4. Improve power quality
5. Rewinding
6. Power factor correction by capacitors
7. Improve maintenance
8. Speed control of induction motor

Load types

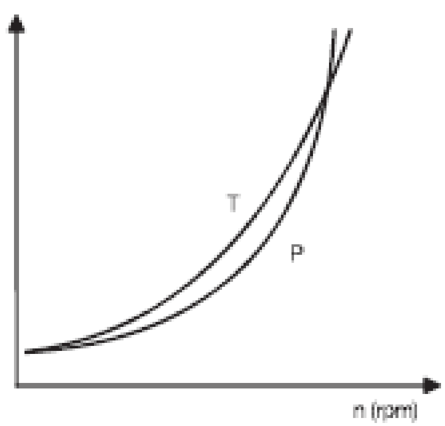
1. Constant torque

For example screw compressors, feeders



2. Quadratic torque

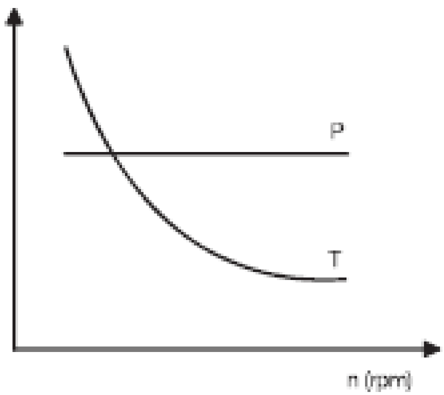
For example centrifugal pumps and fans



Load types

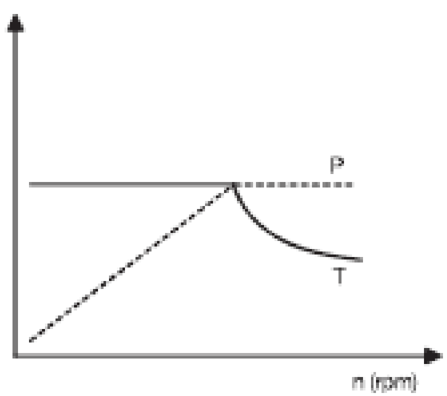
3. Constant power

A constant power load is normal when material is being rolled and the diameter changes during rolling



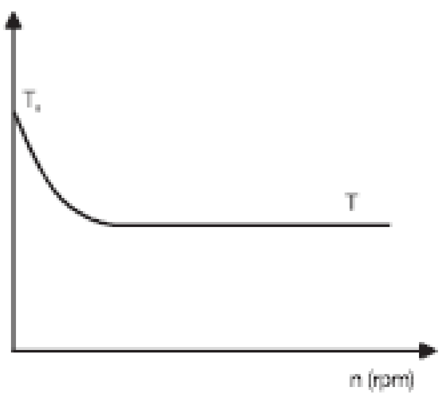
4. Constant power/torque

For example paper industry



Load types

5. Starting/breakaway torque demand



For example extruders and screw pumps, high torque at low frequencies is needed

Motor Drives

- Selecting a Drive:
  - Consider operating speed of equipment & size of drive
- Classification of Drives:
  - **Direct:**
    - Motor connected directly to a machine
    - Machine operates at same speed as motor
    - Flexible Shaft Drive, Flexible Hose Coupling Drive, Cushion-Flange Coupling Drive, Flange Coupling Drive
  - **Speed Conversion (belts & pulleys):**
    - Used to power machines and equipment at speeds different from that of the drive motor
    - V-belt, Webbed multi-V-belt, V-flat drive

Overload Protectors

- Will automatically turn off motor or interrupt power supply if motor is pulling more amperage than it is designed to use
- Help prevent damage to motor which can result from overheating
- May be part of the switch or a fusible link in the power supply

Other Devices

- **Thermostat**: similar to ones that regulate home air conditioners; control heater blowers during fall and winter months

- **Bi-metallic strip:**

Placed in series with run winding

Elongates when too much current is being drawn by motor and causes contact points to open and motor stops.

Motors may have manual or automatic reset button that starts motor once strip has cooled

- **Time Delay Fuses**: used to support short-term, high amounts of current that are necessary to start some motors

Safety Precautions

- Visually inspect motor and machine to be driven for anything harmful
- Listen for strange noises, humming or tapping
- Smell to check for burning
- Feel motor housing to be sure it has not overheated
- Visually check to make sure motor is not vibrating excessively

Review

Q1. What are the advantages of using electric motors over other sources of power?

R1. Efficient, Long Life, Ease of Operation, Automation, Adaptable and Available

Q2. What factors should be considered in selecting electric motors?

R2. Type of electrical power available, Size of motor, Starting load, Speed requirements, Type of bearings, Type of mounting, Environment and Efficiency,

Q3. What are the basic parts of an electric motor?

R3. Rotor (A squirrel-cage rotor, A wound-rotor), stator (one or more pairs of magnetic poles).

Q4. What are the basic types of electric motors and how are they different?

R4. Universal motors, Single Phase Motors and Three Phase Motors

Q5. What are the different types of motor enclosures and how are they different?

R5. Open enclosures, Splash-proof enclosures and totally enclosed motors

Q6. What type of motor would you select to perform each of the flowing jobs? Why?

a) Vacuum cleaner

Ra) Universal motor-For its high torque

b) Refrigerator

Rb) Capacitor start-For its high starting and relatively constant speed at a wide variety of load

c) Air conditioner compressor

Rc) Same as (b) above

d) Air conditioner fan

Rd) Split phase - Fans are low starting torque applications, and split – phase motor is appropriate

e) variable-speed sewing machine

Re) Universal motor – Direction and speed are easy to control with solid state drives

f) Clock

Rf) Hysteresis motor – For its easy starting and operation at Nsyn. A reluctance motor would also do nicely.

g) Electrical drill

Rg) Universal motor-For easy speed control with solid state drives, plus high torque under loaded conditions.


The End

Guided Study-7

Exercise 1

The figure below shows a one line diagram of a simple power system containing a single 480 V generator and loads. Assume that the transmission lines in this power system are lossless, and answer the following questions.

a. Assume that Load 1 is Y-connected. What are the phase voltage and currents in that load?

b. Assume that Load 2 is delta-connected. What are the phase voltage and currents in that load?

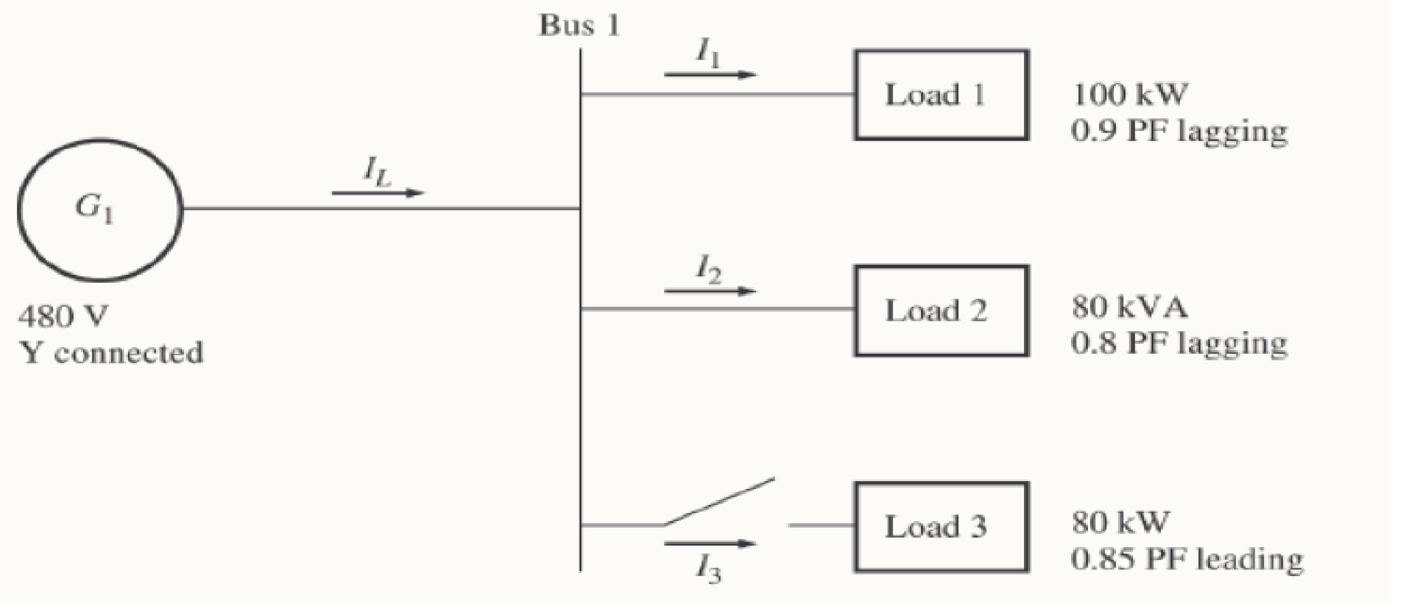
c. What real, reactive, and apparent power does the generator supply when the switch is open?

d. What is the total line current I_L when the switch is **open**?

e. What real, reactive, and apparent power does the generator supply when the switch is **closed**?

f. What is the total line current I_L when the switch is closed?

g. How does the total line current I_L compare to the sum of the three individual currents $I_1 + I_2 + I_3$? If they are not equal, why not?



Answers

a) Assume that **Load 1** is Y-connected. What are the phase voltage and currents in that load?

Since this load 1 is Y-connected, the phase voltage is:

$$V_{\phi 1} = \frac{480}{\sqrt{3}} = 277V$$

The phase current can be derived from equation $P = 3V_{\phi 1} I_{\phi 1} \cos\varphi$ as follows:

$$I_{\phi 1} = \frac{P_1}{3V_{\phi 1}\cos\varphi_1} = \frac{100000}{3 \times 277 \times 0{,}9} = 133{,}7A$$

b) Assume that **Load 2** is delta-connected. What are the phase voltage and currents in that load?

Since this load 2 is delta-connected, the phase voltage is:

$$V_{\phi} = 480V$$

The phase current can be derived from equation $S = 3V_{\phi 2} I_{\phi 2}$ as follows:

$$I_{\phi 2} = \frac{S_2}{3V_{\phi 2}} = \frac{80000}{3 \times 480} = 55{,}56A$$

c) What real, reactive, and apparent power does the generator supply when the switch is **open**?

The real and reactive power supplied by the generator when switch is open is just the sum of the real and reactive power of **loads 1 and 2.**

$$P_1 = 100kW$$

$$Q_1 = P_1 \tan\varphi_1 = 100000 \times 0{,}484 = 48{,}4kVAR$$

$$P_2 = S_2 \cos\varphi_2 = 80000 \times 0{,}8 = 64kW$$

$$Q_2 = S_2 \sin\varphi_2 = 80000 \times 0{,}6 = 48kVAR$$

$$P_{GO} = P_1 + P_2 = 100kW + 64kW = 164kW$$

$$Q_{GO} = Q_1 + Q_2 = 48{,}4kVAR + 48kVAR = 96{,}4kVAR$$

d) What is the total line current I_L when the switch is open?

The line current I_L when the switch is open is given by:

$$I_{LO} = \frac{P_{Go}}{\sqrt{3}V_L \cos\varphi_{GO}} = \frac{164 \times 10^3}{\sqrt{3} \times 480 \times 0{,}862} = 228{,}8A$$

Where $\varphi_{GO} = \arctan\frac{Q_{GO}}{P_{GO}} = \arctan\frac{96{,}4 \times 10^3}{164 \times 10^3} = 30{,}45^\circ$

e).What real, reactive, and apparent power does the generator supply when the switch is **closed**?

The real, reactive power supplied by the generator when the switch is closed is just the sum of the real and reactive power of **loads 1 and 2 and 3**. The powers of loads 1 and 2 have already been calculated.

The real and reactive power of load 3 is:

$$P_3 = 80kW$$

$$Q_3 = P_3 \tan\varphi = 80000 \times (-0{,}619) = -49{,}6kVAR$$

$$Q_{GC} = Q_1 + Q_2 + Q_3 = 48{,}4kVAR + 48kVAR - 49{,}6 = 46{,}8kVAR$$

f) What is the total line current I_L when the switch is closed?

The line current I_L when the switch is closed is given by:

$$I_{LC} = \frac{P_{GC}}{\sqrt{3}V_L \cos\varphi_{GC}} = \frac{244 \times 10^3}{\sqrt{3} \times 480 \times 0{,}982} = 298{,}8A$$

Where $\varphi_{GC} = \arctan\dfrac{Q_{GC}}{P_{GC}} = \arctan\dfrac{46{,}4 \times 10^3}{244 \times 10^3} = 10{,}86^\circ$

g) How does the total line current I_L compare to the sum of the three individual currents $I_1 + I_2 + I_3$? If they are not equal, why not?

The total line current from the generator is 298,8A.The line currents to each individual load are:

$$I_{L1} = \frac{P_1}{\sqrt{3}V_L \cos\varphi_1} = \frac{100 \times 10^3}{\sqrt{3} \times 480 \times 0{,}9} = 133{,}2A$$

$$I_{L2} = \frac{S_2}{\sqrt{3}V_L} = \frac{80 \times 10^3}{\sqrt{3} \times 480} = 96{,}2A$$

$$I_{L3} = \frac{P_3}{\sqrt{3}V_L \cos\varphi_3} = \frac{80 \times 10^3}{\sqrt{3} \times 480 \times 0{,}85} = 113{,}2A$$

The sum of the three individual line currents is 343A, while the current supplied by the generator is 298,8A. These values are not the same, because the three loads have different impedance angles. Essentially, load 3 is supplying some of the reactive power being consumed by loads 1 and 2, so that it does not have to come from the generator.

Motors

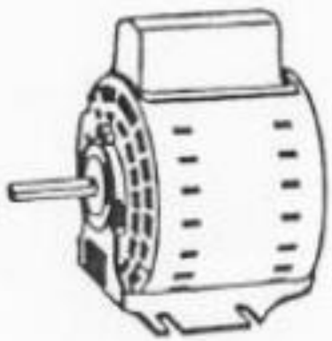
Motor Parts

- Enclosure
- Stator
- Rotor
- Bearings
- Conduit Box
- Eye Bolt

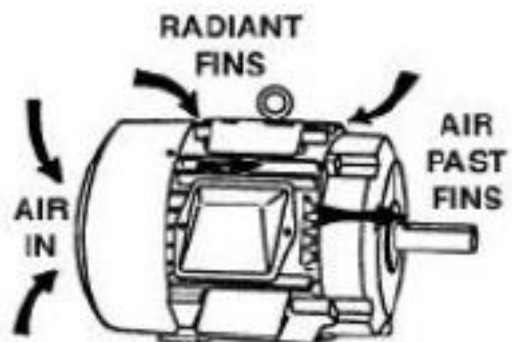
Motors

Enclosure

- Holds parts together
- Helps with heat dissipation
- In some cases, protects internal components from the environment.



Open



ENCLOSED TYPE

Type of Voltage Available

- 230-volt motor should not be used if only 400-volt circuits are available
- Three-phase motor cannot be operated on electrical system with only single-phase service
- Typical Operating Voltages: 230/400-volt

Size of Motor

- Rated in Watt
- Refers to the power that it will develop when the motor is turning at full speed

Starting Load

- Motor selected must produce adequate starting torque to start the load

Bearing Type

- Sleeve bearings or
- Anti-friction bearings
  - Require less maintenance and can be mounted in any position

Base Type

- Determined by application of motor
- Rigid base
- Sliding adjustable base

Environment

- Provide proper protection from surroundings
- Typical motor enclosures:
  - Open drip proof
  - Splash proof
  - Totally enclosed-fan cooled (TEFC)
  - Explosion proof
  - Totally enclosed-air over (TEAO)
  - Totally enclosed-non ventilated (TENV)

Power Availability

- Motor must be located on properly sized electrical circuit and service entrance to function efficiently
- In some situations, motor should be only major load on the circuit

Service Factor (S.F.)

- Amount of overload the motor can tolerate on a continuous basis at rated voltage and frequency
- 1.0 S.F.: no overload is tolerated for extended periods
- 1.25 S.F.: motor can be overloaded 25% for an extended period of time when operated at rated voltage and frequency