UNIT - V

Special Motors

- Hysteresis motor
- Reluctance motor
- Stepper motor
- Synchros
- Linear induction motor
- Permanent magnet Brushless DC motor

Examples of everyday

- **<u>Your car is loaded with electric motors:</u>**

- **Power windows (a motor in each window)**
- **Power seats (up to seven motors per seat)**
- **Fans for the heater and the radiator**
- **Windshield wipers**
- **The starter motor**
- **Electric radio antennas**

- **<u>Motors in all sorts of places:</u>**

- **Your iPod**
- **Several in the VCR**
- **Several in a CD player or tape deck**
- **Many in a computer**
- **Most toys that move**
- **Electric clocks**
- **The garage door opener**
- **Aquarium pumps**

- **EVERYTHING!!!!!**

- **<u>At home:</u>**
- **motors**
- The **fan** over the stove and in the microwave oven
- The **dispose-all** under the sink
- The **blender**
- The **can opener**
- The **refrigerator** - **Two or three** in fact:
  - one for the **compressor**,
  - one for the fan inside the **refrigerator**,
  - as well as one in the **icemaker**
- The **mixer**
- The **tape player** in the answering machine
- Probably even the **clock** on the oven
- The **washer**
- The **dryer**
- The **electric screwdriver**
- The **vacuum cleaner** and the Dust buster mini-vac
- The **electric saw**
- The **electric drill**
- The **furnace blower**
- The **fan**
- The **electric toothbrush**
- The **hair dryer**
- The **electric razor**

HYSTERESIS MOTOR

HYSTERESIS MOTOR

- The phenomenon of hysteresis can be used to produce mechanical torque.

- A hysteresis motor is basically a synchronous motor with uniform air gap and without d.c. excitation.

- These may operate from single phase or three phase source.

- Its operation depends on hysteresis effect i.e. magnetization produced in ferromagnetic material lags behind magnetic force.

Construction

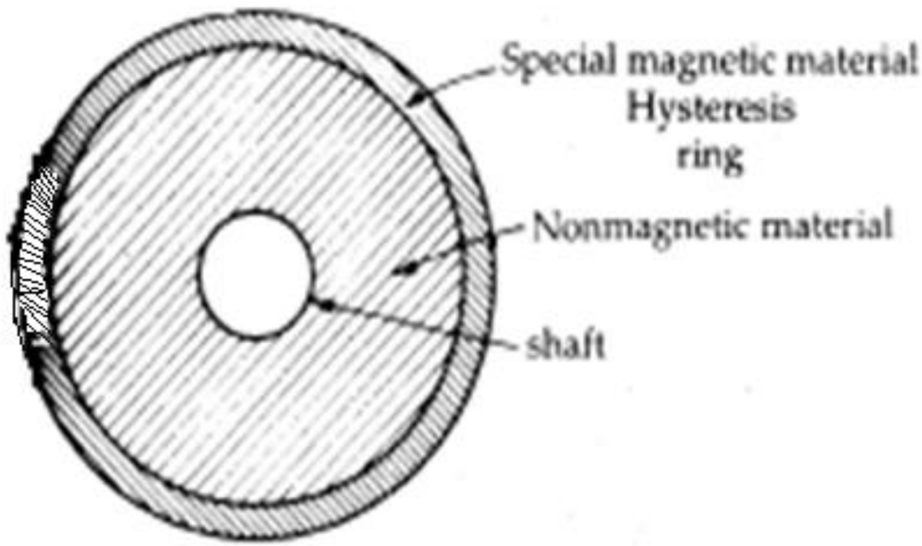
ROTOR

- The rotor of a *hysteresis motor is a smooth cylinder of magnetically* hard steel, without windings or teeth.

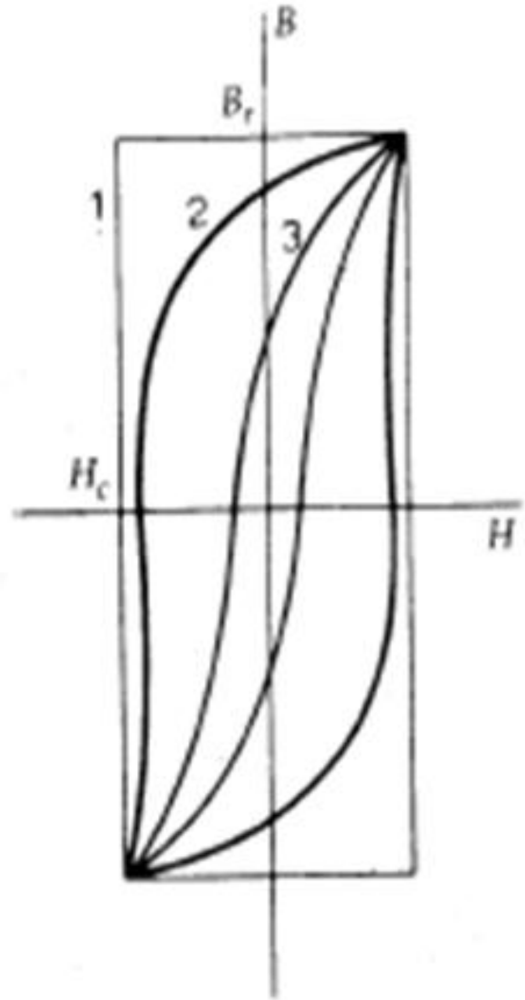
- It is placed inside a slotted stator carrying distributed windings designed to produce as nearly as possible a sinusoidal space distribution of flux.

- It consists of core of aluminum or some other non-magnetic material.

- The outer layer has number of thin rings to form the laminated rotor. The ring is made of special magnetic material such as magnetically hard chromel or cobalt steel having very large hysteresis loop.



ROTOR OF A HYSTERESIS MOTOR



VARIOUS HYSTERESIS LOOPS FOR DIFFERENT MATERIALS

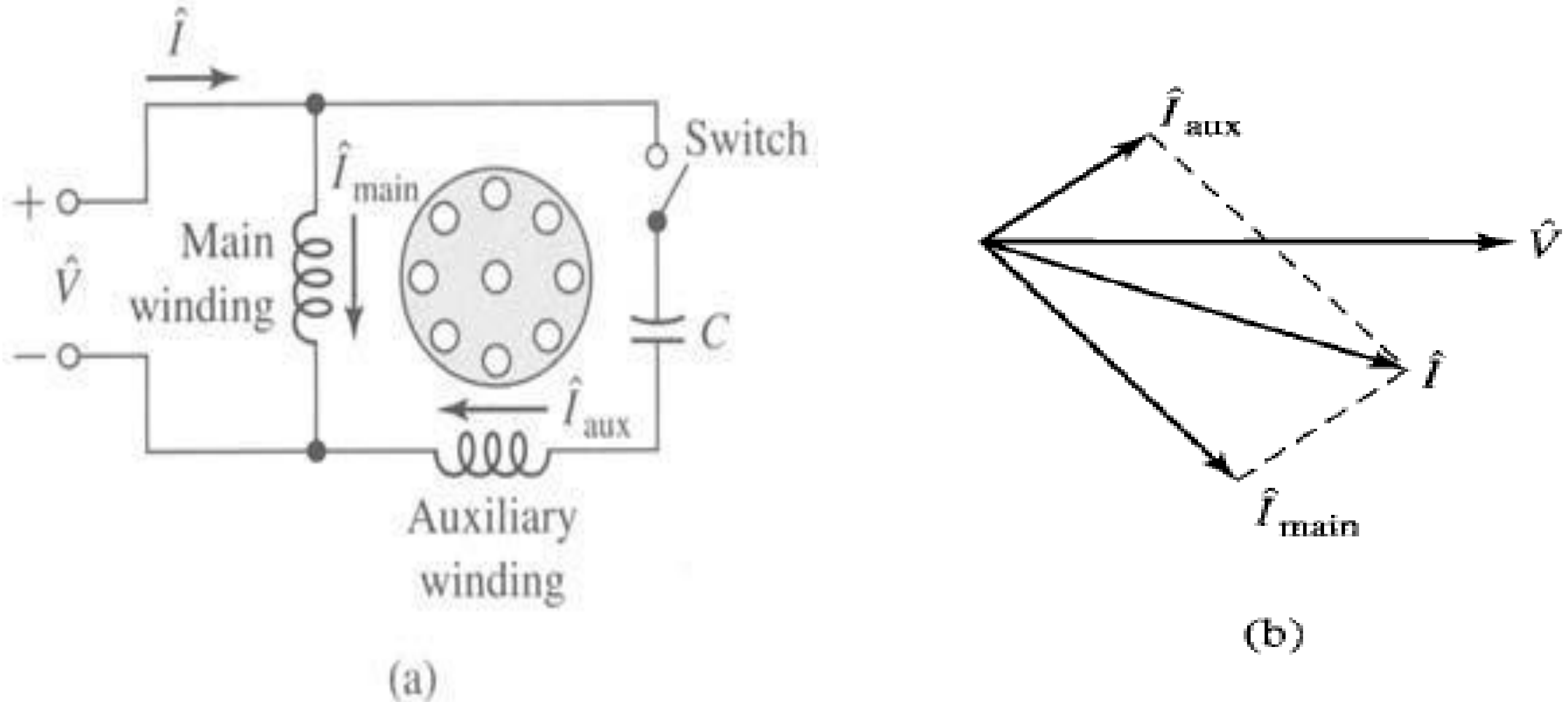
STATOR :

- Rotor is placed inside a slotted stator carrying distributed windings designed to produce as nearly as possible a sinusoidal space distribution of flux.

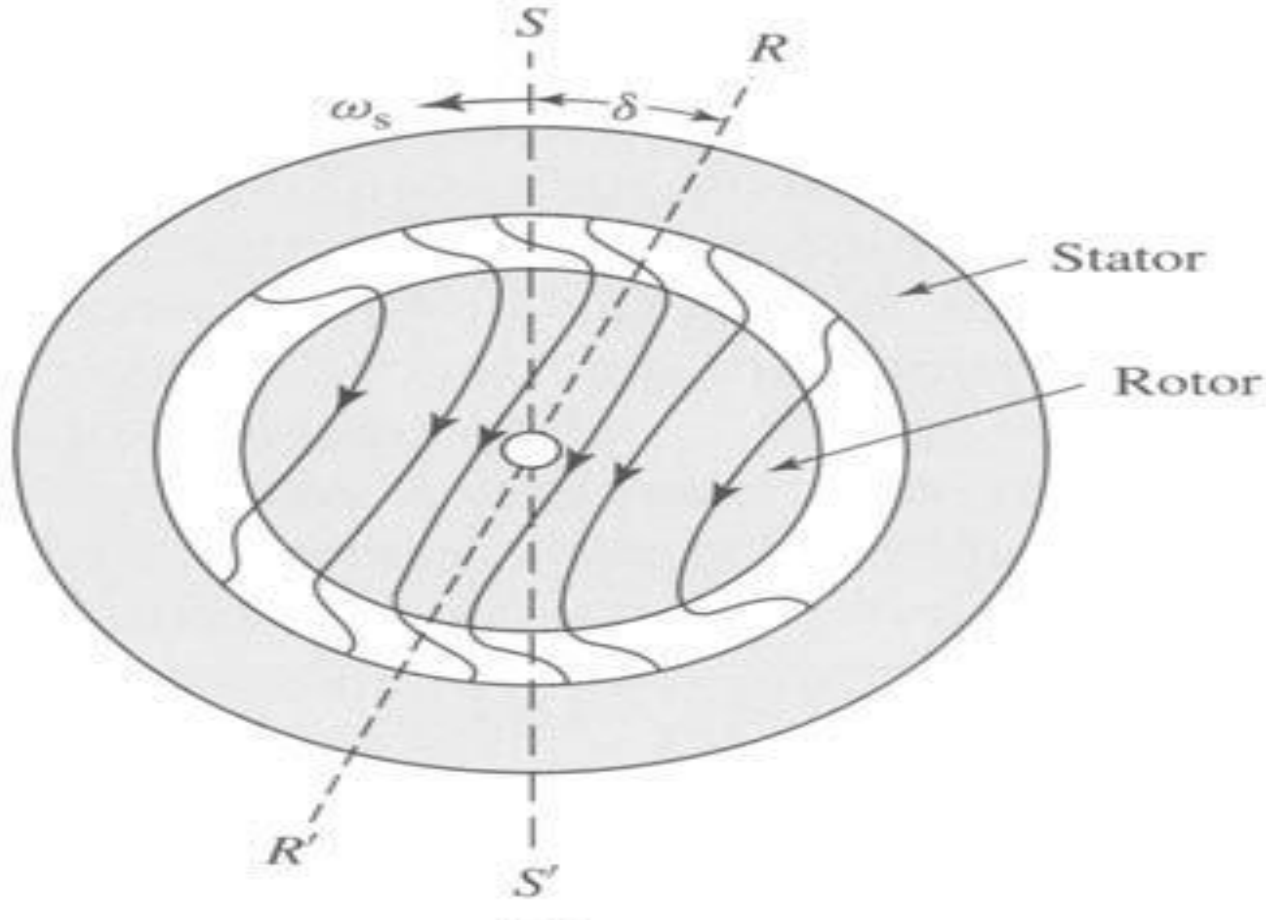
- In single-phase motors, the stator windings usually are of the permanent-split-capacitor type.

- The capacitor is chosen so as to result in approximately balanced two-phase conditions within the motor windings.

- The stator then produces a primarily space-fundamental air-gap field revolving at synchronous speed.

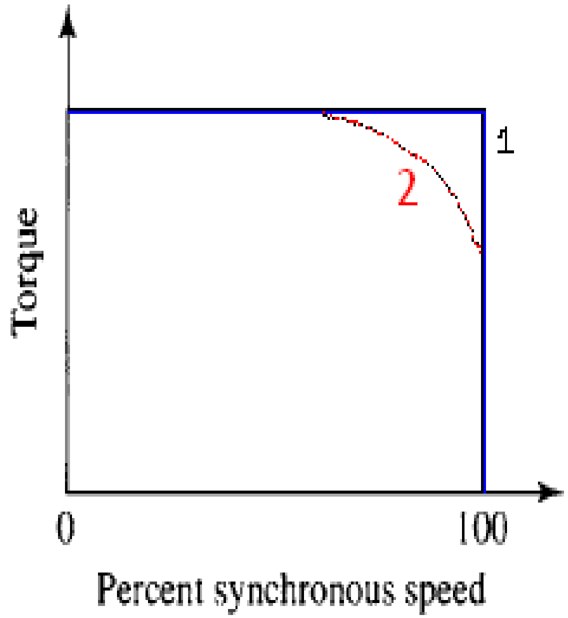


Capacitor-start motor: (a) connections,
(b) phasor diagram at starting



(a)

(a) **General nature of the magnetic field in the air gap and rotor of a hysteresis motor**



Idealized torque-speed characteristic for
1-An ideal motor.
2-A practical motor

- *Starting torque and running torque are almost equal in this motor.*

- *Departure from ideal characteristic is due to presence of harmonics and irregularities.*

- *Direction of rotation can be reversed.*

APPLICATIONS

Due to noiseless operation, it is used in sound recording instruments, sound producing equipments, high quality record players, tape recorders, electric clocks , teleprinters , timing devices etc.

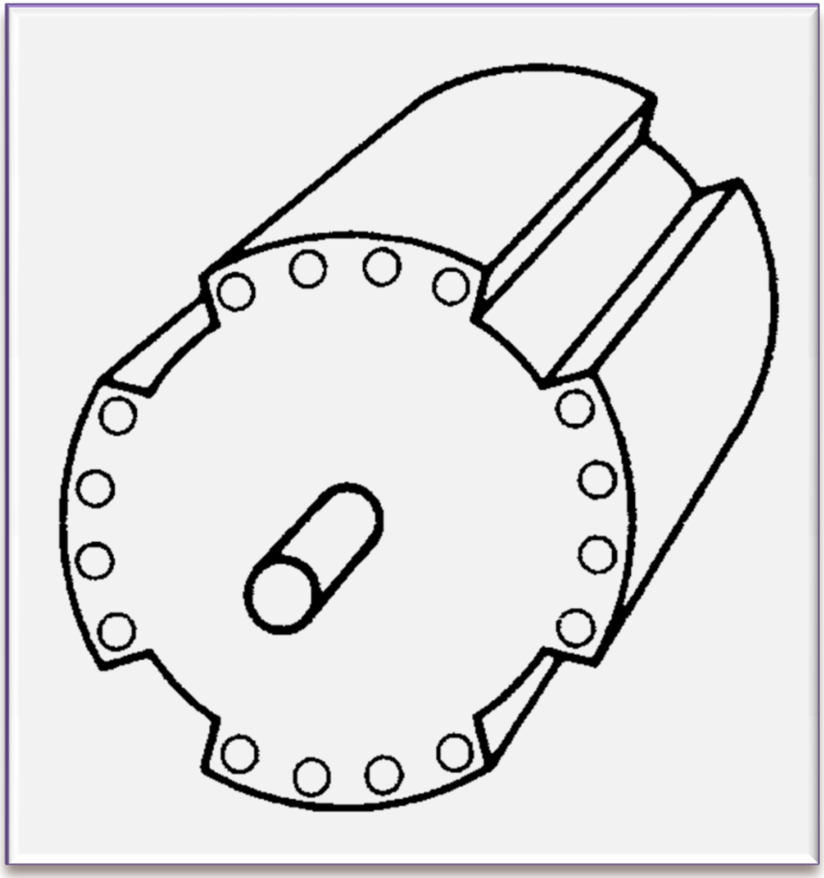
RELUCTANCE MOTOR

RELUCTANCE MOTOR

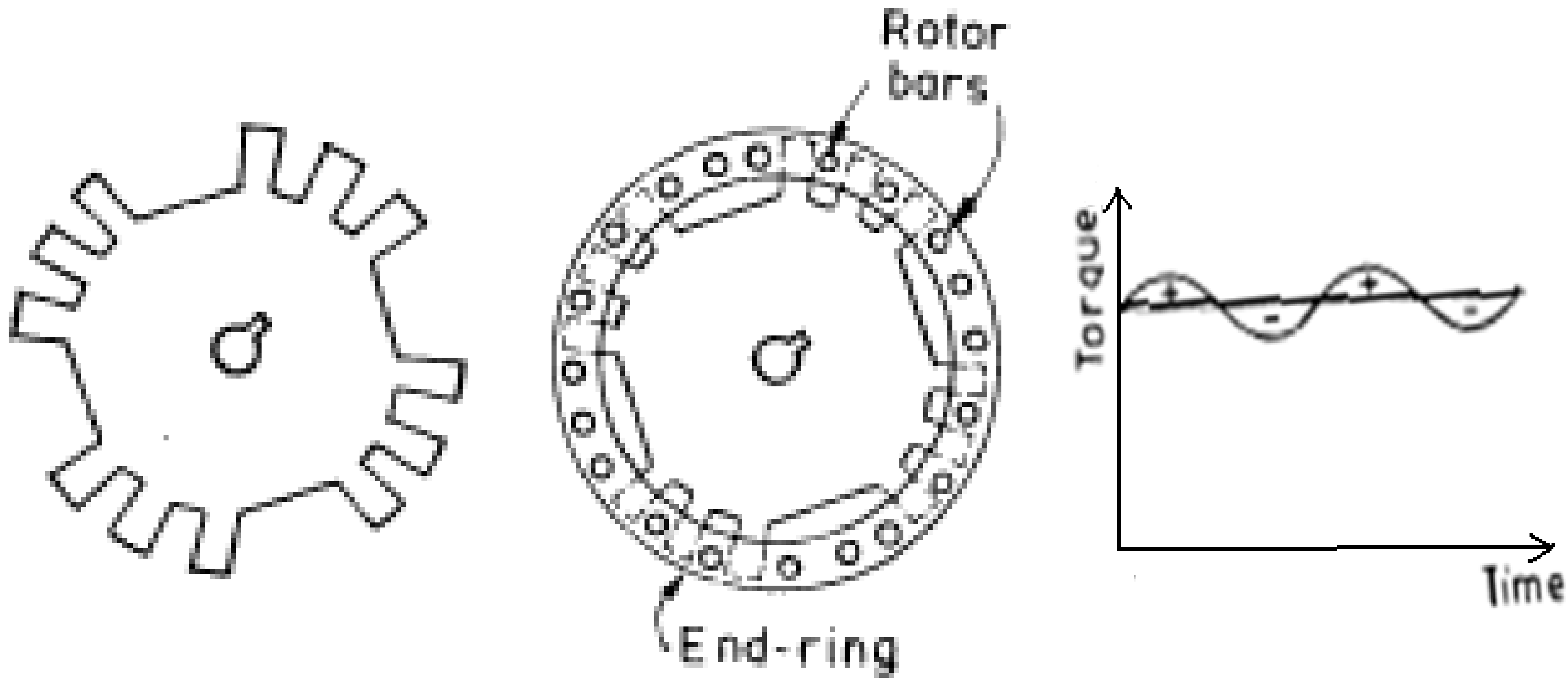
➢A motor which develops torque only due to difference in reluctance in two axis is called reluctance motor.

➢Reluctance motor operates on the following principle-
"Whenever a piece of ferromagnetic material is located in a magnetic field, a force is exerted upon the material, tending to bring it into the position of the densest portion of the field".

➢A reluctance torque is produced in a motor in which the reluctance of air gap is a function of angular position of rotor with respect to stator coils.



ROTOR



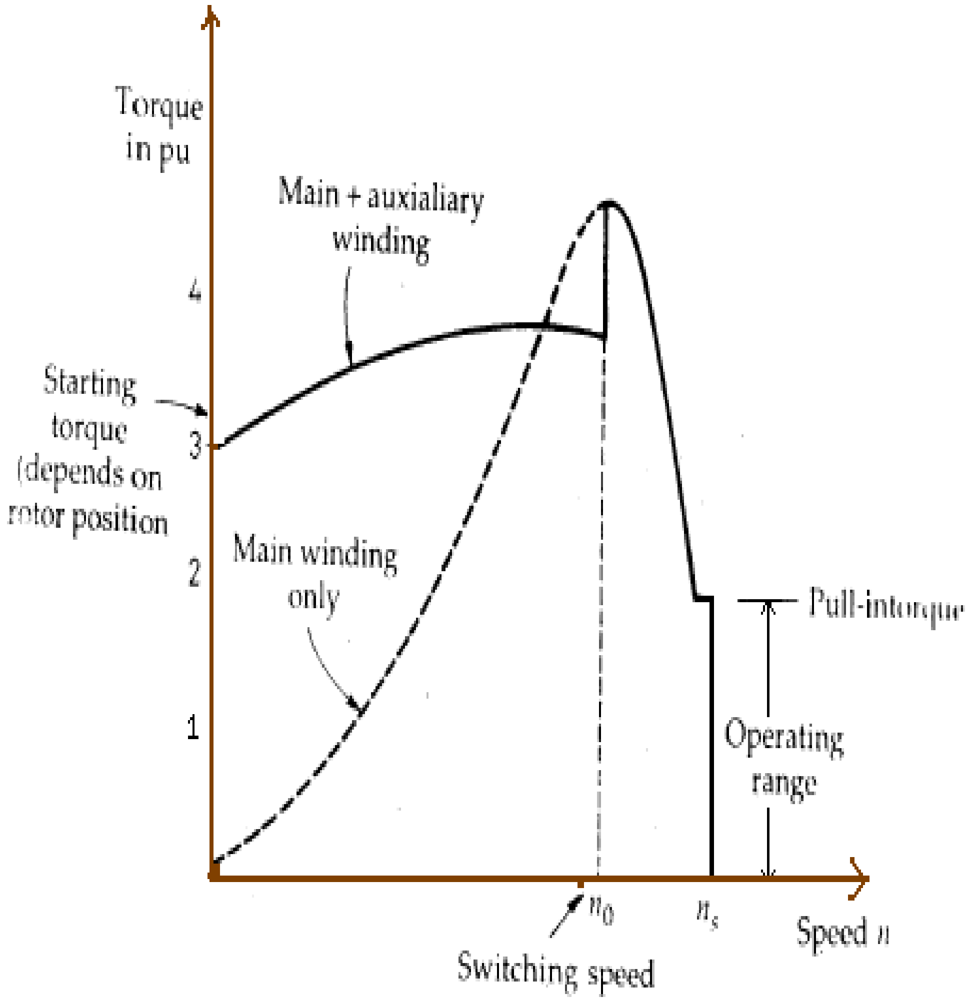
(a) (b) (c)

Single Phase Reluctance Motor

(a) 4-pole Rotor Laminations

(b) 4-pole Rotor Laminations with bars and end rings

(c) Reluctance Torque Pulsations at Small Slip.



Torque speed characteristics

✓Starting torque is dependent upon the rotor position because of the salient pole rotor.

✓Torque that pulls rotor into synchronism is called pull in torque.

ADVANTAGES

- *No d.c. supply is necessary for rotor.*
- *Constant speed characteristics.*
- *Robust construction .(no slip rings, no brushes, no dc field winding)*
- *Less maintenance.*
- *Low cost*

DISADVANTAGES

- *Less efficiency.*
- *Poor power factor.*
- *Cannot accelerate high inertia loads to synchronous speed.*
- *Less capacity to drive the loads.*

APPLICATIONS

- Signaling devices
- Controlling apparatus
- Automatic regulators
- Recording instruments
- Clocks, telephones, teleprinters, phonograph e.t.c.

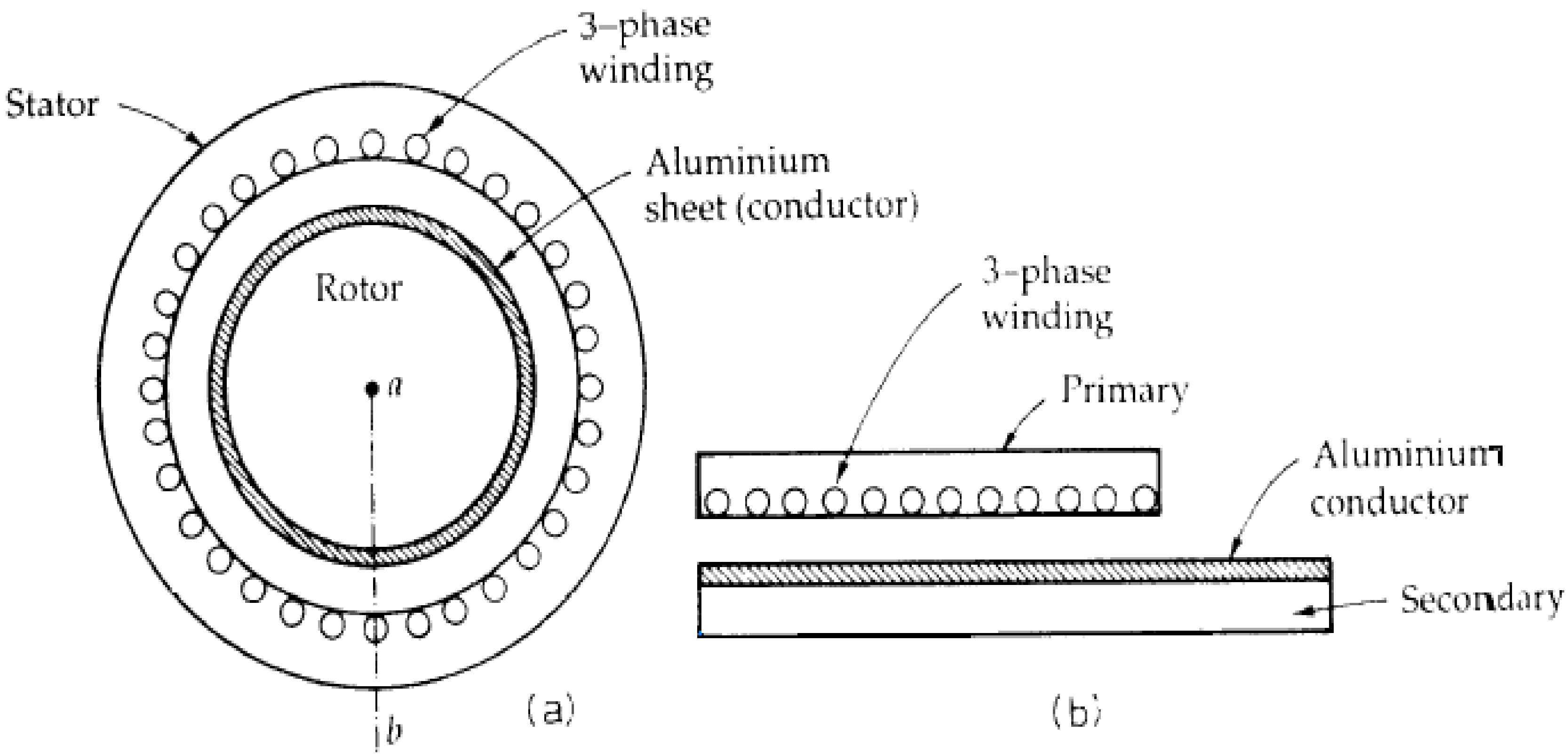
LINEAR INDUCTION MOTOR

Linear Induction Motor

- It gives linear or *translational motion* instead of rotational motion.

- Stator forms the primary and rotor forms the secondary.

- The analysis of linear machines is quite similar to that of rotary machines. In general, linear dimensions and displacements replace angular ones, and forces replace torques.



(a)Rotary Induction motor **(b)Linear induction motor**

WORKING

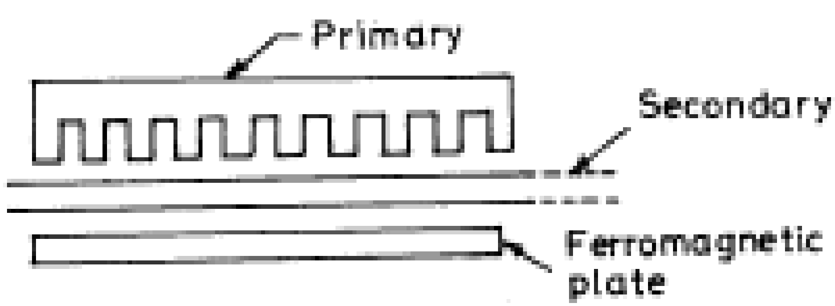
- If primary of linear induction motor is connected to a three phase supply, a straight line travelling flux wave is produced.
- The velocity of this travelling field is given by:

$$\mathbf{v_s} = 2f(\text{pole pitch})$$
$$= f(\lambda)$$

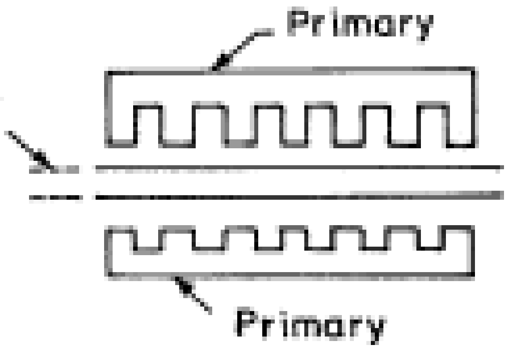
Where λ=wavelength of the travelling field and is equal to two pole pitches.

- Current is induced in the aluminum conductor due to the relative motion between travelling flux wave and aluminum conductor.
- The induced current interacts with travelling flux wave to produce a linear force F.
- A force producing linear motion is called the thrust , propulsion force or traction force.
- The speed of secondary in linear induction motor is given by:

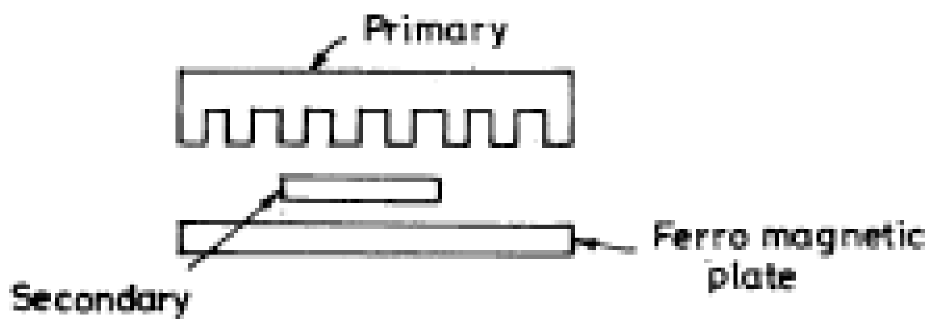
$$\mathbf{v_r = v_s(1\text{-}s)\ m/sec}$$



(a) Short single primary



(b) Short double primary

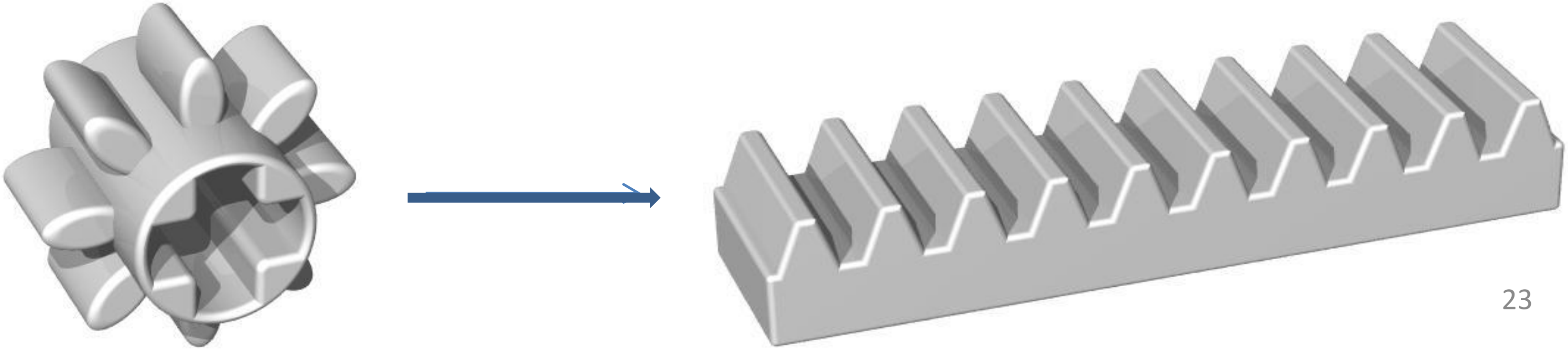


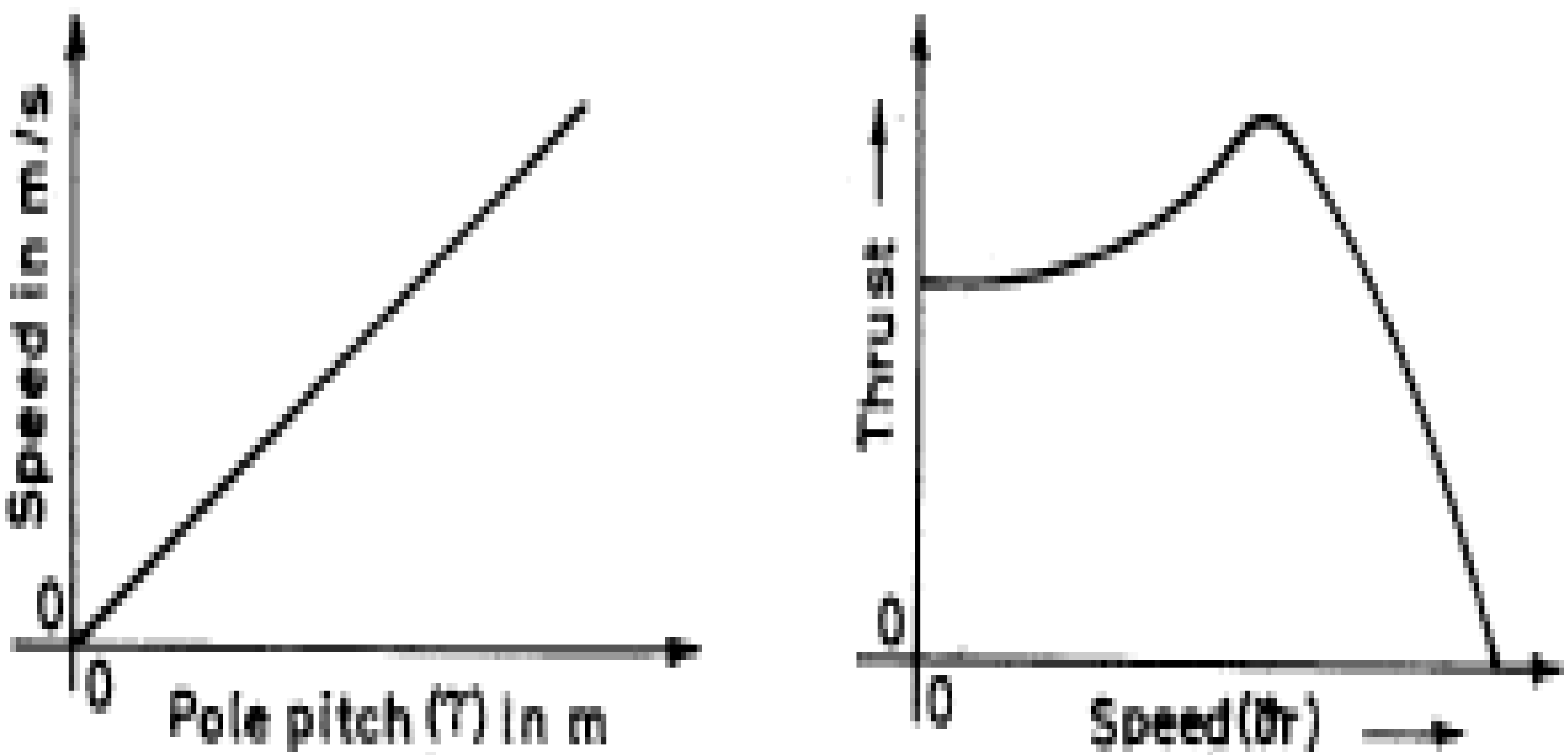
(c) Short secondary

PERTAINING TO LINEAR MOTOR

ADVANTAGES

- ✓*Low initial cost.*
- ✓*Simplicity.*
- ✓*No over heating of rotor.*
- ✓*Low maintenance cost because of absence of rotating part.*
- ✓*No limitation of maximum speed due to centrifugal forces.*
- ✓*No over heating of rotor.*
- ✓*Better power to weight ratio.*





(a) Pole-pitch vs. speed characteristics. (b) Thrust vs. speed characteristics.

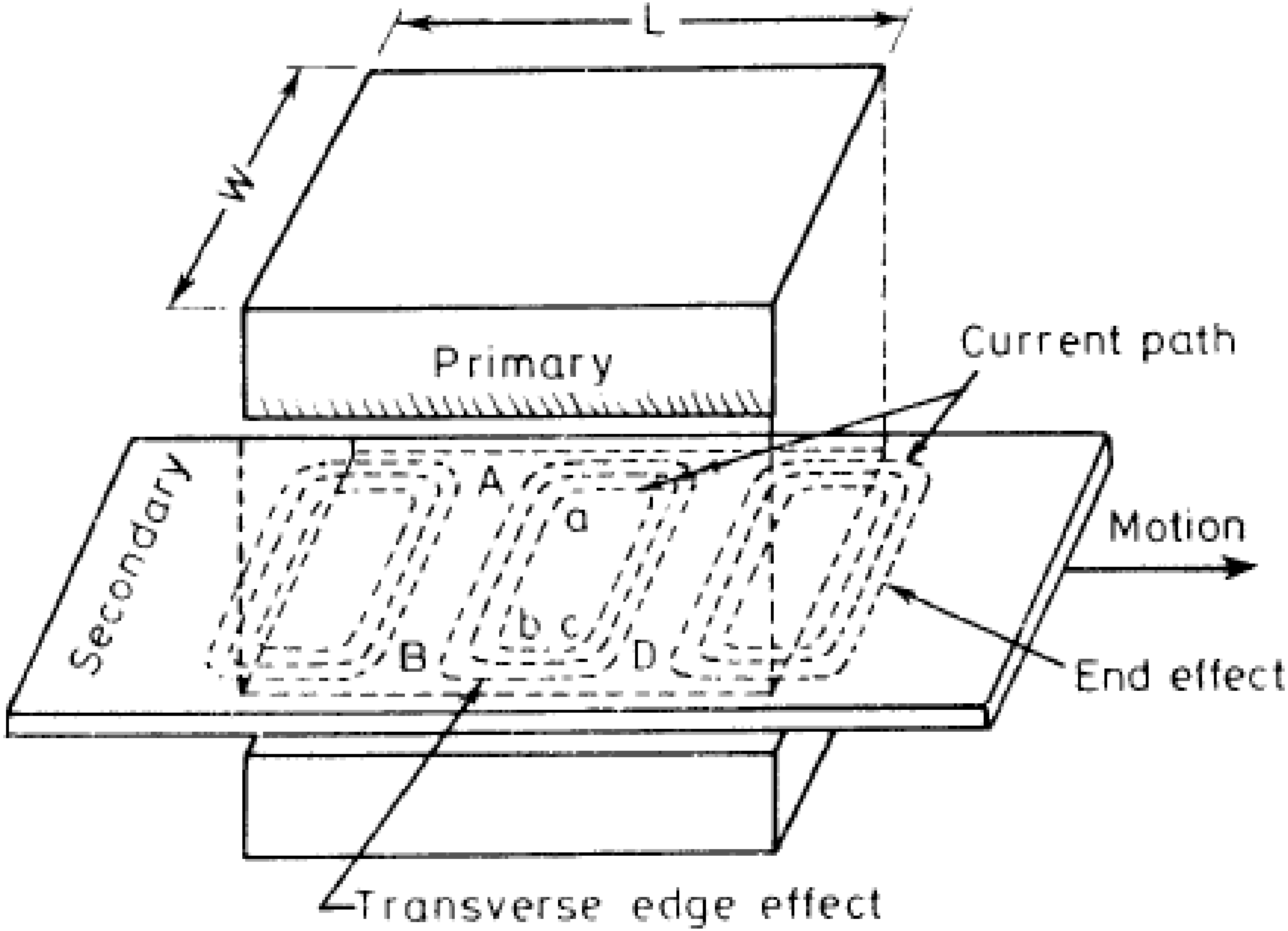
LINEAR MOTOR CHARACTERICTICS

APPLICATIONS

- *Main application is in transportation, including electric tracking.*
- *In conveyers, travelling cranes, haulers, electromagnetic pumps e.t.c.*
- *It can be used on trolley cars for internal transport in workshop, as booster accelerator for moving heavy trains from rest or up the inclines or on curves or as a propulsion unit.*
- *Linear motors have also found application in the machine tool industry and in robotics where linear motion (required for positioning and in the operation of manipulators) is a common requirement.*
- *In addition, reciprocating linear machines are being constructed for driving reciprocating compressors and alternators.*

DISADVANTAGES

- *Poor utilization of motor due to transverse edge effect and end effect.*
- *Larger air gap and nonmagnetic reaction rail need more magnetizing current resulting in poor efficiency and lower power factor.*
- *Very high capital cost of reaction rail fixed along the centre of the track.*
- *Difficulties encountered in maintaining adequate clearance at points and crossings*
- *Complications and high cost involved in providing 3 phase collector system along the track.*



Transverse edge effect and end effect in LEM.

STEPPER MOTOR

Why a Stepper Motor ?

- Unlike the permanent magnet DC motor, stepper motors move in discrete steps as commanded by the stepper motor controller

- Because of their discrete step operation, stepper motors can easily be rotated a finite fraction of a rotation

- Another key feature of stepper motors is their ability to hold their load steady once the require position is achieved

- An example application for stepper motors is for implementing traditional "analog" instrumentation gauges on a dashboard

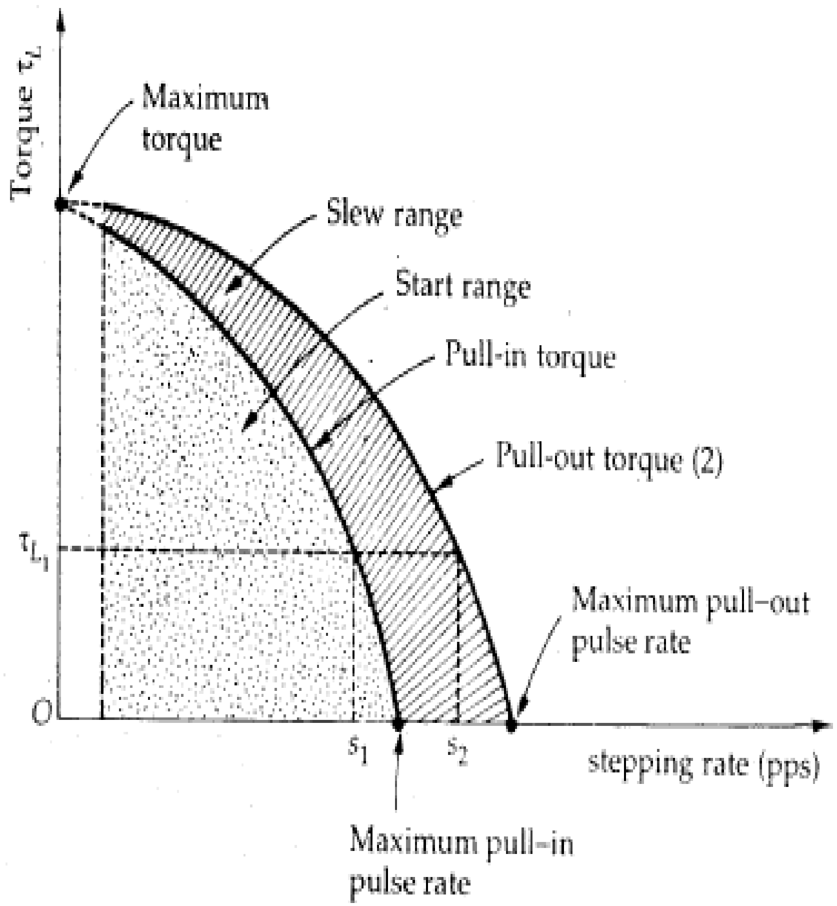
How Does a Stepper Motor Work ?

- *A stepper motor often has an internal rotor with a large number of permanent magnet "teeth"*
- *A large number of electromagnet "teeth" are mounted on an external stator*
- *Electromagnets are polarized and depolarized sequentially, causing the rotor to spin one "step"*
- *Full step motors spin 360^o/(no. of teeth) in each step*
- *Half step motors spin 180^o/(no. of teeth) in each step*
- *Microstep motors further decrease the rotation in each step*

- Stepping motors can be regarded as a digital electromechanical device; it translates the input digital information in the form of electric pulses into discrete steps of shaft rotation.

- If the number of input pulses send to the motor is known ,the actual position of the driven job can be obtained.

- Thus a digital position control system employing a stepping motor needs no rotor position sensors and an expensive feedback loop.



Torque pulse rate characteristics of a stepper motor

Pull in torque characteristics- It shows the maximum stepping rate at which the motor can start, synchronise, stop or reverse for different values of load torque.

Pull out torque characteristics- It shows the maximum stepping rate at which the motor can run for different values of load torque if already synchronised but it cannot start, stop or reverse on command at this rate.

Stepper Motor Control

- The stepper motor driver receives square wave pulse train signals from a controller and converts the signals into the electrical pulses to step the motor
- This simple operation leads stepper motors to sometimes be called "digital motors"
- To achieve microstepping, however, the stepper motor must be driven by a (quasi) sinusoidal current that is expensive to implement

STEP ANGLE

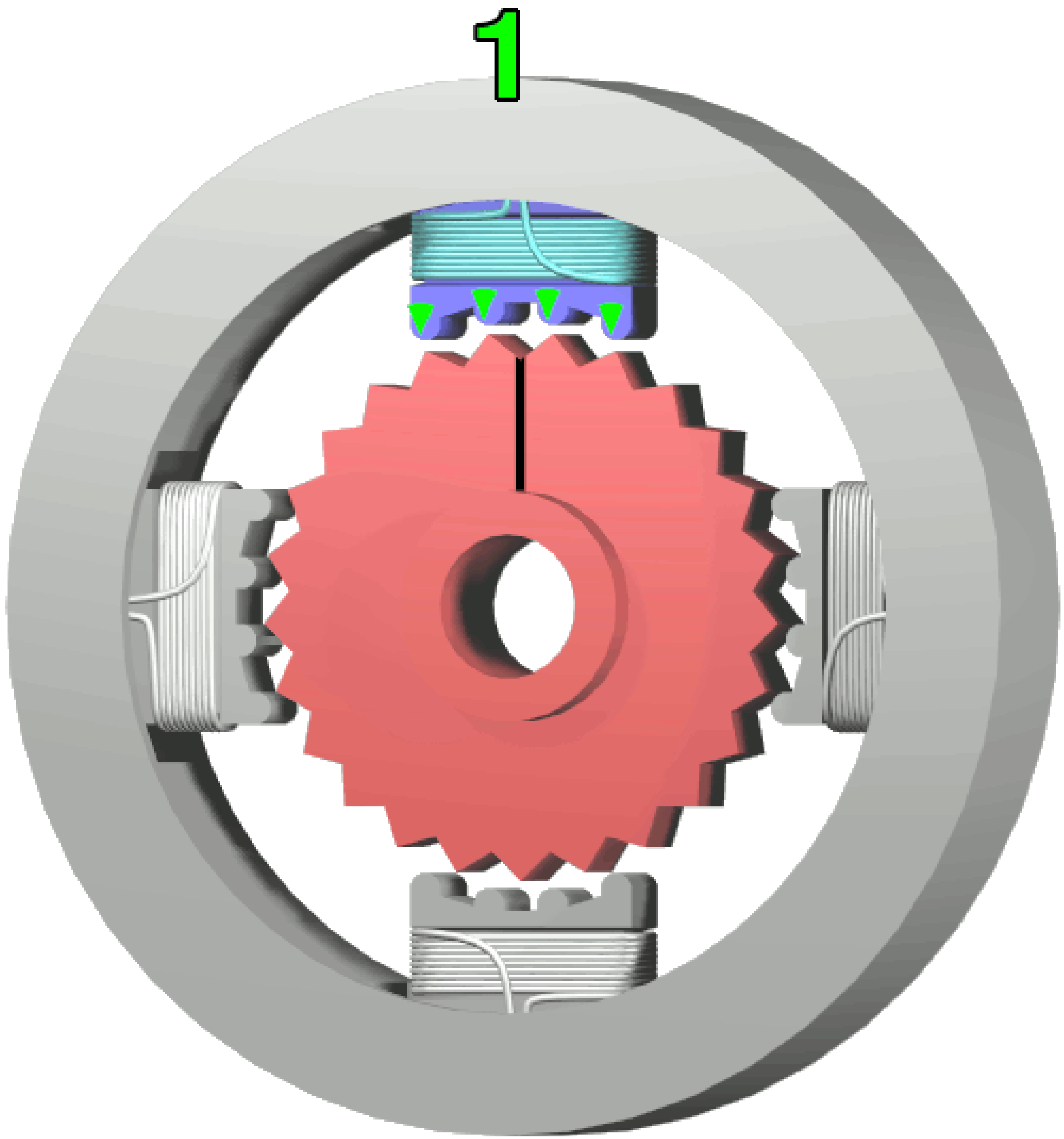
The angle by which the rotor of a stepper motor moves when one pulse is applied to the stator is called the step angle.

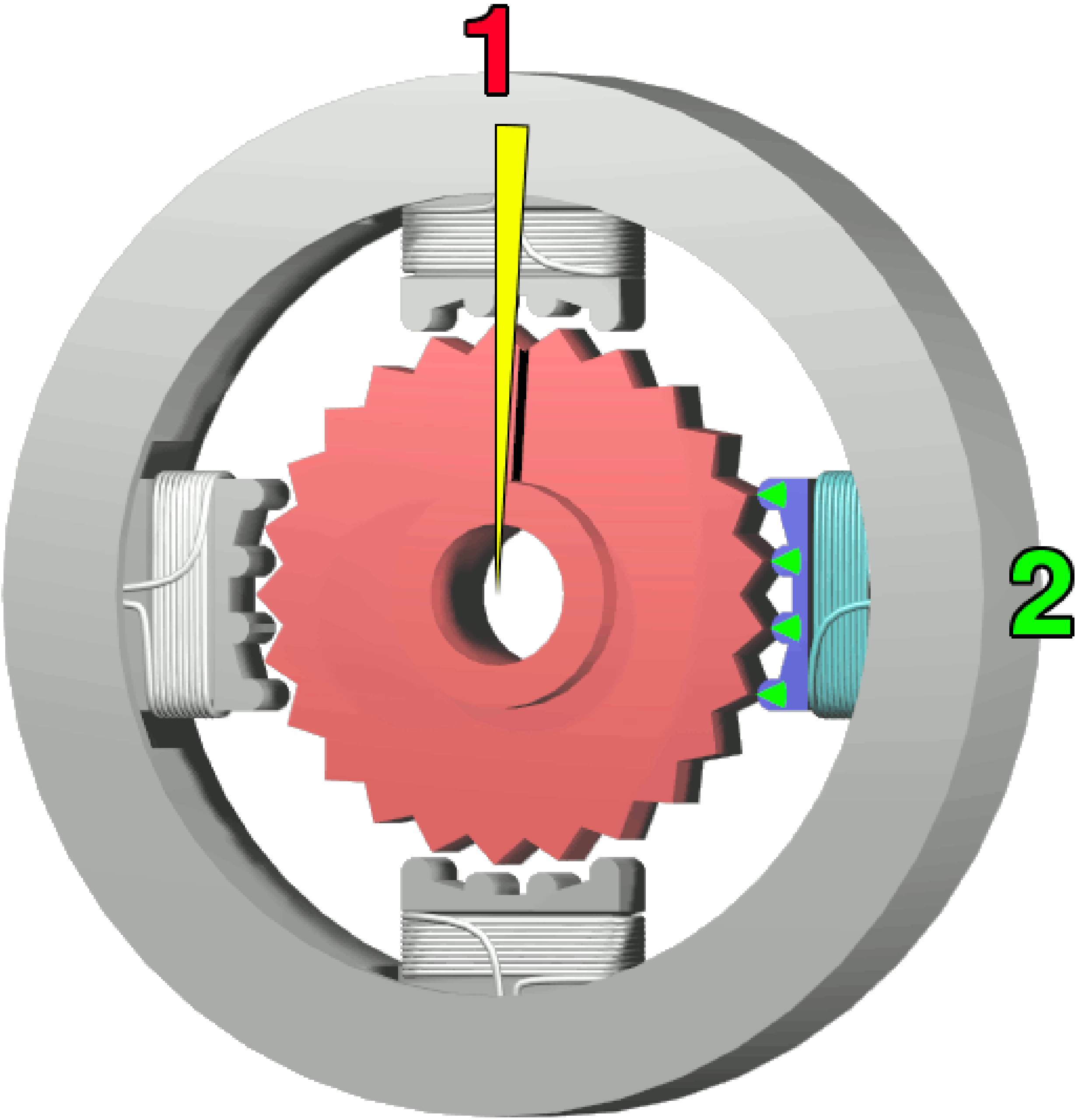
$$\text{Step angle} = 360 / m(Pr)$$

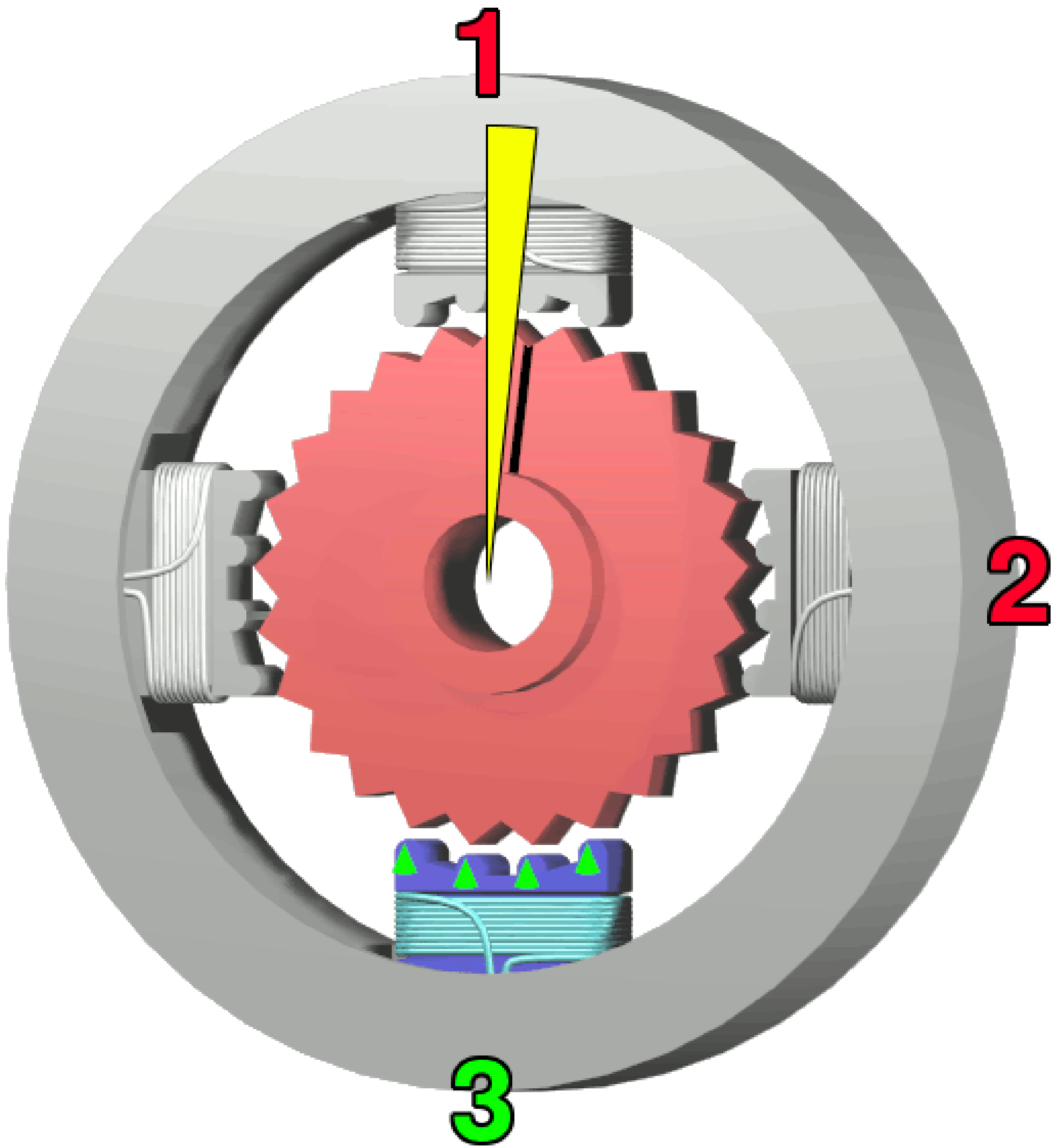
$$Pr = Ps \pm Ps/m$$

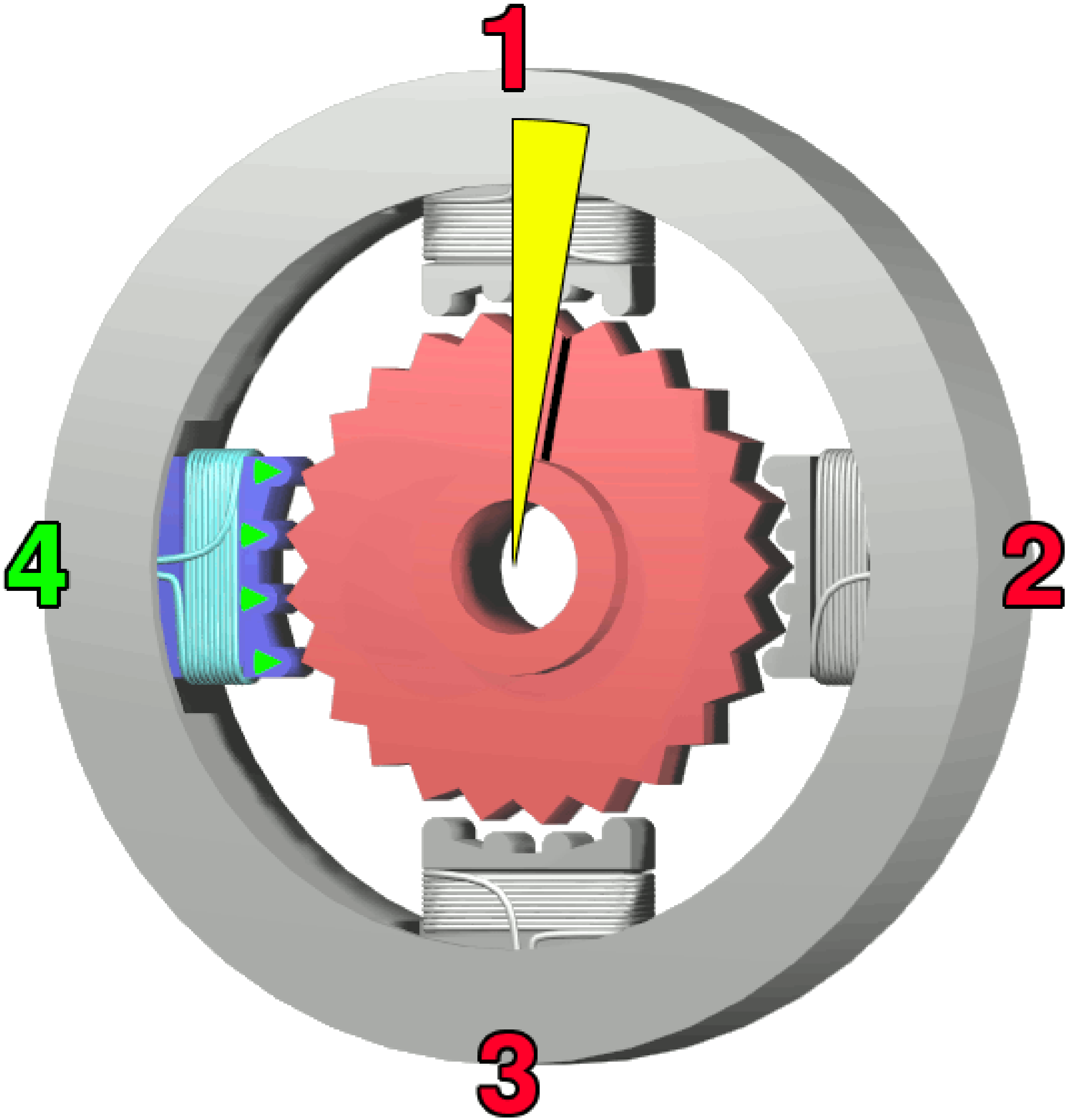
Resolution = No. of steps / No. of revolutions of rotor

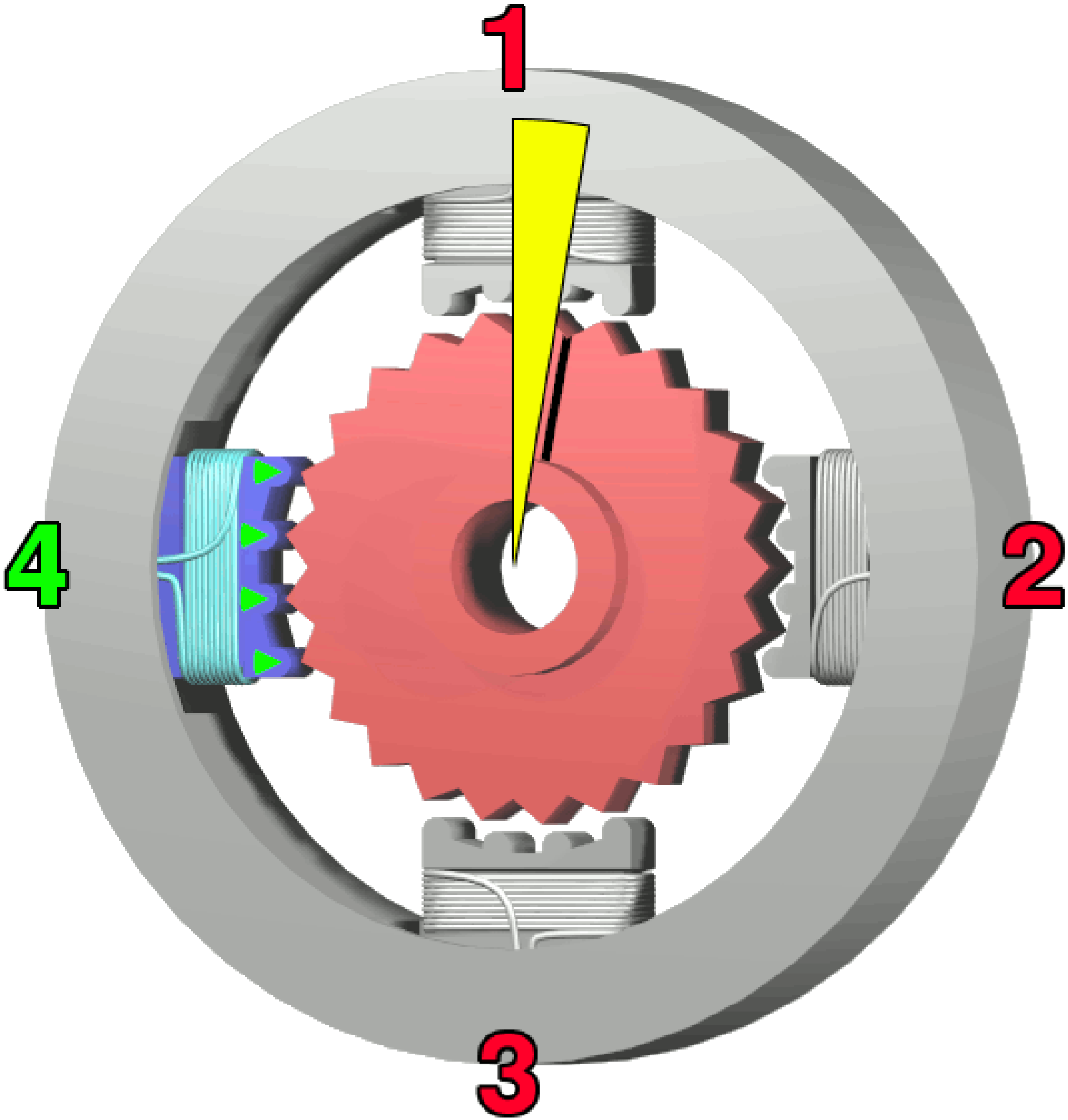
Stepper Motors


1


1
2


1
2
3


1
4
2
3


1
2
3
4

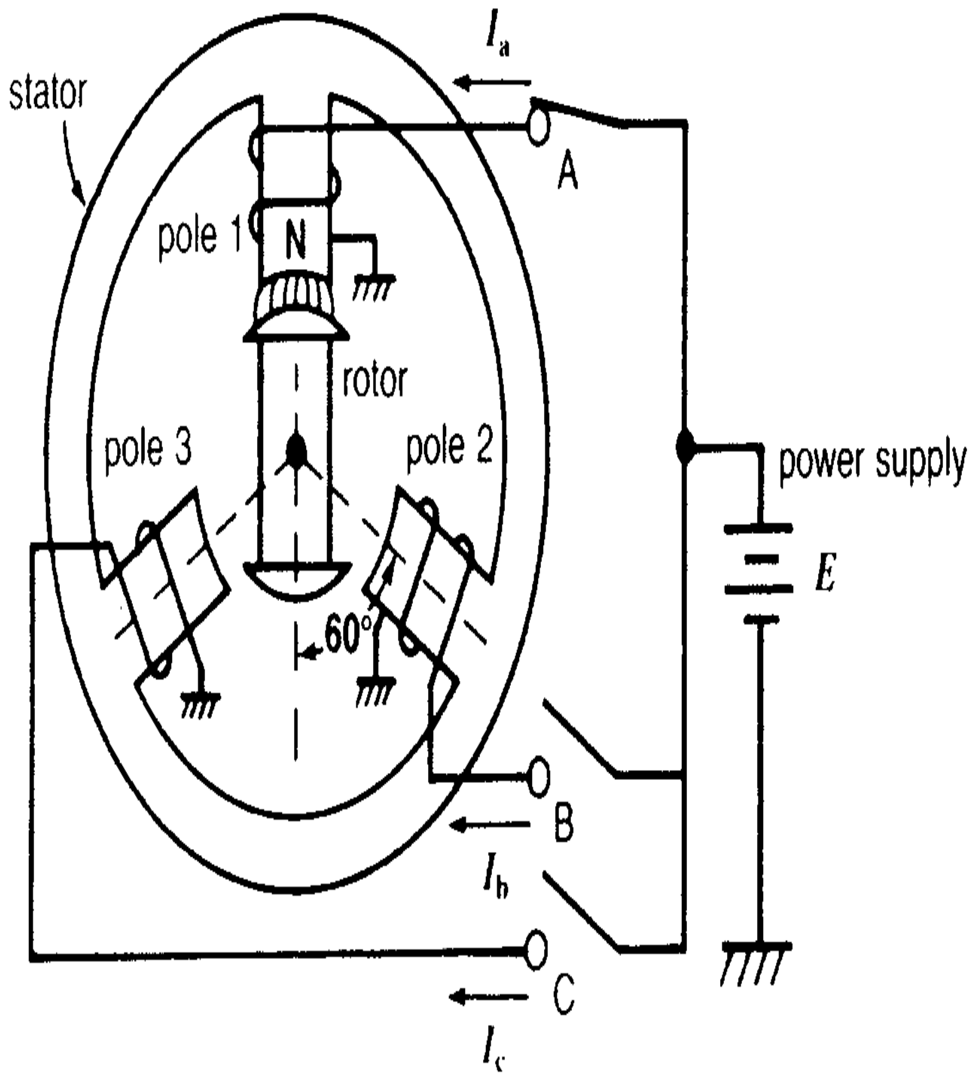
Stepper Motor Selection

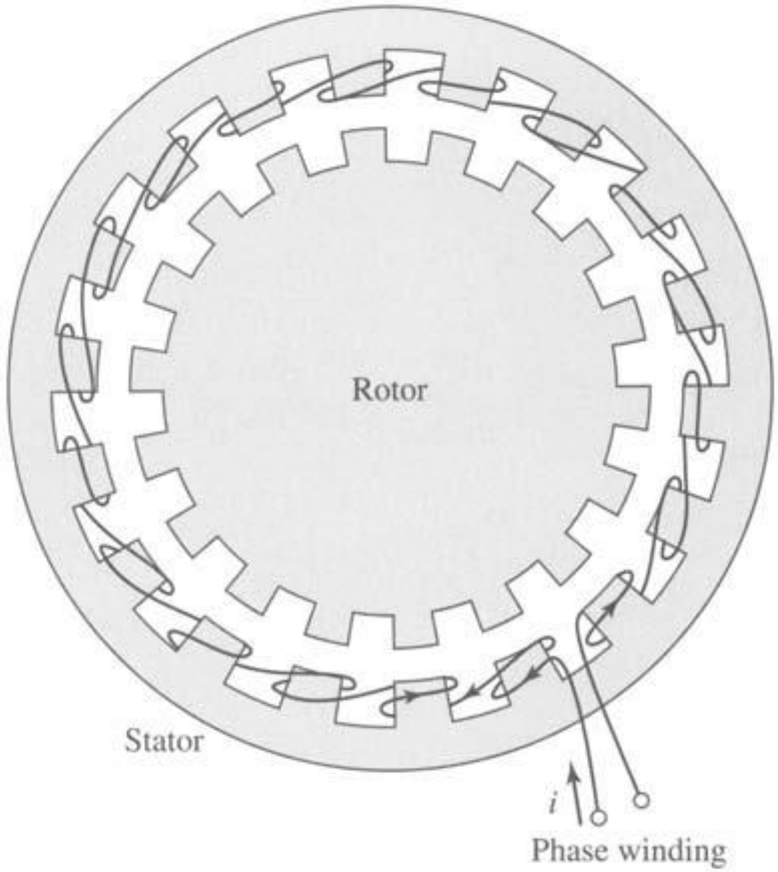
- Permanent Magnet / Variable Reluctance
- Unipolar vs. Bipolar
- Number of Stacks
- Number of Phases
- Degrees Per Step
- Microstepping
- Pull-In/Pull-Out Torque
- Detent Torque

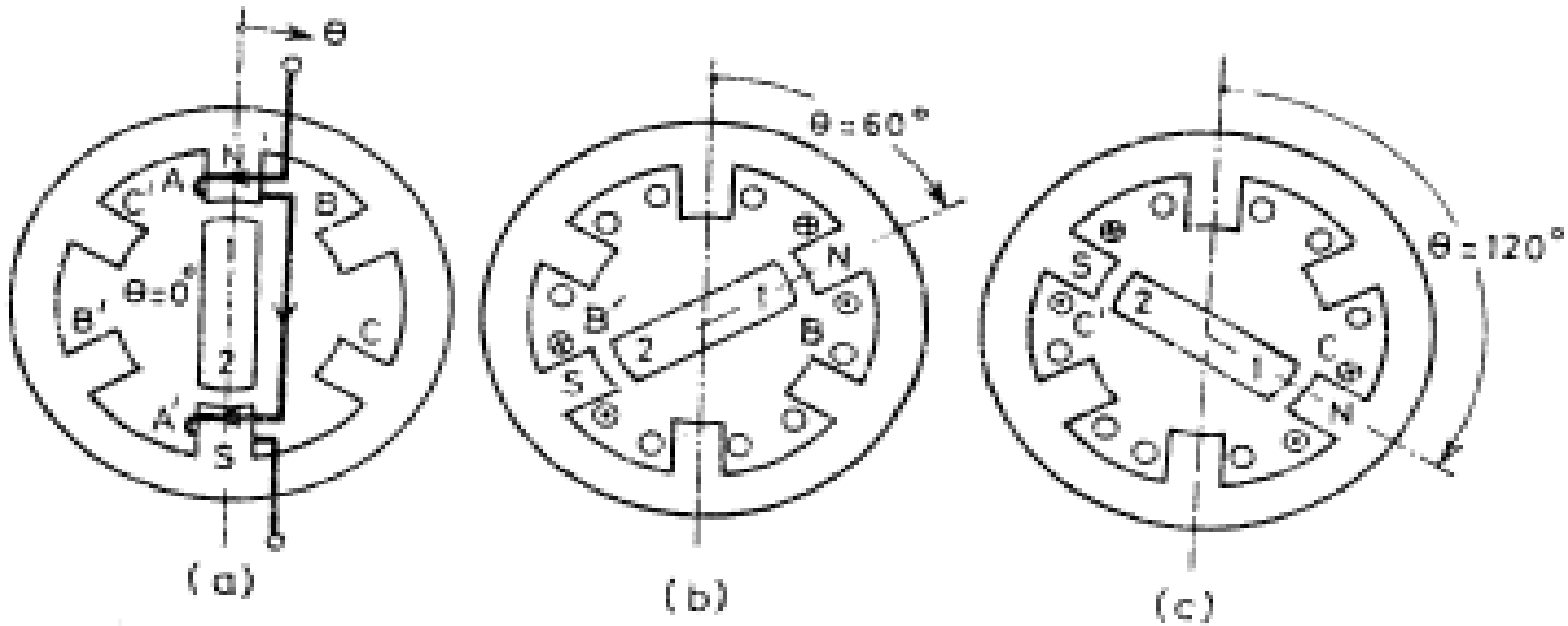
Three main types of stepper motors:

1. *variable reluctance stepper motors*
2. *permanent magnet stepper motors*
3. *hybrid stepper motors*

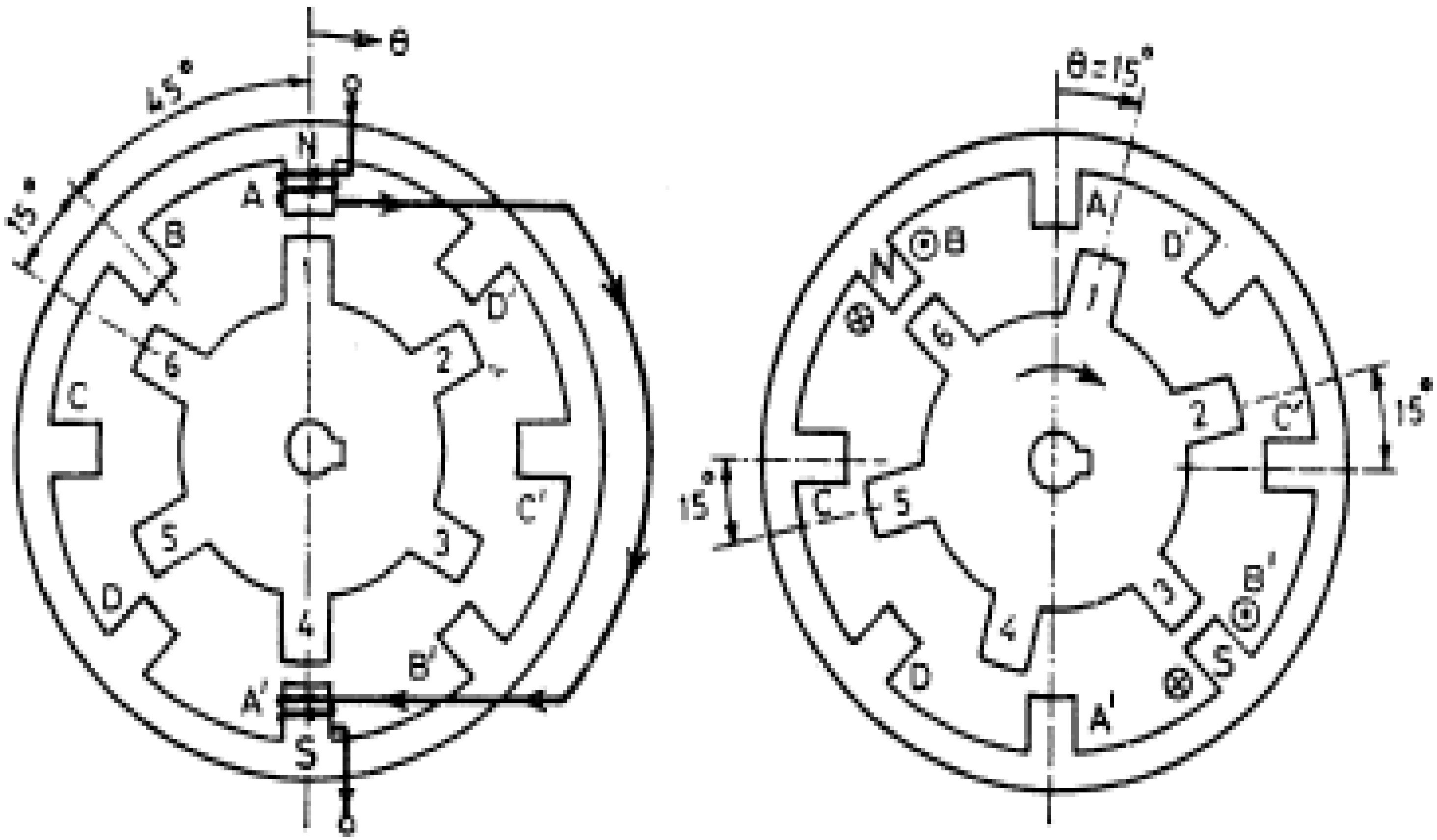
1.Variable reluctance stepper motor:



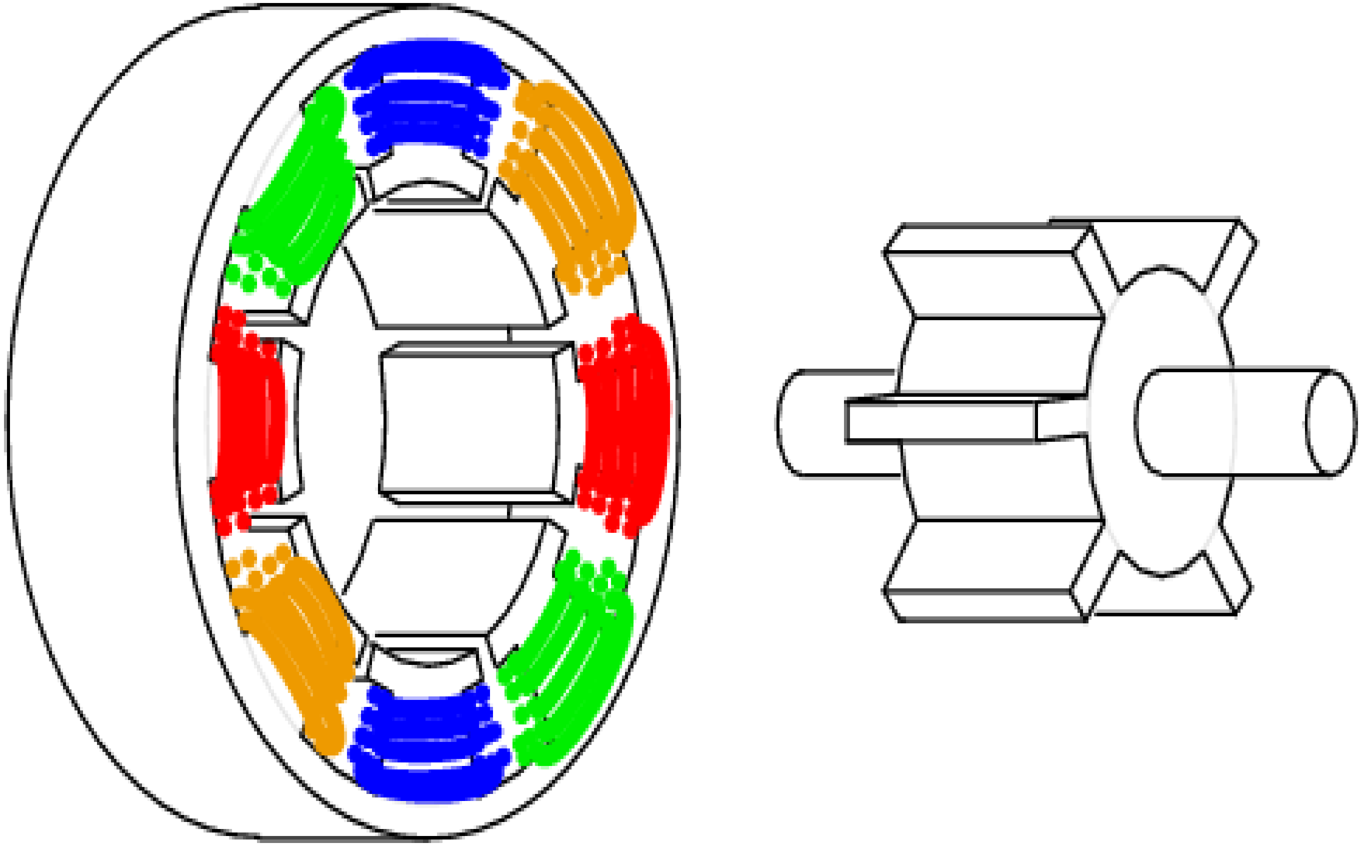


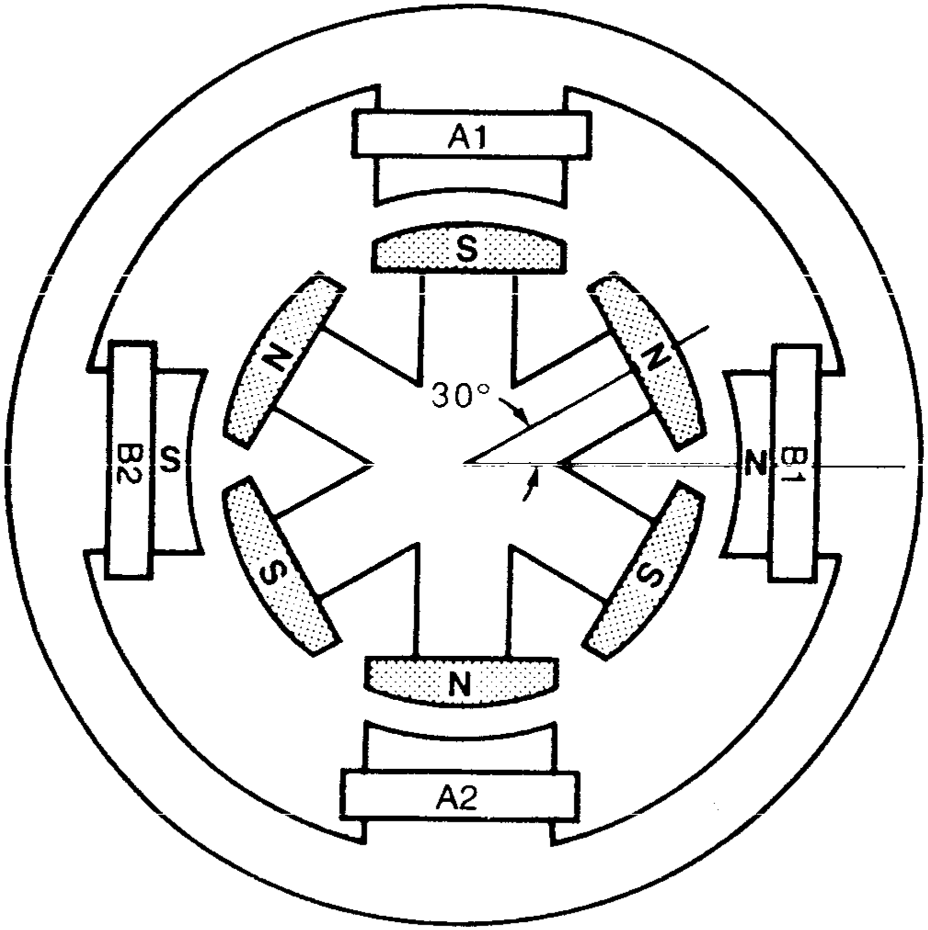


An elementary 3-phase, 6/2 pole variable reluctance stepping motor



Four phase 8/6-pole VR stepping motor

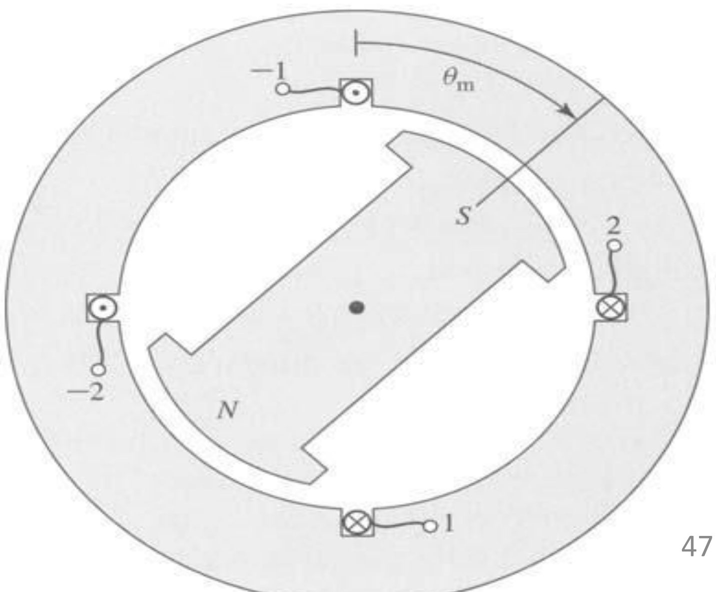


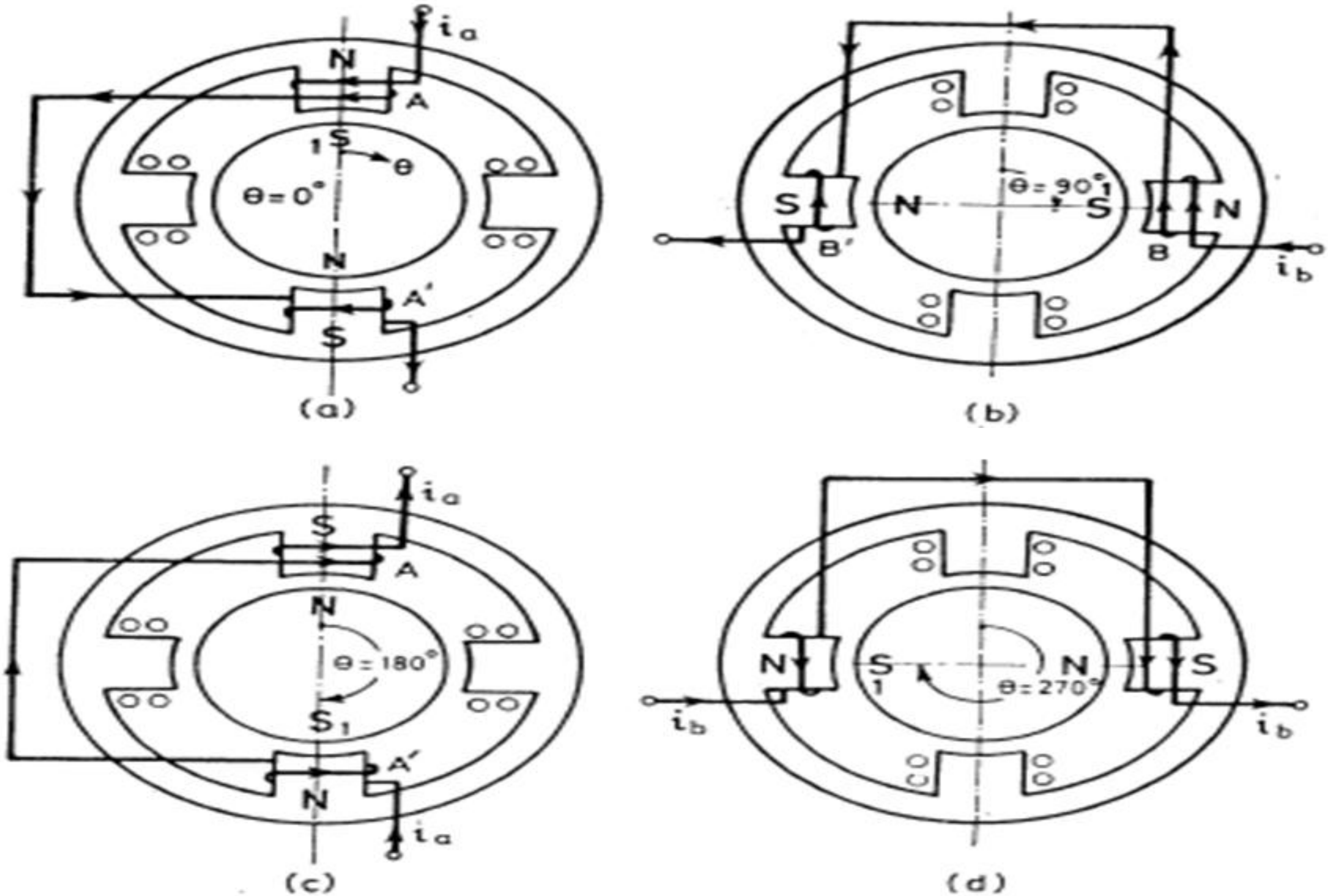


2.Permanent Magnet Stepper Motors

➢Rotor consists of PM
Detent Torque – residual flux holding rotor in place with no field current

➢Higher power applications





Elementary form of two-phase 4/2 pole permanent magnet stepping motor

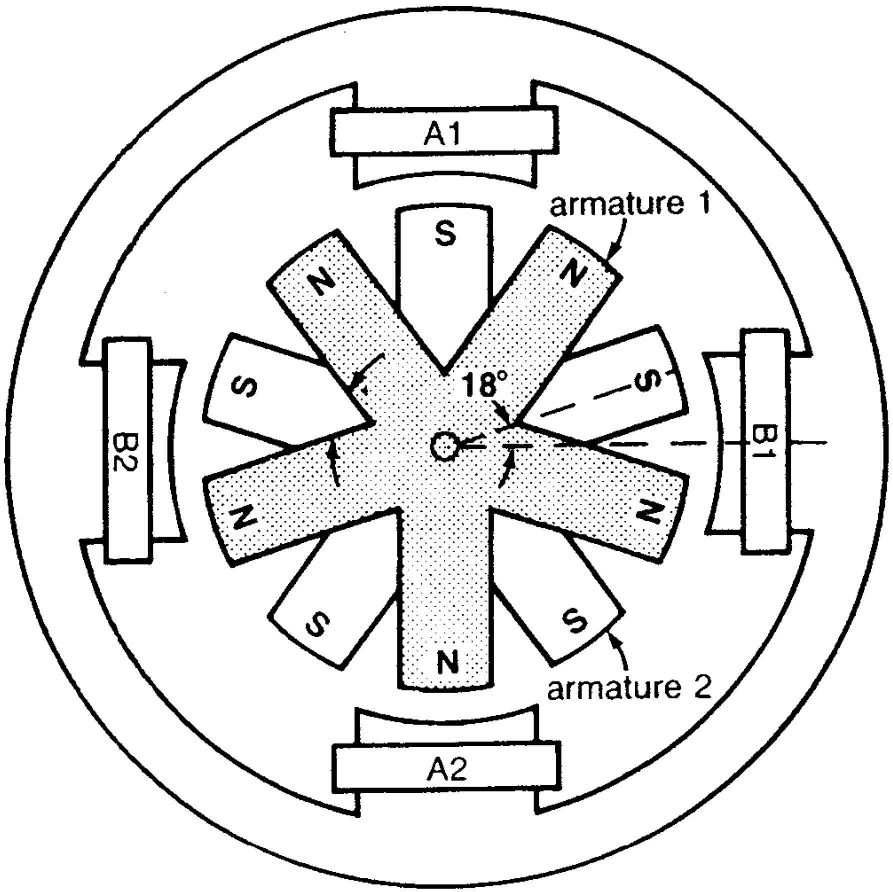
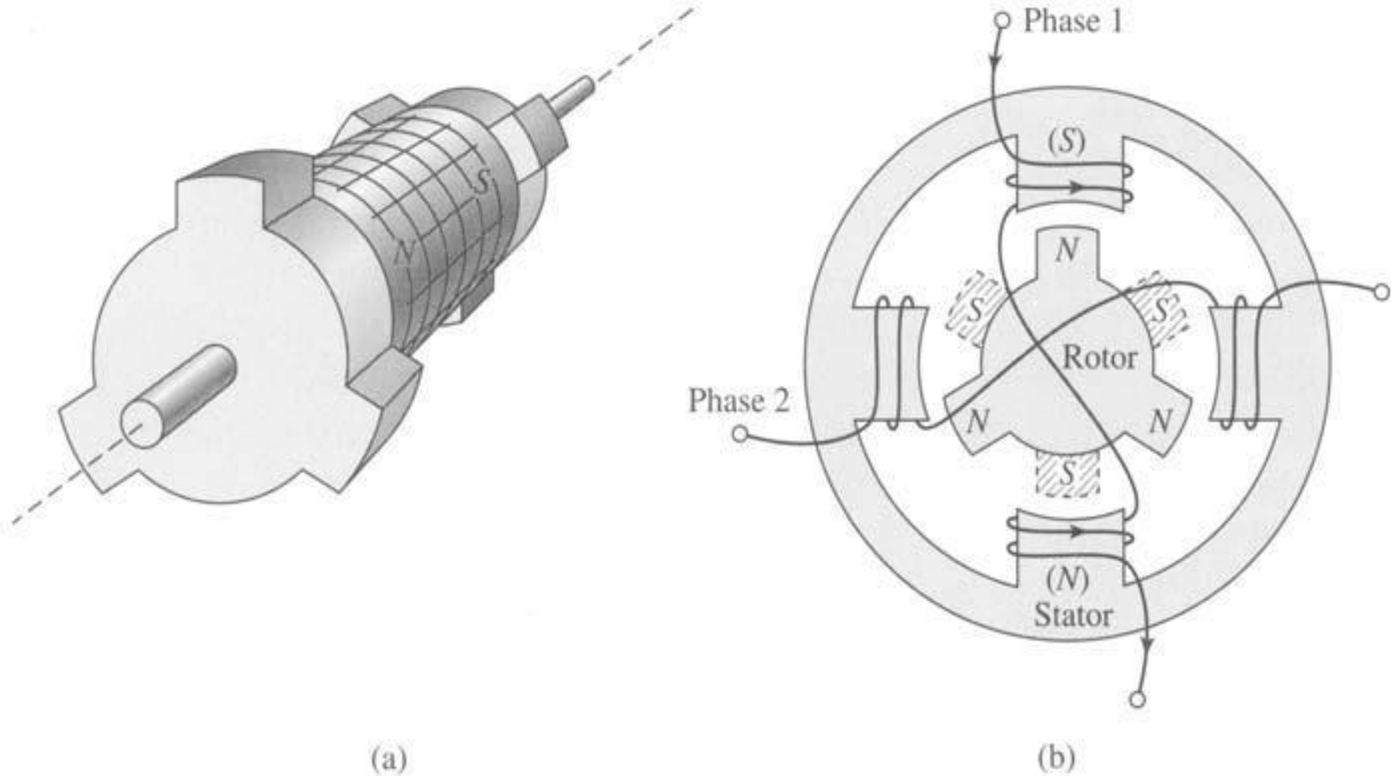


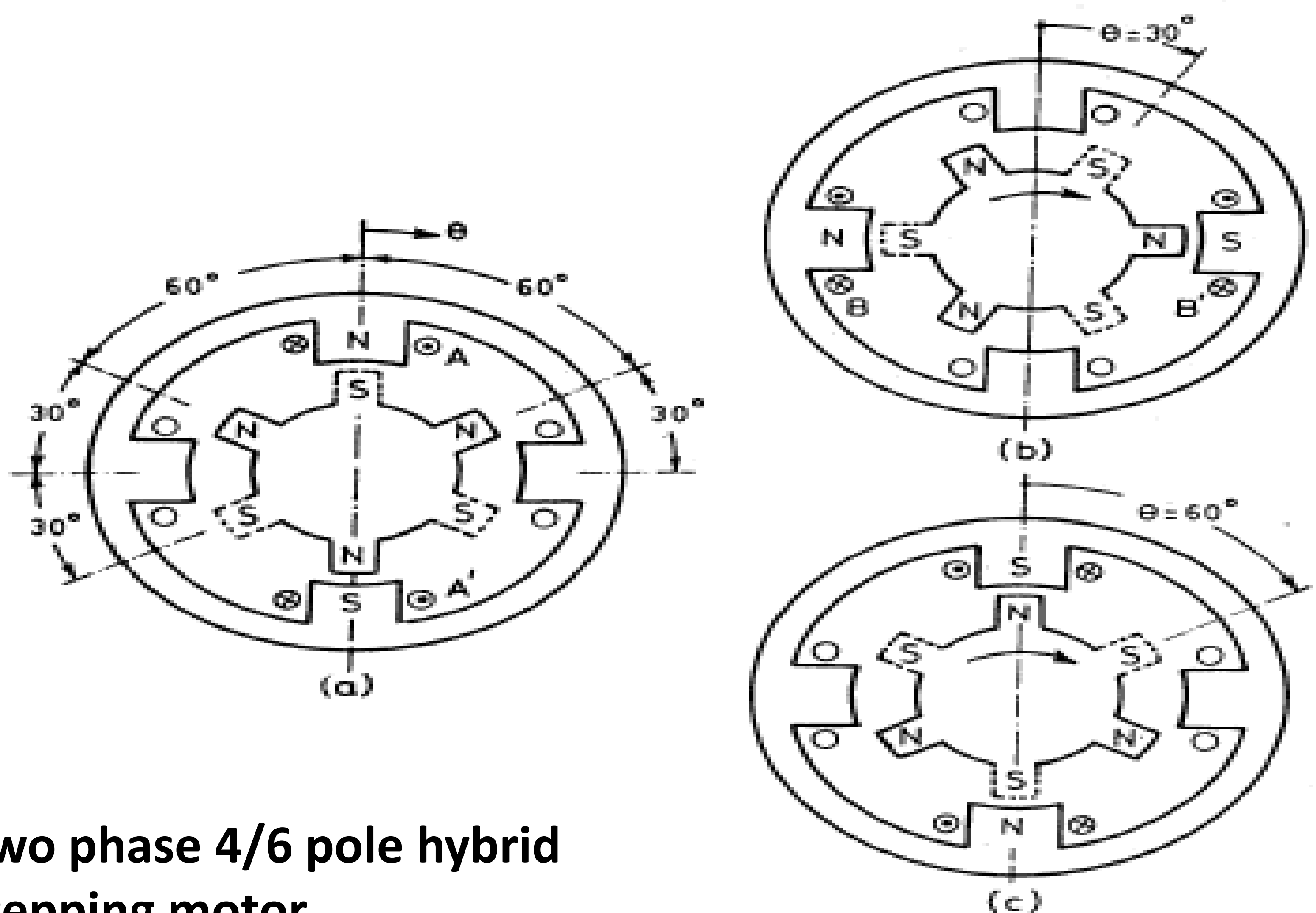
Figure 19.11a
Hybrid motor having a 4-pole stator and two 5-pole armatures mounted on the same shaft. The salient poles on the first armature are all N poles, while those on the second armature are all S poles. Each step produces an advance of 18°.

3.Hybrid Motor:

- 2 Soft Iron armatures interlaced
- PM between Iron armature
- Alternating S N poles
- A1/A2 coils in series



Schematic view of a **hybrid stepping motor**.
(a) Two-stack rotor showing the axially-directed permanent magnet and the pole pieces displaced by one-half the pole pitch.
(b) End view from the rotor north poles and showing the rotor south poles at the far end (shown crosshatched). Phase 1 of the stator is energized to align the rotor as shown.

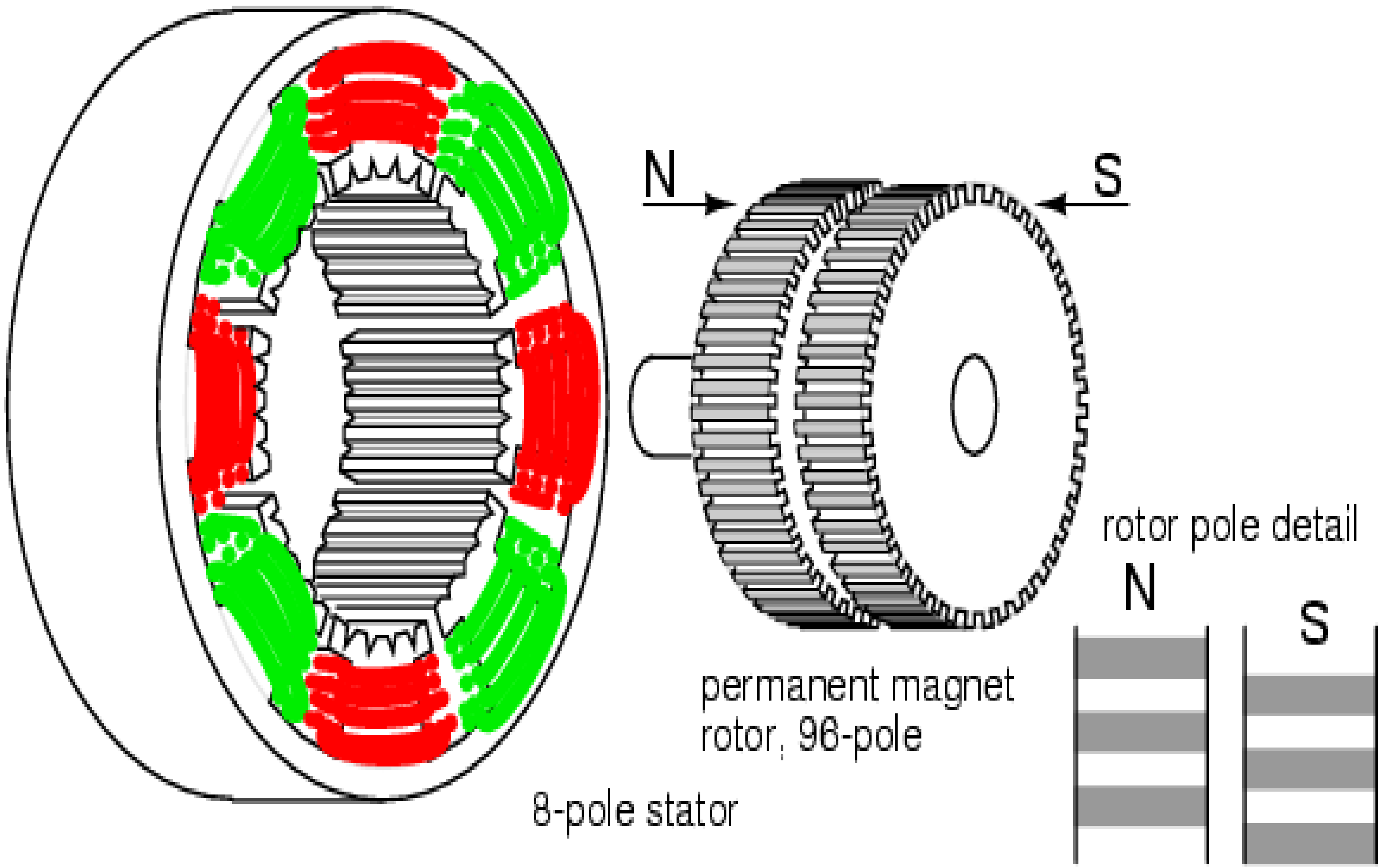


Two phase 4/6 pole hybrid stepping motor

(*a)Stator phase winding A exited.*

(b) Stator phase winding B exited.

(c) Stator phase winding C exited.


N
S
rotor pole detail
N
S
permanent magnet
rotor, 96-pole
8-pole stator

APPLICATIONS

Typical applications include paper fed motors in typewriters and printers , positioning of print heads , pens in x-y plotters , recording heads in computer disk drives , robotics , textile industry, integrated circuit fabrication and worktable and tool positioning in numerically controlled machining equipments.

ADVANTAGES

1. The rotation angle of the motor is proportional to the input pulse.

2. The motor has full torque at standstill. (if the windings are energized)

3. Precise positioning and repeatability of movement since good.

4. Excellent response to starting/stopping/reversing.

5. Very reliable since there are no Contact brushes in the motor. Therefore the life of the motor is simply dependant on the life of the bearing.

DISADVANTAGES

1. Resonances can occur if not properly controlled.

2. Not easy to operate at extremely high speeds.

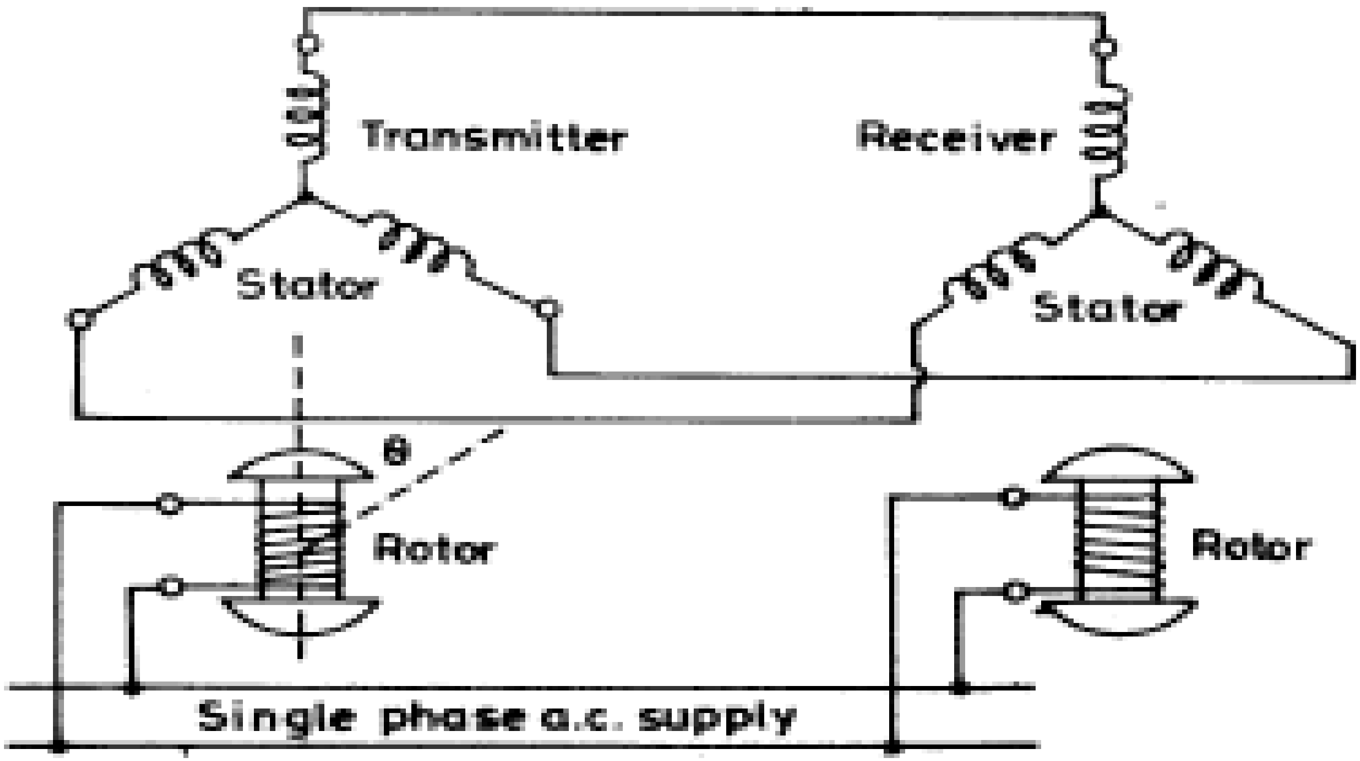
SYNCHROS

- *They are also known by trade name of positon selsyn,autosyns and microsyns.*

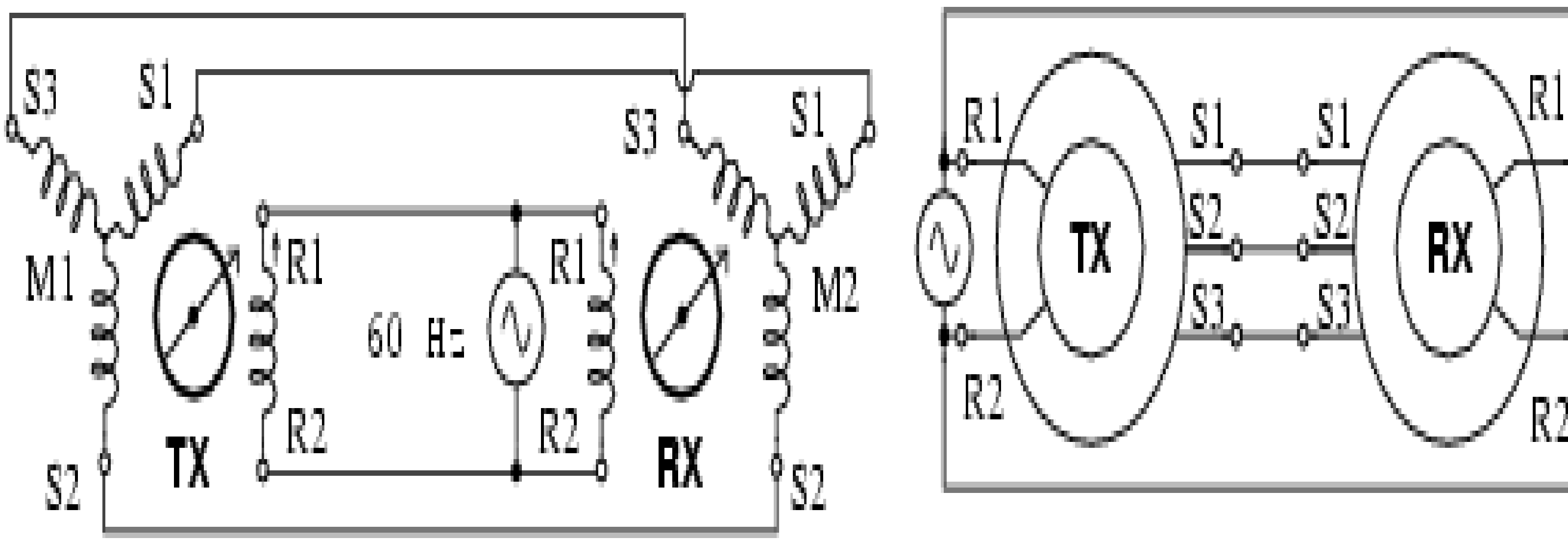
- *It is general name for self synchronising machine, which when electrically energised and electrically interconnected, exerts torque which causes the mechanically independent shafts either to run in synchronism or to make the rotor of one unit follow the rotor position of other.*

Types of synchros

1. Transmitter selsyn
2. Receiver selsyn
3. Differential selsyn
4. Transformer selsyn



Connection of transmitter-receiver selsyn

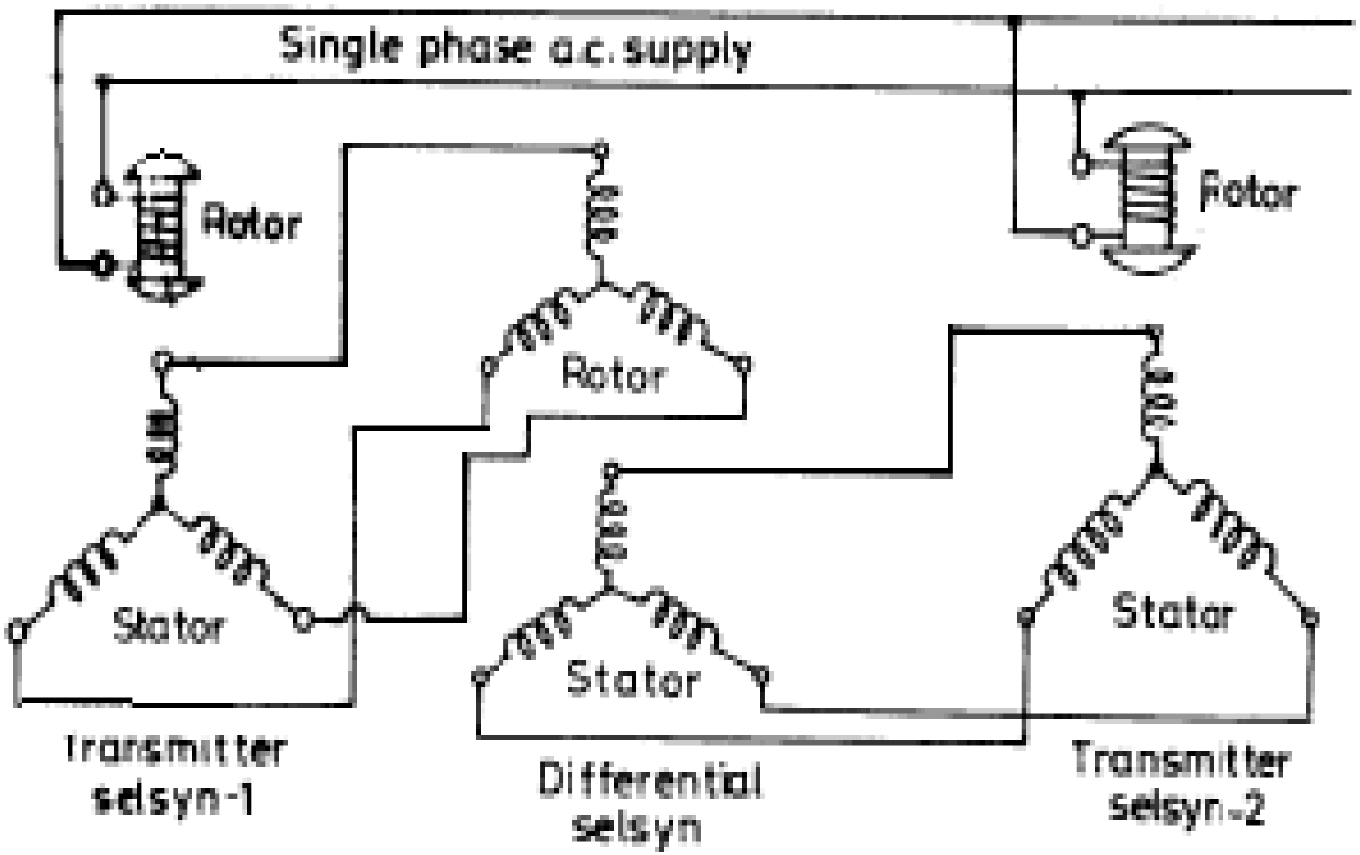


Stator Rotor Rotor Stator Alternate abreviated symbols

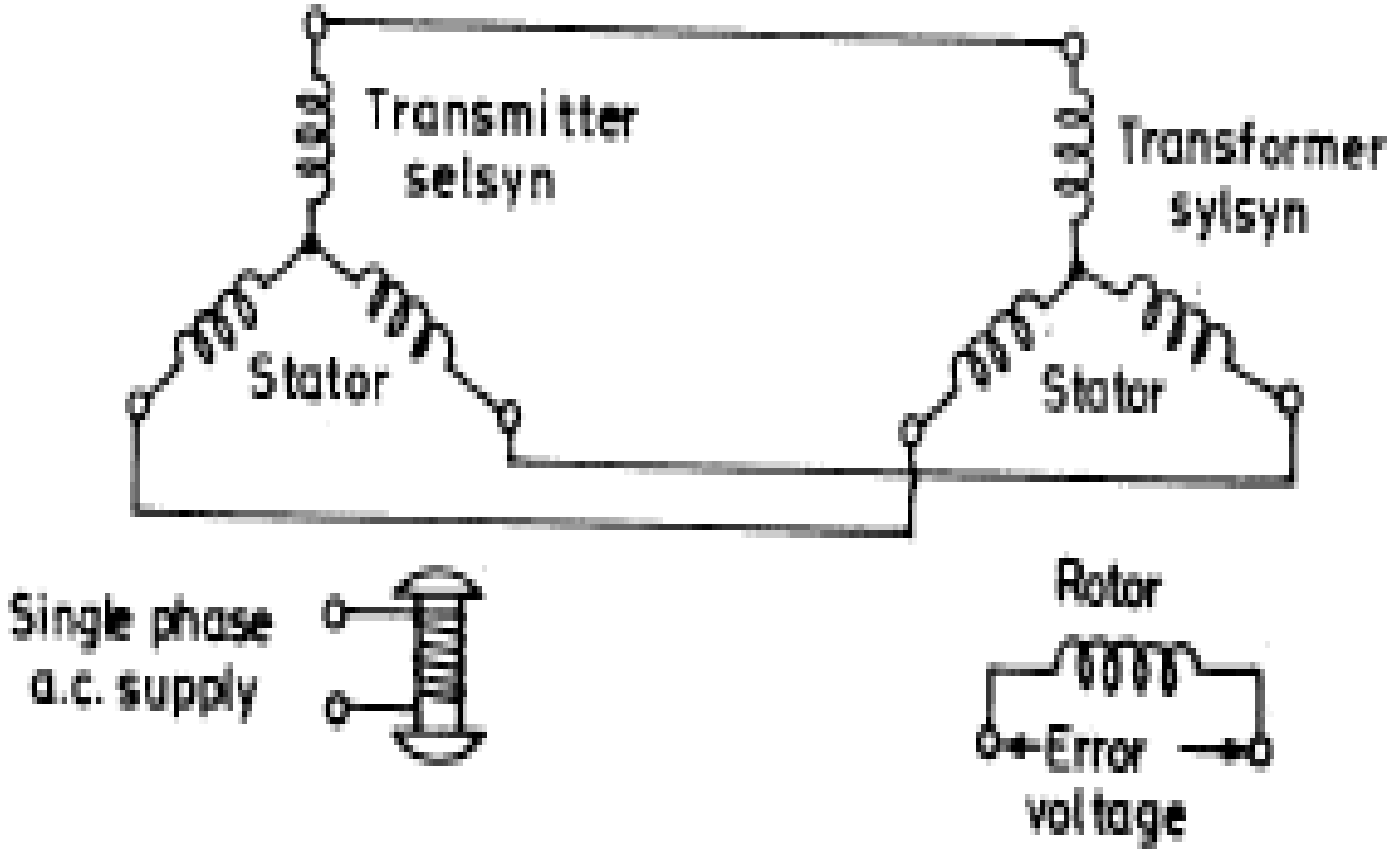
Torque transmitter - TX Torque receiver - RX

Small instrumentation selsyns, also known as *sychros*, use single phase paralleled, AC energized rotors, retaining the 3-phase paralleled stators, which are not externally energized. Synchros function as rotary transformers. If the rotors of both the *torque transmitter* (TX) and *torque receiver* (RX) are at the same angle, the phases of the induced stator voltages will be identical for both, and no current will flow. If one rotor be displaced from the other, the stator phase voltages will differ between transmitter and receiver. Stator current will flow developing torque. The receiver shaft is electrically slaved to the transmitter shaft. Either the transmitter or receiver shaft may be rotated to turn the opposite unit.

Synchro stators are wound with 3-phase windings brought out to external terminals. The single rotor winding of a torque transmitter or receiver is brought out by brushed slip rings. Synchro transmitters and receivers are electrically identical. However, a synchro receiver has inertial damping built in. A synchro torque transmitter may be substituted for a torque receiver.



Connections of differential selsyn



Connection of transformer selsyn

Why a Brushless DC Motor ?

- Many of the limitations of the classic permanent magnet "brushed" DC motor are caused by the brushes pressing against the rotating commutator creating friction
  - As the motor speed is increased, brushes may not remain in contact with the rotating commutator
  - At higher speeds, brushes have increasing difficulty in maintaining contact
  - Sparks and electric noise may be created as the brushes encounter flaws in the commutator surface or as the commutator is moving away from the just energized rotor segment
  - Brushes eventually wear out and require replacement, and the commutator itself is subject to wear and maintenance
- Brushless DC motors avoid these problems with a modified design, but require a more complex control system

Introduction

- A brushless d.c. motor is a polyphase synchronous motor with a permanent magnet rotor.

- It is a motor drive system which combines into one unit an a.c. motor, solid state motor and a position sensor.

- It has permanent magnet field poles on the rotor and polyphase armature winding on the stator.

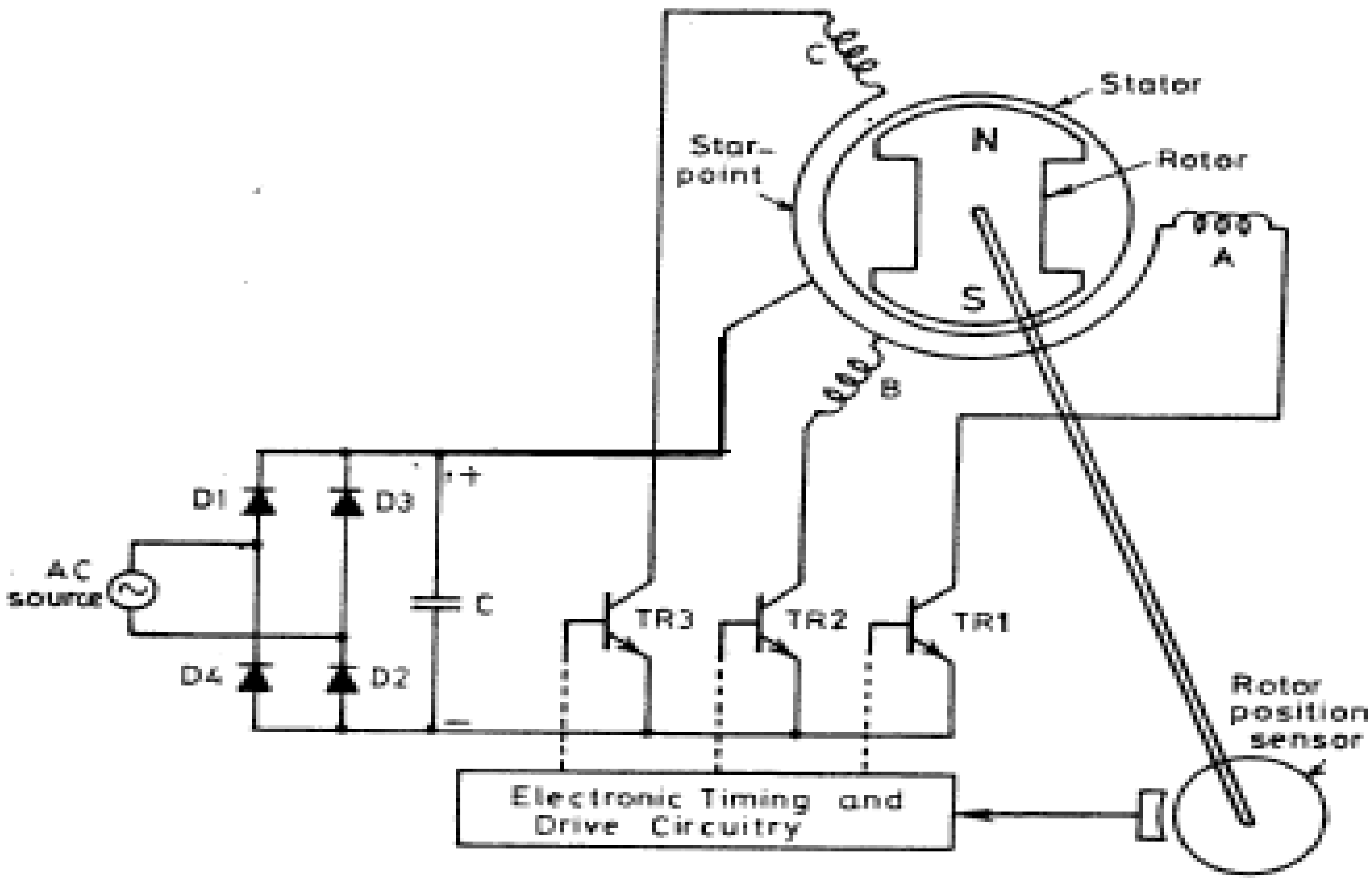
- A brushless DC motor uses electronic sensors to detect the position of the rotor without using a metallic contact.

Permanent Magnetic Materials

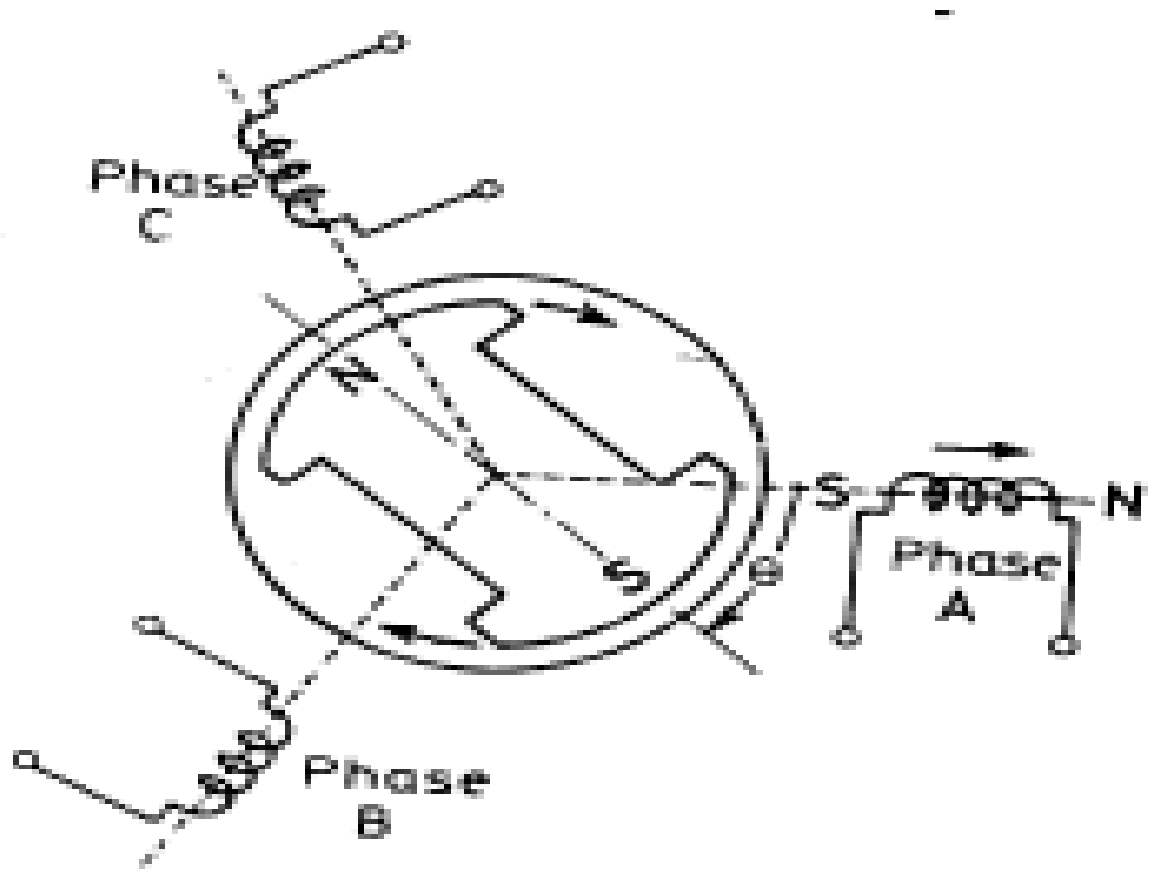
- Alnico - good properties but too low a coercive force and too square a B-H loop => permanent demagnetization occurs easily
- Ferrites (Barium and Strontium) - low cost, moderately high service temperature (400°C), and straight line demagnetization curve. However, B_r is low => machine volume and size needs to be large.
- Samarium-Cobalt (Sm-Co) - very good properties but very expensive (because Samarium is rare)
- Neodymium-Iron-Boron (Nd-Fe-B) - very good properties except the Curie temperature is only 150°C

WORKING

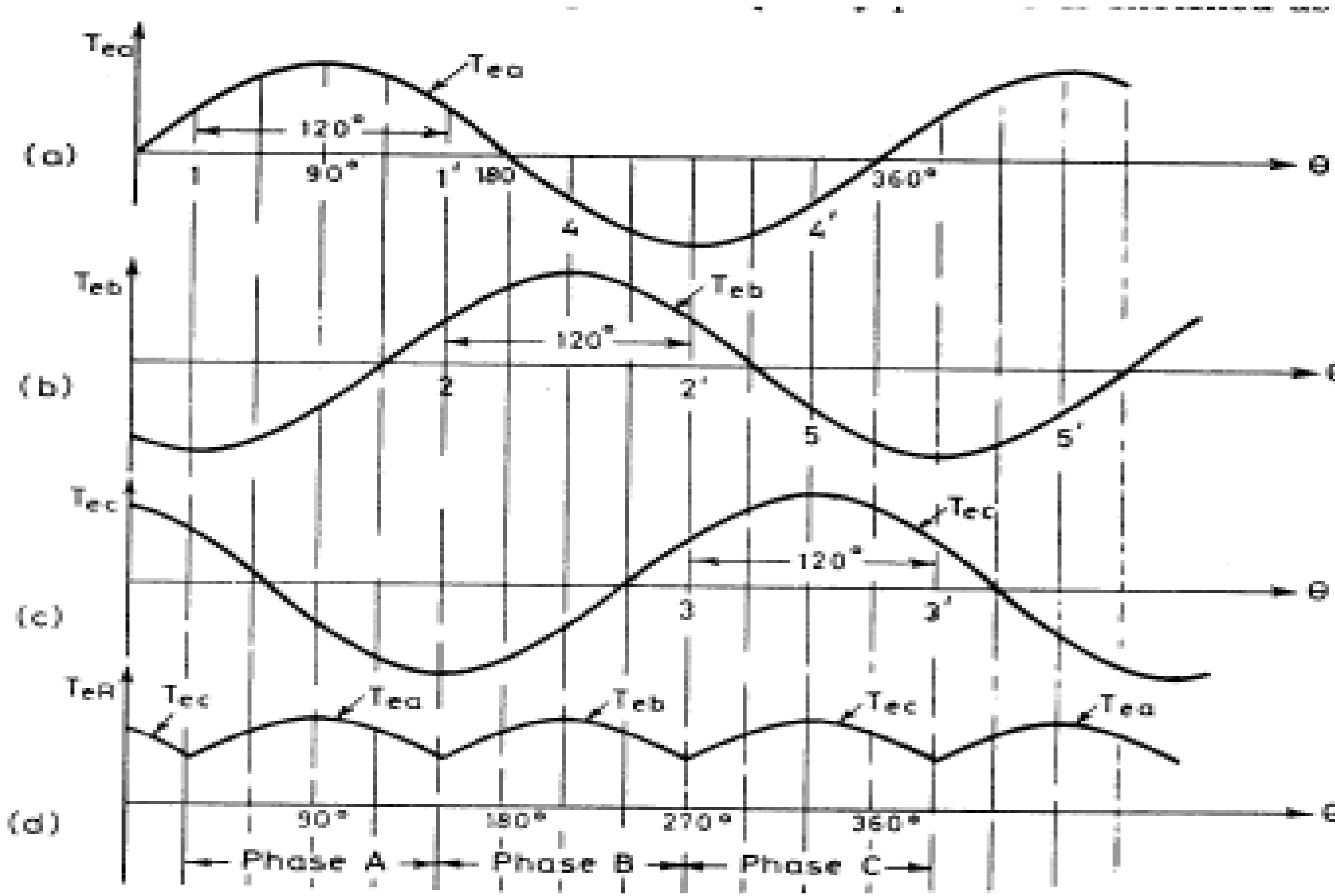
- Using the sensor's signals, the polarity of the electromagnets' is switched by the motor control drive circuitry
- The motor can be easily synchronized to a clock signal, providing precise speed control
- Brushless DC motors may have:
  - An external PM rotor and internal electromagnet stator
  - An internal PM rotor and external electromagnet stator



Three phase three pulse brushless d.c. motor



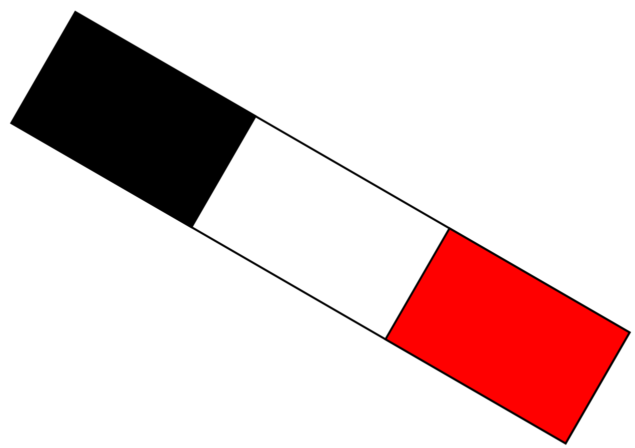
An elementary form of brushless d.c. motor.



Static torque angle characteristics of a brushless d.c. motor.

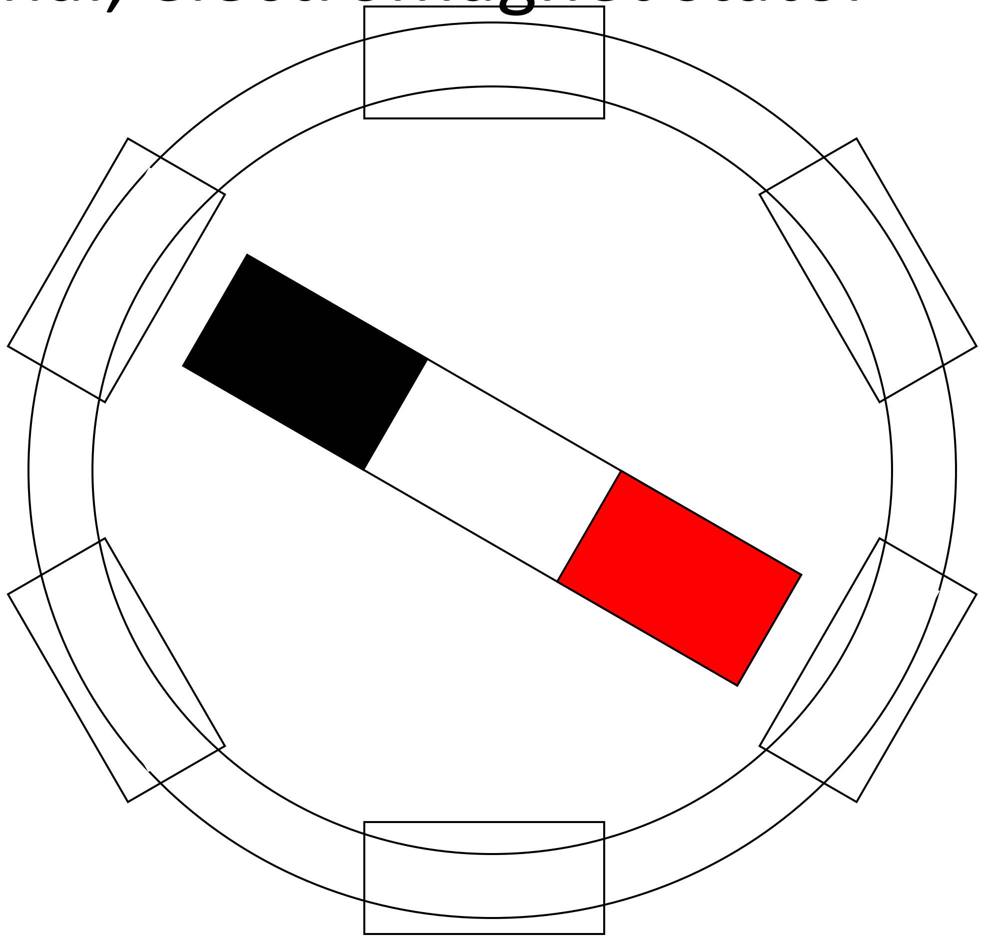
Example Brushless DC Motor Operation

- This example brushless DC motor has:
  - An internal, permanent magnet rotor



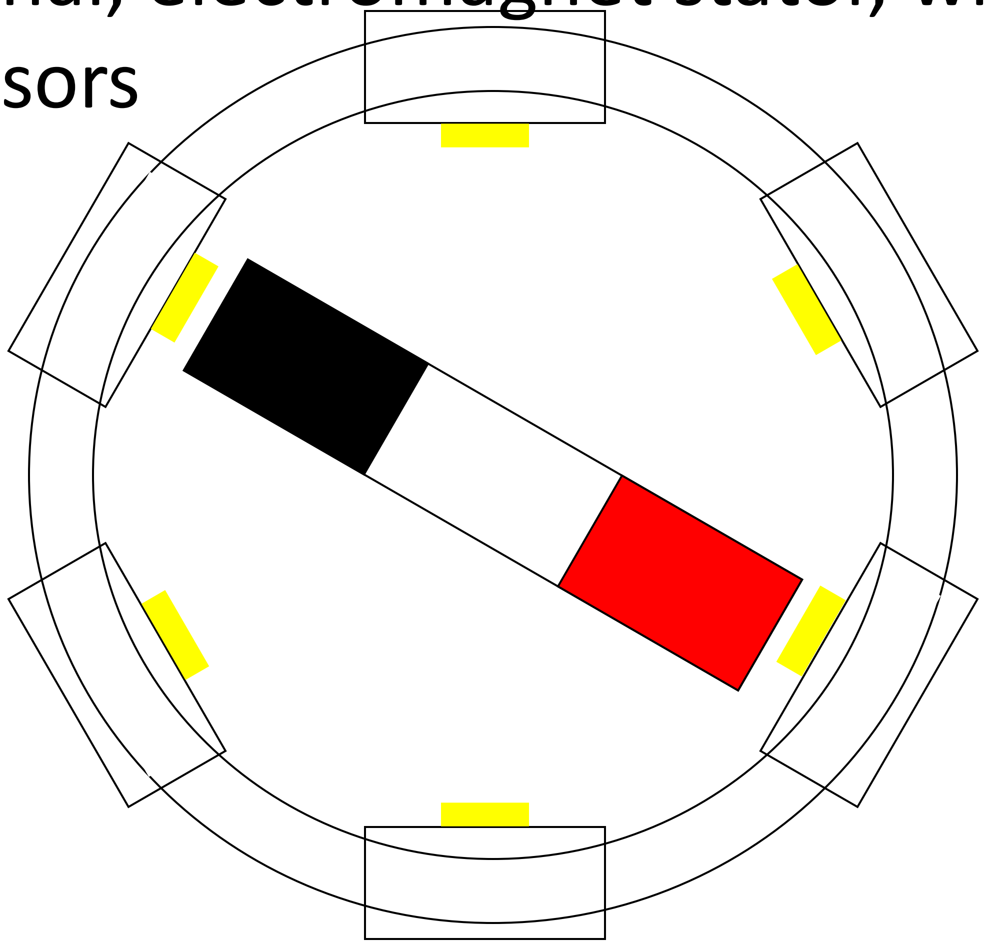
Example Brushless DC Motor Operation

- This example brushless DC motor has:
  - An external, electromagnet stator

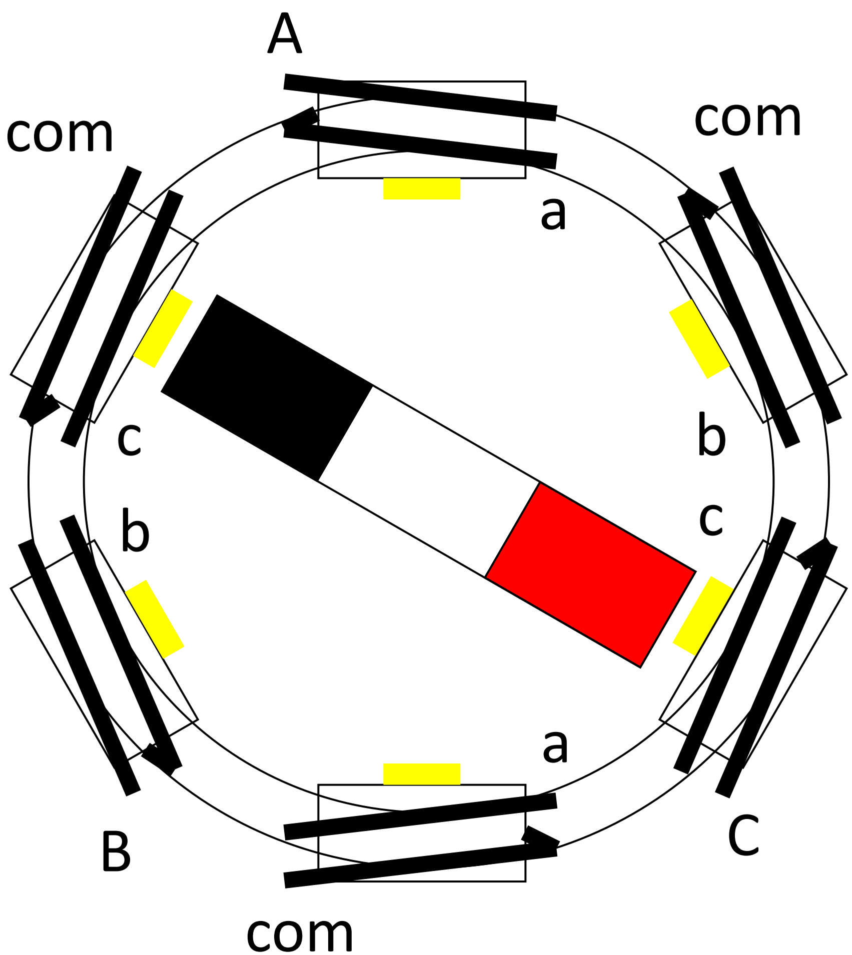


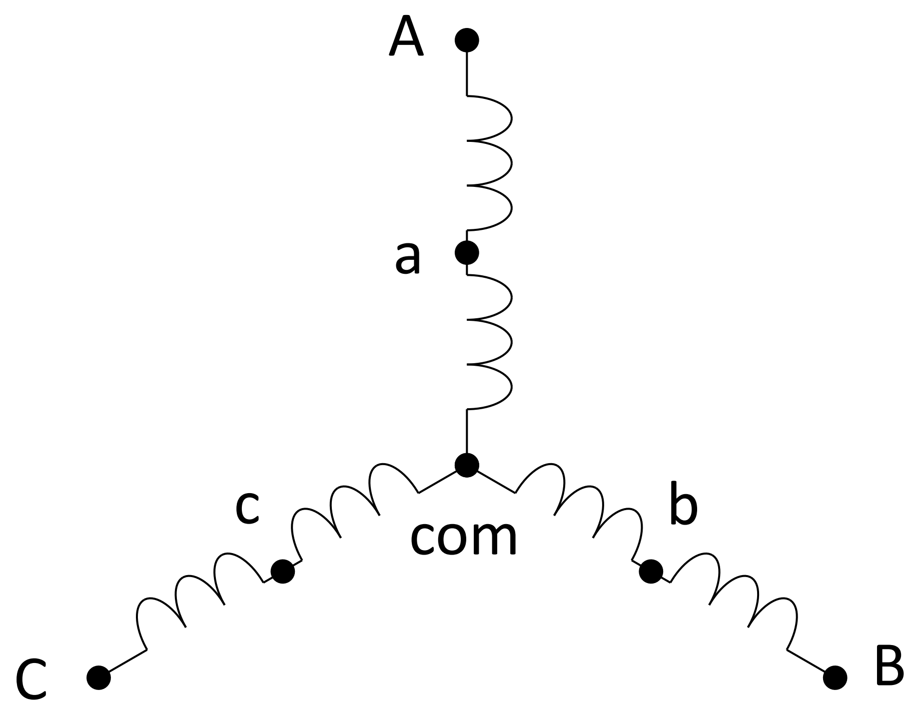
Example Brushless DC Motor Operation

- This example brushless DC motor has:
  - An external, electromagnet stator, with magnetic field sensors

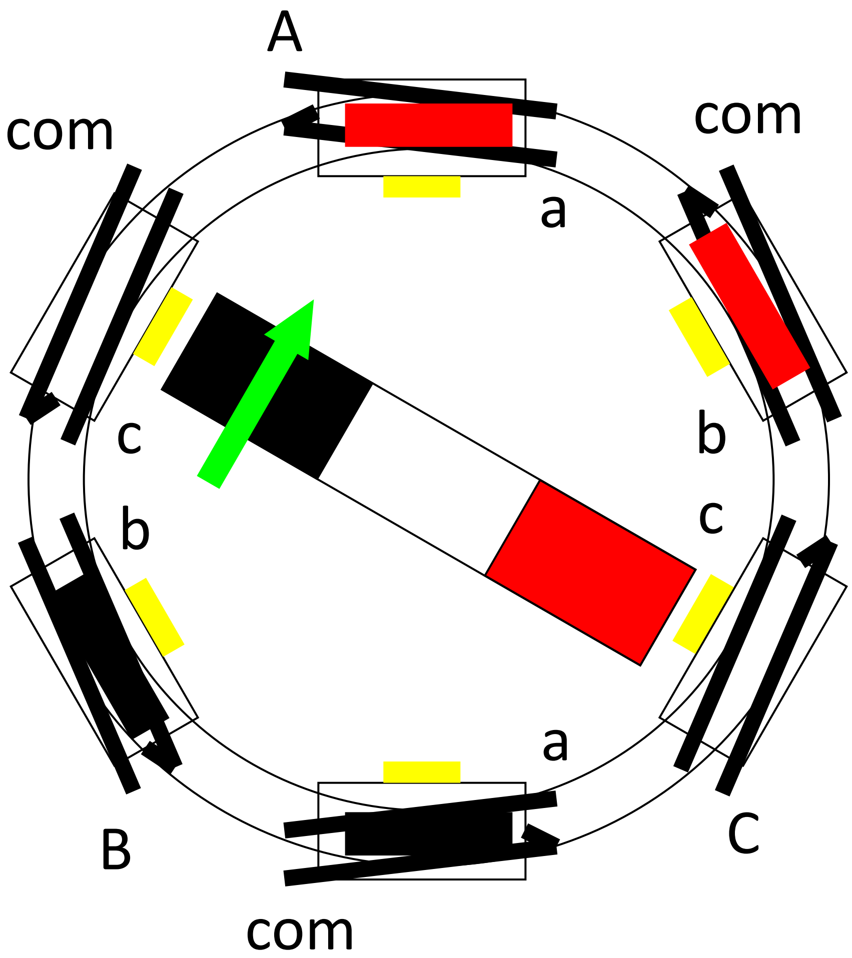


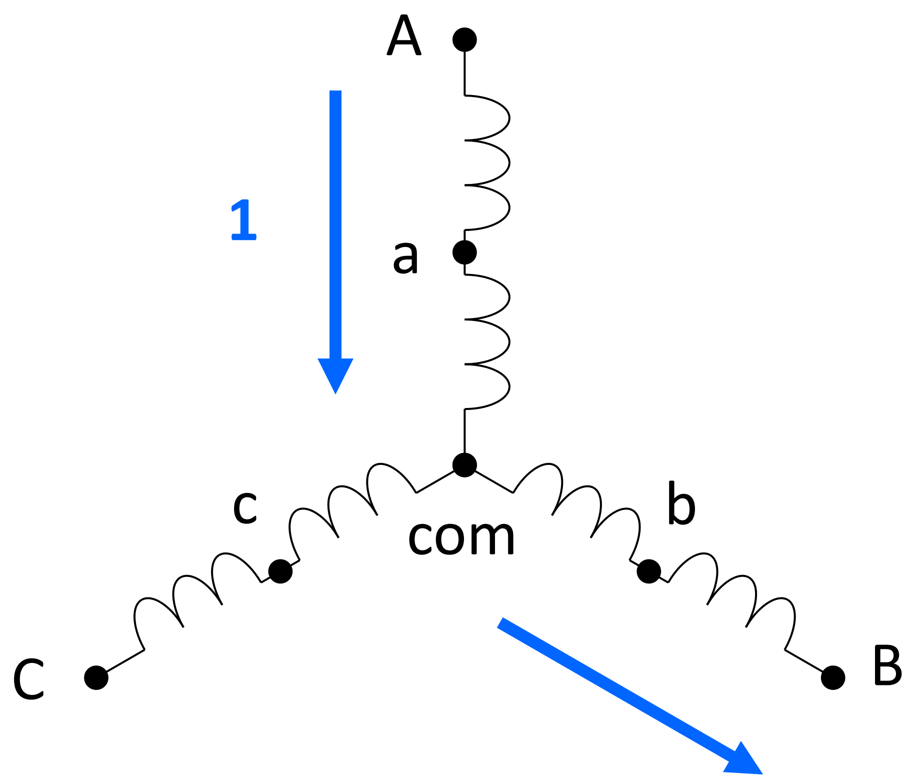
Brushless DC Motor Construction



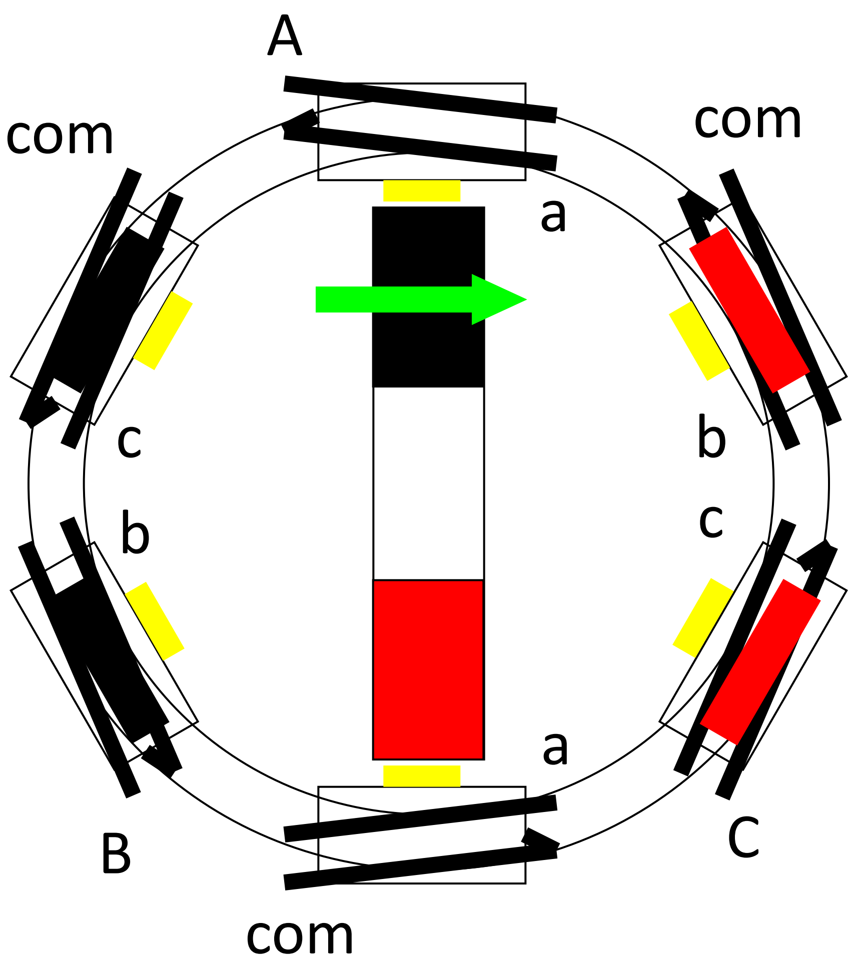


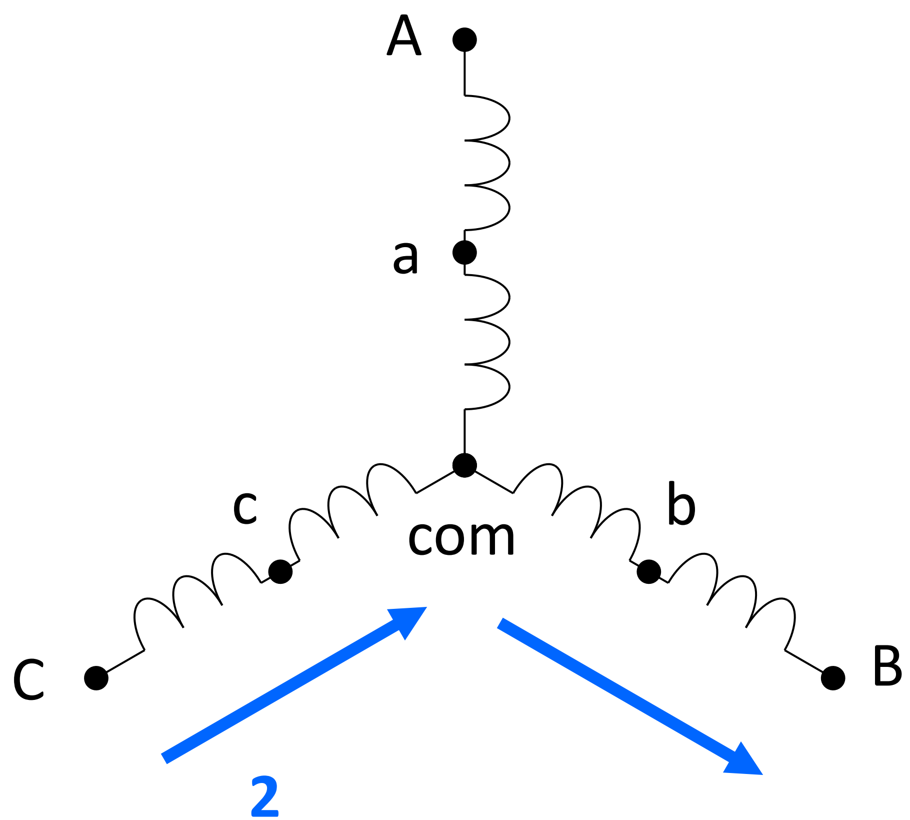
Brushless DC Motor Operation



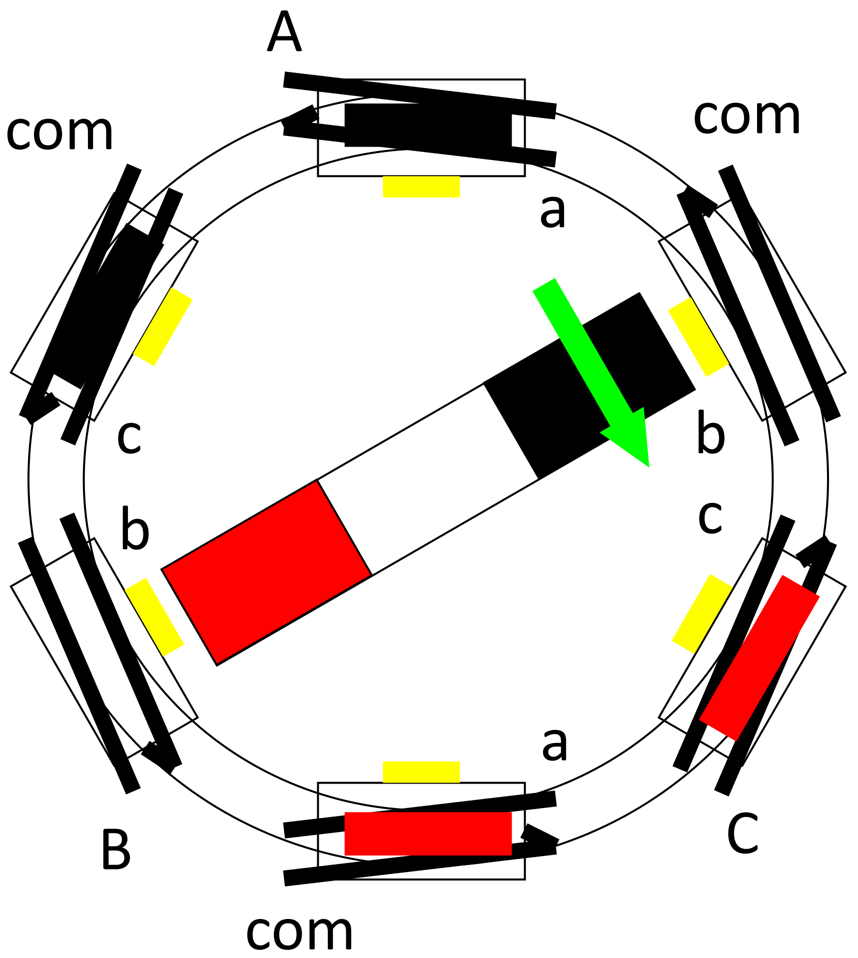


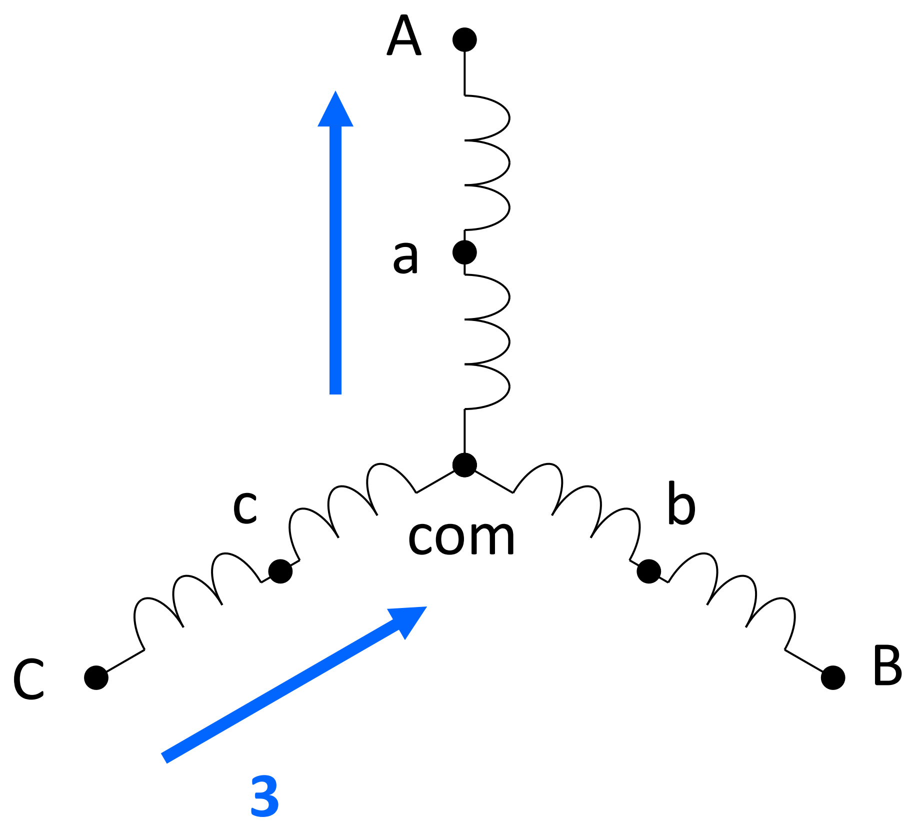
Brushless DC Motor Operation



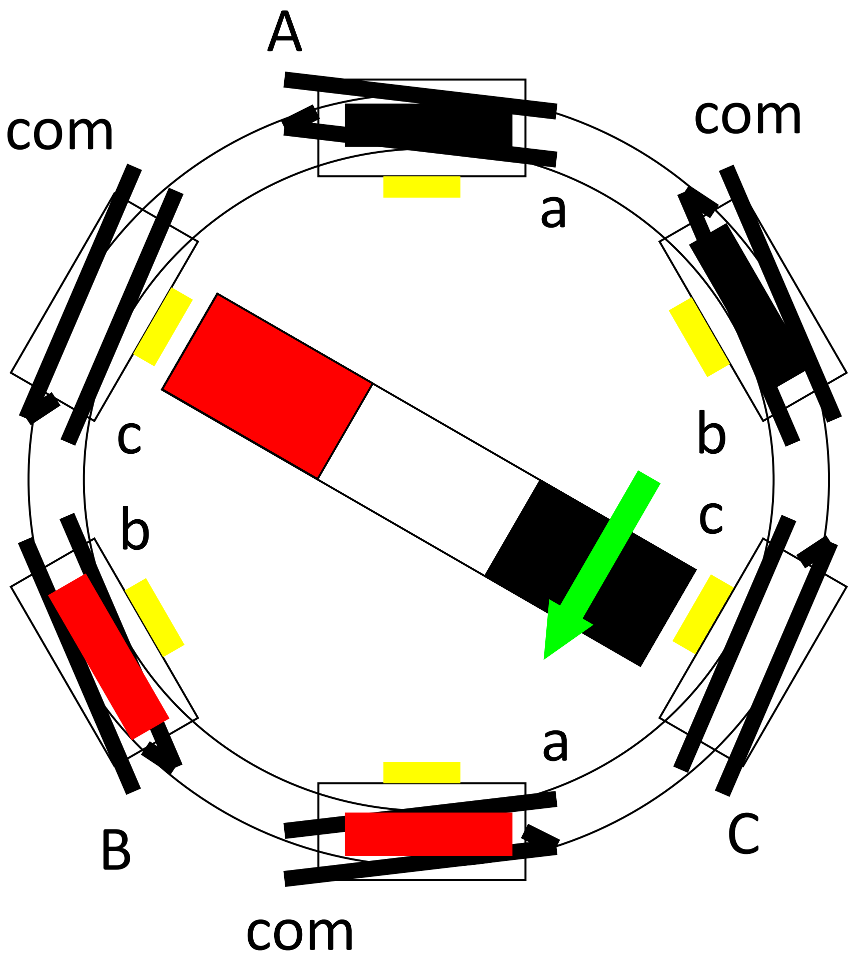


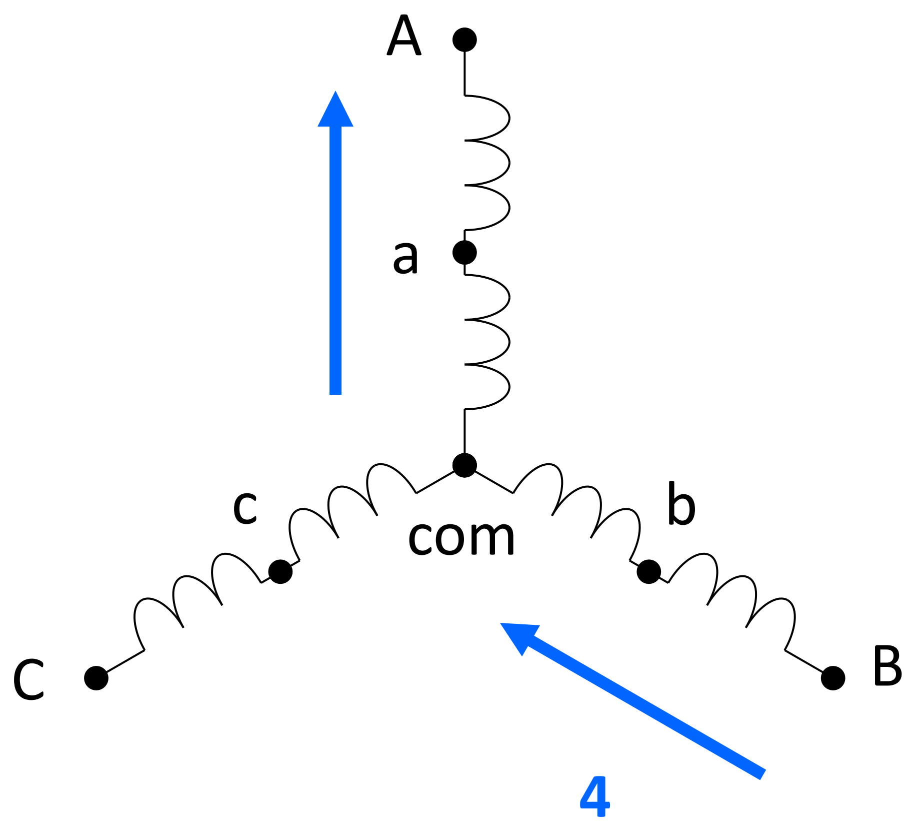
Brushless DC Motor Operation



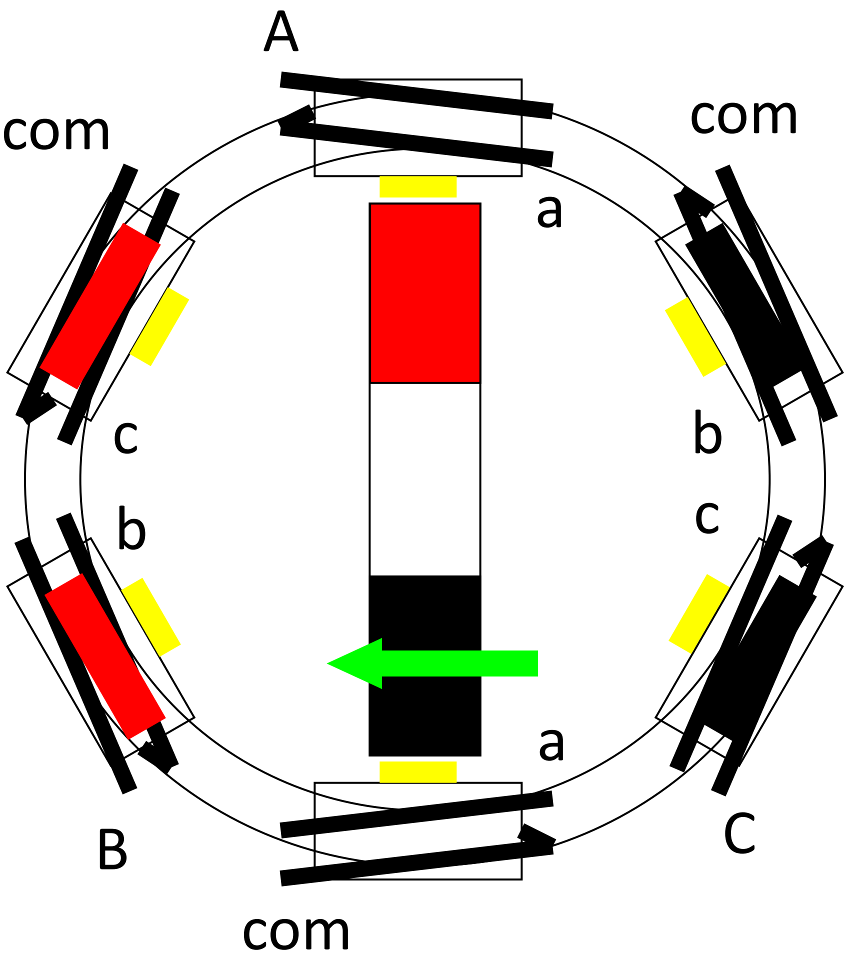


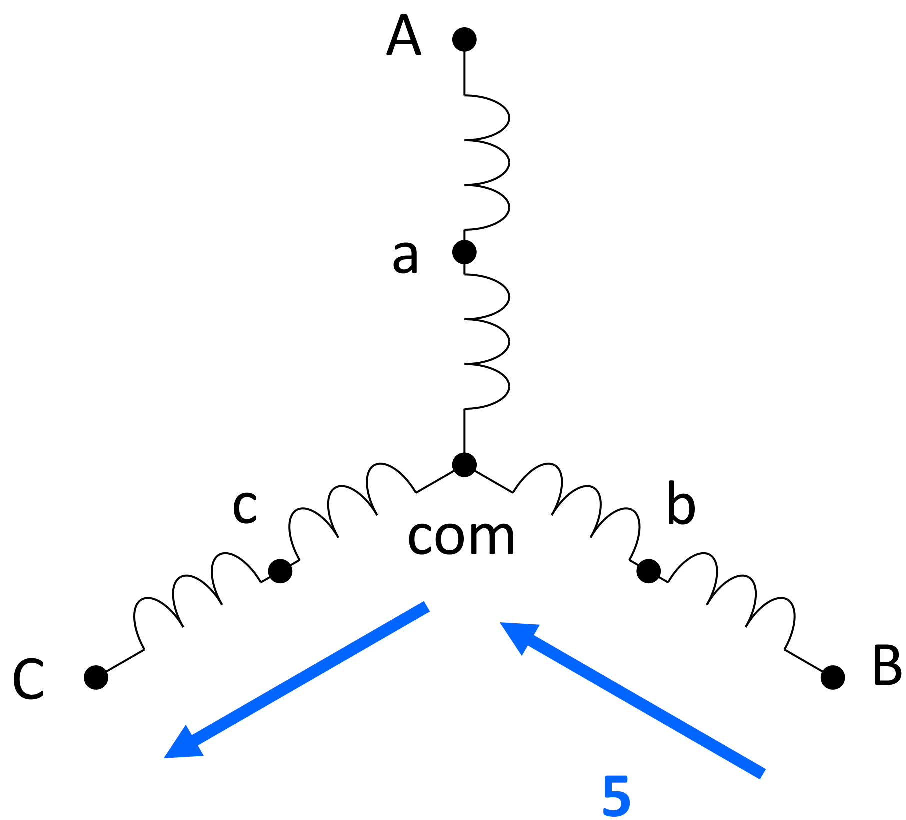
Brushless DC Motor Operation



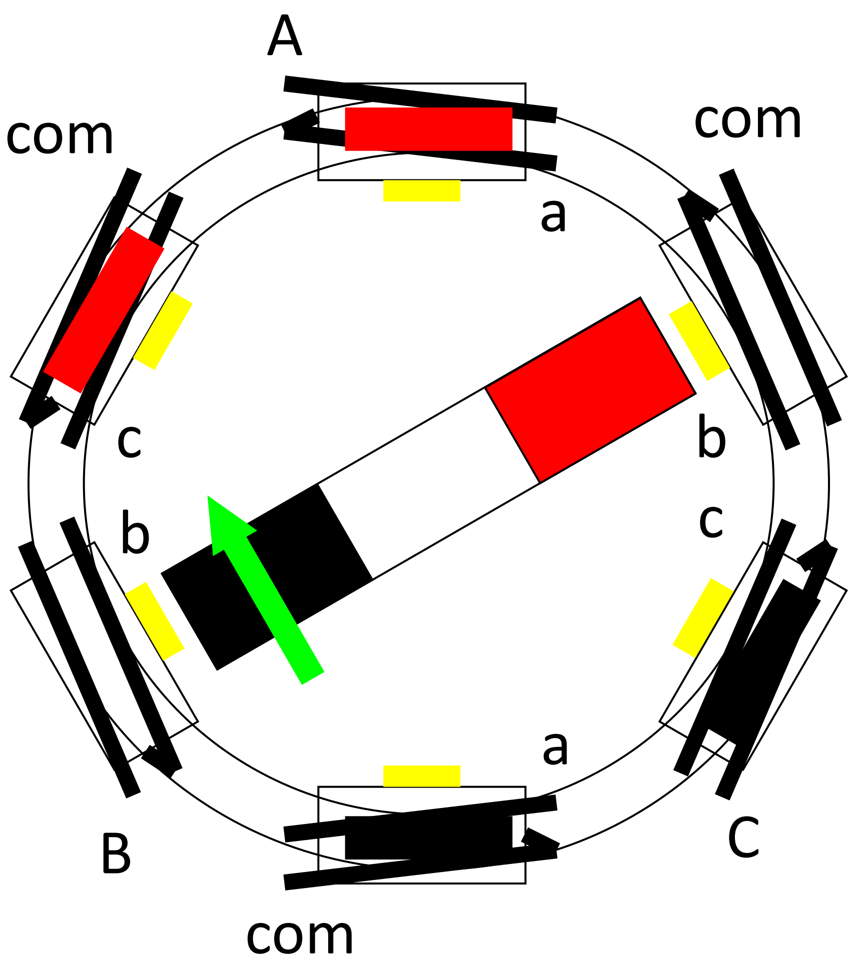


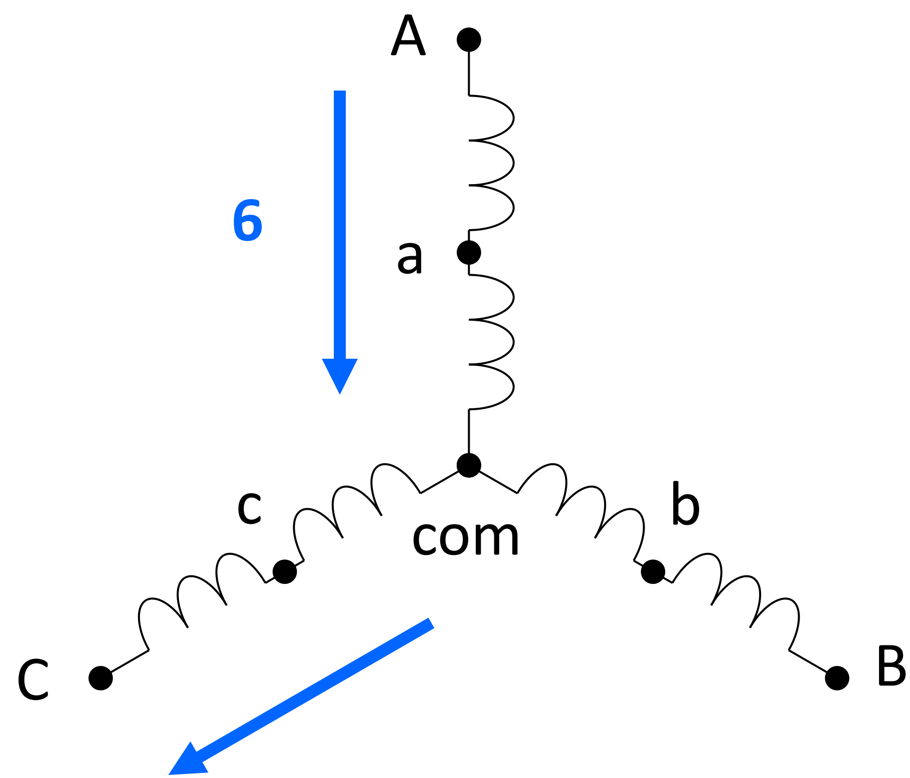
Brushless DC Motor Operation



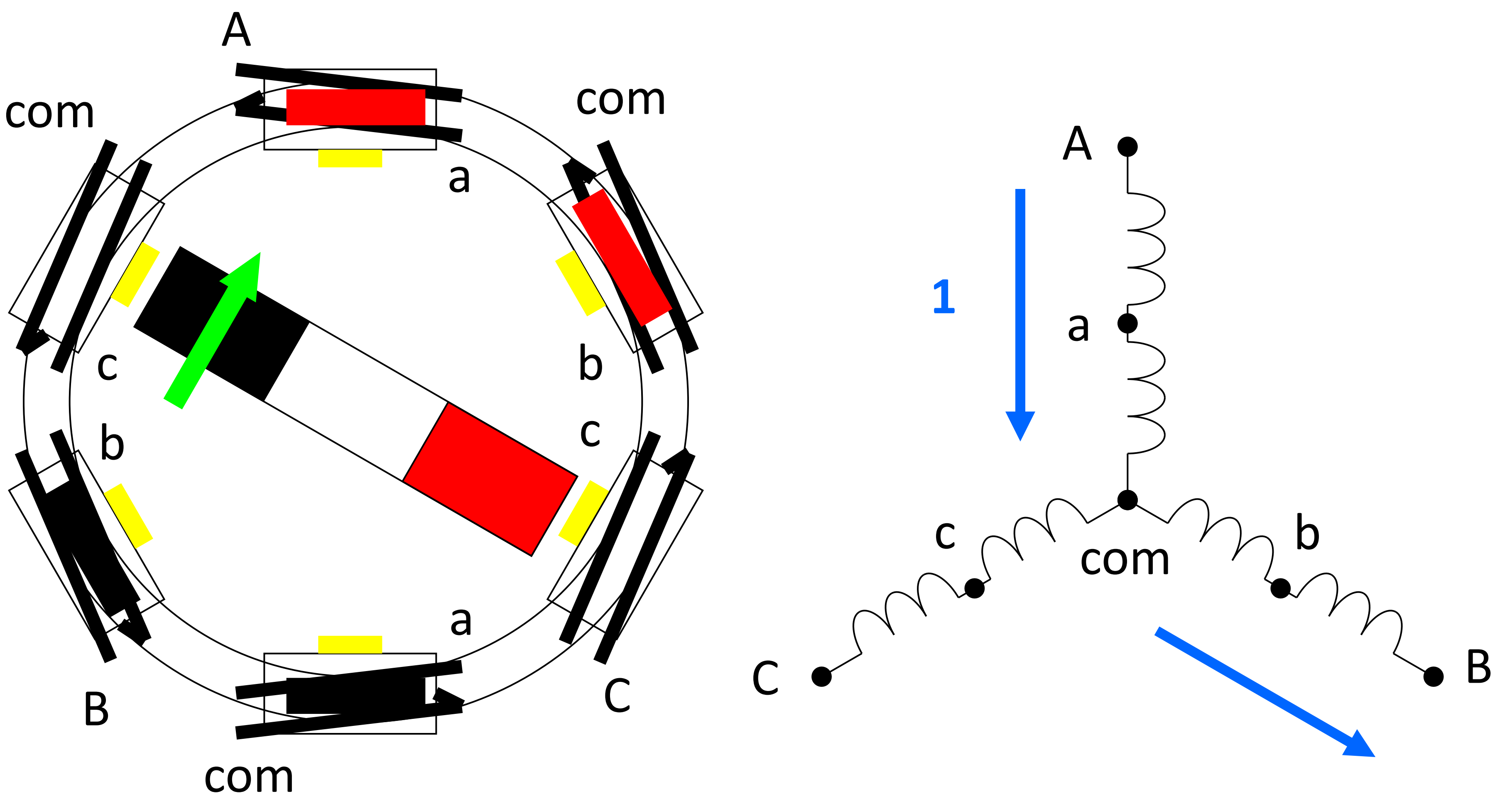


Brushless DC Motor Operation





Brushless DC Motor Operation



Advantages:

+High efficiency

+High reliability

+Low EMI

+Good speed control

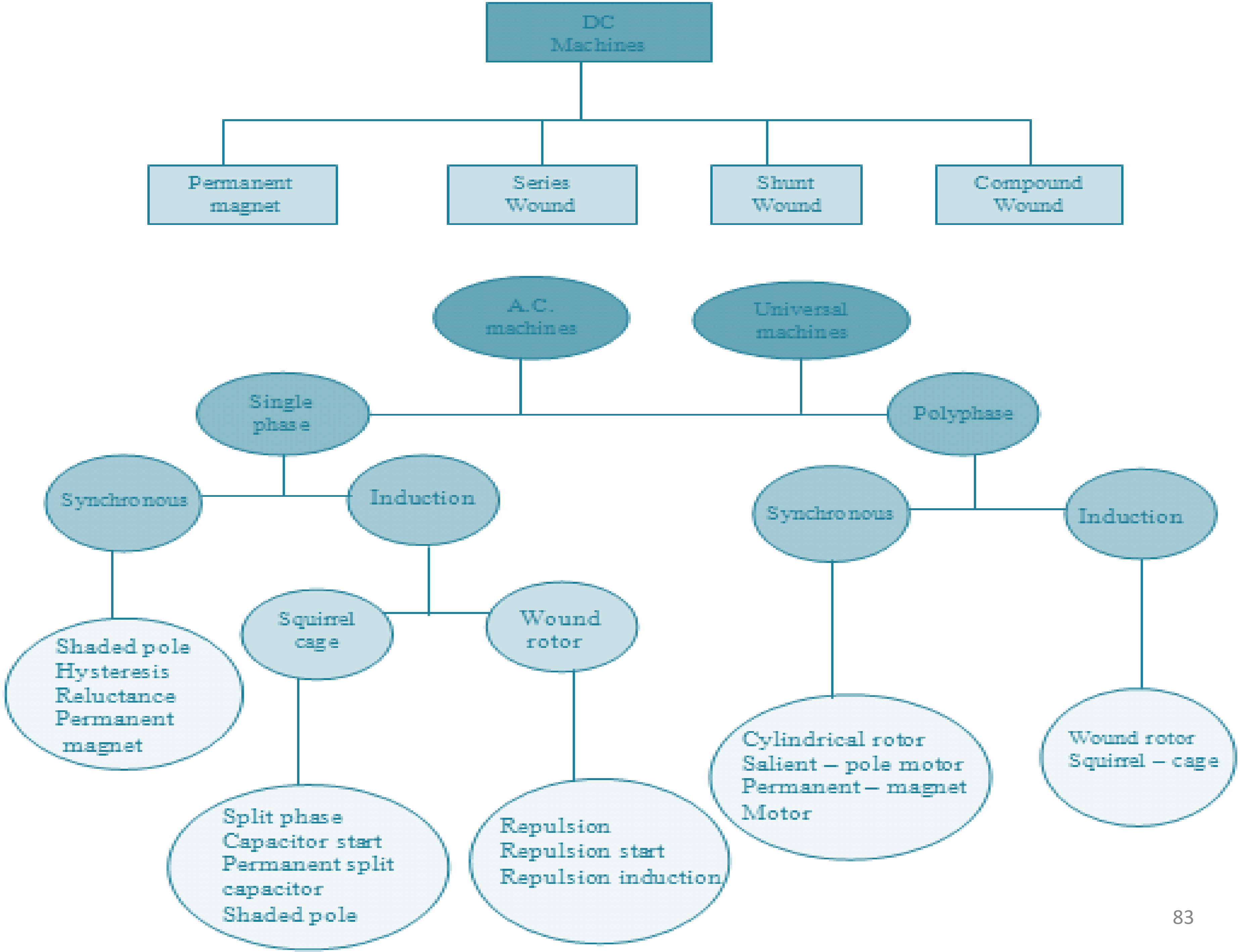
Disadvantages:

May be more expensive than "brushed" DC motors

More complex and expensive drive circuit than "brushed" DC motors

Applications

- Hard disk drives for computers
- In small fans for cooling equipments
- In drives
- Turn Table drives for record players.
- Higher rating d.c. motor find applications in aircrafts and satellite systems.


DC Machines
Permanent magnet
Series Wound
Shunt Wound
Compound Wound
A.C. machines
Universal machines
Single phase
Polyphase
Synchronous
Induction
Synchronous
Induction
Squirrel cage
Wound rotor
Shaded pole
Hysteresis
Reluctance
Permanent magnet
Split phase
Capacitor start
Permanent split capacitor
Shaded pole
Repulsion
Repulsion start
Repulsion induction
Cylindrical rotor
Salient – pole motor
Permanent – magnet Motor
Wound rotor
Squirrel – cage