STEPPER MOTORS

→ In stepper motors, rotor moves in discrete steps. These motors can be classified as (i) Variable reluctance (VR) type

(ii) permanent magnet (pm) type

(iii) Hybrid type, a combination of VR and pm.

(i) Variable Reluctance (VR) stepper motor:

→ It's principle is based on the property of flux lines to occupy low reluctance path. The stator and rotor therefore get aligned such that magnetic reluctance is minimum.

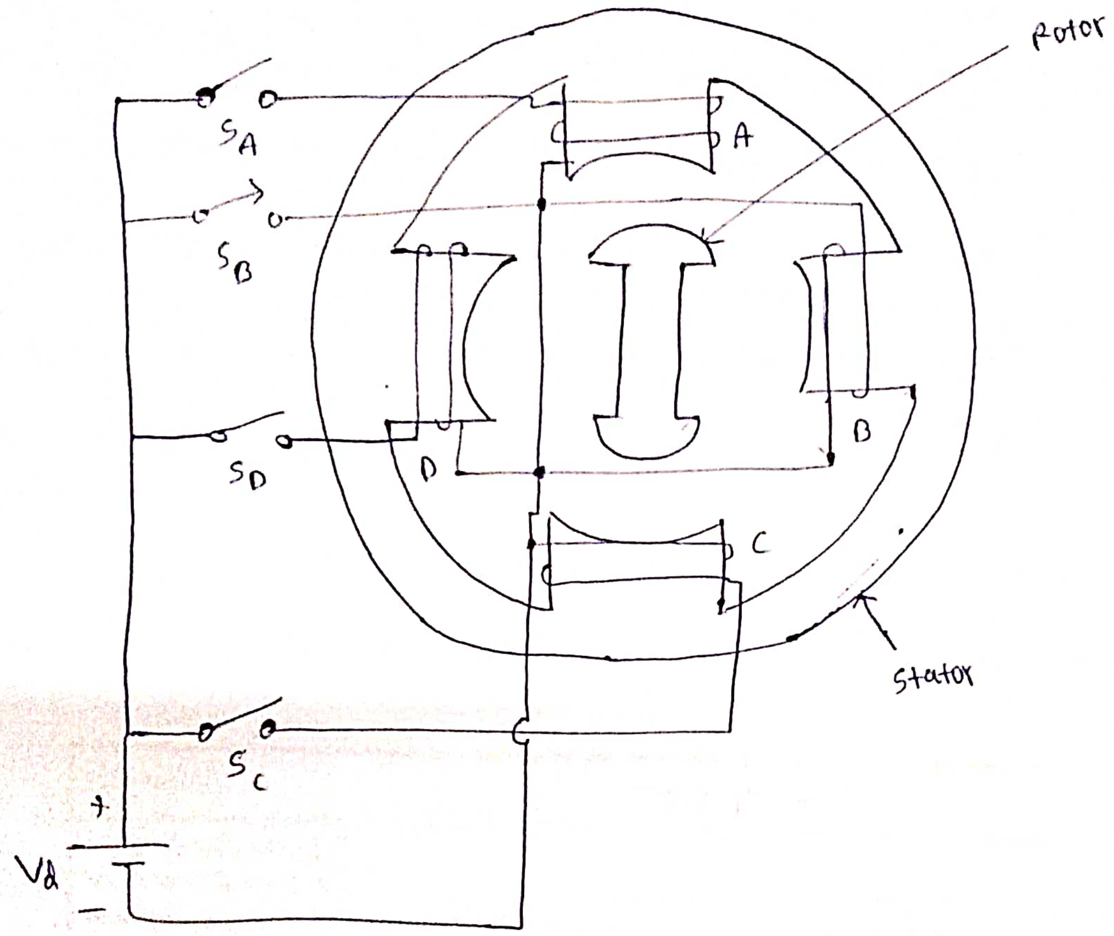
→ It has salient-pole (or tooth) stator. The stator has concentrated windings placed over the stator poles (teeth). The no. of phases of the stator depends upon the connection of stator coils.

→ The rotor is a slotted structure made from ferromagnetic material and carries no winding.

→ Both stator and rotor are made up of high quality magnetic materials having very high permeability.

→ When the stator phases are excited in a proper sequence from dc source with the help of semiconductor switches, a magnetic field is produced. The ferromagnetic rotor occupies the position which presents minimum reluctance to the stator field. That is, the rotor axis aligns itself to the stator field axis.

→ Elementary operation of a variable reluctance motor can be understood through the following diagram.



→ It is a four-phase, 4/2 pole (4 poles in the stator and 2 in rotor), single stack variable reluctance stepper.

→ Four phases A, B, C and D are connected to dc source with help of semi-conductor switches S_A, S_B, S_C and S_D respectively.

→ The phase windings of the stator are energised in the sequence A, B, C, D, A.

→ When winding A is excited, the rotor aligns with the axis of phase A. The rotor is stable in this position and cannot move until phase A is de energised.

→ When phase B is excited and A is disconnected, rotor moves through 90° in clockwise direction to align with the axis of phase B.

→ Further, phase C is excited and B is disconnected, the rotor moves through a further step of 90° in the clockwise direction. Thus as the phases are excited in the sequence A, B, C, D, A the rotor moves through a step of 90° at each transition in clockwise direction.

→ The rotor completes one revolution through four steps.

→ The direction of rotation can be reversed by reversing the sequence of switching the windings i.e. A, D, C, B, A.

→ In stepper motors, the direction of rotation depends only on the sequence of switching the phases and is independent of the direction of currents through phases.

→ The magnitude of step angle for any PM or VR stepper motor is given by

$$\alpha = \frac{360^\circ}{m_s N_r}$$

where α = step angle

m_s = no. of stator phases or stacks

N_r = no. of rotor teeth or poles.

→ The step angle can be reduced from 90° to 45° by exciting phases in the sequence A, A+B, B, B+C, C, C+D, D, D+A, A.

When phase A is excited, the rotor aligns with axis of phase A. When phases A and B are excited together, the rotor moves by 45° in the clockwise direction. Thus if the windings are excited in the sequence A, A+B, B, B+C, C, C+D, D, D+A, A, the rotor rotates in steps of 45° in the clockwise direction. This method is called MICROSTEPPING

(ii) Permanent magnett (Pm) stepper motor:-

→ It has a stator construction similar to that of variable reluctance motor.

→ The rotor is cylindrical and consists of permanent - magnet poles made of high retentivity steel.

→ A 4/2 pole Pm stepper motor is shown below.

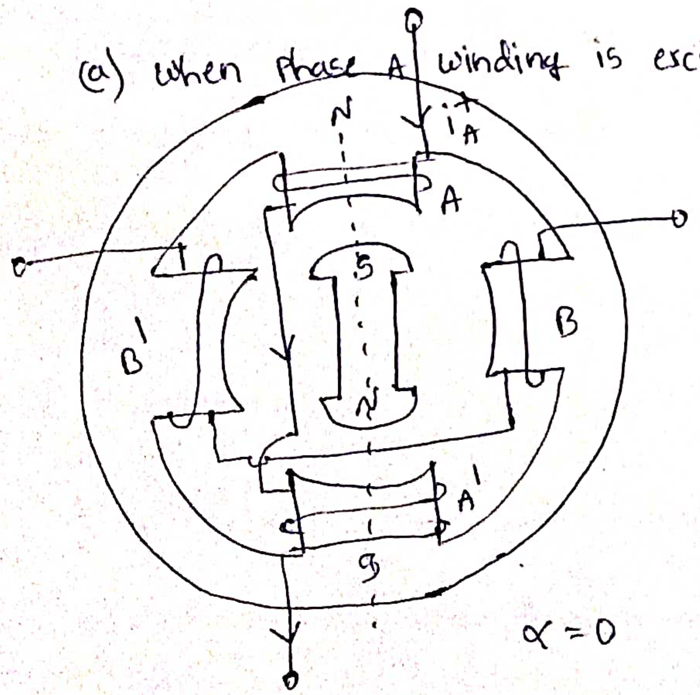
→ The concentrated winding on diametrically opposite poles are connected in series to form 2-Phase winding on the stator.

→ The rotor poles align with stator poles depending on the excitation of phase winding.

→ The two coils A - A' connected in series form phase A winding. similarly, the two coils B - B' connected in series form phase B winding.

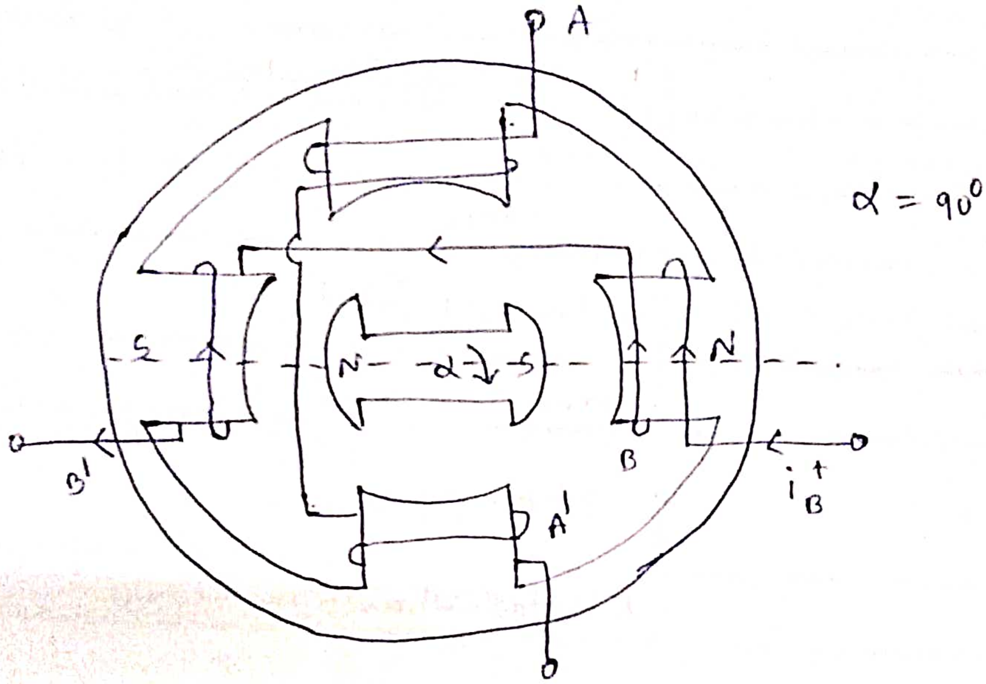
→ The stator windings A and B can be excited as follows:

(a) when phase A winding is excited with current i_A^+,



→ South pole of rotor is attracted by the stator phase pole so that the magnetic axes of the stator and rotor coincide and $\alpha = 0°$.

(b) Phase A winding does not carry any current and Phase B winding is excited by i_B^+. Stator produced poles attract the rotor poles and the rotor moves by a step of 90° in the clockwise direction, i.e $\alpha = 90^\circ$



(c) When phase A winding is excited by i_A^- and Phase B winding is deenergized, the rotor moves through a further step of 90° in the clockwise direction so that $\alpha = 180^\circ$

(d) When Phase B winding is excited by i_B^- and the Phase A winding carries no current, the rotor again moves further by a step of 90° in the clockwise direction so that $\alpha = 270^\circ$.

(e) For further 90° clockwise rotation of rotor i.e $\alpha = 360^\circ$, Phase winding B is de-energized and Phase A winding is excited by current i_A^+. Thus 4 steps complete one revolution of the rotor.

→ In PM stepper motor, the direction of rotation depends on the polarity of Phase currents. For clockwise rotor movement ⇒ $A^+, B^+, A^-, B^-, A^+ \ldots\ldots$

For anticlockwise rotor movement ⇒ $A^+, B^-, A^-, B^+, A^+ \ldots\ldots$

→ pm stepper motors have higher inertia and, therefore, lower acceleration than VR stepper motor.

Applications of stepper motors :

→ Numerical control of machine tools

→ Tapedrives

→ Floppy disc drives

→ printers

→ x-y plotters

→ Robotics

→ Textile industry

→ Electric watches

→ Interarated circuit fabrication.

(Pb) Calculate the stepping angle for a 3-stack, 16-tooth variable reluctance motor

sol

$$\alpha = \frac{360}{m_s N_r} = \frac{360}{3 \times 16} = 7.5^\circ \text{ per step}$$

(Pb) Calculate the stepping angle for a 3-Phase, 24 pole pm stepper motor

sol

$$\alpha = \frac{360}{m_s N_r} = \frac{360}{3 \times 24} = 5^\circ \text{ per step}$$