R.N.G.P.I.T, Bardoli
Electrical Engineering Department

Subject: Electrical Machine-II

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- Experience: 13 Years.

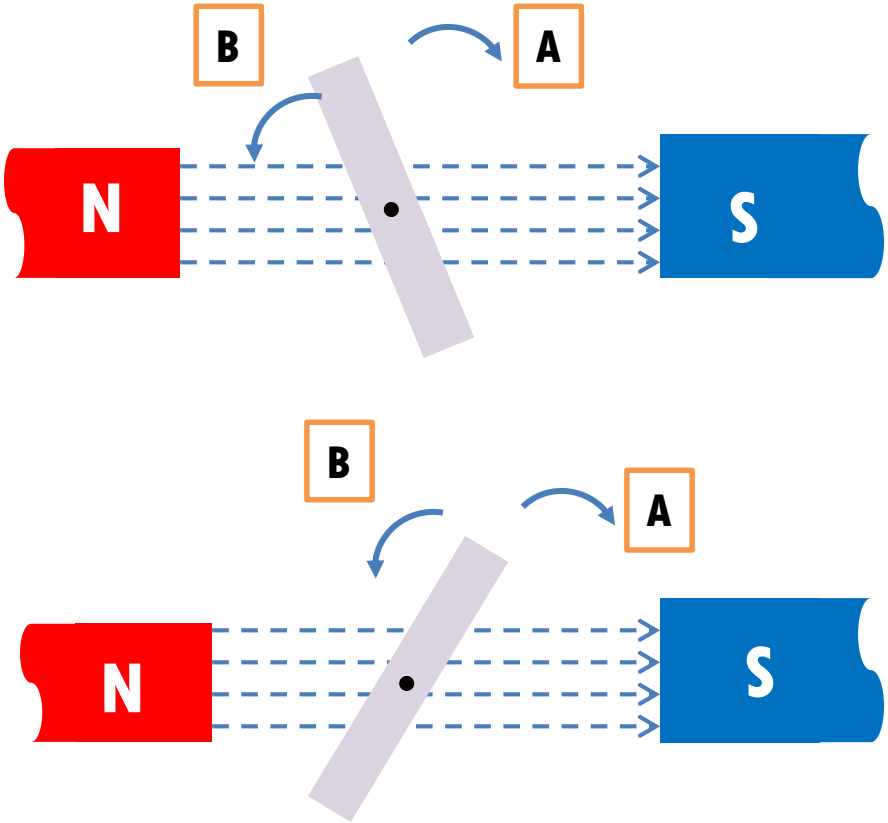
CH: Special Machine

- This Lecture contain

- Theory of multi-stack variable reluctance stepper motor
- Theory of Hybrid Stepper Motor

- By Dr. Shaikh Mohammed Suhel

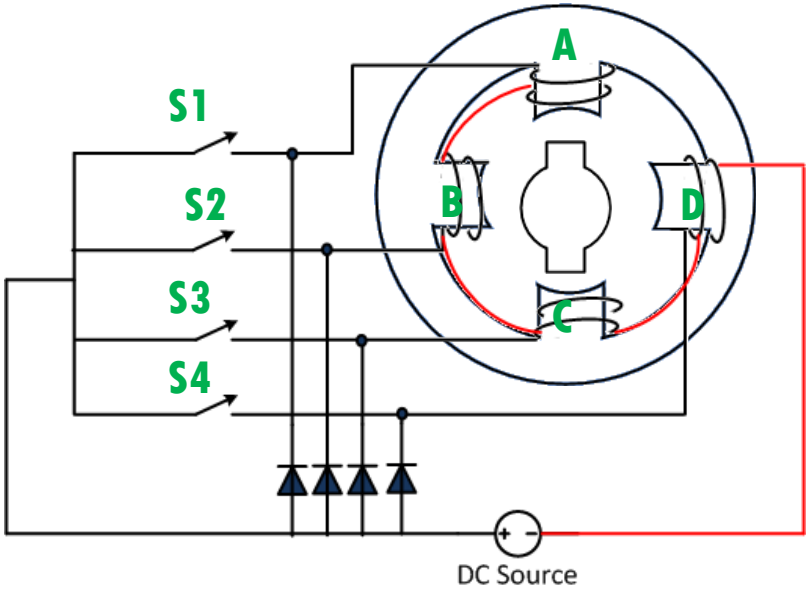
- Variable Reluctance Stepper Motor:



- Basic Variable reluctance Principle
- There is a tendency of the rotor to align along the minimum reluctance position

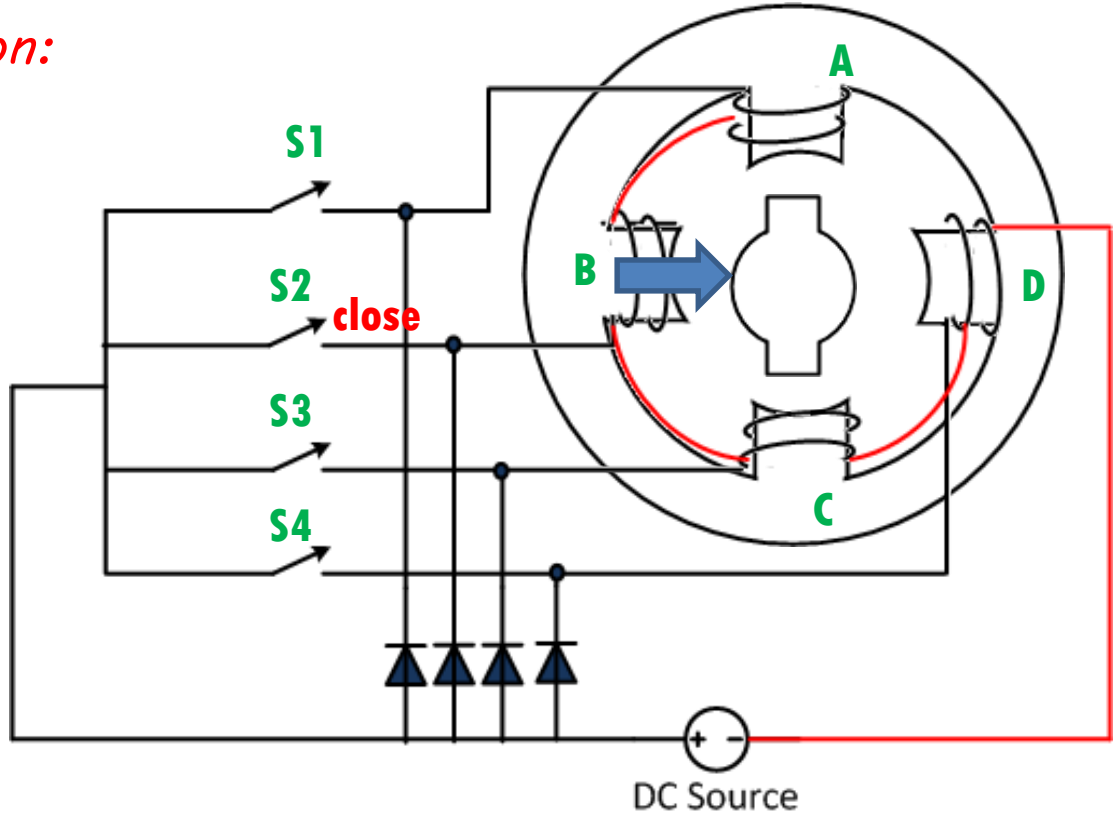
- **Single Stack Variable Reluctance Stepper Motors:**

- Fig. 1 presents the basic circuit configuration of a typical 4-phase, 2-pole, single-stack, variable reluctance stepper motor.
- The stator is made of a single stack of steel laminations with the phase windings wound around the stator poles. The rotor is made of stack of steel laminations without any windings.
- The main principle of operation depends on aligning one set only of stator and rotor poles by energizing the stator windings. Therefore, the number of poles in the stator and rotor windings has to be different.
- The stator windings are energized by a DC source in such a sequence to generate a resultant rotating air-gap field around the rotor in steps.
- The rotor is made of ferromagnetic material that provides a tendency to align the rotor axis along the direction of the resultant air-gap field. Therefore, the rotor tracks the motion of this stepped field.



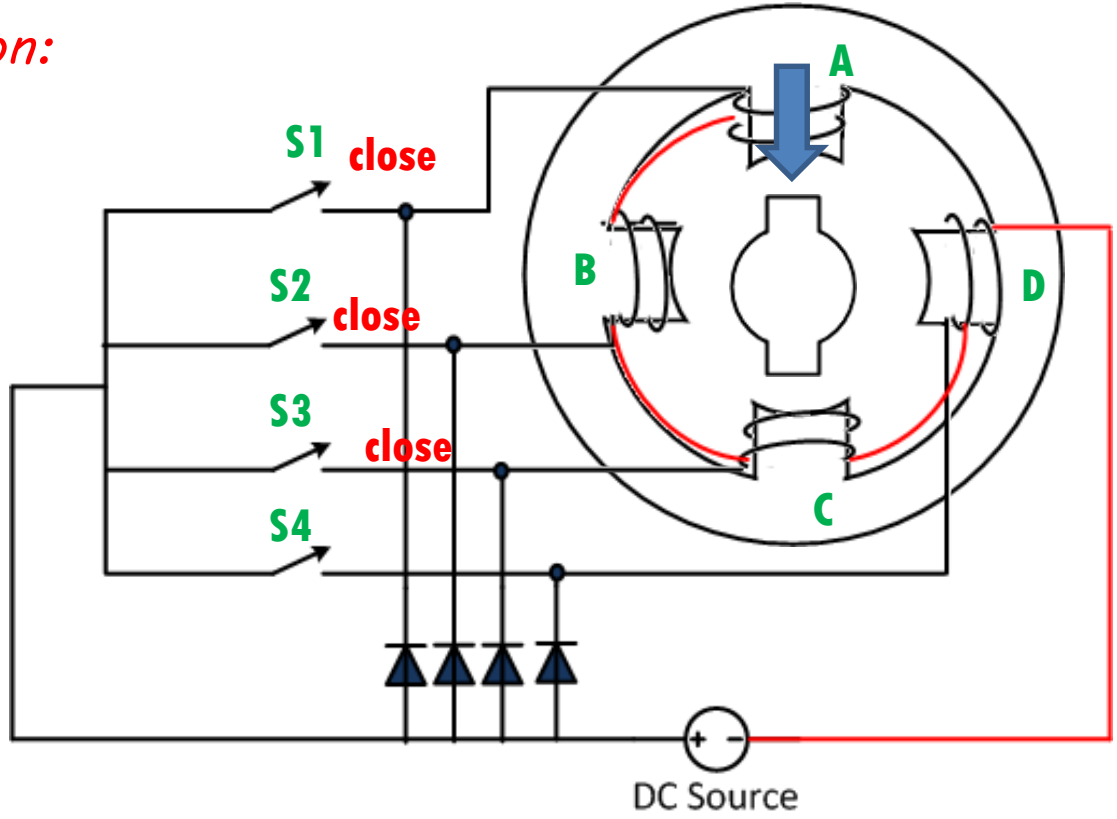
- *The switching Operation:*

- *Full Step, Anti-clockwise switching*
- *A, B , C, D , A*
- *Smooth transition*
- *Current shifts gradually from 'A' to 'B' so mmf also shifts gradually from 'A' to 'B'*



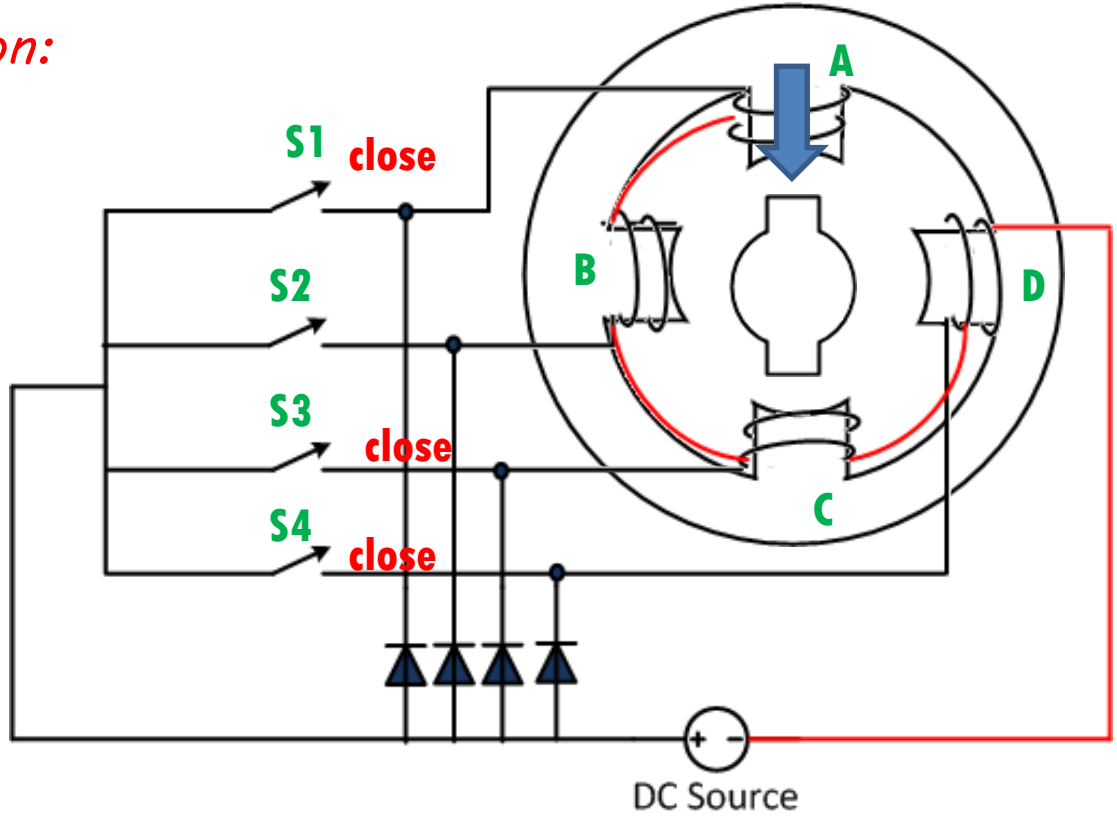
- *The switching Operation:*

- *Full Step, Operation jerky*
- *Micro steeping operation*
- *Two Phases are excited at the same time:*
- *For half stepping anti clock rotation:*
- *A, AB , B, BC, C, CD ,D, DA, A…*

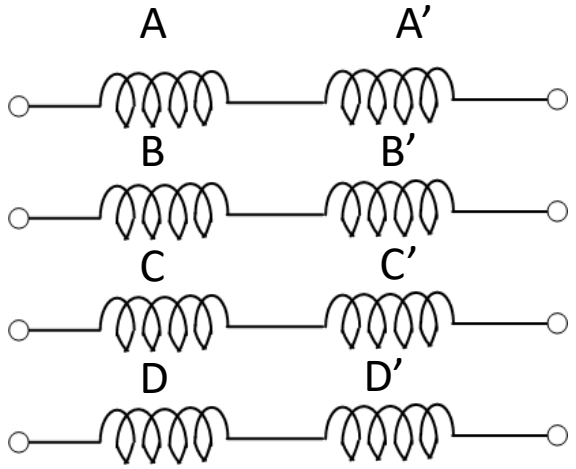


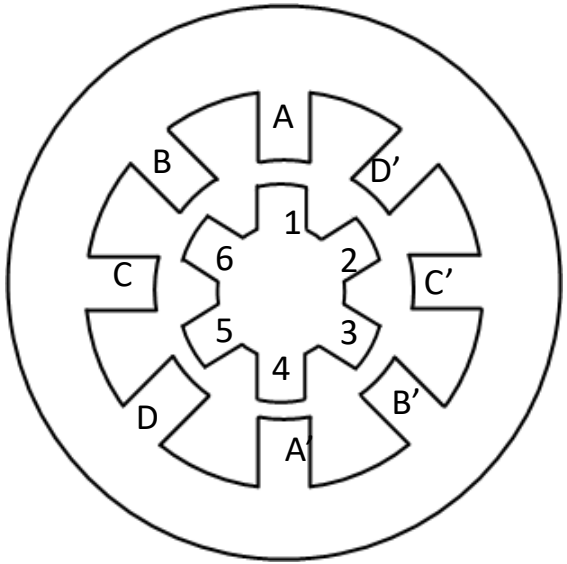
- *The switching Operation:*

- *For half stepping clockwise rotation:*
- *A, AD , D, DC, C, CB…*

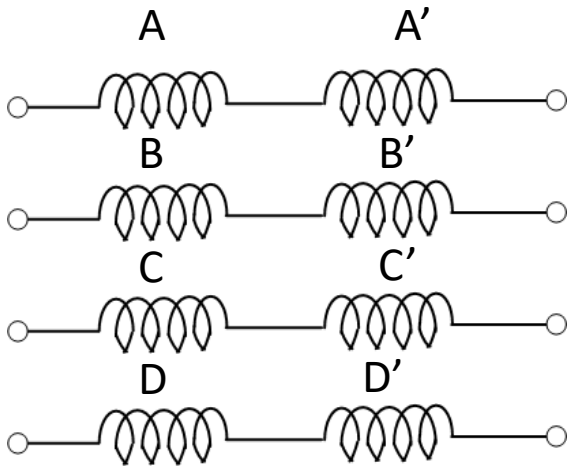


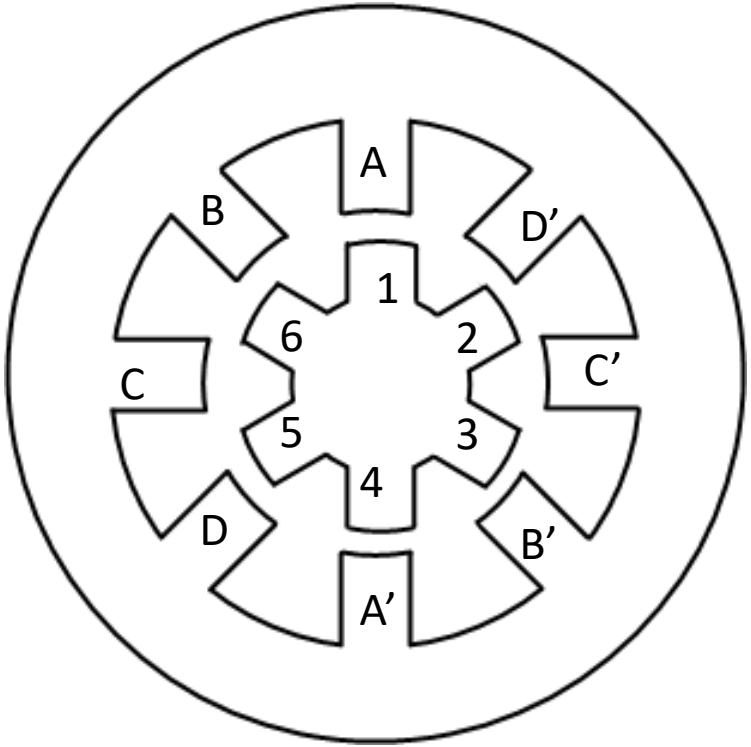
- Four Phase 8/6 pole Variable reluctance type stepper Motor
- Figure presents the circuit configuration and different operation modes for a 4-phase, 6- pole, single stack, variable reluctance stepper motor that rotate in a clockwise direction with a 30° step.



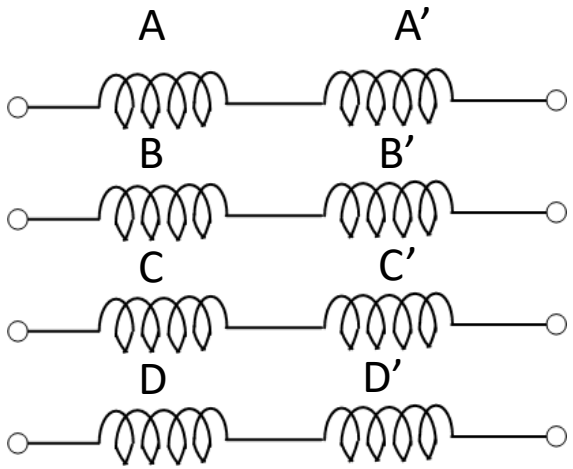


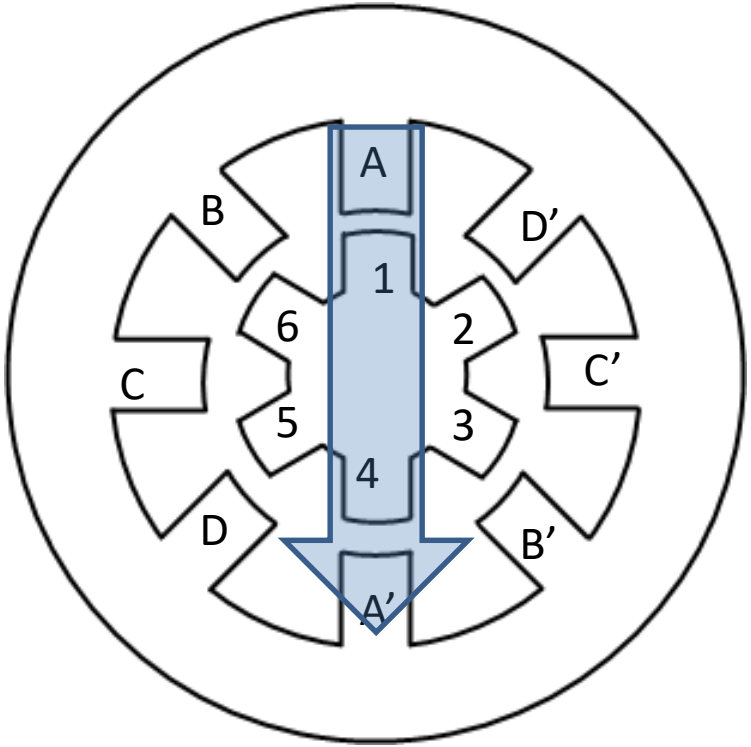
- Four Phase 8/6 pole Variable reluctance type stepper Motor





- Four Phase 8/6 pole Variable reluctance type stepper Motor





- Sequence of switching (Clock wise):
- A, B C, D, A...

- *Variable Reluctance stepper Motor:*

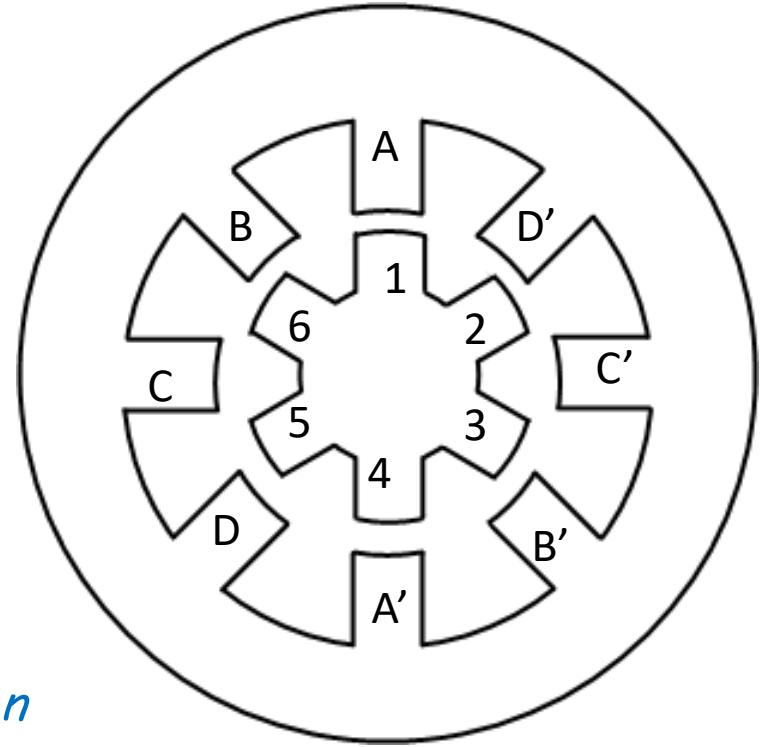
$$\text{stator pole pitch} = \frac{360}{8} = 45^0$$

$$\text{Rotor pole pitch} = \frac{360}{6} = 60^0$$

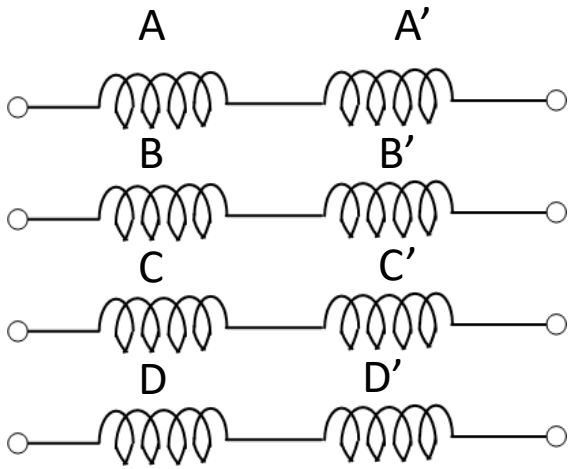
$$\text{Step size}(\beta) = \frac{|N_s - N_r|}{N_s \cdot N_r} \times 360^0 = 15^0$$

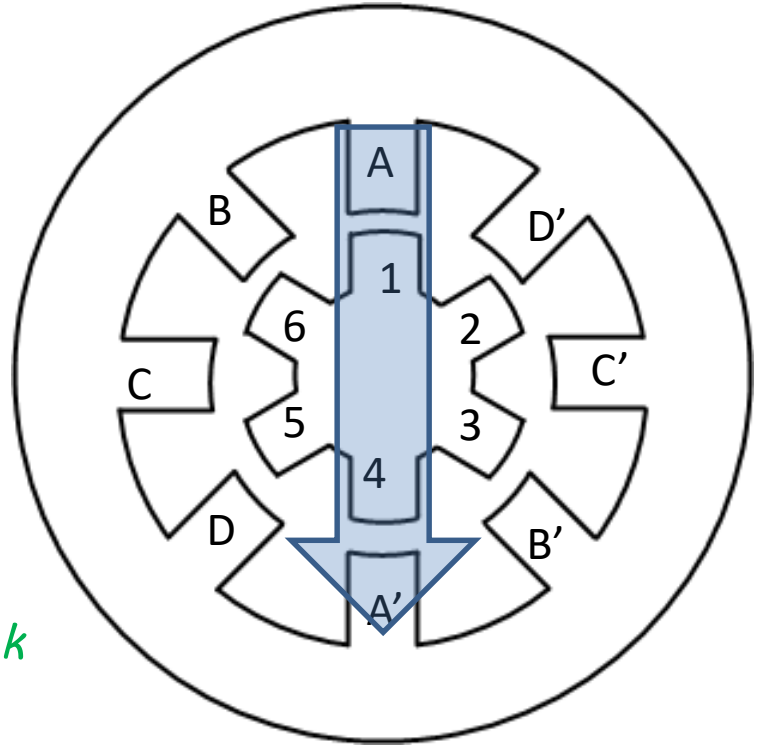
- *Micro stepping clockwise:*
- *A, AB, B, BC*

Note: In V·R· stepper motor direction of mmf doesn't matter



- Four Phase 8/6 pole Variable reluctance type stepper Motor

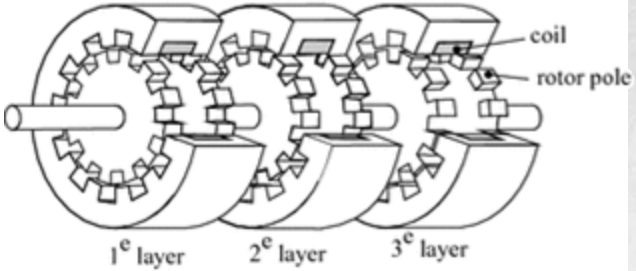


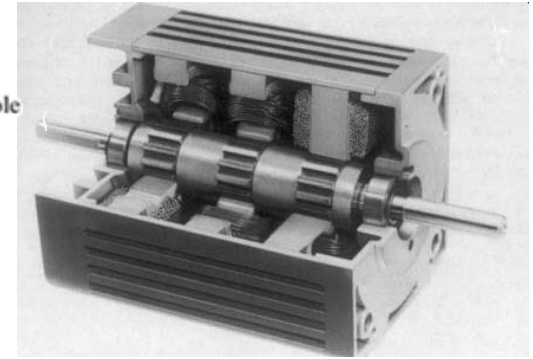


- Sequence of switching (Anti-Clock wise):
- A, D C, B, A...

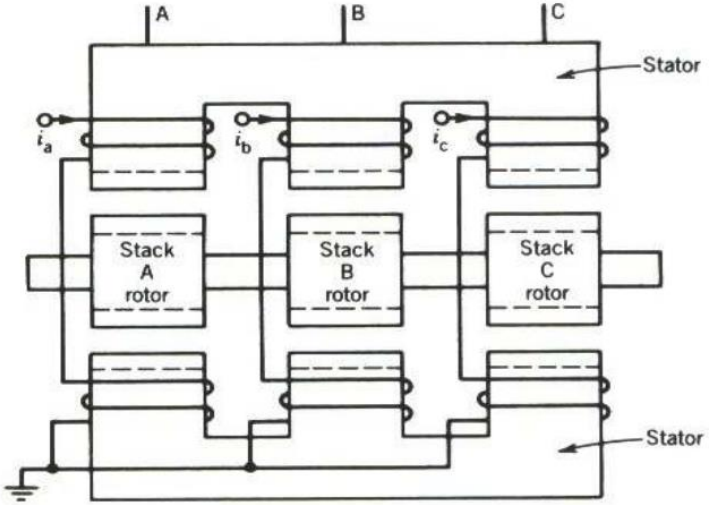
Cycle	A	B	C	D	Position
1	1	0	0	0	0
	0	1	0	0	15
	0	0	1	0	30
	0	0	0	1	45
2	1	0	0	0	60
	0	1	0	0	75
	0	0	1	0	90
	0	0	0	1	105
3	:	:	:	:	:
	:	:	:	:	:

- Multi-stack variable reluctance type Stepper Motor:

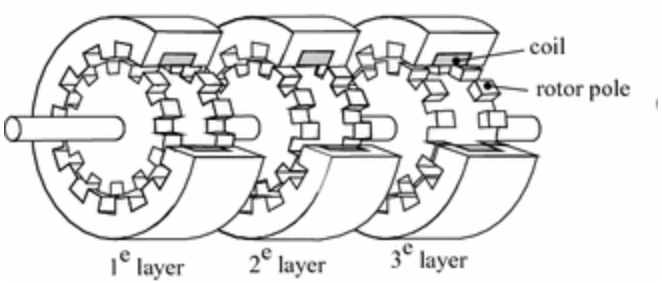


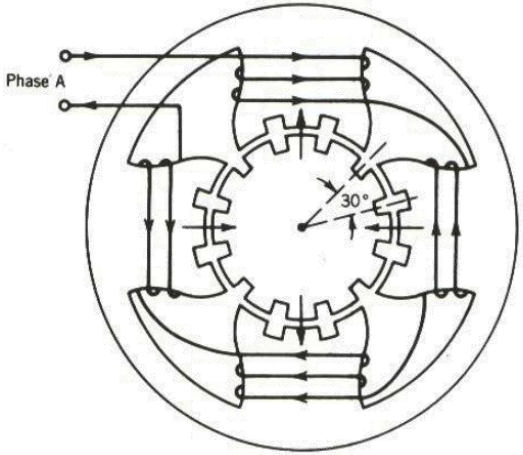


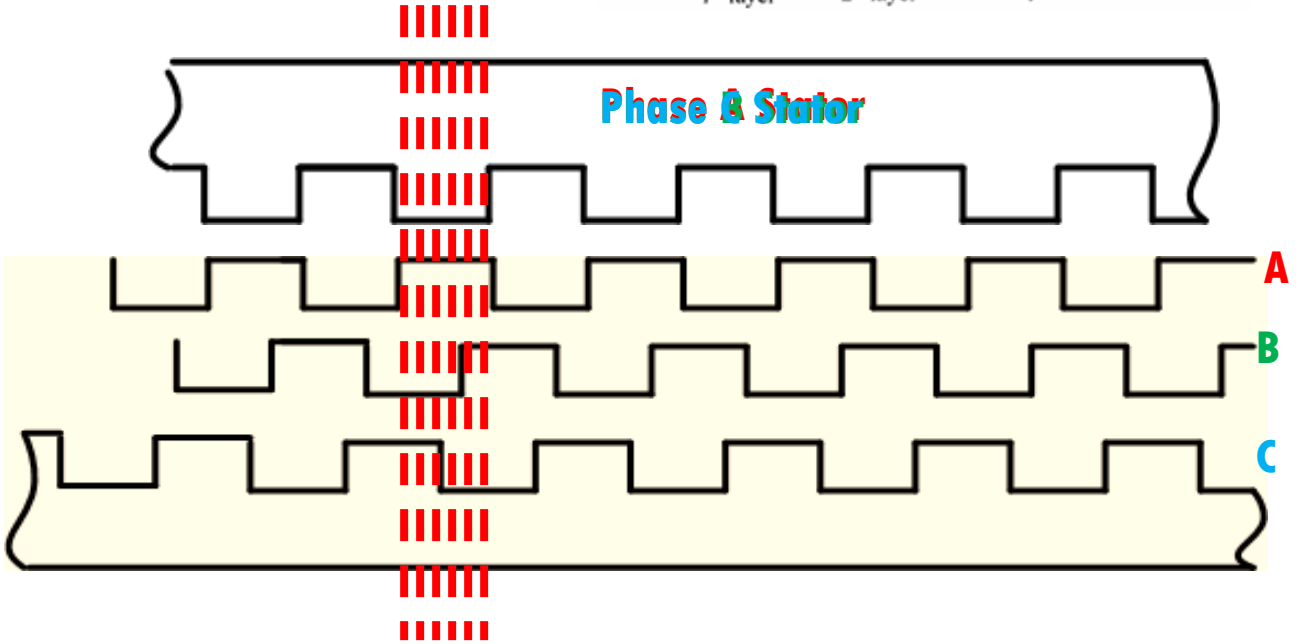
- Number of phases= Number of stack
- In this type, the motor is divided along its axis into a number of stacks. Each stack is energized by a separate winding (phase) as shown in Figure.
- These stacks are magnetically isolated from each other.
- The most common type is the three-stack, three-phase motors;
- however, number of stacks and phases up to seven are also available.



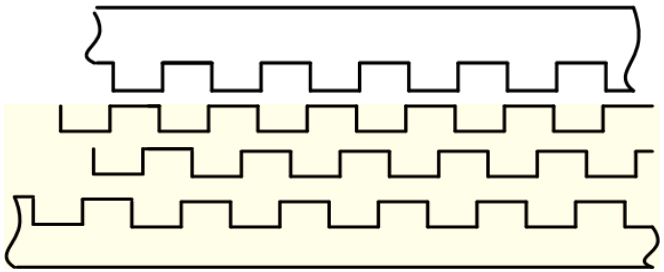
- Stator and rotor teethes are in same number

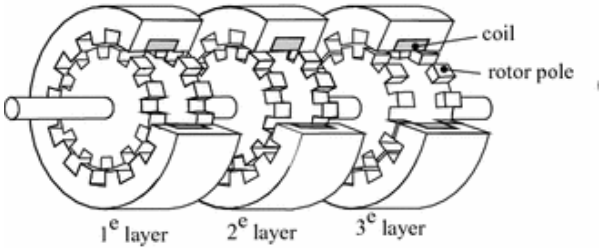






- Fig. also illustrates the rotational sequence of a 3-phase, 4-pole, 12-teeth, three-stack, variable reluctance stepper motor for 10° step in a clockwise direction according to the following energizing sequence A, B, and C. Then this switching sequence is repeated.
- Energizing phase (stack) A: when stack A winding is energized, the rotor teeth will move to align themselves with the stator teeth is stack A as shown in Fig.
- Energizing phase (stack) B: when stack B winding is then energized while stack A winding is de-energized, the rotor teeth will move to align themselves with the stator teeth is stack B. This will result in a clockwise rotation of the rotor by 10° as shown in Fig.
- Energizing phase (stack) C: when stack C winding is then energized while stack B winding is de-energized, the rotor teeth will move to align themselves with the stator teeth is stack C. This will result in another clockwise rotation of the rotor by 10°. After this stage the rotor has moved one rotor tooth pitch as illustrated by Fig.





- The direction of rotation can be reversed by reversing the switching sequence.
- Assume that the total number of stacks (phases) is N while the total number of teeth in each stack is x. The tooth pitch (τ_p) can be expressed by

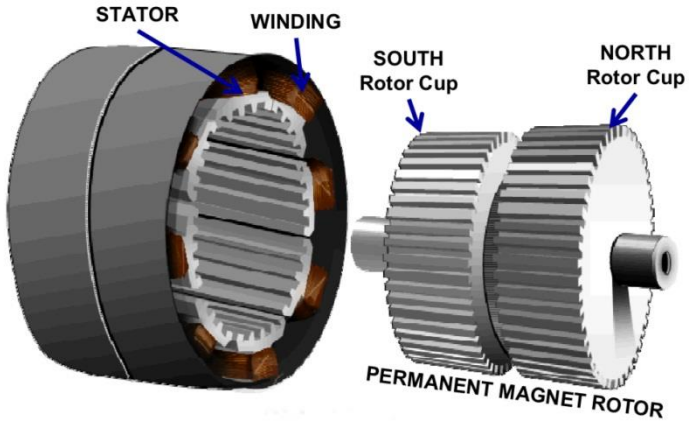
$$\tau_p = \frac{360^o}{x}$$

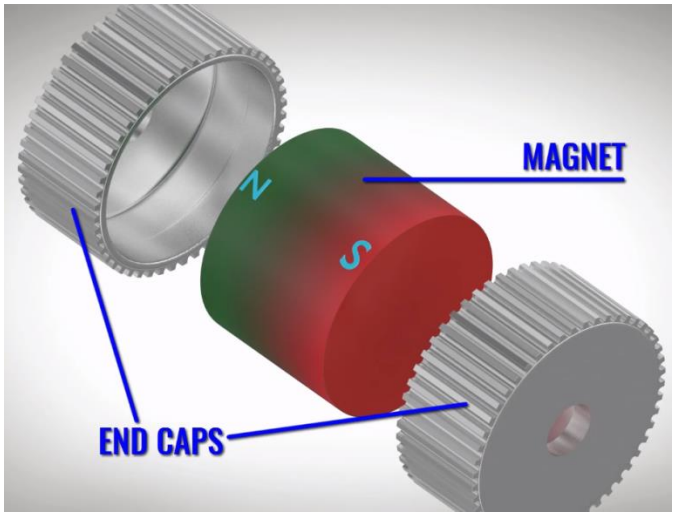
$$\text{Step size } (\Delta\theta) = \frac{360^0}{x \cdot N}$$

$$\text{Number of Step per revolution size} = \frac{360^0}{\Delta\theta}$$

- ***Hybrid Stepper Motor:***

- *Hybrid stepper motors have similar stators' construction to that of variable reluctance stepper motors. However, their rotors constructions combine both variable reluctance and permanent magnet constructions.*
- *The rotors are made of an axial permanent magnet at the middle and two identical stacks of soft iron poles at the outer ends attached to the north and south poles of the permanent magnet.*
- *The rotor poles connected to the north pole of the permanent magnet forms North Pole, while the other forms the south poles as shown in Fig.*
- *Magnetize rotor with toothed steel caps, so one end of rotor becomes the north pole and the other end becomes a south pole*



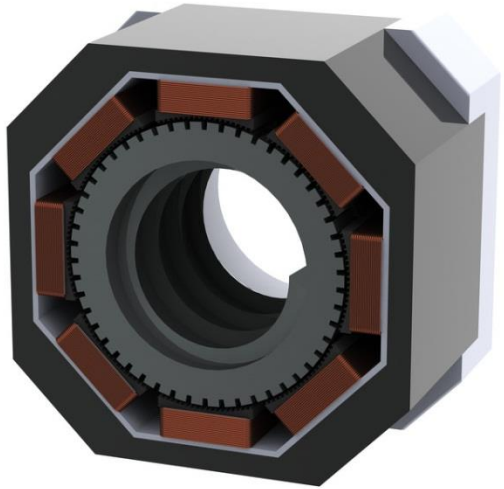


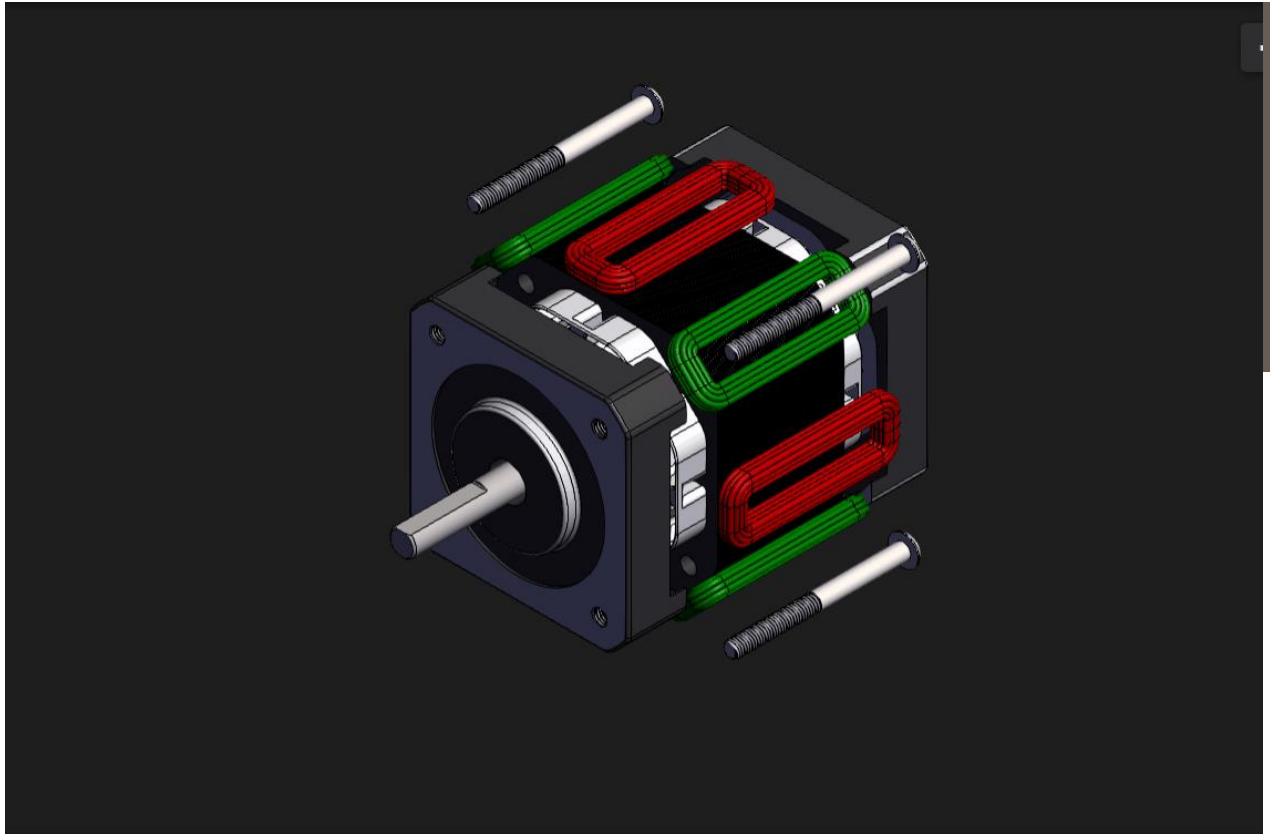
- Hybrid Stepper Motor:

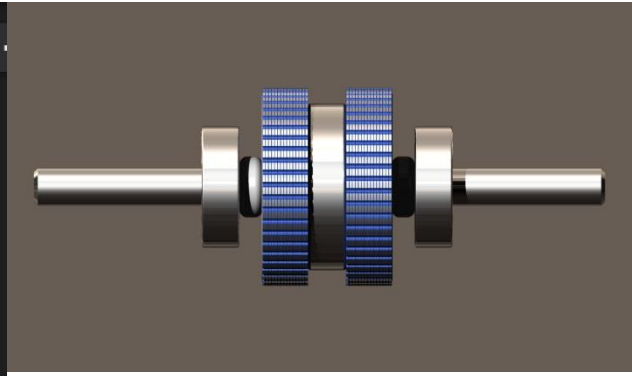
- In this motor torque is produce due to variable reluctance and Permanent magnet.
- This motor is axially Polarized motor

- The rotor has 50 teethes and stator has 48 teethes

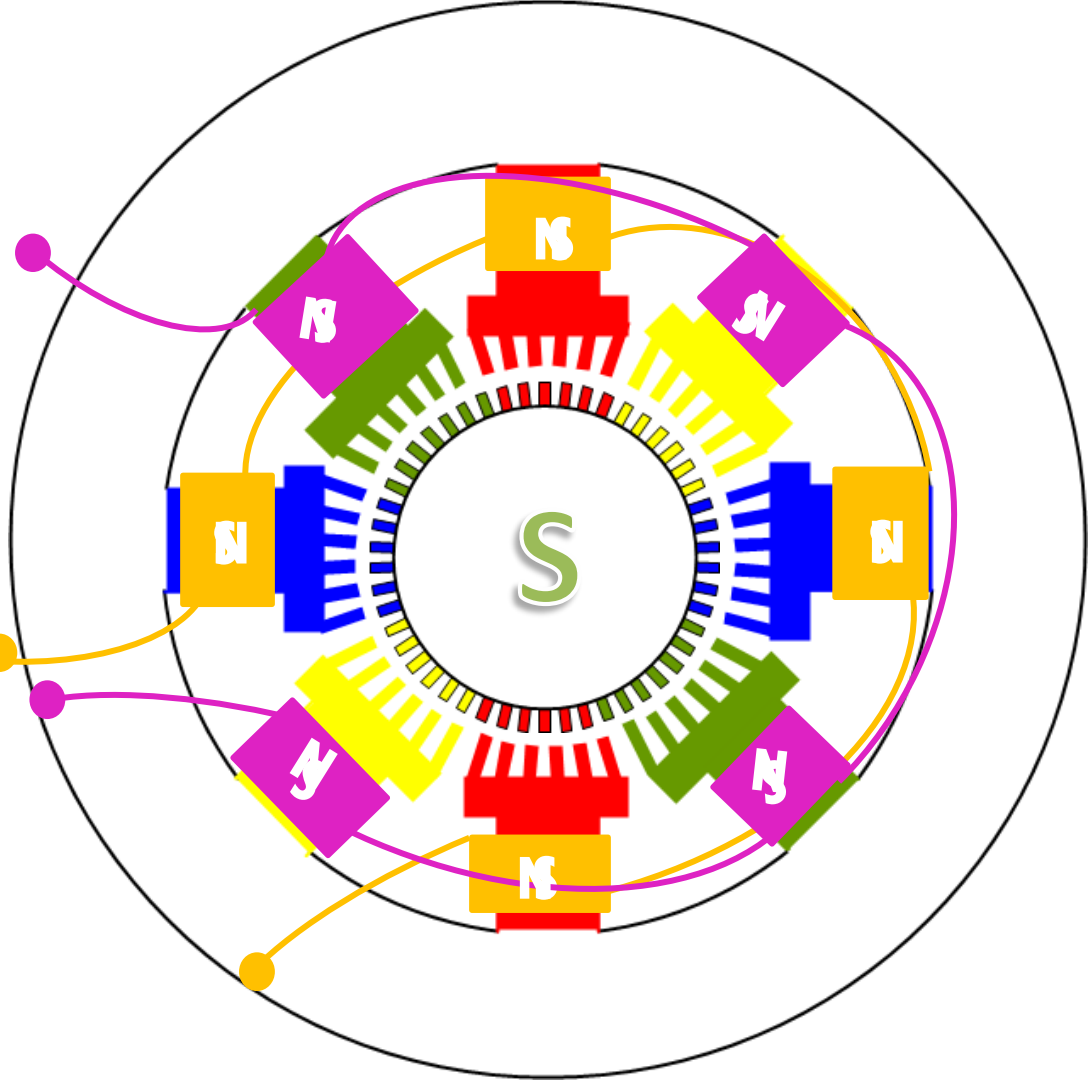
- The step size of this rotor is 1.8°







- All blue teethes are fully aligned to the rotor.
- Due to lesser number of teethes in the stator yellow pole teethes are half aligned and red groups are completely unaligned to the rotor teethes and green groups are half aligned to the rotor teethes.
- The opposite pole attract and they will be aligned and the same polarity pole will be unaligned



step size=1/4 of angular pitch

Angular pitch=360/50=7.2^{o}

- The rotor moves by 1·8 degree
- When in next turn winding A is energize with opposite polarity then again rotor moves by an angle of 1·8 degree·
- This cycle is repeated and highly accurate steps angle can be obtained by the motor
- North cap end teeth is placed in between south end teeth and hence accurately stable position can be obtained

- The features of the hybrid stepper motor mainly include:

- Exact controlling of position
- The motor includes an Electromagnetic Brake
- Controlling is simple using pulse signals
- At the stopped location, this motor holds itself
- High torque can be generated through compact size

- The advantages of Hybrid Stepper Motor are as follows:

- The torque of this motor is high
- It gives detent torque including de-energized windings
- The step length is less
- The efficiency of this motor is high at less speed.

- The disadvantages of the Hybrid Stepper Motor are as follows:

- These motors have high inertia
- This motor weight is high due to the rotor magnet within the motor
- The motor performance will be affected due to magnetic strength.
- This motor is expensive
- The Hybrid Stepper Motor applications are as follows:

- These motors are applicable in the production of automated devices, gauges & machines used as cutting, labeling, packaging, filling, etc.
- These are used in lane diverters, elevators, and conveyor belts.
- These are used in security devices like CC cameras
- These are applicable for consumer electronics like printing machines, scanners, digital cameras, etc.
- These motors are used in the medical field for photography of digital dental, liquid pumps, respirators, the machinery of blood analysis machinery, etc

End

THANK YOU