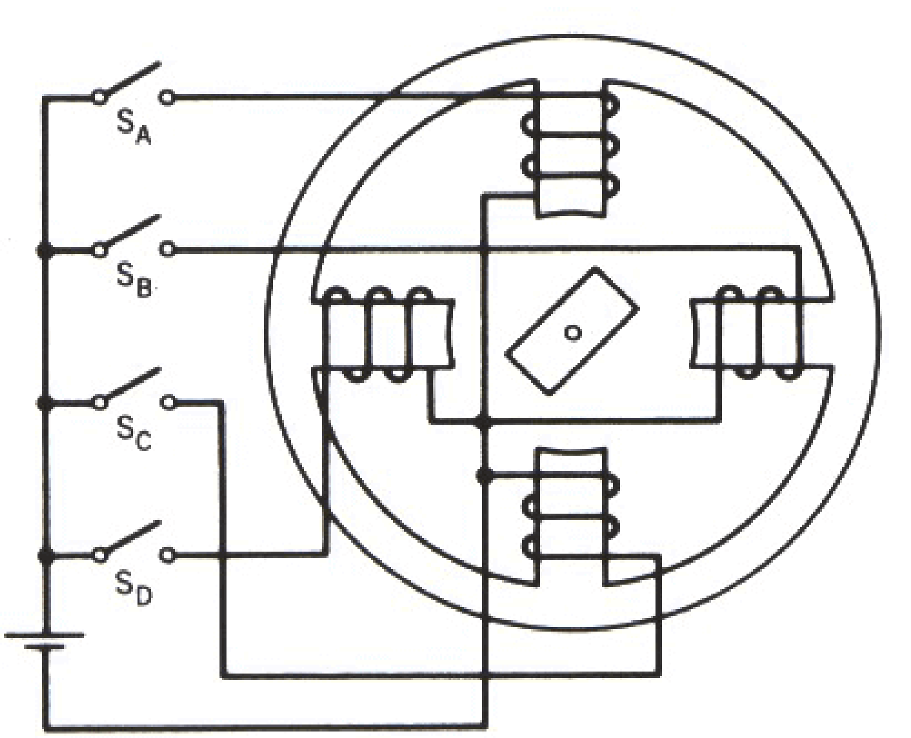
ELECTRICAL MACHINE

Stepper Motor

RAVI • JANUARY 11, 2020 • LEAVE A COMMENT



The DC motor rotates continuously when it supplied by the DC source. The direction of rotation depends on the polarity of the supply. But the stepper motor rotations are not continuously. The rotor of this motor rotates in discrete steps.

The stepper motor is a special kind of motor which designed to rotate through a specific angle. There are two advantages to the stepper motor. The first one is that the stepper motor is compatible with digital systems and the second one is that, there is no need for any sensors for position and speed sensing.

Table of Contents

RECENT POSTS
- Capacitor-start Capacitor-run Induction Motor
- Capacitor Start Induction Motor
- Differential Protection

How does a Stepper Motor Work?

The control circuit used to generate digital pulses. These digital pulses are given to the driver circuit. The driver circuit generates steps according to the pulses.

The number of steps generated by the driver circuit is the same as the number of steps generates by the control circuit.

The rotor rotates in the angular motion. Therefore, this step is known as the **step angle**. Step angle is nothing but the angular movement of the rotor when the control circuit generates one pulse. For example, the step angle is 15 degrees. So, if the control circuit generates one pulse, the motor rotates 15 degrees.

Stepper motors have multiple toothed electromagnets and it energized by the driver circuit. A gear-shaped piece of an iron place in the center of electromagnets.

When the electromagnets energized, it attracts the teeth of a gear. Hence, the gear's teeth are aligned to the first electromagnet. The next electromagnet placed at some angle. When the next electromagnet energized, it attracts the teeth of the gear and tries to align with the next electromagnet.

This is how the stepper motor rotates. According to the working principle, there are three types of the stepper motor.

Types of Stepper Motor

Stepper motors classified into three types;

- Variable reluctance stepper motor
- Permanent magnet stepper
- Hybrid synchronous stepper

Variable Reluctance Stepper Motor

Similar to other motors this motor also consists of stator and rotor. According to the stator stacks variable reluctance motor classified into two types;

- Single stack variable reluctance motor
- Multi stack variable reluctance motor

Single-stack Variable Reluctance Motor

The stator made from steel lamination. It consists of stator poles and winding. The stator winding wounded on the stator poles.

The rotor has no winding and made up of steel lamination.

The motor works on the principle of aligning one set of stator and rotor poles by energizing the stator winding. Because of this reason, must keep a different number of poles for stator and rotor.

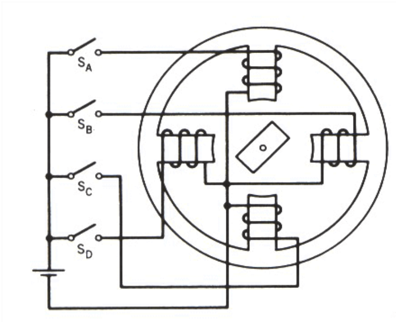
The stator winding energized by the DC source. the DC source is given in such a way that, it produces the sequence to generate a resultant rotating air-gap field around the rotor in steps.

- HRC Fuse: Construction, Operation, Characteristics, and Applications
- Basic Electrical Engineering Laws

CATEGORIES

- Basic Electrical
- Basic Electrical MCQ
- DC Machine
- DC Machine MCQ
- Distribution
- Distribution MCQ
- Electrical Machine
- Electrical Machines MCQ
- Electromagnetic Filed MCQ
- Electronics
- Generation
- Generation MCQ
- Induction Motor
- Induction Motor MCQ
- MCQ
- Power Electronics
- Power Electronics MCQ
- Power System
- Power System MCQ
- Protection and Switchgear
- Synchronous Machine
- Transformer
- Transformer MCQ
- Transmission
- Transmission MCQ
- Uncategorized

The rotor has a tendency to align the rotor axis along the direction of the resultant air-gap field. Hence, the rotor follows the motion of the stepped field and rotates step.

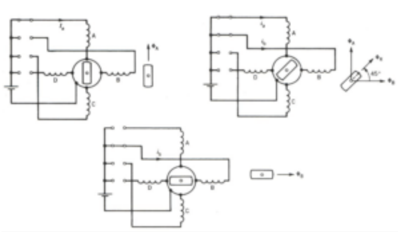


4 Phase 2 Pole Stepper motor

Now consider the above figure which represents the 4-phases and 2-poles, single stack, variable reluctance motor.

Four phases are A, B, C, and D. These phases energized with the switch S1, S2, S3, and S4. The step angle of the motor is depending on how the phases are energized.

The energizing sequence A, A+B, B, B+C, C, C+D, D, D+A. And then this switching sequence is repeated.

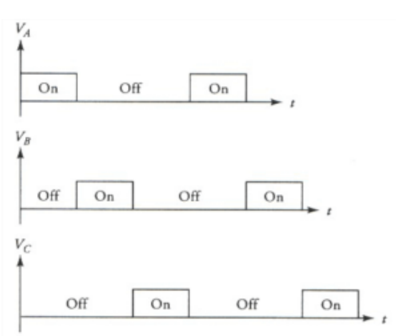


Working of single-stack stepper motor

Energizing winding A: When phase-A energized, along the axis of pole winding A, the resultant air-gap flux will be aligned. Consequently, the rotor aligns itself along with phase A axis.

Energizing winding A and B: When phase-A and phase-B energized together, the resultant air-gap flux will be oriented in the midway between pole A and pole B. Therefore, the resultant MMF rotated 45° in the clockwise direction. And the rotor aligns itself with the resultant MMF (45°).

Energizing winding B: When phase-B energized, the resultant air-gap flux will be aligned along the axis of pole B winding. Therefore, the rotor aligns itself along the phase B axis.

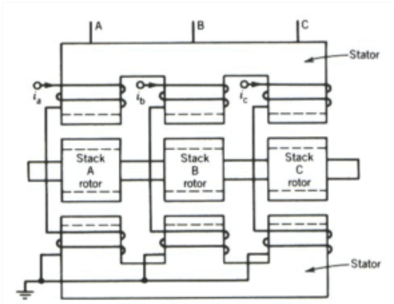


Phase switching sequence of single-stack stepper motor

And it completes quarter round and rotates so on. This is how the stepper motor rotates. The number of poles of rotors and phase energized sequence is designed as per the step angle.

Multi-stack Variable Reluctance Stepper Motors

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



Cross section view of a typical three-stack variable reluctance stepper motor

These motors have the same number of teeth in each of the stator stacks as those in each of the rotor stacks.

The rotational sequence of a 3-phase, 4-pole, 12-teeth, three-stack, variable reluctance stepper explained. According to the following energizing sequence, the motor will rotate at 10° step in a clockwise direction. Then this switching sequence repeated.

Energizing phase (stack) A: When stack A winding energized, the rotor teeth will move to align themselves with the stator teeth is stack A.

Energizing phase (stack) B: When stack B winding energized, while stack A winding 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°.

Energizing phase (stack) C: When stack C winding energized, while stack B winding 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.

The direction of rotation can be reversed by reversing the switching sequence.

Number of stacks in N while the total number of teeth in each stack is x. The tooth pitch can expressed by,

$$\tau_p = \frac{360^0}{x}$$

The step size can be expressed by,

$$\Delta\theta = \frac{360^0}{xN}$$

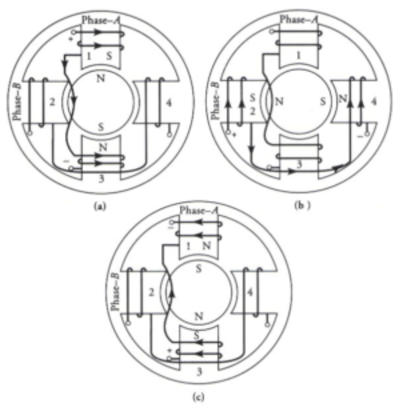
Therefore, the number of steps per revolution (n) is given by

$$n = \frac{360^0}{\Delta\theta} = xN$$

Permanent Magnet Stepper Motor

The construction of Permanent Magnet Stepper Motor is similar to the construction of single-stack, variable reluctance stepper motor. The only difference is that the rotor made up of the permanent magnet.

The below figure represents the circuit configuration and different operation modes for a 2-phase, permanent magnet stepper motor. This motor will rotate in an anticlockwise direction with a 90° step.

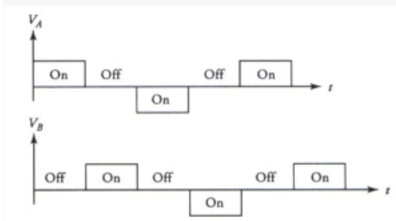


Construction and operation of 2-phase, permanent magnet stepper motor

Reversing the switching sequence will result in reversing the direction of rotation. The below table and figure present each phase switching sequence for one revolution of the rotor.

Cycle	Phase A	Phase B	Position δ°
+	1	0	0
	0	1	90
−	−1	0	180
	0	−1	270
+	1	0	360

Table Phase switching sequence



Phase switching sequence

Compression Between Permanent Magnet Stepper Motor and Variable Reluctance Stepper Motor

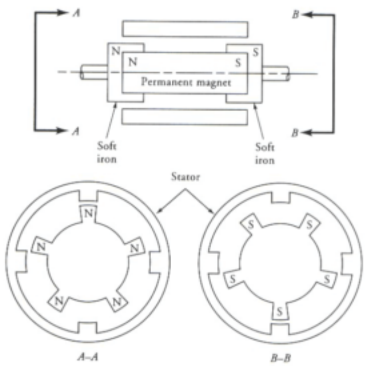
- Higher inertia and consequently lower acceleration (deceleration) rates in a permanent magnet stepper motor.
- The maximum step pulse rate is 300 pulses per second compared to 1200 pulses per second for variable reluctance stepper motors.
- Larger step sizes, ranging from 30° to 90° compared to step sizes as low as 1.8° for variable reluctance stepper motors.
- Generate higher torque per ampere of stator currents than variable reluctance stepper motors.

Hybrid Stepper Motor

Hybrid stepper motors have similar stators's construction to that of variable reluctance stepper motors. However, their rotors constructions combine both variable reluctance and permanent magnet constructions.

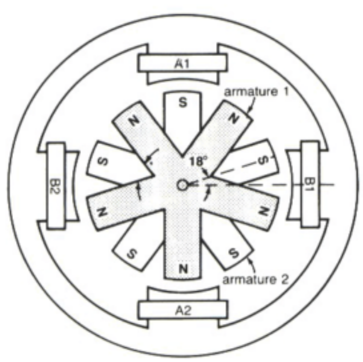
The rotors made of an axial permanent magnet at the middle and two identical stacks of soft iron poles at the outer ends attached to the north and south poles of the permanent magnet.

The rotor poles connected to the north pole of the permanent magnet forms north pole, while the other from the south poles as shown in the below figure. This figure also presents two different views of these motor types.



Construction of 4-pole stator and 5-pole rotor hybrid stepper motor

The below figure presents a complete cross-section view of 4-pole stator and 5-pole rotor hybrid stepper motor.



Cross section view of 4-pole stator and 5-pole rotor hybrid stepper motor

These types of motors have similar operation modes as the permanent magnet types. Moreover, they are characterized by smaller step sizes but they are very expensive compared to variable reluctance stepper motors.

Features of Stepper Motor

- Available resolutions ranging from several steps up to 400 steps (or higher) per revolution.
- Several horsepower ratings.
- Ability to track signals as fast as 1200 pulses per second.

What is a Stepper Motor used for?

The application of stepper motor includes;

- Stepper motor used in computer peripherals, robots, and textile industries for operational control.
- It used in line printer, typewriter, tape drives, floppy disk drives, process control system and XY plotters where requiring incremental motion.
- By keeping the count of pulses sent to the motor, it can obtain position information. And this can be used instead of the very costly position sensor and feedback element.
- It used in the manufacturing of packed food, commercial products and also used in the production of science fiction movies.

LEAVE A REPLY

*Your email address will not be published. Required fields are marked **

Comment *

Name *

Email *

Website

Notify me of follow-up comments by email.

Notify me of new posts by email.

POST COMMENT