1.2 SINGLE STACK VARIABLE RELUCTANCE STEPPER MOTOR: CONSTRUCTION AND PRINCIPLE OF OPERATION

The VR stepper motor characterized by the fact there is no permanent magnet either on the rotor or the stator. The construction of a 3-phase VR stepper motor with 6 poles on the stator and 4-pole on the rotor as shown in figure1.2.1

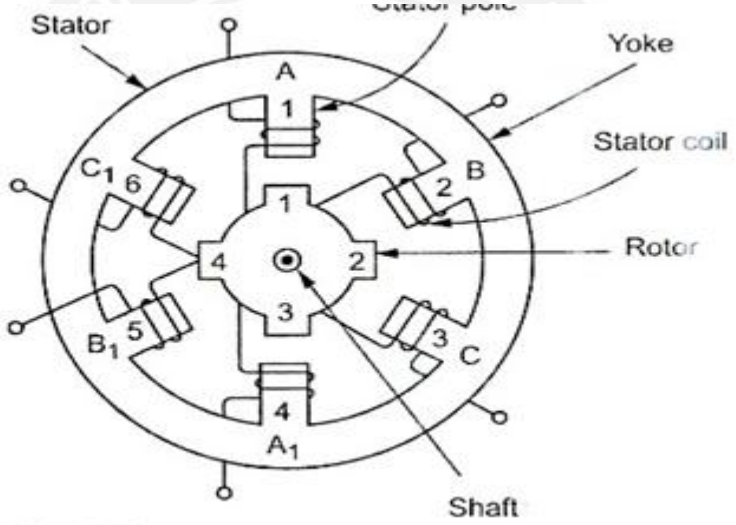

Figure 1.2.1 single stack variable reluctance stepping motor

[Source: "special electric machines" by E.G.Janardanan page:2]

The Stator is made up of silicon steel stampings with inward projected even or odd number of poles or teeth. Each and every stator poles carries a field coil an exciting coil. In case of even number of poles the exciting coils of opposite poles are connected in series. The two coils are connected such that their MMF gets added .the combination of two coils is known as phase winding.

The rotor is also made up of silicon steel stampings with outward projected poles and it does not have any electrical windings. The number of rotor poles should be different from that of stators in order to have self-starting capability and bi direction. The width of rotor teeth should be same as stator teeth. Solid silicon steel rotors are extensively employed. Both the stator and rotor materials must have lowering a high magnetic flux to pass through them even if a low magneto motive force is applied.

Electrical Connection

Electrical connection of VR stepper as shown figure 1.2.2 Coil A and A‘ are connected in series to form a phase winding. This phase winding is connected to a DC source with the help of semiconductor switch S1.Similary B and B‘and C and C‘ are connected to the same source through semiconductor switches S2 and S3 respectively. The motor has 3 –phases a, b and c.

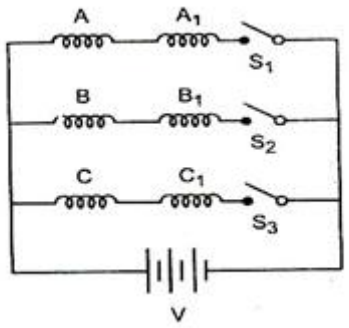

Figure 1.2.2 switching circuit

[Source: “special electric machines” by E.G.Janardanan page:2]

Principle of Operation

It works on the principle of variable reluctance. The principle of operation of VR stepper motor explained by referring figure1.2.3.

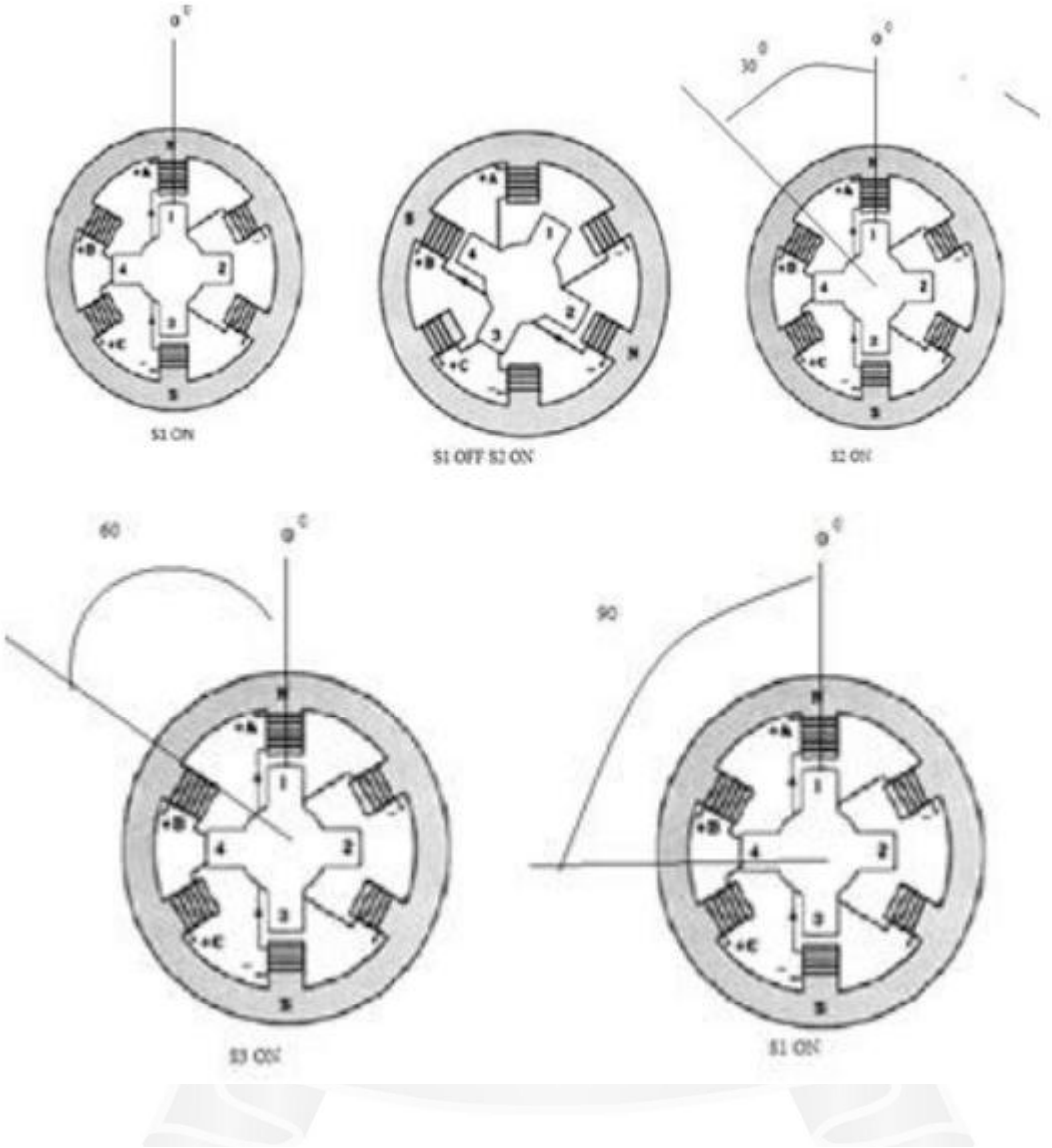

Figure 1.2.3 permanent magnet stepping motor

[Source: "special electric machines" by E.G.Janardanan page:3]

(a).Mode 1 : One phase ON or full step operation

In this mode of operation of stepper motor only one phase is energized at any time. If current is applied to the coils of phase a'(or) phase a'is excited, the reluctance torque causes the rotor to run until aligns with the axis of phase a. The axis of rotor poles 1 and

3 are in alignment with the axis of stator poles A‘and A‘‘. Then angle θ = 0° the magnetic reluctance is minimized and this state provides a rest or equilibrium position to the rotor and rotor cannot move until phase a‘is energized. Next phase b is energized by turning on the semiconductor switch S2 and phase a‘ is de energized by turning off S1.Then the rotor poles 1 and 3 and 2 and 4 experience torques in opposite direction. When the rotor and stator teeth are out of alignment in the excited phase the magnetic reluctance is large. The torque experienced by 1 and 3 are in clockwise direction and that of 2 and 4 is in counter clockwise direction. The latter is more than the former.

As a result the rotor makes an angular displacement of 30° in counterclockwise direction so that B and B‘and 2 and 4 in alignment. The truth table for mode I operation in counter and clockwise directions are given in the table 1.2.1

S1	S2	S3	θ
*	-	-	0
-	*	-	30
-	-	*	60
*	-	-	90
-	*	-	120
-	-	*	150
*	-	-	180
-	*	-	210
-	-	*	240
*	-	-	270
-	*	-	300
-	-	*	330
*	-	-	360

S1	S2	S3	θ
*	-	-	0
-	-	*	30
-	*	-	60
*	-	-	90
-	-	*	120
-	*	-	150
*	-	-	180
-	-	*	210
-	*	-	240
*	-	-	270
-	-	*	300
-	*	-	330
*	-	-	360

Table 1.2.1 Truth table for one phase on mode

[Source: “special electric machines” by E.G.Janardanan page:3]

(b).Mode II: Two Phase on Mode

In this mode two stator phases are excited simultaneously. When phases a and b are energized together, the rotor experiences torque from both phases and comes to rest in a point mid-way between the two adjacent full step position. If the phases b and c are excited, the rotor occupies a position such that angle between AA‘ axis of stator and 1-3 axis of rotor is equal to 45°.To reverse the direction of rotation switching sequence is changed a and b,a and c etc. The main advantage of this type of operation is that torque developed by the stepper motor is more than that due to single phase ON mode of operation.

S1	S2	S3	0°	
*	*	-	15°	AB
-	*	*	45°	BC
-	*	-	75°	CA
*	*	-	105°	AB
-	*	*	135°	BC
-	*	-	165°	CA
*	*	-	195°	AB
-	*	*	225°	BC
-	*	-	255°	CA
*	*	-	285°	AB

	S1	S2	S3	θ
AC	-	*	-	15°
CB	-	*	*	45°
BA	*	*	-	75°
AC	-	*	-	105°
CB	-	*	*	135°
BA	*	*	-	165°
AC	-	*	-	195°
CB	-	*	*	225°
BA	*	*	-	255°
AC				285°

Table 1.2.2 Truth table for two phase on mode

[Source: “special electric machines” by E.G.Janardanan page:4]

Mode III: Half step Mode

In this type of mode of operation on phase is ON for some duration and two phases are ON during some other duration. The step angle can be reduced from 30° to 15° by exciting phase sequence a, a+b, b,b+c, c etc. The technique of shifting excitation from one phase to another from a to b with an intermediate step of a+b is known as half step and is used to realize smaller steps continuous half stepping produces smoother shaft rotation.

S1	S2	S3	θ	
*	-	-	0°	A°
*	*	-	15°	AB°
-	*	-	30°	B°
-	*	*	45°	BC°
-	-	*	60°	C°
*	-	*	75°	CA°
*	-	-	90°	A°
*	*	-	105°	AB°
-	*	-	120°	B°
-	*	*	135°	BC°
-	*	-	150°	C°
*	-	*	165°	CA°

S1	S2	S3	θ	
*	-	-	0°	A°
*	-	*	15°	AB°
-	-	*	30°	B°
-	*	*	45°	BC°
-	-	*	60°	C°
-	*	-	75°	CA°
*	*	-	90°	A°
*	-	-	105°	AB°
*	-	*	120°	B°
-	-	-	135°	BC°
-	*	*	150°	C°
-	*	-	165°	CA°

Table 1.2.3 Truth table for Half step on mode

[Source: "special electric machines" by E.G.Janardanan page:4]