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Report 1: Basic Operation
Of the Switched Reluctance Motor

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The switched reluctance motor (SRM) has a simple machine design with respect to the internal structure. The rotor as well as the stator have salient (prominent) poles. (Figure: 1.)

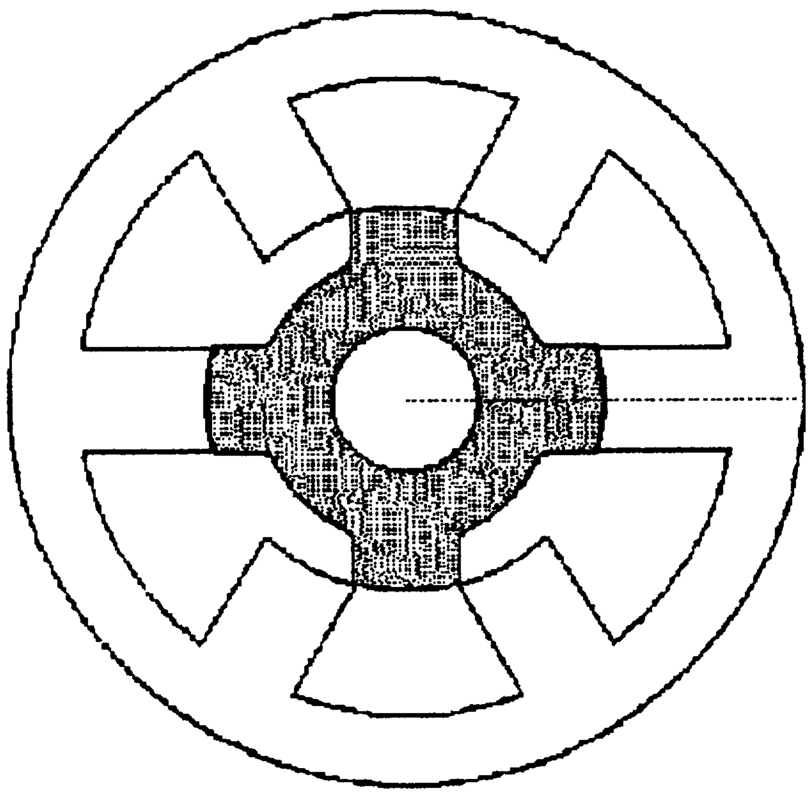

Figure 1: Salient pole stator and rotor of Switched Reluctance Motor.

Typically salient poles have windings forming coils wrapped around the waists (or pole cores) of each pole. This is true for the stator of the SRM but not for the rotor. The rotor has no windings, no coils, no magnets, no commutator, or slip rings it is only comprised of laminated steel sheets stamped in the shape of the pole design (Figure: 2.) and mounted on a shaft. This allows for ease in manufacturing the rotor as well as reducing the rotor's inertia. There is also no electrical loss associated with the rotor since there are no windings, commutator, or slip rings.

Figure 2: Rotor section of Switched Reluctance Motor stamped from sheet steel.

The stator, like the rotor, is made form thin steel sheets stamped with the desired pole design (Figure: 3.) and laminated along the axis of the machine. This again allows for ease in manufacturing.

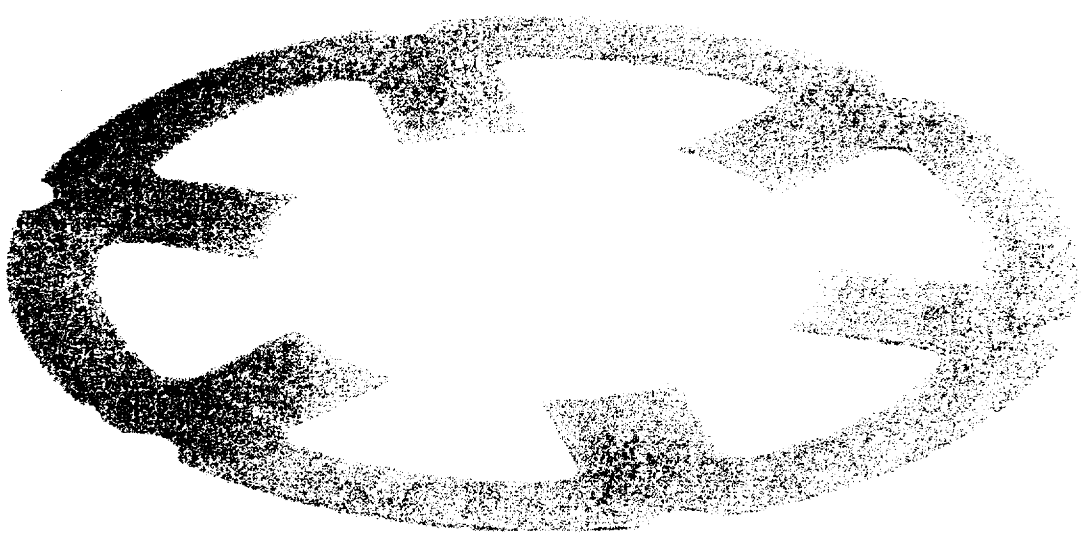

Figure 3: Stator section of Switched Reluctance Motor stamped from sheet steel.

The stator, unlike the rotor, has windings, which form coils (Figure: 4.) on each pole; these coils are initially isolated from each other. In the design of the stator every salient pole has another pole directly opposite and inline with itself. This pole pair and their respective coils from a phase.

Figure 4: Stator winding/coil for one pole. Two are required for each phase.

At this point coils start to get interconnected either in series or parallel by their phase noting that coils across different phases do not interconnect. From this one can see the development of stator pole design if there is only one phase then there has to be two poles on the stator. If there is two phases then four poles are needed, three phases need six poles or a multiple of six i.e. 12, 18, or 24 the phases are just repeated. (Figure: 5.)

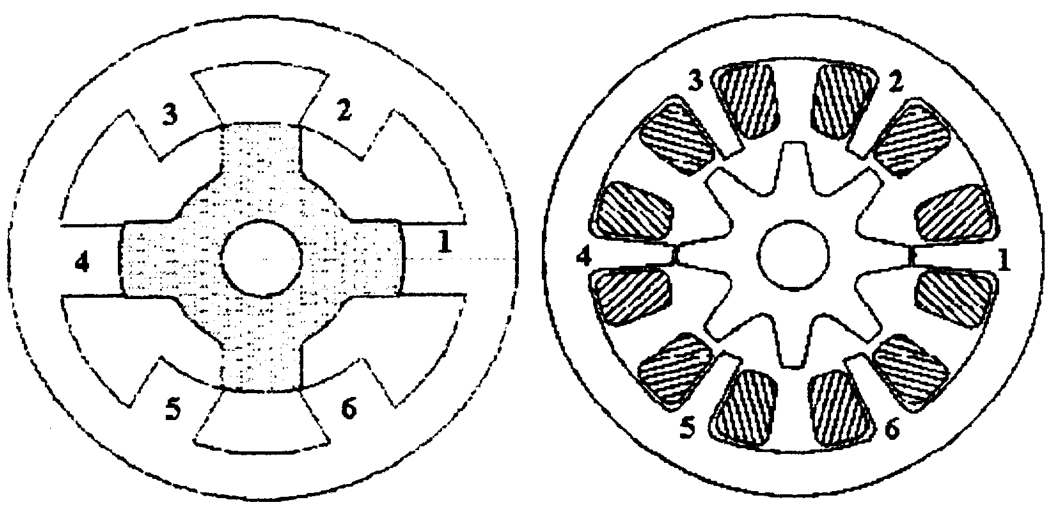

Figure: 5. Two examples of stator/rotor designs for three-phase. Left: 6/4 Right: 6/8

The SRM operates on the interaction of the stator phases and the rotor poles. When current is applied to one phase of the stator one set of rotor poles, again a set is two poles directly opposite each other, will try to align itself with the stator poles. (Figure: 6.) When stator and rotor poles are perfectly aligned reluctance is at its minimum and inductance is at its maximum.

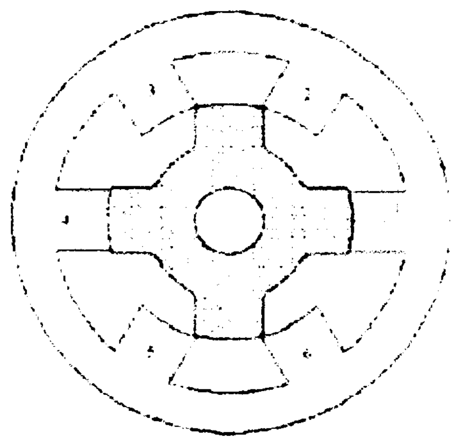

Figure: 6. Rotor pole aligned with stator pole at 1 and 4.

The opposite is true when the poles are unaligned. (Figure: 7.) Torque is developed when the rotor poles move from unaligned to the aligned position.

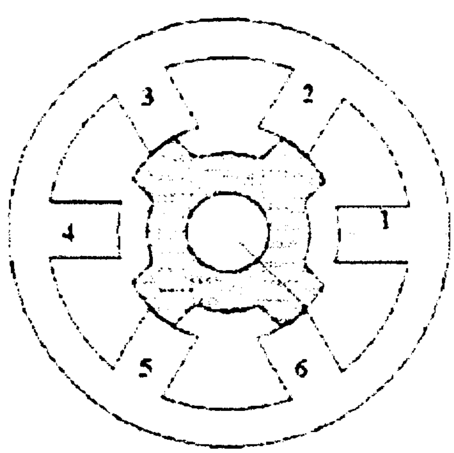

Figure: 7. Rotor pole unaligned with stator poles at 1 and 4.

Once the alignment has occurred the torque ceases and motion stops. If the pole were driven to pass the point of alignment a negative torque will develop. This is where "switched" reluctance enters, just as the poles reach alignment the current gets switched to the next phase causing the next set of rotor poles to generate torque to align with the stator poles. Excitation occurs as a sequence of current pulses to each phase in sequence i.e. 1-2-3-1-2-3-1-2-3-1 for a three-phase stator. Rotation is in the opposite direction to the excitation sequence, if excitation is counterclockwise then rotation is clockwise, refer to figure 8, as current moves from phase 1 to phase 2 (counterclockwise) rotor pole A presently aligned with pole 1 moves clockwise as rotor pole B moves to align with pole 2.

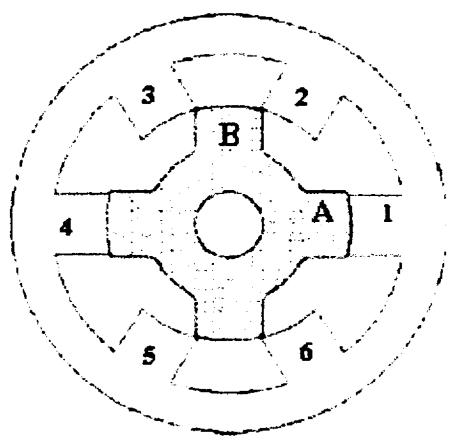

Figure: 8. Illustation of rotor direction vs. excitation sequence.

As mentioned above there is no torque when the poles are aligned. Torque develops when the rotor is displaced to either side of the aligned position; the rotor tries to realign itself. This allows the SRM to operate in either direction the only change needed is the excitation sequence. It is to be noted that during the transition from one phase to the next there is a dip in the torque as it decreases with alignment and then increases with the next phase. This dip in torque is more prominent the lower the phase number (i.e. 1,2,3) and becomes less prominent as phase number increases (i.e. 4,5,6,7) see figure 9. This dip translates to torque ripple as well as a source of noise in the machine.

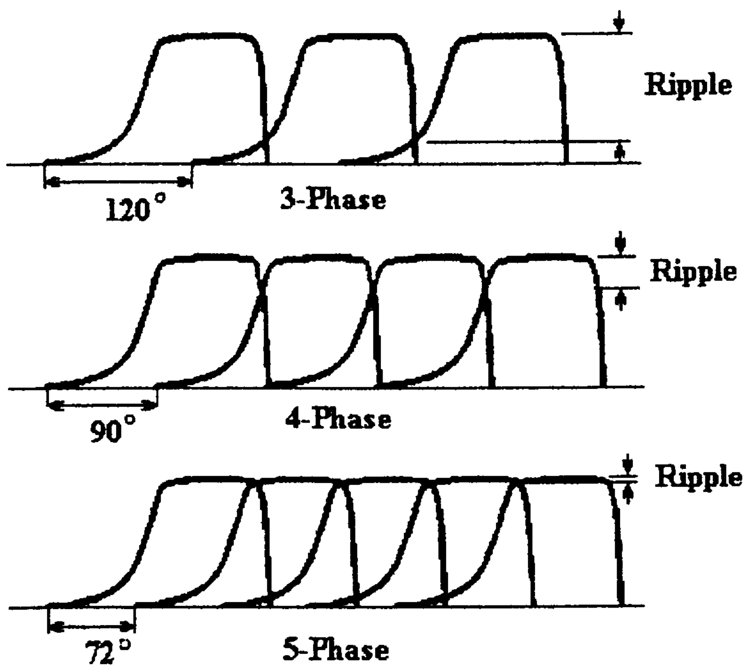

Figure: 9. Varations in torque dip/ripple with change in phase number.

The switched reluctance machine can be used as either a motor or a generator by the timing of the excitation sequence. For motoring operations each phase is excited when inductance is decreasing/reluctance is increasing, this occurs when the rotor is approaching the aligned position, and unexcited when inductance is increasing/reluctance is decreasing as the rotor approaches unalignment. Operation as a generator is the opposite each phase is excited when inductance is decreasing/reluctance is increasing, approaching unalignment, and unexcited when inductance is increasing/reluctance is decreasing, approaching alignment. Also for generation the rotor shaft is supplied power.

There are some important advantages associated with the switched reluctance motor. The first, as previously mentioned, is the simple design, which lends itself to lower manufacturing costs. There is less time needed to manufacture the rotor because of its laminated design as well as the lack of windings or magnets. This brings forth another advantage with a "bare" rotor extremely high speeds can be obtained as compared to rotors with magnets or windings. The simplicity of the stator is another advantage. In addition to the laminated construction the windings are much simpler there is no need to wind directly on the stator the coils can be manufactured separately and installed further along the process. This also lowers maintenance costs if a winding needs to be changed. Another noted advantage is that high starting torque can be achieved without large inrush currents as well as torque is independent of current direction. With the switched reluctance motor high efficiency is maintained over a wide range of speed.

The switched reluctance motor does not escape having some disadvantages such as the non-uniform pulsing characteristic (torque ripple) associated with the torque development, which as previously mentioned changes in magnitude with the number of phases in each motor's design. This is also responsible for part of the motor's noise problem. Another source for noise in the SRM is the ovaling that occurs in the stator from opposite poles attracting and pulling towards one another during excitation and returning to their natural position when unexcited. The need for a minimal air gap is another disadvantage of the SRM in that it lowers manufacturing tolerances on the stator and rotor. There are disadvantages with the control of the SRM. For example, rotor position is needed for excitation control. Also only one motor can be operated per inverter. A disadvantage on manufacturing lines where multiple motors are needed having the same control scheme. Since each phase of the SRM has a set of coil leads to be connected the cabling for the motor is more complex than other machine types. Even though there are a number of disadvantages with the SRM it is still a favorable design. The advantages out weigh the disadvantages as well as work is being done to minimize the disadvantages.