Pump ED 101

A Brief Primer on Reluctance Motors

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Most scientific words have specific meanings but they are often used to describe something that has nothing to do with their intended use. A good example is momentum. In physics, momentum is mass times velocity and since velocity is a vector quantity it also has direction. An object of a certain mass moving at some speed in a specific direction has a momentum of MV. If the mass and / or velocity change, momentum will change proportionally.

Interestingly, momentum is also used to describe political events. For example, during an election campaign politicians are reported to either gain or lose momentum. If we consider mass to be the politician's weight and velocity to be the number of fund raisers they attend per week, their momentum is also MV. If both attend the same number of fund raisers, the heavier politician will have greater momentum. Does that make sense? If we redefine mass to be the quantity of true statements spoken and velocity as the rate at which those statements leave their mouths, chances are momentum will be very small. Regardless of the units of measure, momentum cannot accurately describe any political event. Why? Because velocity is a vector quantity and politicians change direction continuously so their net momentum will almost always be zero. But I digress, let's discuss reluctance.

The dictionary defines reluctance as "unwillingness, hesitation or disinclination" but, in physics it is the resistance to the flow of flux in a magnetic circuit. It is analogous to resistance in an electric circuit and just as current follows the path of least resistance, magnetic flux will always follow the path of least reluctance. The term was first used in the late 1800's and was coined because resistance was already in use. Reluctance is important in our industry because it is the principle of operation for a motor design that is very different than that of the induction motor. The Switched Reluctance Motor (SRM) could become a major player in the municipal / industrial motor market in the near future. It has several advantages over the induction motor and its negatives are being overcome by advances in electronic technology.

The formula for reluctance ($R = F/\Phi$) in an electromagnetic circuit is very similar to

Ohm's Law (R = E/I) in an electrical circuit. In this case E is replaced with F which is the magnetomotive force (MMF) and I is replaced with Φ which is the magnetic flux. MMF is the force that produces magnetic flux and is analogous to the electromotive force (EMF) in an electric circuit. Flux is a measure of the magnetic field that passes through a surface and it decreases as a magnetic field increases.

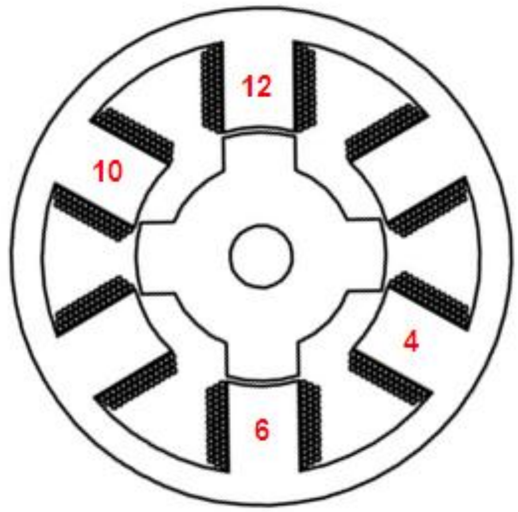

Figure 1 is a cross section of a reluctance motor and shows a construction that is much simpler than that of the induction motor. Its stator consists of individually wound salient pole pairs that project into the motor housing. Unlike the slotted design of the induction motor stator, the reluctance stator completely separates the phase windings. The rotor is also quite simple and typically consists of laminated steel salient poles that are stacked on the shaft and project outward towards the stator poles. It is this simple, low cost construction that makes the reluctance motor a potential rival to the induction motor. When a rotor pole pair is in direct alignment with a stator pole pair the air gap between them and reluctance are at their minimum and inductance is at its peak. In Figure 1 the rotor poles are in complete alignment with the stator poles at the twelve and six o'clock positions. Rotation is achieved by the torque that arises when the unaligned rotor poles are attracted towards the nearest energized stator poles (four and ten o'clock for clockwise rotation). In doing so they are following the path of least reluctance and this is analogous to the force that attracts iron to a permanent magnet. Some reluctance motor designs can operate nearly synchronously on AC power, however, they are limited to low power applications due to the relatively low torque that is produced. Low efficiency and power factor are also characteristic and it is these limitations that have restricted the use of these motors since their development over one hundred years ago. Fortunately, advances in semiconductor technology and the control techniques it can provide have the potential to make the reluctance motor a strong competitor to the induction motor. Enter the Switched Reluctance Motor (SRM).

SRM's use an electronic controller to energize and de-energize the pole pairs in a particular sequence and operates in a fashion that is similar to brushless DC (BDC) motors. A major difference is that no permanent magnets are required by the rotor. But as with the BDC motor the controller must monitor the rotor position in order to properly apply power to a particular set of poles. This can be achieved via sensors that monitor the orientation of the shaft or a sensorless control algorithm. SRM's have been designed to operate on single, two, three, and four phase power. Like the single phase induction motor, a single phase SRM does not create a rotational field during starting and will not start if the poles are aligned. The two phase SRM does create a rotational field but could start in a random direction. Three and four phase SRM's can start reliably in either direction. Many controllers use pulsed width modulation (PWM) to provide both constant and variable speed switching. In constant speed applications they are less complex, cost less than a VFD and some can even operate in single pulse mode.

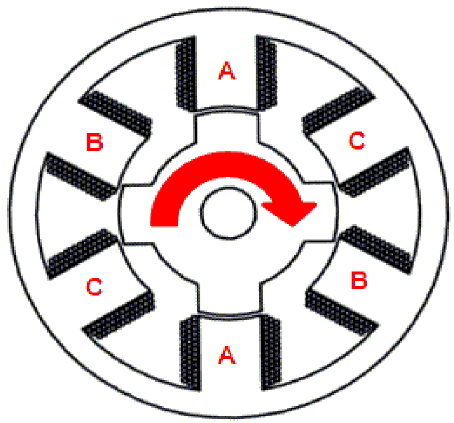

Figure 2 shows the ABC (three phase) switching or commutation sequence for clockwise rotation. As the rotor reaches alignment with the A poles, phase A is switched off, phase B is switched on and the rotor moves into alignment with the B poles. Upon alignment phase B is switched off and phase C is switched on. Clockwise rotation continues as long as the ABC switching sequence is maintained. If the switching sequence is changed to CBA, the motor will rotate counterclockwise. Actually, the switching sequence can be a bit more complex than this simple example. Phase dwell angle and phase overlap among the adjoining poles can be tailored by the controller and provide higher torque and more stable operation.

Some of the advantages of the SRM over the induction motor include potentially lower cost construction, higher efficiency at lower loading, high starting torque, a broad range of speed, and higher ambient temperature tolerance. Disadvantages can include high torque ripple, acoustic noise and complex control. There have been many advancements over the past ten years but don't scrap that induction motor yet - - we still have a ways to go.

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pumps & packaged systems manufacturer & distributor with branches throughout the Pacific Northwest. He can be reached via his website www.pumped101.com. If there are topics that you would like to see discussed in future columns, drop him an email.