3.5 SWITCH RELUCTANCE MOTOR DRIVES

The switched reluctance motor (SRM) is an electrical machine that converts electric power into mechanical power. This electric motor, similarly to conventional motors (induction motor, synchronous motor and others), can operate in the four quadrants: In other words, it can accelerate and decelerate for clockwise and anticlockwise rotor rotations.

SRM control cannot be compared either with the alternated current motor, which is fed with sinusoidal current waveforms or with the direct current motor. In the simplest control, it needs each motor phase (winding) to be magnetized and demagnetized at the right moments of rotor position, so square current waveforms can be used in the simplest control. But as the motor is highly non-linear, the electromagnetic torque does not depend only on the instantaneous current value but also on a non-linear inductance profile, which means that using only square current waveforms will create torque with a high ripple component.

Our aim in this chapter is to describe a variety of fundamental methods to operate the SRM in the four quadrants. Indeed, there are many works published on this subject, and due to this reason, we propose a chapter for beginners who wants to really understand the foundations of SRM drives. For a more extensive and systematic exposition of SRM, the reader is referred to the many good books on the subject. A description about the SRM and a brief description about the controllers are given. Although these works are very complete, they do not give a clear path for the reader to create a SRM drive. So, in this chapter, simple controllers and all fundamental methods to develop a SRM controller and thus contribute to a very steep learning curve in SRM drives are described. And while it is aimed at beginners, we hope that even experts will have something to learn from this chapter.

Linear controllers are presented: voltage impulse, current and torque controllers, respectively. Depending on the required performance and cost, a choice can be made from the cheapest with the lowest performance of impulse control to the most expensive with the best performance of torque control.

As already stated, the motor is highly non-linear, so linearization needs to be performed for control design. The small-signal linearization method which although being very limited is widely used in real systems is described. It will be seen that an ideal current waveform can be calculated to produce constant torque, instead of using a square waveform current. About the power electronic device, a description is given of how the traditional SRM converter works and how it can be controlled to maximize performance.

A simulation environment is also developed in the numerical tool Simulink/Matlab. It is based on the controllers and methods described in the chapter, to which the reader can have access and make his own simulations. This way, one student who works through this text will get an excellent grounding in SRM drives. He or she will actually learn what SRM control is about and how it can be used and will be in an excellent position to go on to more advanced controllers using this material.

In the description of the theory and in the simulation results, the SRM model parameters described in were used.

The chapter is divided into a description of the SRM in Section 2, the fundamental linear control methods in Sections 3, a study of the SRM model and its linearization in Section 4, the current waveform for constant torque in Section 5, a description of the traditional SRM converter and its control in Section 6, a presentation of numerical results using the tool Simulink/Matlab® in Section 7 and to end, the conclusions and bibliography.

Switched reluctance motors

The SRM is constituted by a stator with concentrated windings disposed around polar cores and by a rotor composed by salient poles free of windings or magnets. Normally, each stator phase is composed by a couple of windings diametrically opposed. In Figure 1 a SRM configuration of 6 stator poles and 4 rotor poles is shown. That is the configuration of reference for this chapter.

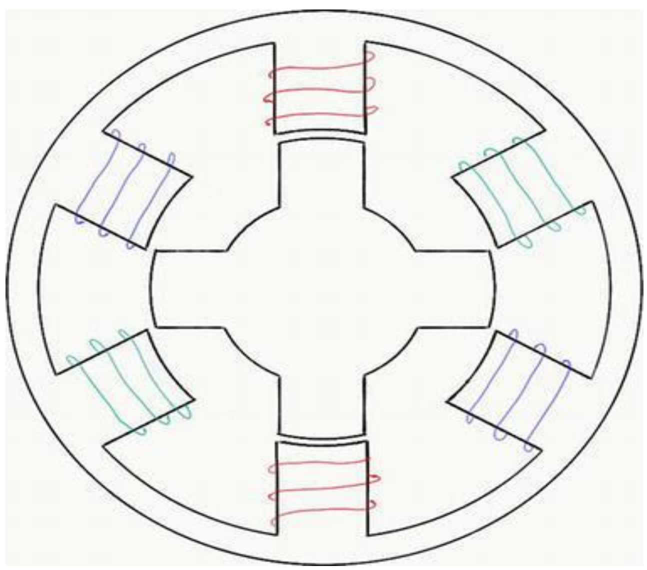

Figure 1.Switched reluctance motor structure.

When a stator phase is magnetized, a closed magnetic field is generated between the stator, the air gap and the rotor. This magnetic field tends to minimize the reluctance by reducing the air gap which creates a rotor movement. When a stator pole is aligned with a rotor pole, it is said that they are in the position of minimum reluctance, and when they are completely unaligned, it is said they are in the position of maximum reluctance.

This characteristic of the motor makes it possible to create a rotational movement of the rotor by magnetizing and demagnetizing each phase in the right position of the rotor.

1.1 Torque characteristics

The SRM suffers from high saturation. The inductance profile is non-linear, making the flux characteristic also non-linear. This can be seen in Figure 2, where the blue line is the unaligned rotor position and the red line the aligned rotor position. Saturation starts to influence the motor characteristic from about 5 A. It is around this point where the torque ampere ration significantly increases.

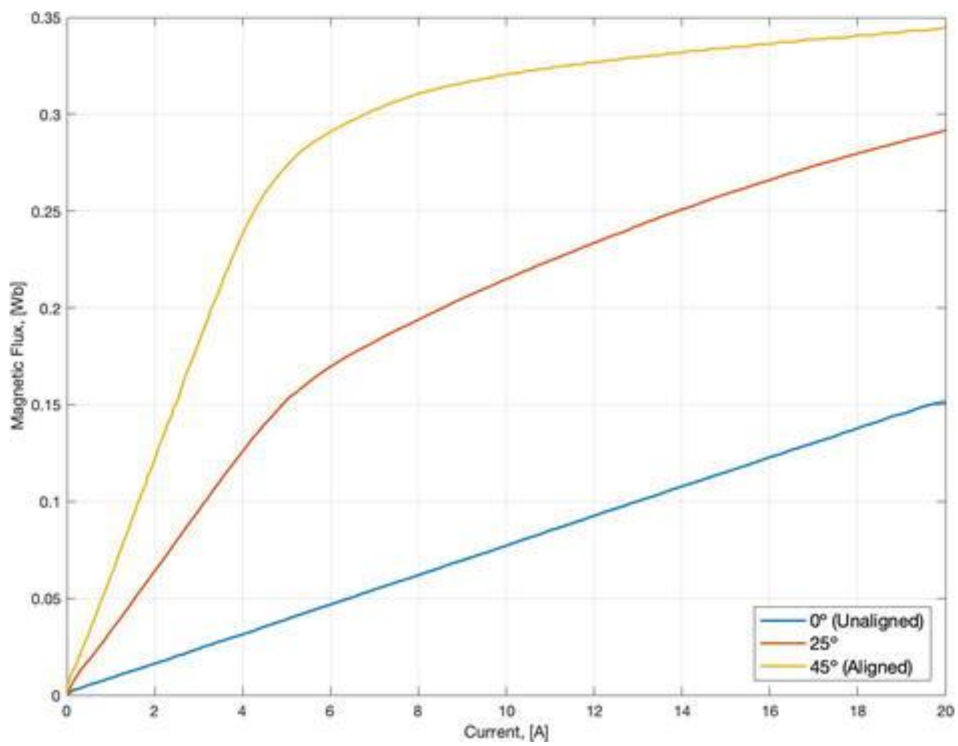

Figure 2.SRM flux characteristic.

The SRM torque characteristic graphic is shown in Figure 3. It represents one phase for 90° of the rotor, as the rest of the 360° are just a repetition for the other 3 rotor poles. The blue line represents a low current profile of 5 A, and the red line represents a high current profile of 20 A, which is the maximum motor current. It can be seen that from 0 to 45°, positive torque is produced and from 45 to 90° negative torque is produced. It can also be seen that the produced torque is not constant for constant current.