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Modelling and Reduction of Torque Ripple in SRM Drive using SVM Based Converter

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ABSTRACT

The Switched reluctance Motor (SRM) is an old member of the Electric Machines Family. Its simple structure, ruggedness and inexpensive manufacturing capability make it more attractive for Industrial applications. However these merits are overshadowed by its inherent high torque ripple, acoustic noise and difficulty to control. This paper presents a control technique for torque-ripple minimization in the switched reluctance motor (SRM) drive, based on a torque-sharing function (TSF) concept. In the proposed method, the reference torque is directly translated into the reference current waveform using the analytical expression. Torque ripple is one of the main disadvantages of Switched Reluctance Motor. In this paper, based on direct torque control theory, the reason of torque ripple was analyzed firstly from the aspects of basic space voltage vector. According to the analysis results a new method of optimized voltage vector was put forward to reduce the torque ripple. This paper presents a space vector modulation for SRM drive. The SRM is fed by a three-phase asymmetrical power converter having three legs, each of which consists of two IGBTs and two free-wheeling diodes.

INTRODUCTION

Electric machines can be broadly classified into two categories on the basis of how they produce torque -electromagnetically or by variable reluctance.

In the first category, motion is produced by the interaction of two magnetic fields, one generated by the stator and the other by the rotor. Two magnetic fields, mutually coupled, produce an electromagnetic torque tending to bring the fields into alignment. The same phenomenon causes opposite poles of bar magnets to attract and like poles to repel. The vast majority of motors in commercial use today operate on this principle. These motors, which include DC and induction motors, are differentiated based on their geometries and how the magnetic fields are generated. Some of the familiar ways of generating these fields are through energized windings, with permanent magnets, and through induced electrical currents.

In the second category, motion is produced as a result of the variable reluctance in the air gap between the rotor and the stator. When a stator winding is energized, producing a single magnetic field, reluctance torque is produced by the tendency of the rotor to move to its minimum reluctance position. This phenomenon is analogous to the force that attracts iron or steel to permanent magnets. In those cases, reluctance is minimized when the magnet and metal come into physical contact. As far as motors that operates on this principle, the switched reluctance motor (SRM) falls into this class of machines.

At an age of more than 150 years, and counting, the switched reluctance motor (SRM) represents one of the oldest electric motor designs around. Partly as a result of recent demand for variable-speed drives and primarily as a result of the development of power semiconductors, a variation on the conventional reluctance machine has been developed and is know as the switched reluctance" (SR) machine. The name \switched reluctance", used by, describes the two features of the machine configuration: (a). switched l the machine must be operated in a continuous switching mode, which is the main reason the machine developed only after good power semiconductors became available; (b). reluctance it is the true reluctance machine in the sense that both rotor and stator have variable reluctance magnetic circuits, or, more properly, it is a double salient machine.

In construction, the SRM is the simplest of all electrical machines. Only the stator has windings. The rotor contains no conductors or permanent magnets. It consists simply of steel laminations stacked onto a shaft. It is because of this simple mechanical construction that SRMs carry the promise of low cost, which in turn has motivated a large amount of research on SRMs in the last decade. The mechanical simplicity of the device, however, comes with some limitations. Like the brushless DC motor, SRMs cannot run directly from a DC bus or an AC line, but must always be electronically commutated. Also, the saliency of the stator and rotor, necessary for the machine to produce reluctance torque, causes strong non-linear magnetic characteristics, complicating the analysis and control of the SRM. Not surprisingly, industry acceptance of SRMs has been slow. This is due to a combination of perceived difficulties with the SRM, the lack of commercially available electronics with which to operate them, and the entrenchment of traditional AC and DC machines in the marketplace. SRMs do, however, offer some advantages along with potential low cost. For example, they can be very reliable machines since each phase of the SRM is largely independent physically, magnetically, and electrically from the other motor phases. Also, because of the lack of conductors or magnets on the rotor, very high speeds can be achieved, relative to comparable motors. Disadvantages often cited for the SRM; that they are difficult to control, that they require a shaft position sensor to operate, they tend to be noisy, and they have more torque ripple than other types of motors; have generally been overcome through a better understanding of SRM mechanical design and the development of algorithms that can compensate for these problems.

SWITCHED RELUCTANCE MOTOR:

Switched-reluctance (SR) motors were developed in the 1800s but, apart from a few embedded-drive applications, they have not been widely applied. Their optimum operation depends on relatively sophisticated switching control, something not economical until the advent of compact but powerful solid-state power devices and ICs. Now, with a new emphasis on energy efficiency, switched-reluctance motors may be ready to take a more prominent role in appliances, industrial equipment, and even off-road gear. The dc machine has been the primary choice for the servo applications, because of their excellent drive performance and low initial cost. The advantages of the ac machine to the dc machine are in the areas of torque-inertia ratio, peak torque capability and power density. Also ac machines do not need commutators and brushes. The low cost, ruggedness and almost maintenance free operation of the induction machines have made it the workhorse of the industry.

The different types of synchronous motors are used because of the high level of accuracy that can be achieved in speed control. In low power applications, the permanent magnet (PM) synchronous motors are extensively used for their high efficiency and good performance.

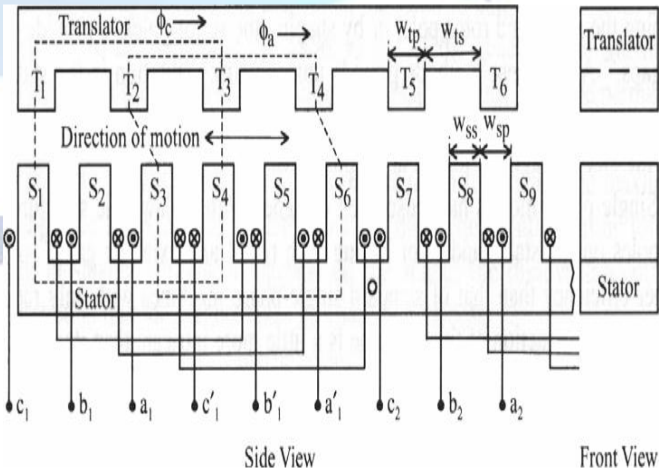

Figure 1: Three phase linear switched reluctance motor

The torque characteristics of switched reluctance motor are dependent on the relationship between the stator flux linkages and the rotor position as a function of the stator current. A typical phase inductance vs. rotor position is shown in Figure 2 for a fixed phase current. The inductance corresponds to that of a stator-phase coil of the motor neglecting the fringe effect and saturation. The significant inductance profile changes are determined in terms of the stator and rotor arcs and number of rotor poles.

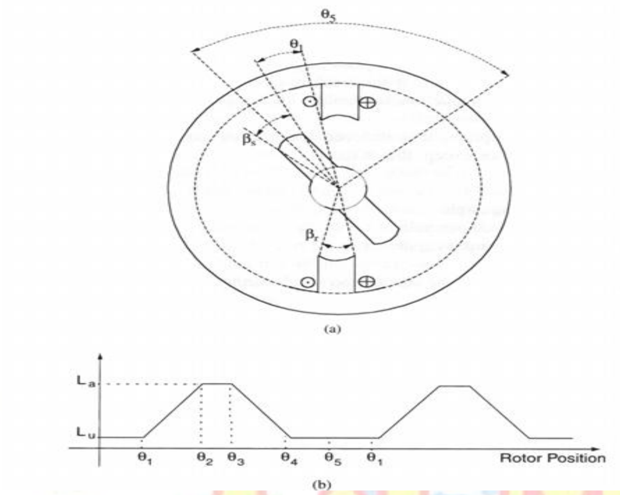

Figure 2: Inductance vs. rotor position

CONTROL METHODS OF SWITCHED RELUCTANCE MOTOR

Appropriate positioning of the phase excitation pulses is the key in obtaining effective performance.

- Control parameters: θon, θdwel and Iph
- Control parameters determine torque, efficiency and other performance parameters.

Figure 3, shows the asymmetric bridge converter. Turning on the two power switches in each phase will circulate a current in that phase of SRM. If the current rises above the commanded value, the switches are turned off. The energy stored in the motor phase winding will keep the current in the same direct until it is depleted. The waveforms are shown in Figure 3.

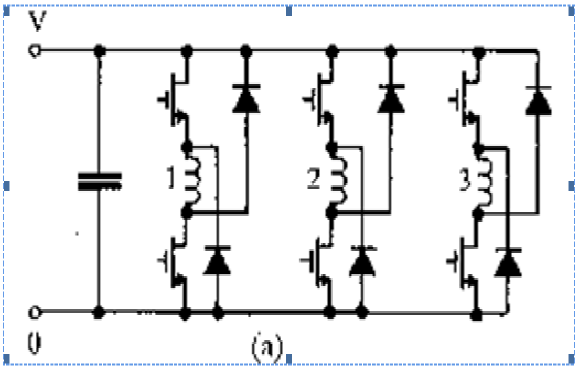

Figure 3: Asymmetric converter for SRM and operation waveforms

C-DUMP CONVERTER:

The C-dump converter is shown in Figure 4 with an energy recovery circuit. The stored magnetic energy is partially diverted to the capacitor *Cd* and recovered from in by the single quadrant chopper comprising of *Tr*, *Lr* and *Dr* and sent to the DC source.

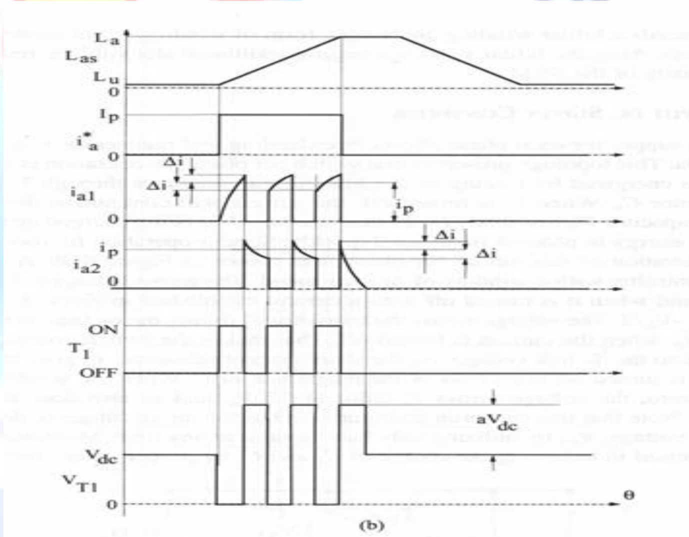

Figure 4: Bifilar type drive and operation waveforms with C-Dump

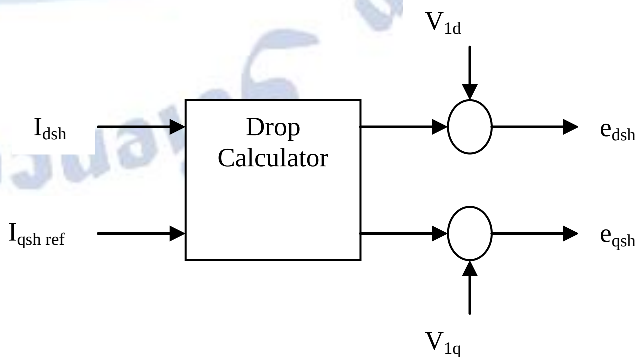

Figure 5: Control Circuit

This configuration has the advantage of minimum power switches allowing independent phase current control. The main disadvantage is that the current commutation is limited by the difference between voltage across *Cd*, *vo* and the DC link voltage.

SVM TECHNIQUE FOR TWO-PHASE INVERTER

In the SVM technique of three-phase inverter. A reference voltage vector V* is realized by computing the duty ratio for two space vectors which are adjacent to V* and by adjusting the switching time of two zero space vectors.

In this paper, the realization method for SVPWM technique of two-phase inverter is proposed without zero space vectors. Figure 6 shows the model sectors to determinate the switching times for the reference vector V* by adjusting four voltage space vectors.

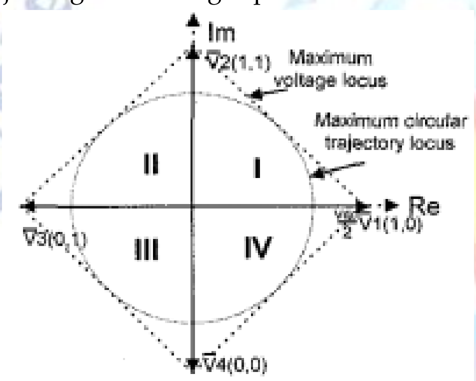

Figure 6: SVM Four possible space vectors

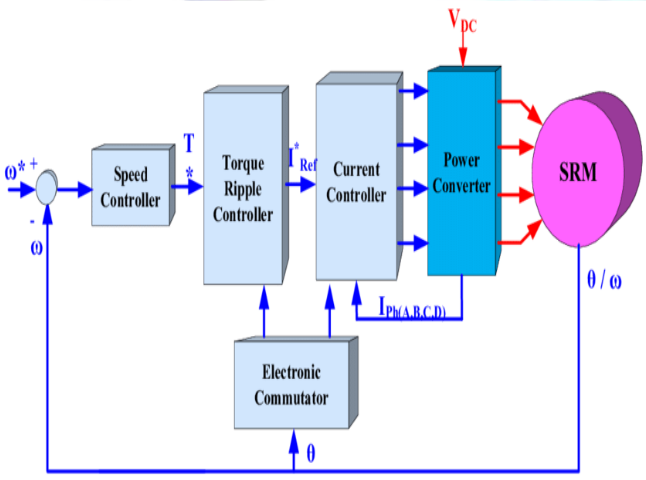

Figure 6: Block Diagram for SRM Drive

Simulink Block Diagram of SRM:

The speed controller for SRM drive and position sensor is shown in figure 7 and figure 8 respectively.

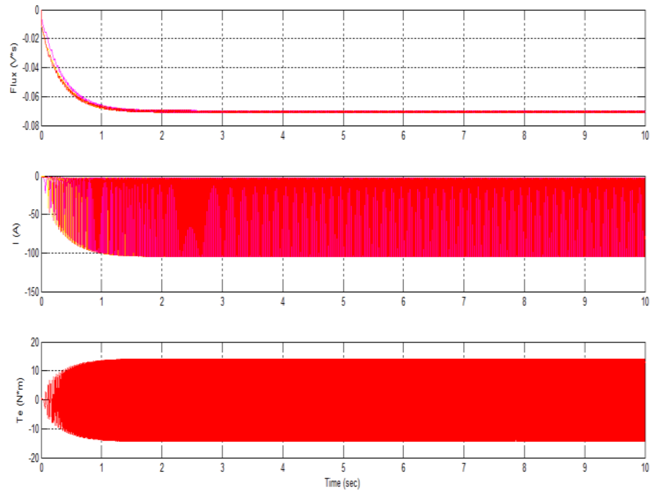

Figure 7: Simulation Waveform of SRM Parameters

The flux, currents, total torque graph, is shown in Fig. 7. R-dump converter is modeled and simulated in Matlab environment. From the Fig. 8 flux and current graph denotes the steady state of three phases such as Phase A, B and C.

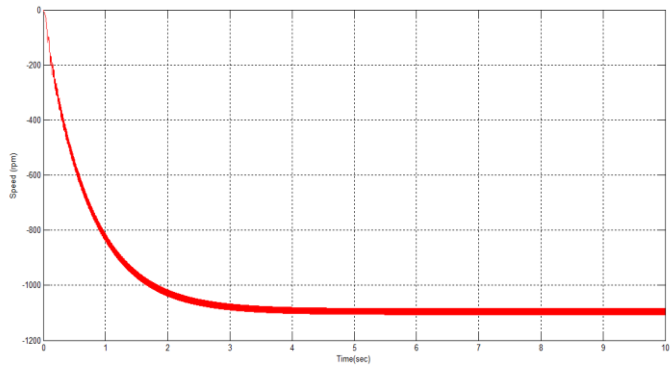

Figure 8: Simulation Waveform of SRM Speed

Figure 9 shows the simulation diagram for Controller of SRM Drive using Space Vector Modulation Technique.

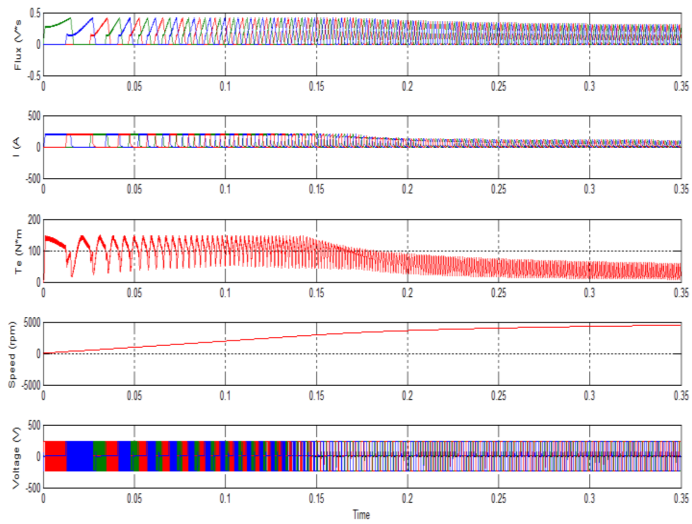

Figure 9: Simulation Waveform for SRM Parameters

The flux, currents, total torque Speed and Voltage graph, is shown in Fig. 9. R-dump converter is modeled and simulated in Matlab environment.

CONCLUSION

The most suitable and flexible Switched Reluctance Motor converter is the asymmetric type converter. This converter has the ability of fault tolerance; continuous operation with reduced power output of the motor drive can also be obtained in case of failure of one winding. By comparing different type converter topologies; it is found that the asymmetric converter type (With MOSFET) is suitable for very high speed operation of SRM drive because of the quick rise and fall times of current and moreover it give negligible shoot through faults. But, for medium speed operation at high power, IGBTs power switches are preferred due to low conduction losses and due to their high input impedance. In future SVM analysis to be conducted for all these converters to analysis to performance of SRM to reduce the torque ripple

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