CHAPTER 17
ENERGY EFFICIENT CONVERTER FOR SRM

17.1 Introduction

Energy saving method is very important for manufacturing in motor industries, since 65% of electrical energy is consumed by electrical motors. Hence the present work describes a new methodology to increase the efficiency of Switched Reluctance Motor (SRM). A new control circuit has been designed to improve the performance and efficiency of SRM. Modified controller is used to explain the energy savings of SRM. This method is also used to reduce the switching losses of SRM. Hence the cost of the drive system is reduced. Stored energy in off-going phase winding is once again used. Hence consumption of electrical energy of motor is reduced.

Selection of switched reluctance motor (SRM) is very important because it is a high speed home appliance motor like washing machine etc. Construction of SRM is simple because there is no winding in rotor. The main disadvantages of an SRM is summarized as follows

- SRM is a salient pole rotor and hence windage losses are high compared to other same diameter of smooth cylindrical rotor motor.
- Switching losses are higher than the other conventional motor.
- High core losses are obtained at demagnetization of coil.

The main aim of this work is described below.

- To reduce the losses in core during demagnetization.
- To increase the efficiency of the SRM by reusing the energy in off-going phase winding.

17.2 Requirements for SRM Converter

Switched reluctance motor (SRM) is not a self-operating motor. It is operated with any one type of converter. Selection of converter is very important for energy efficient operation. A main component for the converter is operating switches. Each and every winding is having separate switches at the existing system. Radial and axial air gap machine designs and Asymmetric half bridge converter with voltage boosting circuit is introduced (Barnes et al 1998). Power electronics converters are also proposed by Barnes et al 1998. C-dump converter analysis described by Souvik Ganguli 2011. The draw back of above converters are having high switching losses.
17.2.1 Basic Requirements

There are certain basic requirements that a converter has to meet to supply power to an SRM. The basic requirements are listed below:

> Each phase of an SRM should be able to conduct independent of the other phases.

> The converter should be able to demagnetize the phase before it steps into the generating region if the machine is operating as a motor and should be able to excite the phase before it steps into the generating region if operated as a generator.

17.2.2 Additional Requirements

In order to improve the performance, such as higher efficiency, faster De-magnetization, fault tolerance etc., the converter must fulfill some additional requirements. Some of these requirements are listed below:

> The converter should be able to energize another phase before the off going phase has completely demagnetized.

> The converter should be able to utilize the demagnetization energy from the off-going phase in a useful way by either feeding it back to the source or using it in the next conducting phase.

> In order to make the commutation period small, the converter should be able to demagnetize the off going phase in a very short time.

> The converter should be able to freewheel during the chopping period to reduce the switching frequency.

17.3 Bridge Converter

The most versatile SRM converter topology is the classic bridge converter topology with two power switches and two diodes per phase. There are four modes of operation in this converter. During the conduction mode of phase LI, both the phase LI switches (Q1 and Q4) are in on state. The input dc source magnetizes the phase. This mode is usually initiated before the start of the rotor and stator pole overlap, so that the phase current reaches the reference value before the phase inductance begins to increase. This helps to reduce the torque ripple. The current reaches the reference value and the converter steps into the current regulation mode. In this mode the current is maintained at the reference value by switching one of the phase switches.
while leaving the other one continuously on till the commutation time is reached. Both of the phase switches are turned off to initiate the commutation. The phase starts to demagnetize through the two diodes and the energy transfers from the motor phase to the dc source. During the commutation, the off-going phase winding sees a voltage of \(-V_{dc}\). While once phase is demagnetizing, another phase can be magnetized. This helps to reduce the torque ripple during the commutation. It is shown in Figure 17.1.

![Bridge Converter Diagram](image)

**Figure 17.1 Bridge Converter**

### 17.3.1 Advantages of Bridge Converter

- Control of each phase is completely independent of the other phases.
- The voltage rating of all the switching devices and diodes is \(V_{dc}\), which is relatively low.
- The converter is able to freewheel during the chopping period at low speeds, which helps to reduce the switching frequency and thus the switching losses of the converter.
- The energy from the off-going phase is transferred back to the source, which results in useful utilization of the energy.

### 17.3.2 Disadvantages of Bridge Converter

- Many numbers of switches are required for each winding, which makes the converter expensive.

For low-voltage applications, the forward voltage drops in two devices may be significant compared to the available dc bus voltage.
17.4 Proposed Converter

The objective of this work is to minimize the number of switches for reducing the switching losses and utilize the suppressing voltage present in the off-going phase winding. In this proposed method, single pulse operation takes place by single switch.

![Proposed Converter Circuit for SRM](image)

**Figure 17.2 Proposed converter circuit for SRM**

It is shown in Figure 17.2 that the operation of switch depends upon the rotor position of the SRM. The components for the proposed converter method are $D_1$, $D_2$, $D_3$, $D_4$ diodes and dumped capacitors like $C_d$. The stored energy in off-going phase winding is dumped into $C_d$. Hence, the suppressing voltage present in the off-going phase winding is once again reused in the system.

17.5 Mode of Operation

There are four modules proposed for the new controller.

17.5.1 Module 1

In this step, the rotor position is aligned with stator winding. At this condition, control signal is used to turn on Transistor T. As a result of this winding, $M_1$ $M_2$ and
relay coil 2 are energized by Diode D5. At this time the auxiliary contact of relay 2 is opened, (Normally close to opened) when relay coil 1 is deenergized. When winding S1, S2 is de-energized due to OFF condition of relay coil 1.

17.5.2 Module 2

SRM rotor position is varied due to energized winding S1 and S2, i.e. unaligned position to aligned position. From the movement of rotor position the switch T goes to OFF position. The first phase (M1, M2) winding is de-energized. The stored energy in off-going phase winding (M1, M2) is transferred into C0. The Second phase winding (S1, S2) is energized with auxiliary conductor of relay coil 2. The suppressing voltage in dumped capacitor is used to increase the supply voltage. Hence, the speed of the switched reluctance motor is also maintained.

17.5.3 Module 3

SRM rotor position is once again rotated to energize winding M1, M2 i.e. and aligned position to unaligned position. From the movement of rotor position, the transistor T is once again going to ON position. The same procedure is (Same as Module 1) repeated. Once again the speed of the SRM is also maintained.

17.5.4 Module 4

SRM rotor position is once again rotated to second position. The same procedure is repeated (same as for Module 2). The Freewheeling Diodes FD1 and FD2 are connected in parallel with each winding at reverse direction. These diodes are helped to provide a smooth current to the load and also eliminate the negative voltage across the load.

17.6 Experimental Setup and Results

The experimental results are obtained and tabulated. The efficiency of SRM for various turn-on and turn-off are tested. The results are shown in Figure 17.3.
Table 17.1 Torque-speed analysis of SRM

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Voltage in volts</th>
<th>Current in amps</th>
<th>Input in Watts</th>
<th>Torque in Nm</th>
<th>Speed in rpm</th>
<th>Output in watts</th>
<th>Efficiency in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>230</td>
<td>0.3</td>
<td>69</td>
<td>0</td>
<td>14,900</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>02</td>
<td>230</td>
<td>0.9</td>
<td>207</td>
<td>0.058</td>
<td>14,800</td>
<td>89.87</td>
<td>43.4</td>
</tr>
<tr>
<td>03</td>
<td>228</td>
<td>1.4</td>
<td>319.2</td>
<td>0.1076</td>
<td>14,600</td>
<td>164.48</td>
<td>51.5</td>
</tr>
<tr>
<td>04</td>
<td>224</td>
<td>2.1</td>
<td>470.4</td>
<td>0.2648</td>
<td>14,000</td>
<td>388.14</td>
<td>82.5</td>
</tr>
<tr>
<td>05</td>
<td>218</td>
<td>3.5</td>
<td>763</td>
<td>0.5</td>
<td>13,400</td>
<td>701.49</td>
<td>91.9</td>
</tr>
<tr>
<td>06</td>
<td>207</td>
<td>4.2</td>
<td>869.4</td>
<td>0.58</td>
<td>12,800</td>
<td>777.29</td>
<td>89.4</td>
</tr>
<tr>
<td>07</td>
<td>206</td>
<td>5.4</td>
<td>1112.4</td>
<td>0.632</td>
<td>12,000</td>
<td>793.79</td>
<td>71.3</td>
</tr>
</tbody>
</table>

Figure 17.3 Speed–Torque characteristics of SRM

17.7 Conclusion

A new proposed converter with single transistor is implemented for SRM. This proposed work is validated with experimental work. The existing work has \((n+1)\) switches for SRM operation. But in this method only one switch is used for operating the rotor of SRM. This proposed system helps to reduce the losses. Hence, the efficiency of the SRM is also improved with low cost.