ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 2, April 2014

Analysis and Performance Prediction of 8/6 Pole Switched Reluctance Motor with New Converter Topology for Electric Vehicle

Saranraj U[1], B.Hemamalini[2]

PG Student, Dept. of EEE, Anna University-CEG, Chennai-25, Tamilnadu, India [1]

Visiting faculty, Dept. of EEE, Anna University-CEG, Chennai-25, Tamilnadu, India [2]

ABSTRACT: Switched reluctance motors (SRM) have many advantages in the field of electric vehicle. In this paper, a new and cost effective modified single-switch-per-phase converter for SRM drives is proposed. The most commonly used Converter for SRM is asymmetric bridge converter, but it has some disadvantages like poor utilization, size and cost. This paper presents the proposed converter, which performs better utilization than the asymmetric bridge converter. The requirements of switched reluctance motor drives on converters and the operation of the proposed converter are analyzed and discussed. The performance of proposed converter topology is verified through MATLAB simulation.

KEYWORDS: Switched reluctance motor, Modified single-switch-per-phase converter.

I.INTRODUCTION

The most commonly used motor for electrical vehicle is brushless dc (BLDC) motor. But the major drawback of the BLDC is the permanent magnet, because the cost of the permanent magnet is high. With the absence of the permanent magnet, Switched Reluctance motor is the best one to overcome the BLDC motor[1]-[6]. SRM is simple with wide speed range and it is suitable for the high speed application.

This paper is presented by the following ways, section II is about SRM drives apply for electrical vehicle. Section III deals with structure of Switched reluctance motor. Section IV discusses with converter topology for SRM drives, here both asymmetric and proposed converters are explained. Section V deals with developed simulation block diagram in Matlab/Simulink with proposed converter. Section VI analyse the results and conclusions.

II. SWITCHED RELUCTANCE MOTOR FOR ELECTRICAL VEHICLE

The electric vehicle is an electromechanical device, which convert electric energy into mechanical energy. Electric energy is provided by the battery and the mechanical energy is used for moving its wheels. The battery, mechanical structure and rider of the bike is known as the electrical device system. The electric bike with electrical device system is shown in the Fig.1. The main parts of the system are electric motor, power unit and controller.

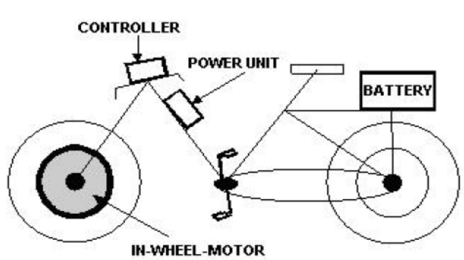


Fig. 1. Structure of the electric bike

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 2, April 2014

III. SWITCHED RELUCTANCE MOTOR

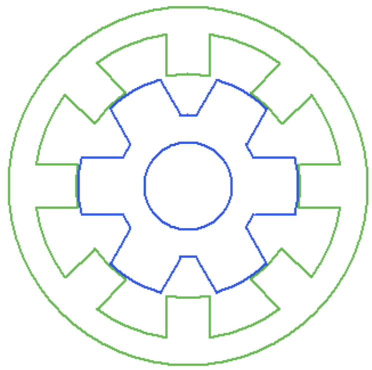


Fig. 2. Switched reluctance machine with four phase and 8/6 poles on both stator and rotor.

The SRM motor is the main component for the electric vehicle, the motor structure is simple and both the stator and rotor is salient pole. There is no winding in the rotor and the winding is presents only on the stator. The stator and rotor pole combination of the SRM is like 6/4, 8/6,… etc. Higher no of pole combination gives minimum torque ripple. It can be seen fig. 2.

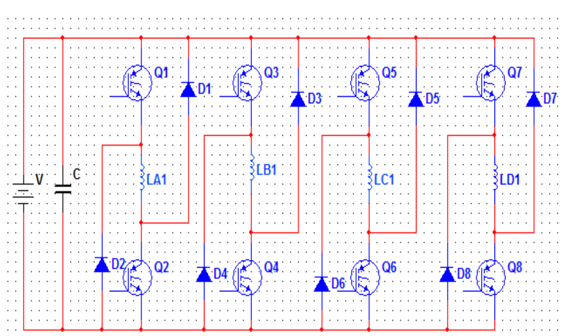
Torque is developed by the tendency of the magnetic circuit, the rotor moves from minimum reluctance position and independent of the direction of current flow. The torque calculated by the magnetic field energy. The expression of the torque is follows.

$$T_e(\theta, i)\; T_e(\theta, i)\frac{1}{2} i^2\ \frac{dL}{d\theta}$$

Where, θ is the rotor angle angle, i is the independent phase current.

IV. CONVERTER TOPOLOGY FOR SRM DRIVES

For switched reluctance motors the converter topology is not fixed one. The converters used for the SRM are split dc, bifilar and asymmetric bridge converter. Among this converter topology asymmetric bridge converter is most frequently used and good performed one. For the SRM drives, currents is unidirectional, so the induced torque is independent of the direction of current. So in this type of converter for four-phase SRM, the phase windings are connected in series, in this converter each phase branch used for two switching device and two freewheeling diodes. Fig. 3 shows the Circuit diagram of the 4-phase asymmetric converter for SRM drives. However, the poor utilization and high switching components count is the main disadvantages of this converter topology.



ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 2, April 2014

Fig. 3. Circuit diagram of the 4-phase asymmetric converter for SRM drives

A. Proposed converter

Single switch per phase converters are appealing due to their compactness of converter package and hence a possible reduction in their cost and size compared to other converters. Fig.4. Shows modified single-switch-per phase converter configuration. In this converter note that four switches, D1, D2, D3 and D4 are fast, freewheeling diodes and D5, D6, D7, and D8 are slow diodes.

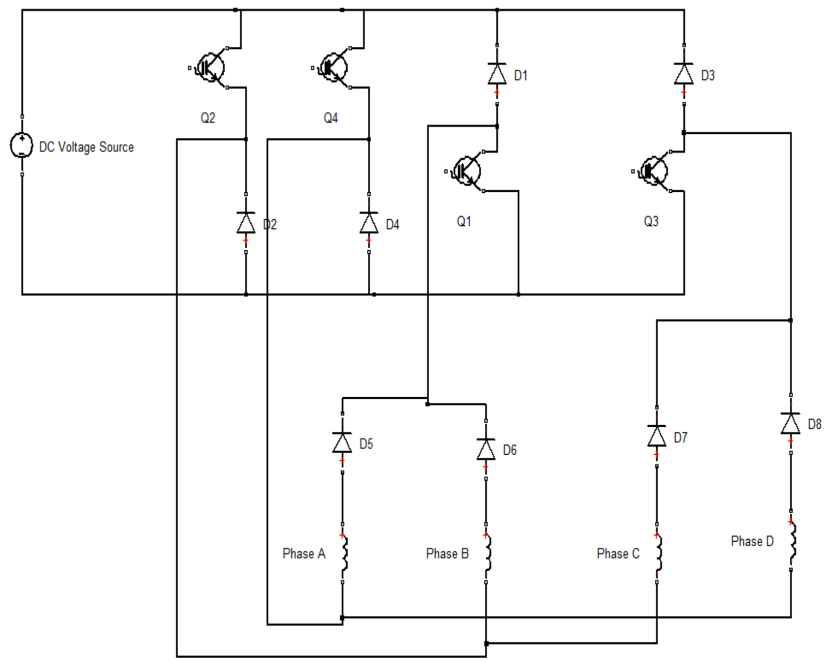


Fig. 4. Modified single-switch-per-phase converter

A. Circuit operation

Phase A - Q1, and Q4 switches are on.
Phase B - Q2 and Q1 switches are on.
Phase C - Q2 and Q3 switches are on.
Phase D - Q4 and Q3 switches are on.

As for the proposed converter, the operation of each phase includes three modes, charging, freewheeling and discharging, respectively. The mode of operation is analyzed in the following discussion.

Mode1: Charging

Referring to fig. 5. If the switching device Q4 and Q1 are turned on, Dc link voltage is then applied to phase A and the current rises rapidly in the phase winding..

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 2, April 2014

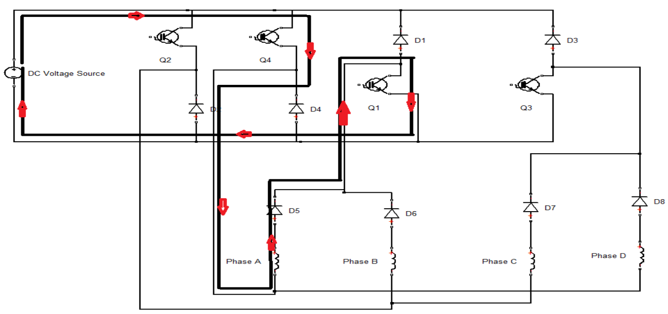


Fig.5.charging mode

Mode 2: Discharging

As shown in fig. 6. The switches Q1 and Q4 are turned off. The voltage across the winding becomes –Vdc, which indicates that the energy is being transferred from the winding to the dc link.

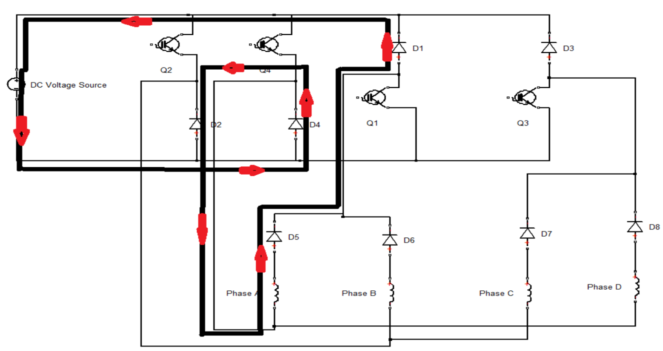


Fig. 6. Discharging mode

Mode 3: Freewheeling

Consider Q4 is on while Q1 is turned off for one switching cycle and vice versa for the next switching cycle to reduce the rms rating of the switches Q1 and Q4 and for their equality. This action shown in fig. 7. During this operation, two diodes and one switch are series with the winding.

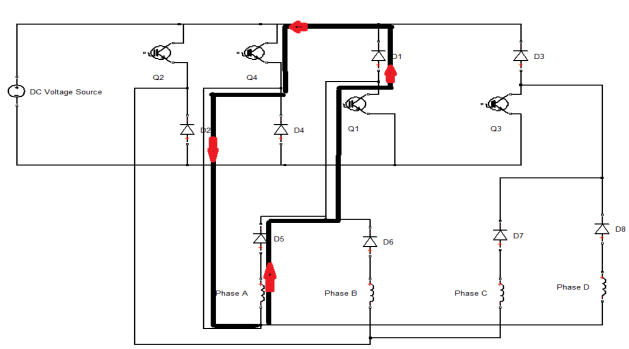


Fig. 7. Freewheeling

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 2, April 2014

With current in phase A winding, if phase B current is to be built up, then switches Q2 and Q1 have to be turned on. Turning on T1 will turn off the diode D1, which implies that the decaying phase A current will circulate though the A-phase winding, diode D5, switch Q1 and freewheeling diode D4. This reduces the voltage across the A-phase winding to zero, as shown in fig. 8 .

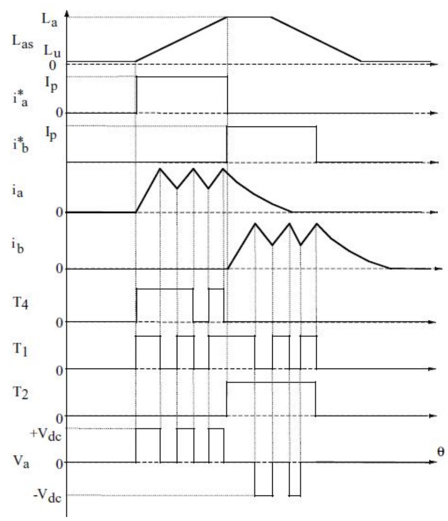


Fig. 8. for overlapping current conduction

V. MATLAB/SIMULINK Modelling and simulation results

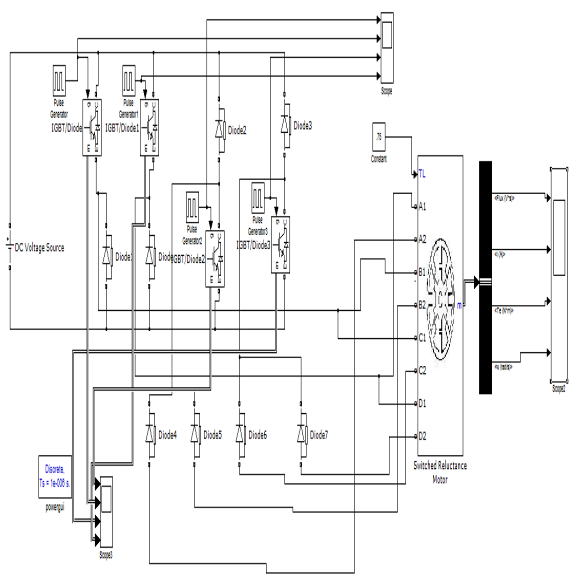


Fig. 9. Proposed Converter with SRM model

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 2, April 2014

The new converter topology consists of modified single-switch-per-phase and its function is implemented using MATLAB/SIMULINK. The new converter circuit for four phases is shown in the fig. 9.

Its two adjacent phases are connected in order to acquire high starting torque and low torque ripple of SRM. The typical gate signal and corresponding current profile are shown in Fig. 10 and fig. 11.

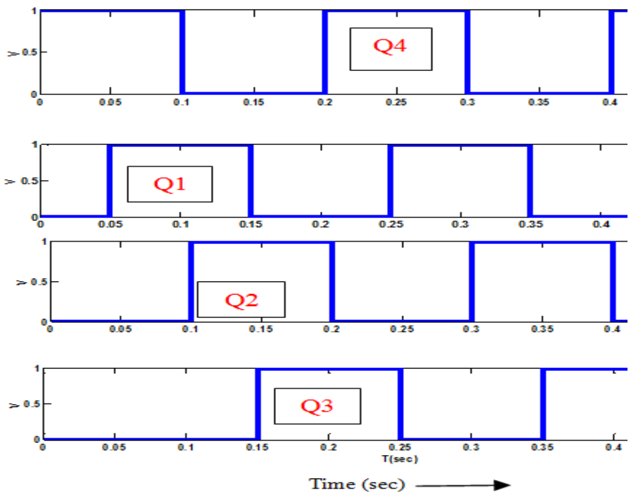


Fig.10. The typical gate signal

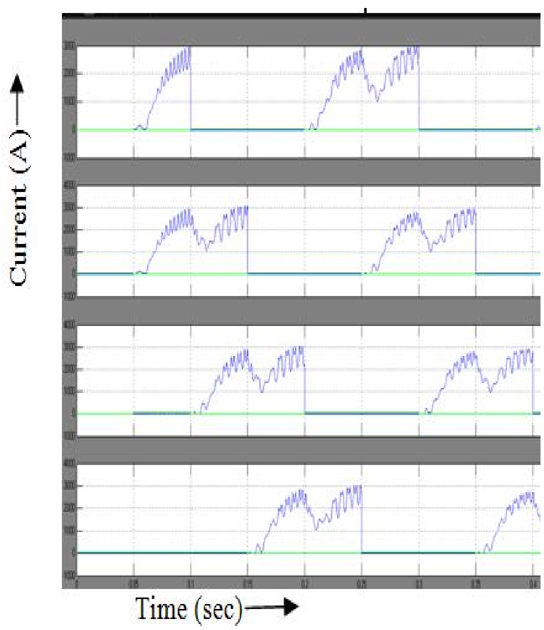


Fig. 11 Current profile

In order to verify the proposed converter for SRM drives, the simulation based on MATLAB/SIMULINK was carried out. The model of SRM drives is divided into several blocks such as position sensor block, converter block,

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 2, April 2014

speed controller block etc. The implementation of various control blocks are explained in detail. The block diagram of the SRM drives is shown fig. 12.

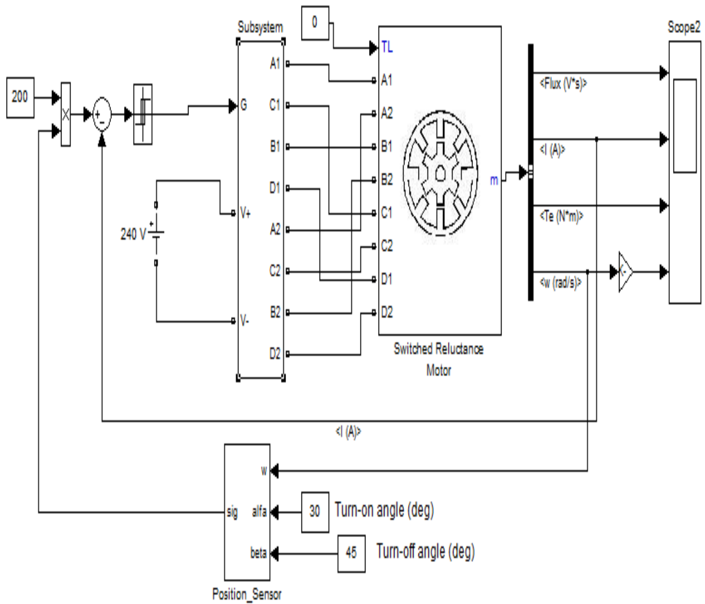


Fig. 12. Complete block diagram of SRM drives

Higher number of pole combination should gives the minimum torque ripple. The performance of the SRM drives depends on the Converter topology, control strategy and the design of SRM. Thus the dynamic simulation of whole of SRM drives has become very important. The various control blocks are explained in detail.

In order to determine the rotor position, the angle reference and the zero angle is considered. For four phase 8/6 SRM, each phase inductance has periodicity of 60 degree. Initial conditions such as 0, 15, 30, 45,…….. the position sensor blocks are shown in fig.13.

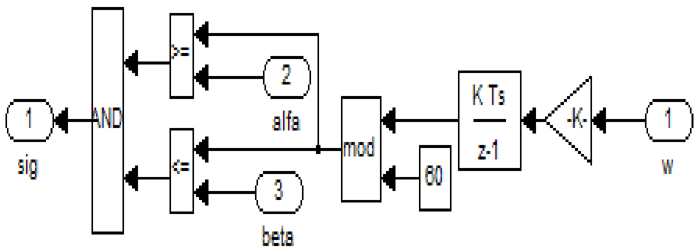


Fig. 13. Position sensor blocks

Simulation has been carried out and flux variation, current variation and torque variation in four phases has been shown in fig. 14.

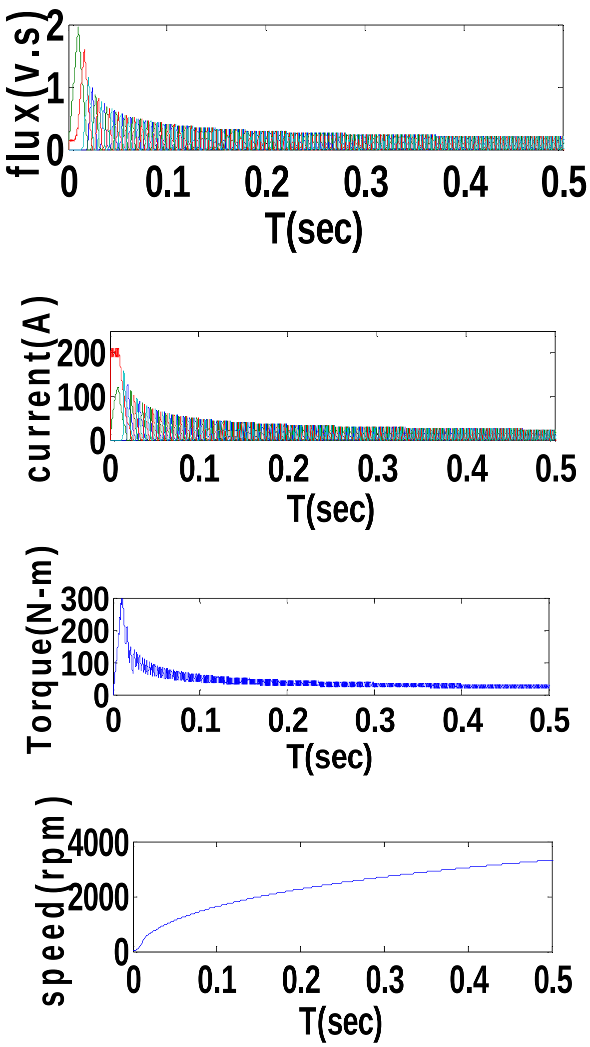


Fig. 14.. Performance characteristics of proposed converter for SRM drive

Even though this converter uses only four switches, each carries the current of two phases. Because of its higher current rating per switch, this configuration may not be better than other configurations. Moreover, this configuration requires an even number of machine phases, which restricts is applicability in practice

VI.CONCLUSION

In this paper, a new effective converter topology for switched reluctance motor drives has been proposed. Compare to the conventional asymmetric bridge converter, the proposed one modified single-switch-per-phase converter is more compact, higher utilization of switches and lower cost. By comparing the simulation results of conventional asymmetric bridge converter and proposed converter, both the converters produce the same current, flux, torque and speed values. The proposed new method arrangement allows the reduction in circuit components by nearly half. The method can be applied for all even numbers of phases of switched reluctance motor. Here speed control is carried out using PI controller which shows the suitability of variable speed drives, and is satisfied for the demand of the electric vehicle performances.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 2, April 2014

REFERENCES

[1] Miller, T.J.E.: "Brushless permanent-magnet reluctance motor drives".Oxford University Press, 1989.
[2] Pollock and B.W. Williams, "Power Converter Circuits for Switched Reluctance with the Minimum Number of Switches", IEE Proc., vol. 137, Pt. B, no. 6, pp. 373-384,1990.
[3] Slobodan Vukosavic, Victor R.Stefanovic, "SRM inverter topologies: A comparative evaluation," IEEE Transactions on industry applications, Vol.27, No.6, pp.1034-1047, 1991.
[4] Kalan BA, Lovatt HC, Prout G, "Voltage control of switched reluctance machines for hybrid electric vehicles," ESC Record IEEE Annual PESC,Vol 4, pp.1656-1660, 2002.
[5] Krishnan, R., "switched reluctance motor drives modeling, simulation, analysis and application" CRC Press 2003
[6] Wang Shuanghong, Zhan Qionghua, Ma Zhiyuan, et a1., "Implementation of a 50-kW four-phase switched reluctancemotor drive system for hybrid electric vehicle," IEEE Transactions on Magnetics, 41(1):pp.501-50,2005.