

P-SPICE SIMULATION OF SPLIT DC SUPPLY CONVERTER

Rajiv Kumar¹, Mohd. Ilyas², Neelam Rathi³

¹Research Scholar, AFSET Faridabad, India

²Assistant Professor, EEE Deptt., AFSET Faridabad, India

³Assistant Professor, EEE Deptt., HCTM. Kaithal, India

ABSTRACT

This paper describes a new split source type converter topology for switched reluctance motor drives. The general operating principle of split DC supply converter is done. The discussions of the advantages, disadvantages and applications are done. The phase current and Fourier analysis of the converter is done using P-spice simulation. The main advantage of the converter is fast suppression of the tail current in the phase-winding, hence, resulting in minimization of negative torque using doubly boosted voltage in the demagnetizing mode. The control characteristic of the converter is compared with those of the asymmetric bridge converter that is widely used.

KEYWORDS: *switched reluctance motor, split DC supply, convertor topologies, p-spice simulation.*

I. INTRODUCTION

The switched reluctance motor (SRM) represents one of the earliest electric machines which was introduced two centuries back in the history. It was not widely spread in industrial applications such as the induction and DC motors due to the fact that at the time when this machine was invented, there was no simultaneous progress in the field of power electronics and semiconductor switches which is necessary to drive this kind of electrical machines properly. The problems associated with the induction and DC machines together with the revolution of power electronics and semiconductors late in the sixties of the last century (1969), led to the re-invention of this motor and redirected the researchers to pay attention to its attractive features and advantages which help with overcoming a lot of problems associated with other kinds of electrical machines such as; brushes and commutators in DC machines, and slip rings in wound rotor induction machines, besides the speed limitation in both kinds. The simple design and robustness of the switched reluctance machine made it an attractive alternative for these kinds of electrical machines for many applications recently, specially that most of its disadvantages which are mentioned in the following chapter could be eliminated or minimized using the high speed and high power semiconductor switches.

In industry, there is a very wide variety of designs of the switched reluctance machines which are used as motors or generators, these designs vary in number of phases, number of poles for both stator and rotor, number of teeth per pole, the shape of poles and whether a permanent magnet is included or not.

These previous options together with the converter topology used to drive the machine lead to an enormous number of designs and types of switched reluctance machine systems, which means both the switched reluctance machine with its drive circuit to suit different applications with different requirements. It is to be noted that it is well known to those who are interested in this kind of electrical machines that the drive circuit and the machine is one integrated system, one part of such a system can't be separately designed without considering the other part.

II. SWITCHED RELUCTANCE MOTOR

Switched Reluctance Motor (SRM) drive systems have been paid renewed attention because of the several advantages. Switched reluctance motor (SRM) has become a competitive selection for many applications of electric machine drive systems recently due to its relative simple construction and its robustness. The advantages of those motors are high reliability, easy maintenance and good performance. The absence of permanent magnets and windings in rotor gives possibility to achieve very high speeds (over 10000 rpm) and turned SRM into perfect solution for operation in hard conditions like presence of vibrations or impacts. Such simple mechanical structure greatly reduces its price. Due to these features, SRM drives are used more and more into aerospace, automotive and home applications. The major drawbacks of the SRM are the complicated algorithm to control it due to the high degree of nonlinearity; also the SRM has always to be electronically commutated and the need of a shaft position sensor to detect the shaft position, the other limitations are strong torque ripple and acoustic noise effects [2].

A typical SRM drive system is made up of four basic components: power converter, control logic circuit, position sensor and the switched reluctance motor.

The essential features of the power switching circuit for each phase of reluctance motor are comprised of two parts

1. A controlled switch to connect the voltage source to the coil windings to build up the current.
2. An alternative path for the current to flow when the switch is turned off, since the trapped energy in the phase winding can be used in the other strokes. In addition, this protects the switch from the high current produced by the energy trapped in the phase winding

There are several topologies suggested to achieve the above function of the drive circuit. These topologies are well classified in based on the number of switches used to energize and commutate each phase. Like as the asymmetric bridge converter considering only one phase of the SRM, (n+1) Switches Converter Topology, resonance converter topology, Variable dc Link Voltage with Buck-Boost Converter Topology, C-dump converter, R-dump converter, split DC supply converter topology.

III. SPLIT DC SUPPLY CONVERTER

A split dc supply for each phase allows freewheeling and regeneration as shown in figure 1.

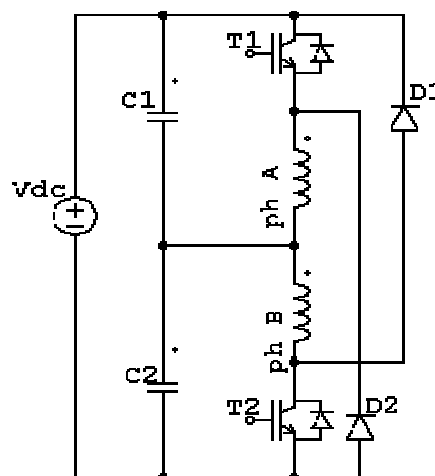


Figure 1. Circuit Diagram for Split DC Supply Converter

This topology preserves one switch per phase; its operation is as follows. Phase A is energized by turning on T1. The current circulates through T1, phase A, and capacitor C1. When T1 is turned off, the current will continue to flow through phase A, capacitor C2, and diode D2. In that process, C2 is being charged up and hence the stored energy in phase A is depleted quickly. Similar operation follows for phase B. A hysteresis current controller with a window of Δi is assumed. The phase

voltage is $V_{dc}/2$ when T1 is on, and when it is turned off with a current established in phase A, the phase voltage is $-V_{dc}/2$. The voltage across the transistor T1 during the on time is negligible, and it is V_{dc} when the current is turned off. That makes the switch voltage rating at least equal to the dc link voltage. As the stator current reference, goes to zero, the switch T1 is turned off regardless of the magnitude of i_a . When the winding current becomes zero, the voltage across T1 drops to $0.5 V_{dc}$ and so also does the voltage across D2. Note that this converter configuration has the disadvantage of derating the supply dc voltage, V_{dc} , by utilizing only half its value at any time. Moreover, care has to be exercised in balancing the charge of C1 and C2 by proper design measures [3, 5].

For balancing the charge across the dc link capacitors, the number of machine phases has to be even and not odd. In order to improve the cost-competitive edge of the SRM drive, this converter was chosen in earlier integral horse power (hp) product developments, but its use in fractional hp SRM drives supplied by a single phase 120-V ac supply is much more justifiable; the neutral of the ac supply is tied to the midpoint of the dc link and so capacitors can be rated to 200 V dc, thus minimizing the cost of the converter.

The switches and Diode used per phase in Split DC Supply converter are described here. The number of switches used per phase in Split DC Supply converter is one. The number of diodes used per phase in Split DC Supply converter is one.

The advantages of the Split DC supply converter are as follows

1. Compactness of converter package.
2. Lower cost due to minimum number of switches and diodes.
3. Capability of regeneration of stored energy.

The disadvantages of the Split DC supply converter are as follows

1. De-rating of the supply voltage.
2. Suitable only for motors with an even number of phases.

Application of Split DC supply Converter is in Fractional hp motors with even number of phases.

IV. P-SPICE SIMULATION OF SPLIT DC SUPPLY CONVERTER

Split dc supply converter using p spice is shown in figure 2. In this figure V_{g1} and V_{g2} are connected to Q1 and Q2 through resistances RB1 and RB2 for providing the proper biasing. Two dummy voltage source V_x and V_y are connected between node 6-7 and 8-9 to measure the current. The simulation results are shown through different waveform in figure 3, 4 & 5.

The values of the different components used in figure 2 are given below.

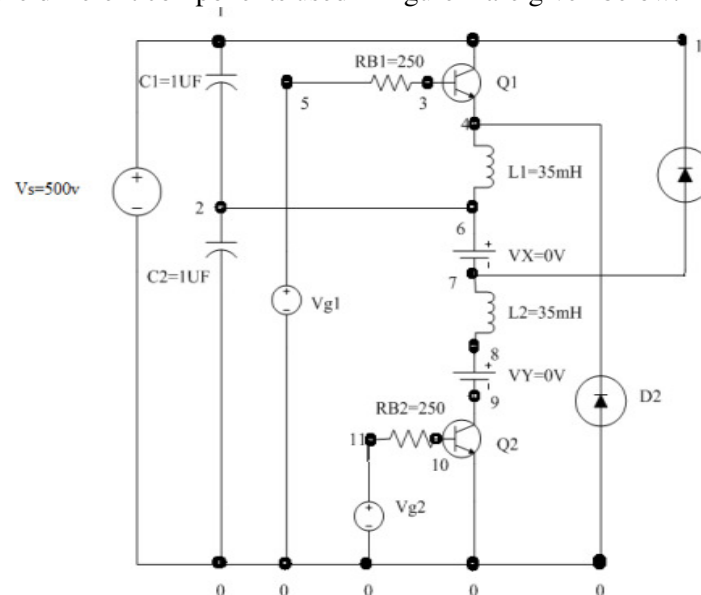


Figure 2. P- Spice simulation for the Split DC supply converter.

4.1 Circuit Element Values

Voltage supply- DC 500 Volt

4.2 Diodes Values

Saturation Current ($I_S=0.5 \mu A$)

Reverse breakdown voltage ($BV=5.20$ Volt)

Reverse breakdown Current ($IBV=0.5 \mu A$)

Parasitic Resistance ($R_S=1.0$ ohms)

4.3 Transistors Values

P-N saturation current ($I_S=6.734F$)

Ideal maximum forward beta ($BF=416.4$)

Base-Emitter leakage saturation current ($ISE=6.734F$ Amps)

Ideal maximum reverse beta ($BR=.7371$)

Base –emitter zero-bias P-N capacitance ($CJE =3.638P$ Farads)

Base-Collector P-N grading factor ($MJC=.3085$)

Base-Collector built –in potential ($VJC=.75$ Volts)

Base –collector zero-bias P-N capacitance ($CJC=4.493P$ Farads)

Base-Emitter P-N grading factor ($MJE=.2593$)

Base-Emitter built –in potential ($VJE=.75$ Volts)

Ideal reverse transit time ($TR=239.5N$ Seconds)

Ideal forward transit time ($TF=301.2P$ Seconds)

Phase Winding ($L1$) =35mH

Capacitance ($C1, C2$) =1.0Uf

V. SIMULATION RESULTS

5.1 Fourier Analysis

Temperature = 27.000 Deg C

Fourier Components Of Transient Response I (Vx)

Dc Component = -4.250385e-05

Table 1 Fourier analysis for the split dc supply converter

Harmonic No	Frequency (Hz)	Fourier Component	Normalized Component	Phase (Deg)	Normalized Phase(Deg)
1	1.200e+02	8.496e-05	1.000e+00	-9.259e+01	0.000e+00
2	2.400e+02	8.483e-05	9.984e-01	-9.518e+01	9.000e+01
3	3.600e+02	8.460e-05	9.957e-01	-9.777e+01	1.800e+02
4	4.800e+02	8.428e-05	9.920e-01	-1.004e+02	2.700e+02
5	6.000e+02	8.388e-05	9.872e-01	-1.029e+02	3.600e+02
6	7.200e+02	8.338e-05	9.814e-01	-1.055e+02	4.500e+02
7	8.400e+02	8.281e-05	9.746e-01	-1.081e+02	5.401e+02
8	9.600e+02	8.214e-05	9.668e-01	-1.106e+02	6.301e+02
9	1.080e+03	8.140e-05	9.580e-01	-1.132e+02	7.202e+02

Total Harmonic Distortion = 2.777149e+02 percent

So the Input Current Threshold =27.77%= 0.2777

5.2 Plot results for the split dc supply converter

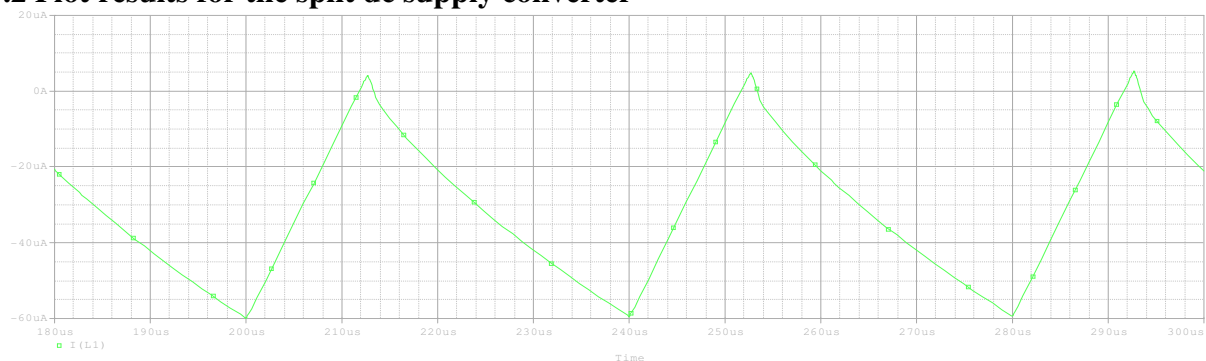


Figure 3. Current versus time plot results for the split dc supply converter

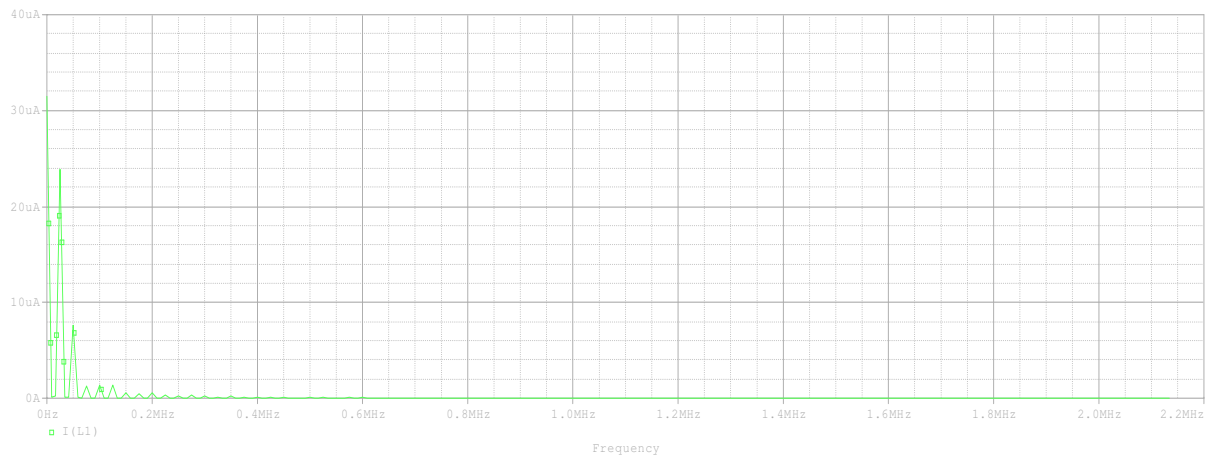


Figure 4. Plot shows fast Fourier analysis for the phase winding of Variable dc link converter

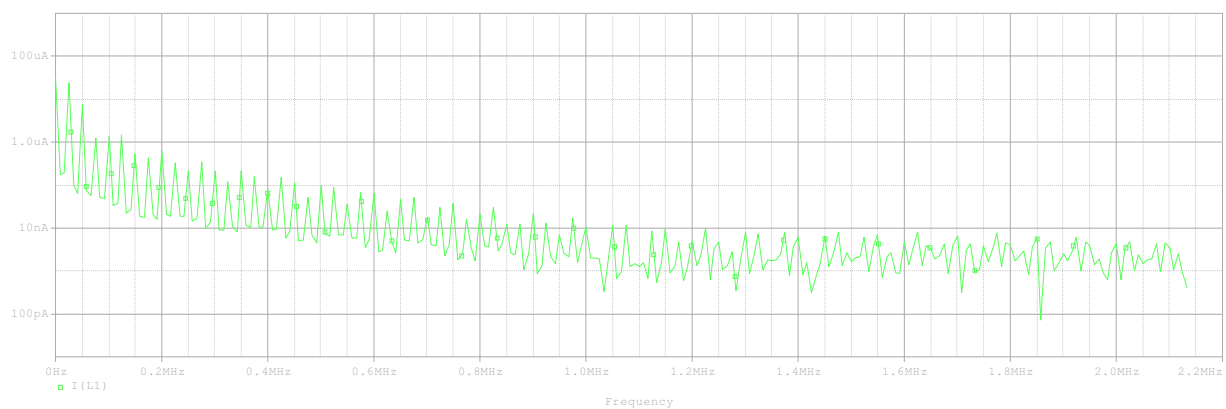


Figure 5. Plot shows the variation of the phase current with respect to frequency.

VI. CONCLUSION

This topology provides fast suppression of the tail current in the phase winding and hence resulting in minimization of negative torque using doubly boosted voltage in the demagnetizing mode. This topology has higher efficiency and more output power than the other counterpart in the heavy load conditions and in high speed operations. From this topology we can use more positive torque region and enable to get more power from it. It has advantage over asymmetric bridge converter in the viewpoint of efficiency and output power varying the load and dwell angle.

VII. FUTURE WORK

More analysis and research has to be conducted to find an empirical or mathematical relation between the switching frequency of the switched capacitance circuit and the various parameters of the resulting current profile, such as the rise and fall times, the peak value, and the average or RMS value. The switched capacitance circuit can be introduced to all converter topologies of the SRM drives such as the resonant converter topology, R-dump Converter topology.

REFERENCES

- [1] Yuen-Chung Kim, Yong-Ho Yoon, Byoung-Kuk Lee, Hack-Seong Kim and Chung-Yuen Won, "Control Algorithm for Four-Switch Converter of Three-Phase Switched Reluctance Motor". 37th IEEE power electronics specialists conference, pp. 1-5, 2006
- [2] Huijun Wang, Dong-Hee Lee, and Jin-Woo Ahn, "A Modified Multi- Level Converter For Low Cost High Speed SR Drive". IEEE Power Electronics Specialists Conference, pp. 1790 – 1795, 2007.

- [3] Tao Sun, Ji-Young Lee, and Jung- Pyo Hong, "Investigation on the Characteristics of a Novel Segmental Switched Reluctance Motor Driven by Asymmetric Converter and Full-Bridge Inverter". IEEE International Electric Machines & Drives Conference, Vol.1, pp. 815 – 820, 2007 .
- [4] Zhang Zhu, and N.C. Cheung, "Investigation and Comparison on different switching Circuit Topologies for Linear Switched Reluctance Motors". Australasian Universities Power Engineering Conference, pp .1 – 5, 2008.
- [5] M.Asgar, E. Afjei and A.Siadatan, "A New Class of Resonant Discharge Drive Topology For Switched Reluctance Motor" .13th European Conference on Power Electronics and Applications, pp. 1 – 9, 2009.
- [6] M.Asgar, E. Afjei , A.Siadatan and Ali Zakerolhosseini, "A New Modified Asymmetric Bridge Drive Circuit Switched Reluctance Motor". European Conference on Circuit Theory and Design, pp 539 – 542, 2009.
- [7] V.L.Do and Minh Cao Ta, "Modelling, Simulation and Control of Reluctance Motor Drives for High Speed Operation ". IEEE Energy Conversion Congress and Exposition, pp. 1 – 6, 2009.
- [8] Ehab Elwakil " A New Converter Topology for High-Speed-Starting-Torque Three-Phase Switched Reluctance Motor Drive System". Department of Electronics and Computer Engineering School of Engineering and Design, PhD Thesis, Brunel University, London, UK Publication, January, 2009 .
- [9] Mohan, Undeland and Riobbbins, Power Electronics: Converters, Applications and design, Wiley India Edition, 2009.
- [10] Muhammad H. Rashid, Power Electronics: Circuits, Devices and Applications, Pearson Prentice Hall, 2009.
- [11] Muhammad H. Rashid, Spice for power electronic circuits, Pearson Prentice Hall, 2009.
- [12] 'Switched Reluctance Generator- " Modelling, Design, Simulation, Analysis and Control-A Comprehensive Review." 2010 International Journal of Computer Applications (0975-8887) Vol. 1 – No.2, pp. 10-16, 2010.

Authors Biography

Rajiv Kumar was born in Karnal (Haryana), India. He obtained his B.Tech in Electrical and Electronics Engineering in 2008 from Kurukshetra University, Kurukshetra. He is pursuing Mtech in power system from Maharishi Dayanand University, Rohtak (Haryana), India. His interested subjects areas are Network analysis and synthesis, Signal and System, power system & microprocsser



Mohd. Ilyas was born on 2nd April 1976 in Delhi, India. He has obtained his M.Tech. in electrical Power system & management from Jamia Millia Islamia new Delhi, India. He is pursuing his PhD. from Maharishi Dayanand University, Rohtak (Haryana), India. He is currently working as a assist Prof. in Al-falah School of Engg. & Technology, Dhauj, Faridabad, Haryana, India.

Neelam Rathi was born in Kaithal (Haryana) ,India. She obtained her B.Tech in Electrical and Electronics Engineering in 2008 from Kurukshetra University, Kurukshetra. She is M. Tech. in power system from Maharishi Dayanand University, Rohtak (Haryana), India. Her interested subject areas are Transmission and distribution , Power System Protection.

