International Journal of Electrical and Computer Engineering (IJECE)
Vol. 7, No. 2, April 2017, pp. 604~609
ISSN: 2088-8708, DOI: 10.11591/ijece.v7i2.pp604-609

Implementation of PWM Control of DC Split Converter Fed Switched Reluctance Motor Drive

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Article Info

Article history:

Received Jul 27, 2016
Revised Mar 4, 2017
Accepted Mar 20, 2017

Keyword:

DC split converter
PWM control
Switched reluctance motor

ABSTRACT

The phase winding of Switched Reluctance Motor is excited during the positive increasing region of the phase inductance to get the motoring action. This is performed through a converter. This paper presents the speed control of DC Split converter fed 4 phase 8/6 Switched Reluctance Motor drive using PWM controller. The speed of the motor is controlled by varying the duty ratio of the PWM controller. Simulation results are verified with hardware implementation of the controller. The Hall sensors provided in the motor provide signals corresponding to the position of the rotor. The pulses to the IGBT switches are generated by TMS320F2407A DSP controller. The waveforms of the PWM signals and Hall sensor signals are captured by means of Digital Storage Oscilloscope. Motor phase currents, phase voltages and associated numerical values are captured and analyzed by Power Analyzer. Steady state analysis of the drive has been carried out.

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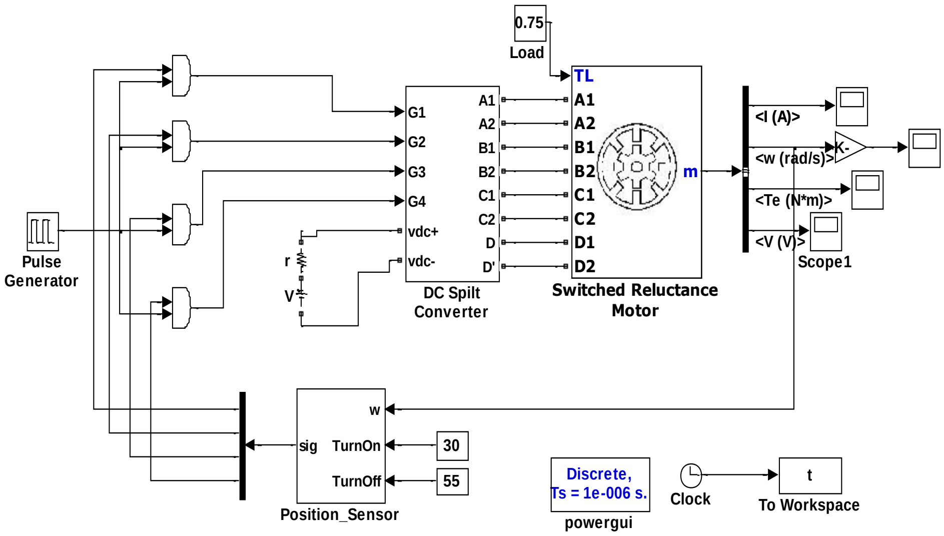
1. INTRODUCTION

Switched Reluctance Motor (SRM) is considered as an alternative to conventional motors because of its advantages like high speed, robustness, high reliability, low cost and high rotor temperature handling capability. The phase winding is excited during the positive increasing region of the phase inductance to get the motoring action through a converter [1-4]. The conventional asymmetrical converter has the advantages of both hard chopping and soft chopping [1], [2]. The disadvantage of the asymmetrical converter is that it requires two switches in a phase. Two switches per phase can be eliminated by DC split converter [5]. The control strategies of SRM are mainly the Hysteresis Current Control, PWM Control and the Single Pulse Voltage Control. Hysteresis Current Control and PWM Control are used for low and medium speed operations. The Single Pulse Voltage Control controls the speed and torque by regulating the turn-on and turn-off angles. This is suitable for high speed operation, but not to low speed operation because of high current peaks [6-8]. The speed control of asymmetrical converter fed 4 phase SRM using DSP is investigated experimentally in [9].

This paper presents the speed control of DC Split converter fed 4 phase 8/6 Switched Reluctance Motor drive using PWM controller. The speed is regulated through a PWM controller [10], [11] in which, the average phase voltage during the conduction period is controlled by varying the duty ratio of the switches. The simulation results are verified and validated through the experimental setup.

2. SIMULATION OF PWM CONTROLLED DC SPLIT CONVERTER FED SRM DRIVE

The performance of the PWM controlled DC Split converter fed drive is analyzed through simulation. The specifications of the motor are given in Appendix A. In this simulation, the MATLAB inbuilt SRM model is used. The simulation is performed at 2000 rpm & 4000 rpm for three different load torques i.e at no load, 0.5 Nm and 0.75 Nm. Figure 1(a) shows the simulation diagram of drive with PWM control. Figure 1(b) shows the DC Split converter. The diagram consists SRM model, Position sensor, DC Split converter, PWM controller and Pulse generator. The switching frequency of the IGBTs is 15 kHz for all loads. The simulation is executed for 4000 rpm and 2000 rpm at three different load torques.



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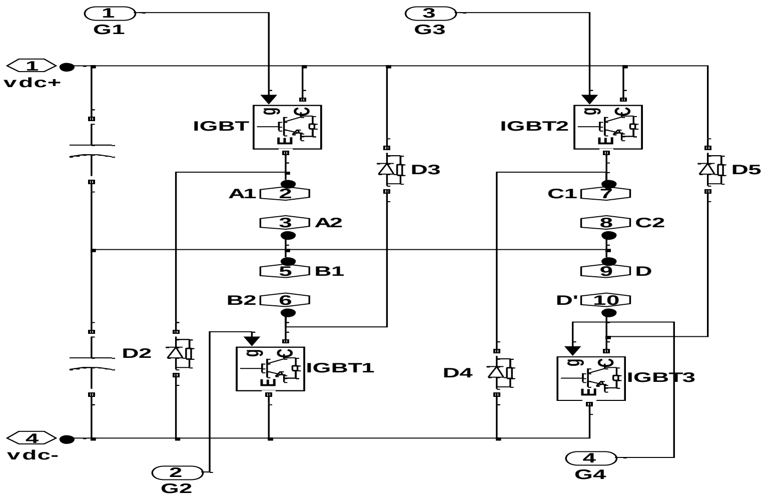

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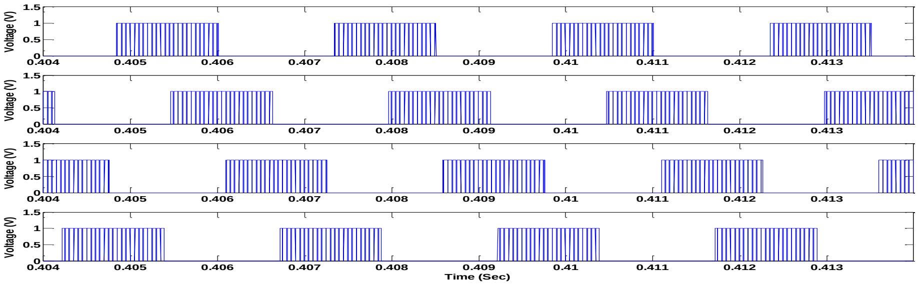
Figure 1. (a) Simulation diagram of SRM drive with PWM control, (b) DC Split converter

The simulation waveforms of the PWM controlled DC Split converter fed drive at a speed of 4000 rpm and for a load torque of 0.75 Nm are shown in Figure 2. PWM gate signals applied to IGBTs S_1 to S_4 are shown in Figure 2(a). The sensor signals are shown in Figure 2(b). The motor currents in four phases is shown in Figure 2(c). The peak current and average current in each phase are 22.53 A and 7.50 A respectively. Motor voltages in four phases is shown in Figure 2(d). Current and voltage of one phase is shown in Figure 2(e).



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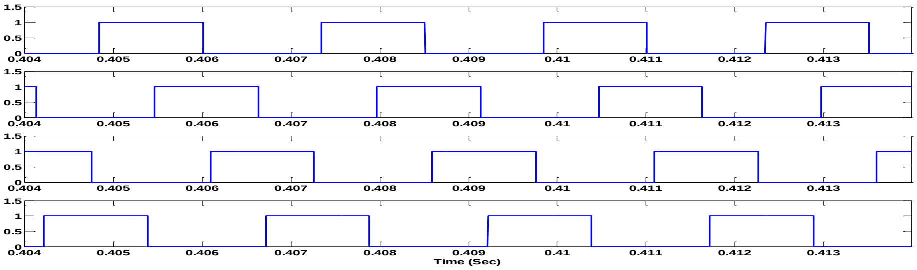

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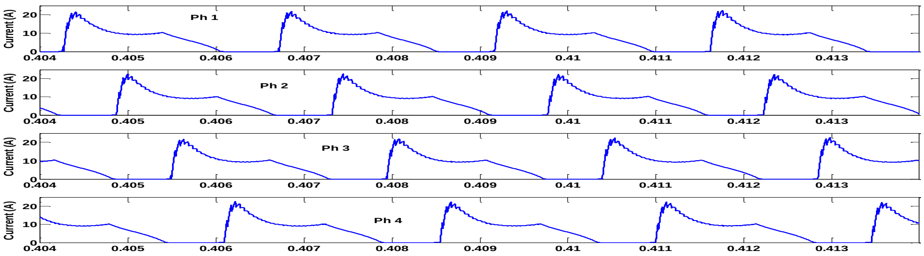

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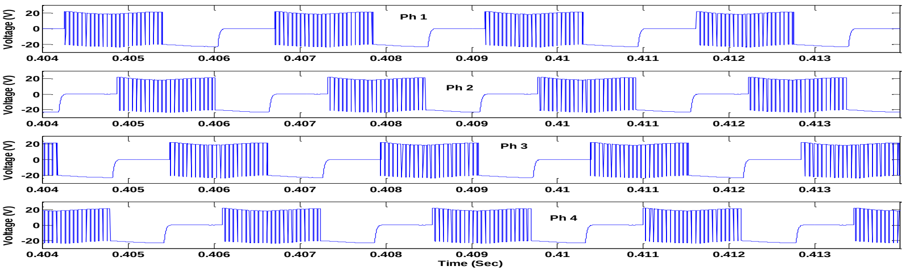

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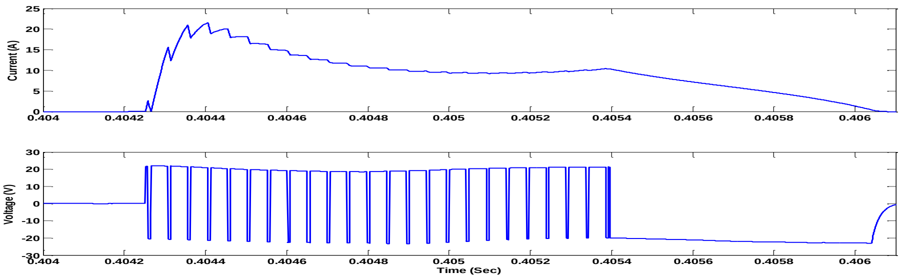

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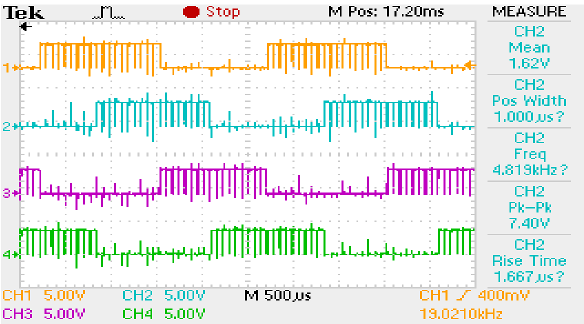
Figure 2. (a) PWM gate signals to IGBTs (S_1 to S_4) at N = 4000 rpm, T_L= 0.75 Nm, (b) Sensor signals at N = 4000 rpm, T_L= 0.75 Nm, (c) Current waveforms of four phases at N = 4000 rpm, T_L= 0.75 Nm, (d) Voltage waveforms of four phases at N = 4000 rpm, T_L= 0.75 Nm, (e) Current and voltage waveforms of one phase at N = 4000 rpm, T_L= 0.75 Nm

3. HARDWARE IMPLEMENTATION OF PWM CONTROLLED SRM DRIVE

In order to verify the simulation results, experiments have been performed at 4000 rpm and 2000 rpm at same load torques as executed in simulation. The specifications of the SRM are given in Appendix A. The PWM signals applied to IGBTs and Hall sensor output signals are captured by Digital Storage Oscilloscope. The waveforms of the phase currents, phase voltages and various associated numerical values are measured, captured and analyzed by Power Analyzer. The practical waveforms are shown for 4000 rpm at three different load torques. The load is applied by means of Eddy current loading.

The practical waveforms of the PWM controlled DC Split converter fed drive at 4000 rpm & T_L = 0.75 Nm are shown in Figure 3. PWM gate signals applied to IGBTs S_1 to S_4 are shown in Figure 3(a). Switching frequency is 14.47 kHz. The sensor signals are shown in Figure 3(b). The motor currents in four phases is shown in Figure 3(c). The peak current and average current in each phase are 23.00 A and 8.45 A respectively. The motor voltages in four phases is shown in Figure 3(d). The expanded view of current and voltage of one phase is shown in Figure 3(e).



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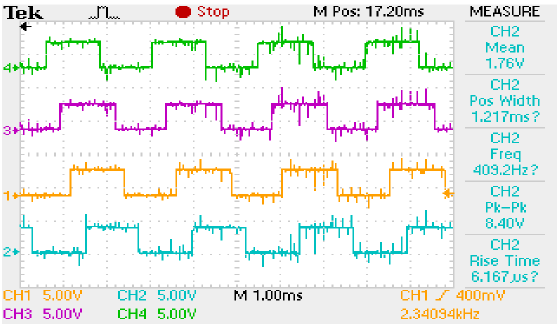

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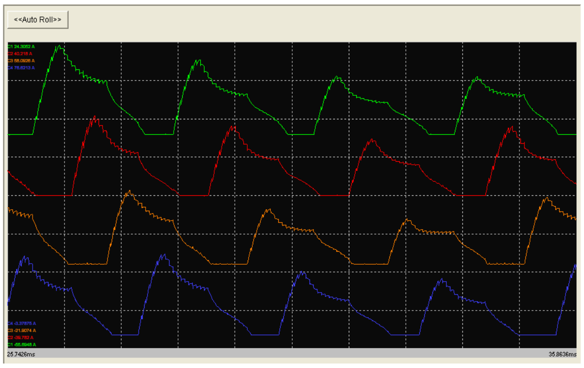

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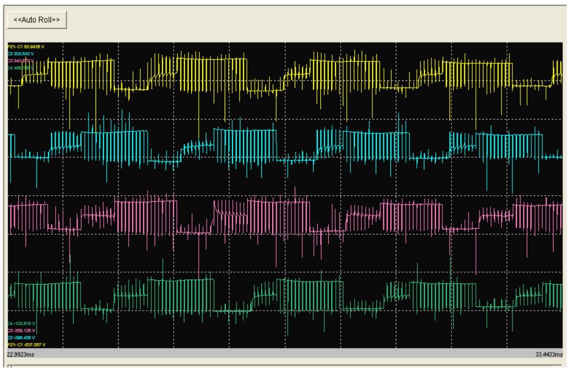

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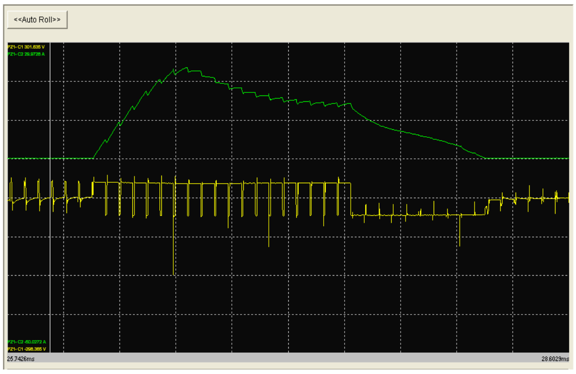

(e)

Figure 3. (a) PWM gate signals to IGBTs (S_1 to S_4) at N = 4000 rpm & T_L= 0.75 Nm, (b) Hall Sensor signals at N = 4000 rpm & T_L= 0.75 Nm, (c) Currents of four phases at N = 4000 rpm & T_L= 0.75 Nm, (d) Voltages of four phases at N = 4000 rpm & T_L= 0.75 Nm, (e) Current and voltage of one phase at N = 4000 rpm & T_L= 0.75 Nm

The peak current, average current, peak voltage and average voltage obtained through simulation and experiment for 2000 rpm and 4000 rpm at three different load torques is tabulated in Table 1.

Table 1. Comparison of Simulation and Experimental results using DC Split converter fed SRM drive

			Simulation			
Load (Nm)	Speed (rpm)	%Duty ratio	Peak Current (A)	Average Current (A)	Peak Voltage (V)	Average Voltage (V)
0.75	4003	88.76	22.53	7.50	24	20.51
0.50	4002	81.34	17.02	5.89	24	19.95
No load	4003	56.96	4.86	1.09	24	9.80
0.75	2002	70.88	20.08	7.11	24	19.79
0.50	2002	63.98	16.21	5.63	24	19.20
No load	2003	53.12	4.01	0.82	24	9.80
			Experiment			
Load (Nm)	Speed (rpm)	%Duty ratio	Peak Current (A)	Average Current (A)	Peak Voltage (V)	Average Voltage (V)
0.75	4005	87.13	23.00	8.45	24	20.40
0.50	4005	80.76	16.50	6.11	24	19.92
No load	4006	56.12	5.02	1.24	24	9.70
0.75	2003	69.13	20.63	7.22	24	19.68
0.50	2003	63.01	16.30	5.80	24	19.10
No load	2004	52.12	4.10	0.91	24	9.70

From the above table, it is clear that the simulation results are in close agreement with experimental results at different speeds and load torques.

4. CONCLUSION

The performance of PWM controlled DC Split converter fed SRM drive is analyzed through simulation and by hardware experimentation. The gating signals of the required duty ratios are fed to the IGBTs through DSP. The switching frequency is maintained at 15 kHz. The switching frequency obtained in experiment is 14.47 kHz. The controller is tested at 2000 rpm and 4000 rpm for three different load torques. It is observed that the peak current, average current, peak voltage and average voltage obtained through simulation and experiments are nearly same. The duty ratios are almost same in simulation and experiment. Thus, the simulation results are in correlation with the experimental results.

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Appendix-A

Specifications of SRM for Simulation and Hardware Implementation

Power	:	1 HP
Voltage	:	48 V DC
Current	:	10 A
Speed	:	6000 rpm
Aligned Inductance	:	4.85 mH
Unaligned Inductance	:	0.345 mH
Resistance	:	0.3 Ω