단상 SRM 구동을 위한 Passive Converter 동작특성

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Driving Characteristic of Passive Converter for Single Phase SRM

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Abstract - At the high speed operation, the high demagnetization voltage can reduce the negative torque, so the output power and efficiency can be improved. In this paper, a novel power converter for single phase SRM with high demagnetization voltage is proposed. A simple passive capacitor circuit is added in the front-end, which consists of three diodes and one capacitor. Based on this passive network, the two capacitors can be connected in series and parallel, so the phase winding of SRM obtains general dc-link voltage in excitation mode and the double dc-link voltage in demagnetization mode. The operation modes of the proposed converter are analyzed in detail. Some computer simulation results is done to verify the performance of proposed converter.

1. INTRODUCTION

Switched Reluctance Motors(SRM) is investigated for wide industrial applications due to the mechanical strength and cost advantages[1]. SRM has high power-to-weight, torque- to-weight ratios, a wide speed range, robust structure and intense temperature variations. So SRM is suitable for high speed application.

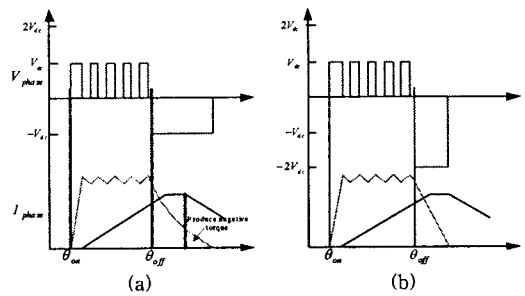
However, the excitation and demagnetization voltage is limited by the fixed dc-link voltage in conventional SR drive. So the fast excitation and demagnetization is very difficult to achieve in the high speed region. In order to improve the output torque and efficiency, the high demagnetization voltage is required. The high demagnetization voltage can obtain faster reduction of tail current after aligned position, which leads to smaller the negative torque and longer conduction angle.

Boost and buck-boost converter are used to boost dc-link voltage. The dc-link voltage can be boosted, but these types of converters require additional inductance, diode, capacitor and power switch. The high cost and complicated boost voltage control method confine their applications. The two types passive boost dc-link converter are proposed[3-4]. One is series type passive boost converter, and another is parallel type. Although this two types converter are simple, and the demagnetization current charges an additional capacitor and supplies effectual boost voltage higher than the input dc-link voltage. But additional boost voltage has relationship with recovered energy, so it can not be controlled in wide vary speed application.

In this paper, a novel power converter for single phase SRM with high demagnetization voltage is proposed. A passive capacitor circuit is added in the front-end, which consists of three diodes and one capacitor. Based on this passive network, the two capacitors can be connected in series or parallel, so the phase winding of SRM obtains general dc-link voltage in excitation mode and the double dc-link voltage in demagnetization mode. Due to high demagnetization voltage, the efficiency and output power can be improved. The operation modes of the proposed converter are analyzed in detail. Some computer simulation results have been done to verify the performance of proposed converter.

2. PROPOSED POWER CONVERTER FOR SINGLE PHASE SRM

The conventional SR drive applies a diode bridge rectifier and a large capacitor on the front-end. This capacitor keeps a steady dc link voltage as a filter. Another function of that is stored magnetic field energy from turn off of SR motor.



(a) (b)

Fig. 1 Conventional and proposed SR drive operation
(a) Conventional SR drive (b) Proposed SR drive

It is easy to known that amplitudes of excitation and demagnetization voltage are close to terminal voltage of filter capacitor. The fixed dc-link voltage confines the performance of SR drive in high speed operation.

However, the high demagnetization voltage can improve high speed performance of SR drive. From Fig. 1, the advantage of high demagnetization is shown clearly. Firstly, the dwell angle can be

extended. Secondly, it can reduce the negative torque, so the average torque and efficiency can be increased.

The proposed passive SR drive is shown in Fig. 2. Compare with conventional SR drive, a passive capacitor circuit is added in the front-end, which consists of three diodes and one capacitor. Based on this passive network, when asymmetric converter works in excitation mode, the two capacitors connected in parallel. When in demagnetization mode, the two capacitors connected in series. So the phase winding of SRM obtains general dc-link voltage in excitation mode and the double dc-link voltage in demagnetization mode.

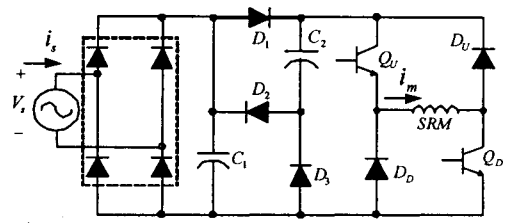


Fig. 2 Proposed passive SR drive

To analyze the operation of the proposed converter in single phase SR operation, the converter is divided into five modes from different states of switches, i.e. boost capacitor excitation mode, dc-link capacitor excitation mode, two capacitors excitation mode, freewheeling mode and fast demagnetization mode, respectively. There are shown in Fig. 3.

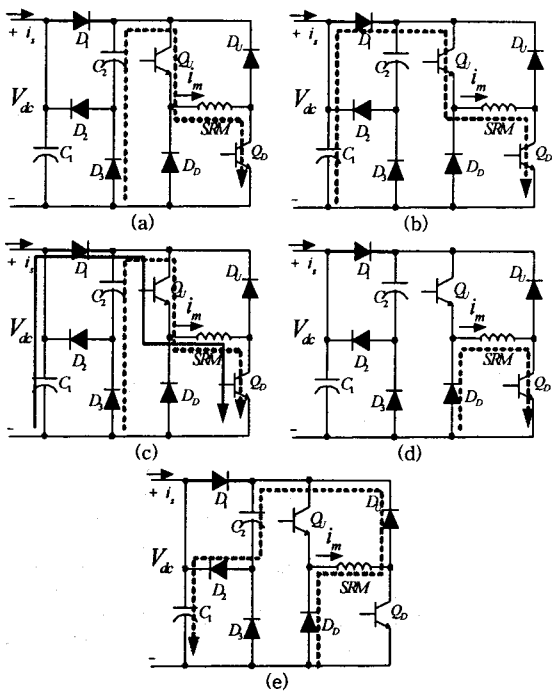


Fig. 3 Operation modes of proposed converter
(a) Boost capacitor excitation mode
(b) Dc-link capacitor excitation mode
(c) Two capacitors excitation mode
(d) Freewheeling mode
(e) Fast demagnetization mode

Compare with asymmetric converter, the excitation mode has been separated to three modes from different boost capacitor voltage. The voltage states, switch states and phase voltage are shown in Tab. 1.

Tab. 1 The operation modes of proposed converter

Mode	Voltage States	Switch States	Phase Voltage
Excitation-1	$V_{C_1} > V_{C_2}$	(Q_U, Q_d, D_3) on (D_1, D_2 ,D_U, D_D) off	$V_{C2} - V_D - 2V_Q$
Excitation-2	$V_{C_1} < V_{C_2}$	(Q_U, Q_d, D_1) on (D_2, D_3,D_U, D_D) off	$V_{C1} - V_D - 2V_Q$
Excitation-3	$V_{C_1} = V_{C_2}$	(Q_U, Q_d, D_1, D_3) on (D_2, D_U, D_D) off	$V_{C2} - V_D - 2V_Q$
Freewheeling		(Q_d, D_D) on (Q_U,D_1,D_2,D_3,D_U) off	$-(V_D + V_Q)$
demagnetization		(D_U, D_D, D_2) on (Q_U, Q_d,D_2, D_3) off	$-(V_{C_1} + V_{C_2} + 3V_D)$

3. SIMULATION OF PROPOSED CONVERTER

In order to verify the performance of proposed converter, the proposed converter has been simulated using Matlab/Simulink. The contrastive simulation results of conventional and proposed converter have been shown in Fig.4 and Fig. 5.

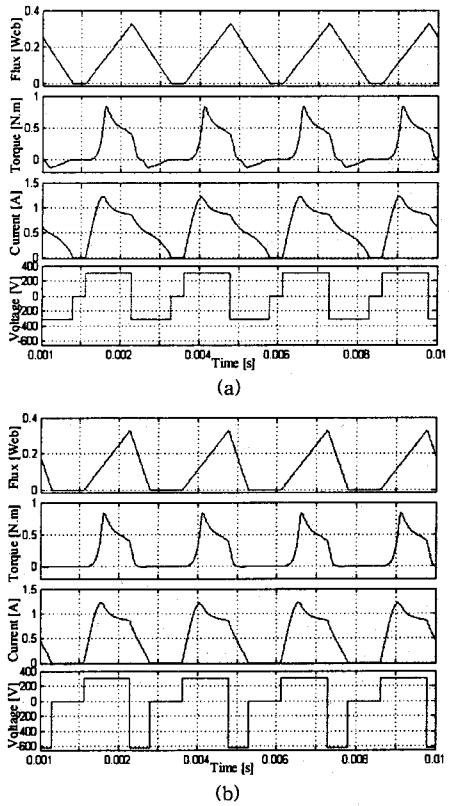
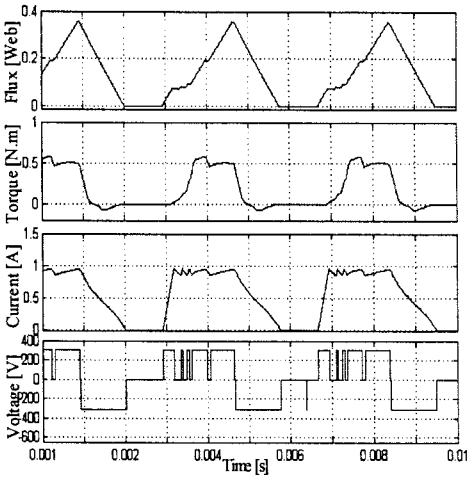
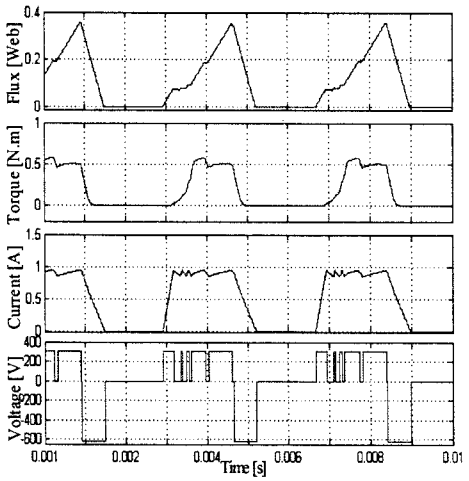


Fig. 4 Two converters operate at high speed region
(a) Conventional converter (b) Proposed converter



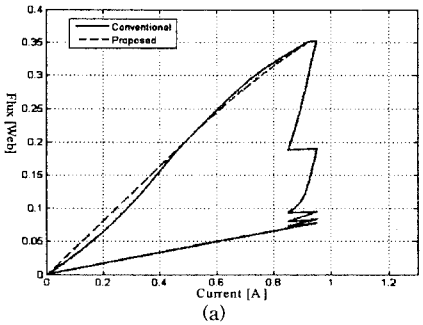
(a)



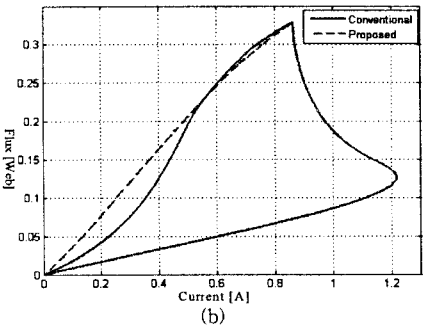
(b)

Fig. 5 Two converters operate at middle speed region
(a) Conventional converter (b) Proposed converter

The double dc-link demagnetization voltage is shown in simulation result clearly. The high demagnetization voltage of proposed converter obtains a short tail current and reduces the negative torque after the aligned position. Based on the passive capacitor circuit, the demagnetization voltage can be stable at vary speed application.



(a)



(b)

Fig. 6 Flux verse current trajectory
(a) middle speed region (b) high speed region

The increased output power can be seen from the increased area enclosed by the flux verse current trajectory shown in Fig. 6. In the high speed operation, the improvement of output power is more clearly. So the proposed converter is more suitable work in high speed region.

4. CONCLUSION

In this paper, a novel power converter for single phase SRM with high demagnetization voltage is proposed. A passive capacitor circuit is added in the front-end. The some passive components are required, and the voltage rate of power switch need to increased. That will increase some cost of converter. However, based on this passive network, the two capacitors can be connected in series and parallel, the double dc-link voltage in demagnetization mode can be obtained. Due to high demagnetization voltage, the efficiency and output power can be improved. Some computer simulation results have been done to verify the performance of proposed converter.

Acknowledgment

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[REFERENCES]

[1] R. Krishnan, "Switched Reluctance Motor Drives: Modeling, Simulation, Analysis, Design, and Applications", CRC Press, 2001

[2] J. W. Ahn, "Switched Reluctance Motor", Osung Media, 2004

[3] Dahmane, A.; Meebody, F.; Sargos, F.-M.; "A novel boost capacitor circuit to enhance the performance of the switched reluctance motor", Power Electronics Specialists Conference, 2001. 17-21 Pp:844 - 849 vol.2, June 2001

[4] Chan, S.; Bolton, H.R.; "Performance enhancement of single-phase switched-reluctance motor by DC link voltage boosting", Electric Power Applications, IEE Proceedings B Vol 140,Issue 5, Pp:316 - 322, Sept. 1993

[5] Do-Hyun Jang; "The converter topology with half bridge inverter for switched reluctance motor drives", ISIE 2001. IEEE International Symposium on, 12-16 Pp:1387 - 1392 vol.2, June 2001