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Engineering

TORQUE RIPPLE REDUCTION IN PMSM DRIVE SYSTEM USING M-SEPIC CONVERTER AND THREE LEVEL NPC INVERTER

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ABSTRACT Permanent Magnet Synchronous Motor (PMSM) drives are widely used in high performance applications where torque smoothness is of greater importance. Cogging torque, which causes torque ripples and the non- sinusoidal back emf is an well known issue in PMSM drives. High commutation torque ripple is an important origin of vibration, speed ripple and prevents the use of the PMSM drive system in high-performance and high-precision applications. A new power converter topology consists of modified SEPIC and a MOSFET based 3 level Diode Clamped Multi Level Inverter is used to reduce the torque ripples in a PMSM drives system. For efficient suppression of torque pulsation, the dc-bus voltage selector circuit is used to apply the regulated dc-bus voltage from the Modified SEPIC converter during the commutation time interval.

KEYWORDS : Torque Ripple Reduction;PMSM drive system;Voltage Control Strategy

1.INTRODUCTION

Recent advancements in the permanent magnet technology gained increasing importance for the permanent magnet machines. A lot of research has been going on in PMSM drives due to its compactness, high power density, ease of maintenance and simplicity. Some of the many real time applications of PMSM drives are Robotics, Electric Vehicles, Manufacturing and Machining technologies and many more industrial applications.

The main disadvantage of PMSM drive system is the generated torque during the commutation interval which is badly effect the higher performance applications. Torque ripple will leads to speed oscillations which effect the servo performance of PMSM.Thus the key issue of control problem in PMSM focuses on torque ripple suppression. Since the torque ripples are mainly arises from non-ideal back emf from stator side. In order to reduce the ripple content further, numerous techniques have been proposed. The effective technique to reduce the amount of ripple in torque. Multi level Inverter is used ,which helps to achieve higher power and rms voltage with relatively lesser ripple content in its response.

NOVEL TOPOLOGY FOR PMSM DRIVE SYSTEM

The proposed system is used to reduce the torque ripple of the PMSM drive system. The proposed system is composed a modified SEPIC converter and a MOSFET-based 3-level NPC Inverter. The modified SEPIC converter operates with high static gain and less switching voltage stress than any other classical DC-DC converters.

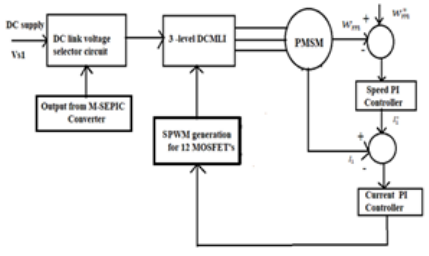


Fig.1 Block diagram for torque ripple suppression

The modified SEPIC converter is used to reduce the torque ripple suppression circuit and the duty cycle is adjusted to obtain the desired dc-bus voltage based on the spinning speed of the PMSM. The 3-level NPC Inverter is used to reduce the current ripple and as well as the resultant torque ripple in the system.

DC-BUS VOLTAGE SELECTOR CIRCUIT FOR PMSM

A system diagram of a proposed new converter topology for PMSM drive system based on a 3-level DCMLI and a modified SEPIC converter . 3-level DCMLI is proposed to reduce current ripple, and modified SEPIC converter is included to adjust the dc-bus voltage based on the rotational speed of the PMSM.

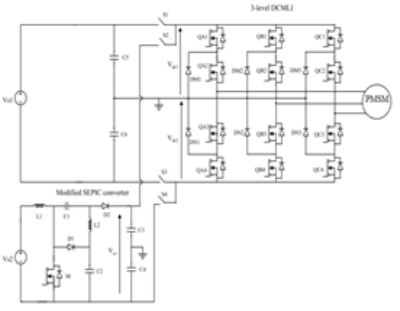


Fig.2 Converter topology with a dc-bus voltage selector circuit for PMSM

The dc bus voltage selector circuit is constructed with the power MOSFETs (S1, S2, S3, and S4). It is mainly used to select the desired dc-bus voltage for torque ripple reduction during commutation interval

The MOSFET-based 3-level NPC Inverter is operated at a switching of 80 kHz, which provides significant torque ripple suppression further. In this 3-level NPC Inverter, the dc-bus voltage is divided into 3-levels by the capacitors C5 and C6. To obtain the desired commutation voltage, the duty cycle of the modified SEPIC converter is adjusted during the non-commutation period to maintain Vdc = 8Em.

The mathematical expression for output voltage of modified SEPIC converter is given by, Here,D is the duty ratio of the modified SEPIC converter.

$$V_0 = \frac{1+D}{1-D} * V_S$$

The back-EMF (Em) is proportional to the motor speed which is given by, where, is the back emf coefficient.

$$E_m = k_e \omega$$

Duty cycle of the MOSFET can be estimated based on measured motor speed.

$$D = \frac{4K_e\omega - V_s}{V_s + 4K_e\omega}$$

PROPOSED VOLTAGE CONTROL STRATEGY FOR COMMUTATION TORQUE RIPPLE SUPPRESSION.

The commutation period of the PMSM is shorter when compared with the time taken by the modified SEPIC converter for dc –link voltage adjustment which is much closer to 8Em.

The MOSFET-based voltage selector circuit is used to regulate the dc bus voltage for efficient torque ripple suppression. Figure 3 below shows the flow chart of proposed voltage control method.

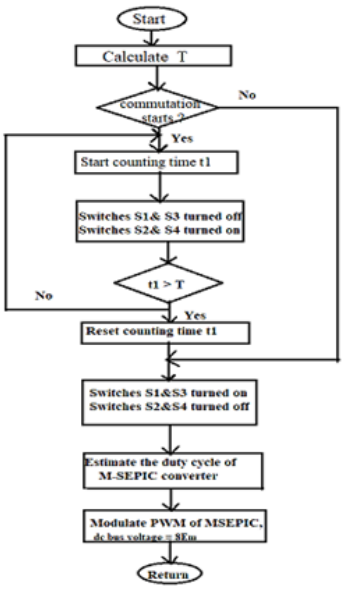


Fig.3 Proposed voltage control strategy for torque ripple reduction.

PROPOSED DC-LINK VOLTAGE BALANCING SCHEME

Fig.4 shows the control circuit block diagram for the three level npc inverter with the proposed DC-link voltage balancing circuit. The two capacitor voltages are measured by two voltage sensors then the difference between them is passed through a logical control block. When the upper capacitor voltage is higher than the lower one, SPWM control uses the upper capacitor to discharge, using the positive small voltage vectors and when the lower capacitor voltage is higher, the control circuit uses the negative small voltage vectors associated with the lower capacitor to discharge.

As the difference between two capacitor voltages is noted at each stepping time, this system keeps the two capacitor voltage differences as very small.As the voltage difference is updated at each time step, it changes the duty cycle in between each switching frequency time period is determined. Hence, it introduces higher switching losses and also high voltage THD.

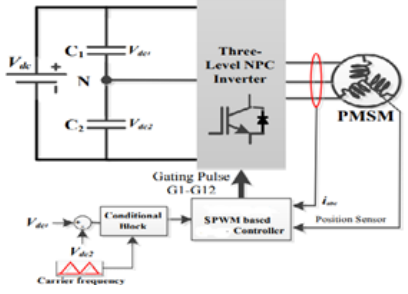


Fig. 4. NPC inverter control circuit with DC-bus voltage balancing

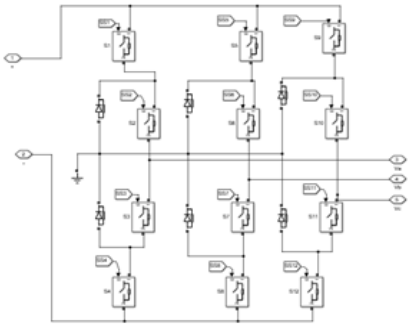


Fig.5 Three level NPC Inverter

The feedback from the carrier signal is added to the conditional block, it allows the duty cycle to change only at the starting of each switching cycle. It can reduce the switching losses and also higher voltage THD. It keeps the output voltage as symmetrical. Hence basically two control strategies are demonstrated. In the first strategy, the difference between the two capacitor voltages (Δv) is passed directly to the S-PWM based on voltage controller, which is called the high switching loss based strategy and in the second strategy Δv is passed through a conditional block. The output of the conditional block updates at starting of each switching cycle, which reduces the switching losses, by restricting the change in duty in between each switching time period (Ts). This strategy is demonstrated as a low switching loss based strategy.

SIMULATION RESULTS

In this section simulation results are presented using M-SEPIC converter and Three Level NPC inverter.The simulation results are performed in MATLAB/Simulink software environment.

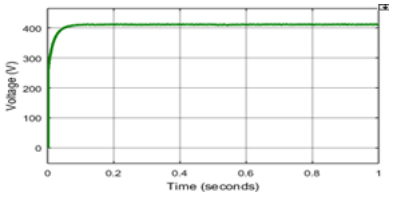


Fig.6 Output voltage waveform of M-SEPIC converter

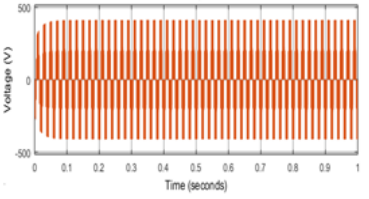


Fig.7 Output voltage waveform of 3-level NPC Inverter

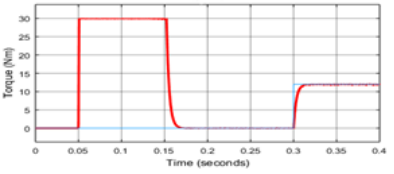


Fig.8 Generated torque in pmsm drive system

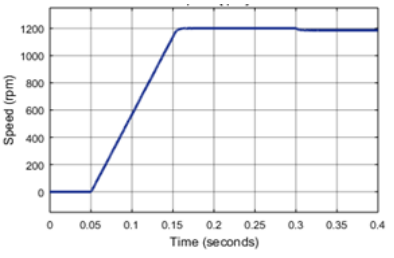


Fig.9 Speed of permanent magnet synchronous motor

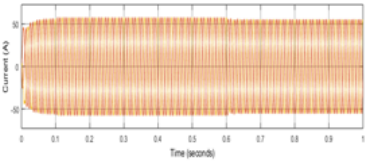


Fig.10 Line current in pmsm

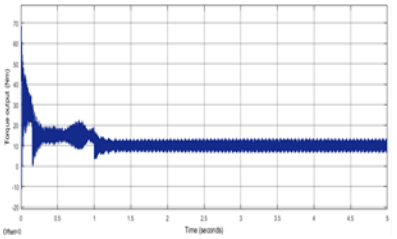


Fig.11 Generated torque after imp;ementing voltage control strategy

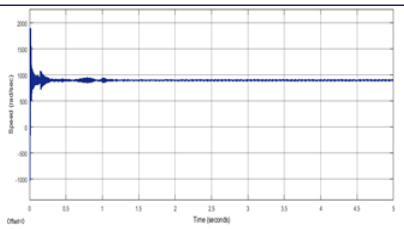


Fig.12 Speed of pmsm drive system after implementing voltage control strategy

CONCLUSIONS

In this paper, torque ripple reduction circuit is proposed using Three Level NPC Inverter and Modified SEPIC converter along with a dc link voltage selector circuit. The proposed converter topology has been verified with the MATLAB/ Simulink.DC link voltage control strategy is more effective in torque ripple suppression. Due to quietness and higher efficiency ,the combination of M-SEPIC and Three Level NPC Inverter is the most suitable choice to obtain high performance operation in PMSM drive system for the aerospace and electric vehicle applications.

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