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Research Article

PMSM Control using the 3DSVPWM to Decrease Motor Torque Ripple and Motor Current THD with a New Model

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Abstract

In this paper, a new model for a PMSM (permanent magnet synchronous motor) driver is proposed. The proposed model is envisioned as a better modulating drive current waveform. In the proposed system the modulating drive motor current waveform is more similar to ideal sinusoidal waveform. Advanced IGBTs and snubber circuits can be employed in the design of the driver to obtain high performance with a simultaneous reduction in THD (total harmonic distortion) and torque ripple of the motor. The proposed concept offers a significant decreasing for driver harmonics compared to classical SVPWM used. The inverter can be operated in 3-phase and 20 kHz switching frequency. A PMSM motor is operated at 3kW and 48V with the proposed model is evaluated via simulation with a corresponding SVPWM (space vector pulse width modulation) method. Results of torque ripple and THD of the motor currents on the model are discussed.

Keywords: Motor Torque Ripple, PMSM, SVPWM, THD

Yeni Bir Modelle Motor Tork Dalgalanmalarını ve Motor Akımının Toplam Harmonik Bozuntusunu Azaltmak için 3DSVPWM Kullanarak PMSM Kontrolü

Öz

Bu çalışmada, bir SMSM (sabit mıknatıslı senkron motor) sürücüsü için yeni bir model önerilmiştir. Önerilen model, daha iyi modüle edici bir tahrik akımı dalga biçimi olarak öngörülmüştür. Önerilen sistemde, modülasyonlu tahrik motor akımı dalga formu ideal sinüzoidal dalga formuna daha benzerdir. THB (toplam harmonik bozulma) ve tork dalgalanmasında azalma ile yüksek performans elde etmek maksadıyla sürücünün tasarımında gelişmiş IGBT'ler ve sönümleme devreleri kullanılabilir. Önerilen konsept, kullanılan klasik SVPWM'ye kıyasla sürücü harmonikleri için önemli bir düşüş sunuyor. Evirici, 3 faz ve 20 kHz anahtarlama frekansında çalıştırılabilir. Bir PMSM motoru, önerilen model ile 3kW ve 48V'da çalıştırılır ve bir UVDGM (uzay vektörü darbe genişliği modülasyonu) metodu ile simülasyon yoluyla değerlendirilir. Modeldeki motor akımlarının tork dalgalanması ve THB sonuçları tartışılmıştır.

Anahtar Kelimeler: Motor Torkunda Dalgalanmalar, SMSM, UVDGM, THB.

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1. Introduction

Inverter design is very important for stable, compact and technologic motor drivers. Designed inverter must be overcome undesired effect of system due to nonlinear loads [1-3]. In order to get the better driver, the better PWM must be generated [1-6]. Generated PWM signals supply with desired voltage waveform in the inverter output. Moreover, better PWM signals can be achieved thanks to a better control approach. Therefore, the control strategy must be decided very well [7-11]. Although a PMSM design cannot be enough to the desired torque ripple and the desired motor current for the desired harmonics, it can be achieved to desired results by using the control strategy and PWM techniques.

This paper investigates the torque ripple and THD of motor currents issue of PMSM. Thanks to 2 cases, better results are found for these issues. Case 1 is composed of classical SVPWM and field oriented control (FOC) method and Case 2 consist of the 3DSVPWM and FOC. After the simulation results, the torque ripples and motor currents are discussed. In addition, the driver of this study is given in Fig. 1. Here, 400/50V autotransformer, a diode rectifier, 2 parallel big capacitor, a 3kW inverter, a sensor card and FOC method are given below.

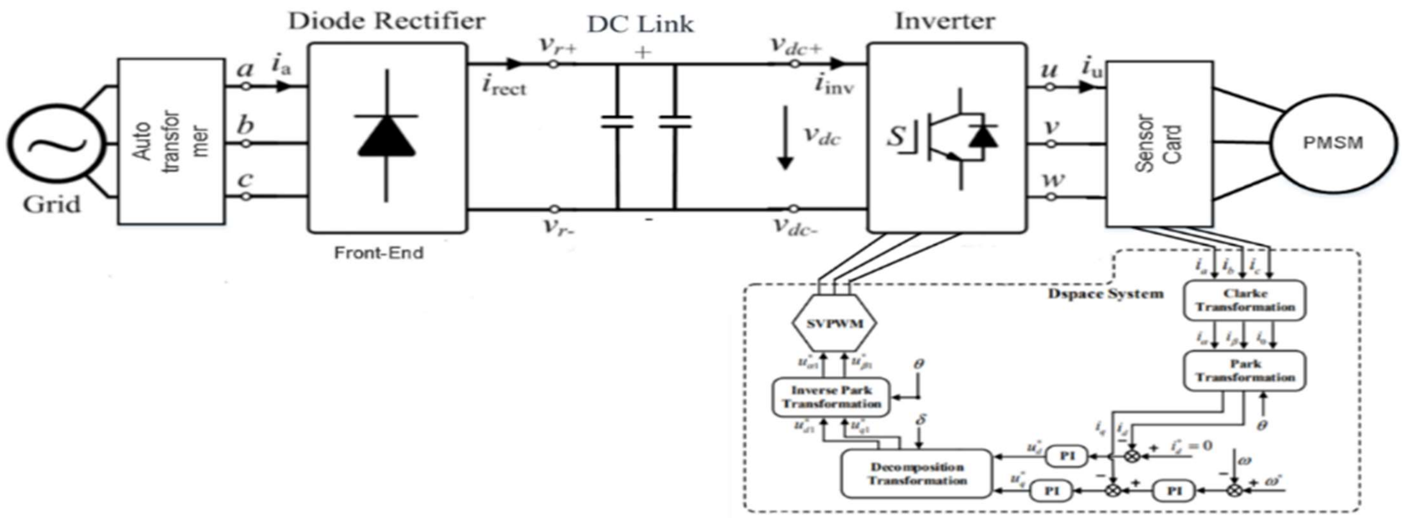

Figure 1. Driver Block Diagram.

In this paper, five sections consist of this study. In Section II, the PMSM model is described. The 3DSVPWM is explained in Section III. Then, simulated 2 cases are investigated and simulation results are discussed. Lastly, the paper is summarized in conclusion section.

2. PMSM MODEL

The mathematical equations of the modelled PMSM are given in the dq reference frame as,

$$\begin{bmatrix} v_{sd} \\ v_{sq} \end{bmatrix} = \begin{bmatrix} R + sL_{sd} & -\omega_r L_{sq} \\ \omega_r L_{sd} & R + sL_{sq} \end{bmatrix} \begin{bmatrix} i_{sd} \\ i_{sq} \end{bmatrix} + \begin{bmatrix} 0 \\ \omega_r \lambda \end{bmatrix} \tag{1}$$

$$T_e = \frac{3}{2} P(\lambda i_{sq} + (L_{sd} - L_{sq}) i_{sd} i_{sq}) \tag{2}$$

where, id is presumed to 0, it can be expressed that

$$V_{sd} = -\omega_r L_{sq} i_{sq} \tag{3}$$

$$V_{sq} = R i_{sq} + sL_{sq} i_{sq} + \omega_r \lambda \tag{4}$$

All parameters of the PMSM is given in Table 1.

Table 1. Parameter of the PMSM

Parameter	Describtion
R	stator resistor
λ	flux
P	number of pole pairs
Lsd, Lsq	stator inductances in the dq-frame
Te	electrical torque
ωr	rotor speed
vsd, vsq	stator voltages
isd, isq	stator currents

3. 3DSVPWM

This proposed modulation technique supplies is a three phased and balanced inverter. In addition, the relationship between the A, B and C voltages are given in Eq. 5.

$$V_{A0}(t)+V_{B0}(t)+V_{C0}(t)=0 \tag{5}$$

These voltages can be expressed in α-β planes.

$$\vec{V}(t)=V_{\alpha}(t)+jV_{\beta}(t) \tag{6}$$

$$\begin{bmatrix} V_{\alpha}(t) \\ V_{\beta}(t) \end{bmatrix}=\frac{2}{3}\begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V_{A0}(t) \\ V_{B0}(t) \\ V_{C0}(t) \end{bmatrix} \tag{7}$$

$$\vec{V}(t)=\frac{2}{3}\left(V_{A0}(t)e^{j0}+V_{B0}(t)e^{j2\pi/3}+V_{C0}(t)e^{j4\pi/3}\right) \tag{8}$$

Each vector switching status are given in Table 2. Here, 18 vectors are used in this proposed techniques.

Table 2. Each Vector Switching Status

<table>
<tr><td rowspan="3">$\vec{V}0$
[00 00 00]
[00 00 11]
[00 11 00]
[00 11 11]
[11 00 00]
[11 00 11]
[11 11 00]
[11 11 11]
[01 01 01]
[10 10 10]
[S1S2S3S4S5S6]
Switch on :1
Switch off: 0</td>
<td>$\vec{V}1$
[00 01 01]
[11 01 01]
[10 00 00]
[10 00 11]
[10 11 00]
[10 11 11]</td>
<td>$\vec{V}2$
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[10 10 11]
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[00 11 01]
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<tr><td>$\vec{V}13$
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<td>$\vec{V}14$
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<td>$\vec{V}16$
[01 10 10]</td>
<td>$\vec{V}17$
[01 01 10]</td>
<td>$\vec{V}18$
[10 01 10]</td></tr>
</table>

4. Simulation Results

The designed cases give the torque ripple results and THD of motor currents results. Torque ripple on electrical torque in given in Table 3.

Table 3. Torque Ripple on Te.

Models	Te (Nm)	RMS(Nm)	Torque ripple (Nm)
Case 1	4.060	3.615	0.445
Case 2	4.071	3.632	0.439

In table 3, electrical torque of Case 1 is 4.060Nm and electrical torque of Case 2 is also 4.071Nm. RMS values are respectively 3.615Nm and 3.632Nm. However, torque ripple of Case 1 is 0.445Nm and torque ripple of Case 2 is 0.439Nm. Electrical torque of two cases are illustrated in Fig 2.

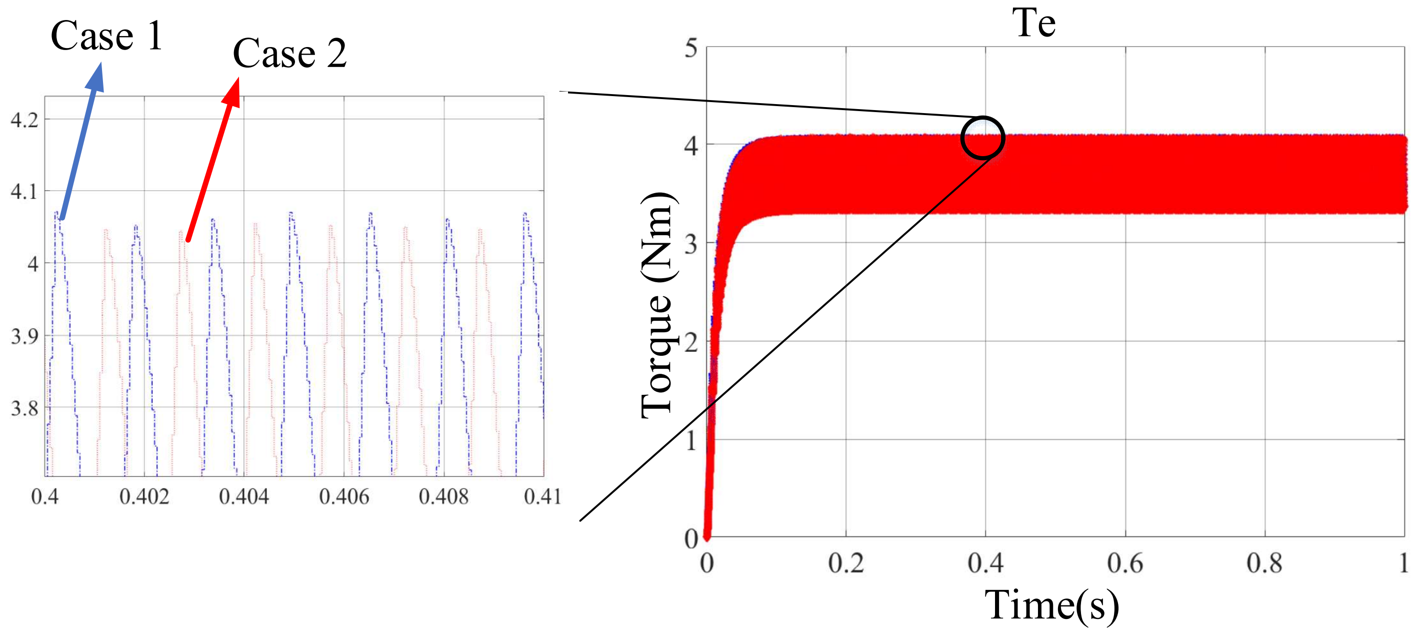

Figure 2. Electrical Torque of Two Cases

Motor currents of two cases are shown in Fig 3.

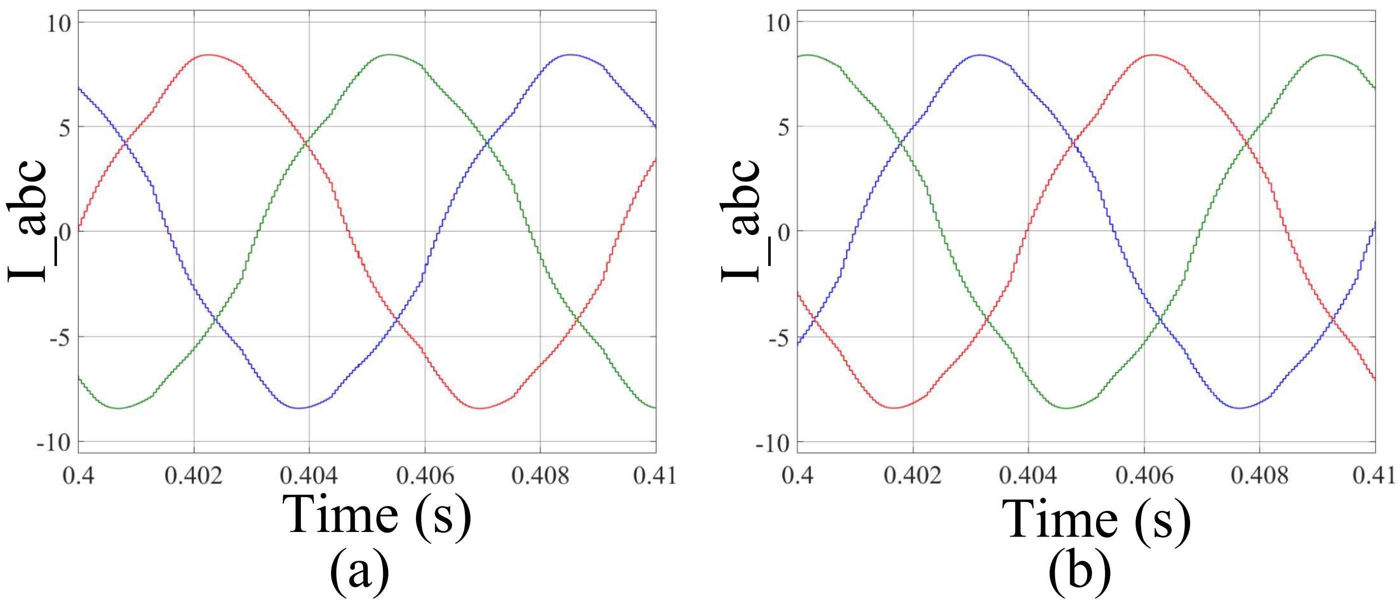

Figure 3. Motor Currents of Two Cases. ((a) is Case 1 and (b) is Case 2)

According to the Fig 3. THD of motor currents are expressed in Table 4.

Table 4. THD of Motor Current

Models	THD
Case 1	41.65%
Case 2	37.35%

Above THD of Case 1 is 41.65% and THD of Case 2 is 37.35%. It is clearly seen that both torque ripple results and THD results of Case 2 is better than results of Case 1. Thus, it is mentioned that the 3DSVPWM has good effect on torque ripple and THD.

5. Conclusion

The proposed new model with the 3DSVPWM for a PMSM driver is expressed. The proposed model is envisioned as a better modulating drive current waveform. In order to obtain high performance thanks to the decreasing THDi and torque ripple of the motor, the classical SVPWM and the 3DSVPWM is applied in two cases. After the case results, it is precisely understood that the 3DSVPWM can be preferred in many PMSM driver study. Because it has very good effect on motor torque ripple and THD of motor currents.

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