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A DTC of A Three Phase Induction Motor Using a Two Leg Inverter

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Abstract— **This Work is to achieve a Direct Torque Control of a three phase induction motor using a two leg inverter. Actually a three phase induction motor will drive using six switches alternatively, this may leads to the increase in switching losses. In order to reduce the switching losses, we are reducing the number of switches, using four switches instead of six switches to run a three phase induction motor. The Direct Torque Control of a three phase induction motor can be implemented using space vector modulation technique. Thereby, harmonics can be eliminated. And also the overall cost will be reduced. This can be implemented in the electric vehicles and electric hybrid vehicles applications.**

Index terms - **Direct torque control, Two leg inverter topology, Vector selection table, switching losses, harmonic distortion, torque ripple.**

I. INTRODUCTION

DIRECT torque control (DTC) strategies of induction motor drives are widely used in variable speed applications. The earlier DTC strategy has been proposed by *Takahashi* in the middle of the eighties [1]. Since then, many DTC strategies based on analytical foundations have been developed so far.Two major classes of DTC strategies could be distinguished: (i)strategies without controlled switching frequency [2]-[7],and (ii) strategies with controlled switching frequency [8]-[15]. Obviously, the second class of DTC strategies offers higher performance in terms of torque ripple reduction and efficiency improvement. However, these strategies would nevitably require control systems with higher CPU-frequencies in so far as their implementation schemes are more complicated than those of the first class. The major drawbacks of these latter are their high torque ripple and switching losses .In recent years, several studies investigated the possibility to associate space-vector modulation (SVM) techniques with DTC strategies in order to control the switching frequency[8], [13]-[15]. SVM is the most popular real-time technique enabling the control of the inverter power switches. They offer the lowest harmonic distortion of the motor phase current associated with reduced inverter switching losses [16]- [19].Further reduction of these losses could be gained by combining SVM and two leg inverter technique.

Basically, two leg inverter topology employ special switching sequences in order to run the three phase induction motor. Actually, the association of SVM to DTC strategies requires the six switches to run the three phase induction motor, whereas in this technique we are replacing the two switches by two capacitors and only four switches are used to drive the three phase induction motor. Space vector modulation used in this technique, leads to controlled switching frequency DTC strategies.

Within this approach, the paper proposes a novel DTC strategy which belongs to the uncontrolled switching frequency class. Based on the two leg inverter topology, the proposed strategy is characterized by low inverter switching losses and low harmonic distortion of the motor phase current, leading to reduced torque ripple in a wide speed range.

II.BACKGROUND OF DTC STRATEGIES

Introduced in the late 1980s by *Takahashi*, direct torque control (DTC) strategies of induction motor drives have revealed interesting performance. Basically, DTC strategies allow a direct control of the motor variables through an appropriate selection of the inverter control signals. This is achieved according to the outputs of two hysteresis regulators: (i) a two-level regulator providing the output $c_A$to control the stator flux and (ii) a three-level regulator providing the output $c_T$to control the electromagnetic torque. The selection of the stator voltage vector for each control combination is based on the variation of the stator flux vector $\Phi_s$which is governed by equation (1).

$$\frac{d}{dt}\Phi_s = V_s - r_s I_s \quad (1)$$

Neglecting the voltage drop $r_sI_s$across the stator resistance and taking into account that the voltage vector is constant in each sampling period Ts, the stator flux vector variation turns to be proportional to the applied voltage vector.

Maintaining the stator flux constant, the variation of the electromagnetic torque Tem depends on the direction of the applied voltage vector, such that:

$$Tem = Np\frac{M}{IsIr - M2}\|\Phi s\|\|\Phi r\|\sin\theta \quad (2)$$

Where $\Phi r$is the rotor flux referred to the stator, $\theta$is the angle between the stator and rotor fluxes, $Np$is the pole pair number, and ls, lr and M are the stator self inductance, the

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rotor self-inductance and the mutual inductance, respectively. The major drawback of the *Takahashi* DTC strategy is due to the systematic application of zero voltage vectors to maintain the electromagnetic torque (c_T=0). The application of these voltage vectors during a sampling period Ts yields a slight decrease of the stator flux at high speeds. However, at low speeds and especially for reduced DC bus voltages, the application of zero voltage vectors leads to a high reduction of the stator flux, yielding the so-called "demagnetization phenomenon" which affects the electromagnetic torque. An approach to avoid this phenomenon consists in limiting the application of zero voltage vectors to the cases where the stator flux should be reduced which leads to the control combinations (c_A=-1, c_T=-1) in the case of an anti-clockwise rotation, and (c_A=-1, c_T=+1) in the case of a clockwise rotation. This approach represents the major rule of the proposed DTC of a three phase induction motor using a two leg inverter.

III.THE PROPOSED SYSTEM

A. A DTC of a three phase induction motor

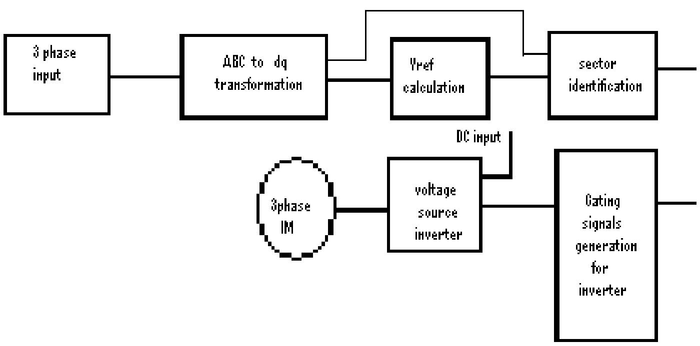

Figure.1.Block diagram of proposed DTC of a three phase IM

In the proposed DTC, the three phase ac supply is given .the three phase rotating A,B,C, is converted into stationary d,q transformation using a park's transformation method. This Vref and angle can be calculated from d,q transformation. From angle sectors can be identified and divided. Space vector modulation technique is used to divide the sector and generate the gate pulses. The generated gate pulses is given to the voltage source inverter. Induction motor can drive through the voltage source inverter.

B. SPACE VECTOR PWM:

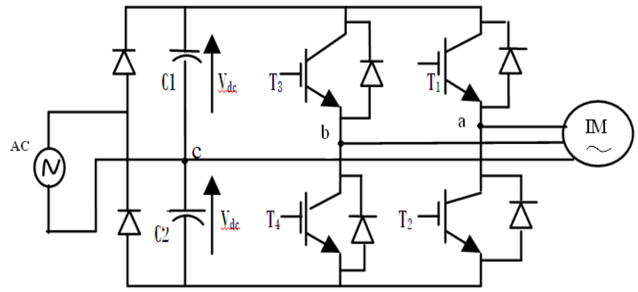

Figure. 2. SVPWM for two leg inverter

Space vector modulation treats the sinusoidal voltage as a constant amplitude vector rotating at a constant frequency. The PWM technique approximates the reference voltage $v_{ref}$by combination of the four switching patterns (v1to v_4). The coordinate transformation (abc reference frame to the stationary dq frame) has been done. three phase voltage vector is transformed into a vector in the stationary dqco ordinate frame, which represents the spacial vector sum of the three phase voltage. the vectors (v_1 to v_4) divide the plane into four sectors,each sector 90 degrees. v_{ref} is generated by two adjacent non-zero vectors and two zero vectors.

C. *Realization Of Space Vector Pwm*:

- step1:Determine V_d,V_q,V_{ref} and angle(∝)
- step2: :Determine time duration T_1, T_2, $T_{0.}$
- step 3: :Determine the switching time of each transistor $s_1$to $s_{4.}$

D. Determine time duration T1,T2,T0

Alpha

$$v_1*T_1*\cos(-120)+v_2*T_2*\cos(-0)=v_s*T_s*\cos(180+60+\theta)$$

$$v_1*T_1*(-1/2)+v_2*T_2*(\sqrt{3}/2)=-v_s*T_s*\cos(60+\theta) \quad (3)$$

beta

$$v_1*T_1*\cos(210)+v_2*T_2*\cos(120)=v_s*T_s*\cos(180+30-\theta)$$

$$v_1*T_1*(\sqrt{3}/2)+v_2*T_2*(-1/2)=-v_s*T_s*\cos(30-\theta) \quad (4)$$

$$T1=\frac{VsTs\cos\theta}{V1} \qquad T2=\frac{VsTs\sin\theta}{V2} \quad (5)$$

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Table.1 Phase voltage Line voltage

	Sa	Sb	Van	Vbn	Vcn	Vab	Vbc	Vca
V1	0	0	-Vdc/3	-Vdc/3	-2Vdc/3	0	-Vdc	Vdc
V2	1	0	Vdc	-Vdc	0	2Vdc	-Vdc	-Vdc
V3	1	1	Vdc/3	Vdc/3	-2Vdc/3	0	Vdc	-Vdc
V4	0	1	Vdc	Vdc	0	Vdc	Vdc	Vdc

E. Space Vector Representations

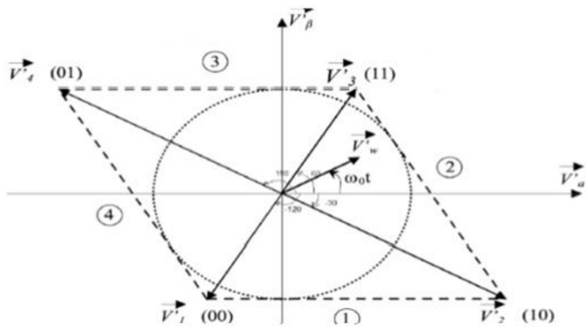

Figure .3 Space vector representations

The Phase voltage and the line voltage of the 3 phase induction motor corresponding to the switching sequence is seen in the table 1.

Table 2 Time period for each sector:

Sector1	Sector2
$T1 = \frac{3VrefTs \cos\alpha}{2Vdc}$ $T2 = \frac{\sqrt{3}VrefTs \sin\alpha}{2Vdc}$ T0=Ts-(T1+T2)	$T2 = -\frac{\sqrt{3}VrefTs \sin\alpha}{2Vdc}$ $T3 = -\frac{3VrefTs \cos\alpha}{2Vdc}$ T0=Ts-(T3+T2)
Sector3	**Sector4**
$T3 = -\frac{3VrefTs \cos\alpha}{2Vdc}$ $T4 = \frac{-\sqrt{3}VrefTs \sin\alpha}{2Vdc}$ T0=Ts-(T3+T4)	$T4 = \frac{\sqrt{3}VrefTs \sin\alpha}{2Vdc}$ $T5 = \frac{3VrefTs \cos\alpha}{2Vdc}$ T0= Ts-(T4+T5)

The two active vector T1, T2 and the zero vector T0 for each sector has been calculated in the above table 2.

F. Switching times for each sector:

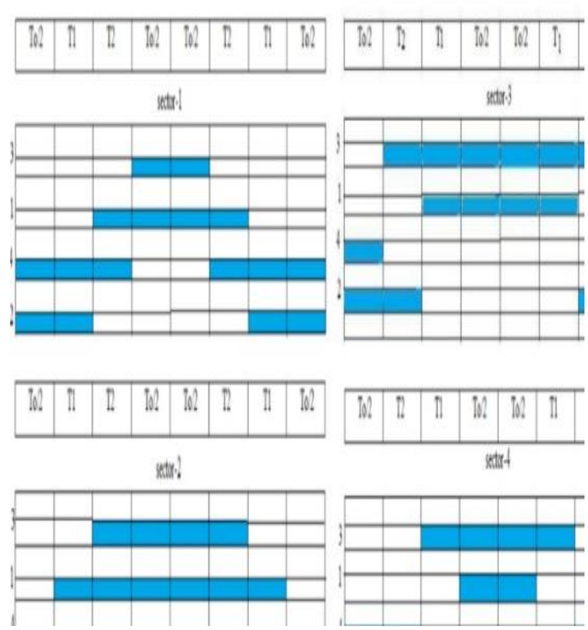

Figure .4 switching times for each sector

E. *G. Sector for two leg inverter corresponding to the angle:*

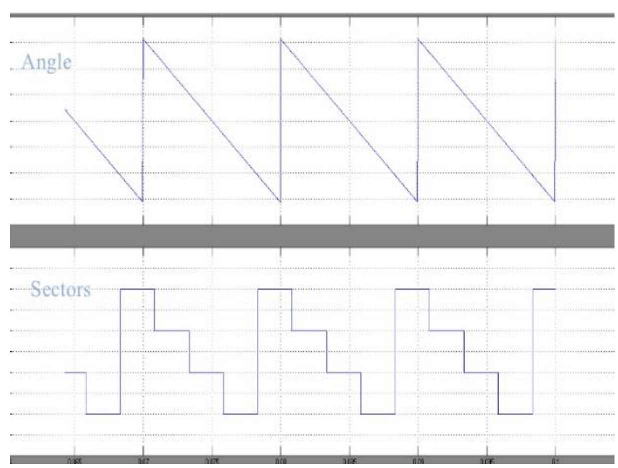

Figure 5 Sectors for corresponding angle

F. *H. Stator flux control*:

In this proposed model, it is clear that the four switches are used to drive the three phase induction motor based on the space vector modulation technique. The torque equation for the three phase induction motor is well known and is stated as

$$Tem = Np\frac{M}{IsIr - M2}\|\Phi s\|\|\Phi r\|\sin\theta \qquad (6)$$

Where Φr is the rotor flux referred to the stator, θ is the angle between the stator and rotor fluxes, Np is the pole pair number, and ls, lr and M are the stator self inductance, the rotor self-inductance and the mutual inductance, respectively.

Therefore from the above equation, we know that the torque varies as the angle between the stator and rotor flux varies . the rotor flux is completely depend upon the load applied to the motor. But the stator flux can be varied by controlling the switching sequence of the two leg voltage source inverter. The gate pulses to these voltage source inverter can be generated using a space vector modulation technique.

By giving the correct sequence of switching to the four switches alternatively we can obtain a stator flux which is predetermined. Thus the angle between the stator and rotor fluxes is controlled thereby direct control of torque can be achieved effectively.

IV. SIMULATION RESULTS

In order to perform a more detailed evaluationof theproposed DTC of the three phase induction motor.. MATLABis used. Thecomplete topology is modeled using SIMULINK toolbox andthe control logic is tested. Figure 6 shows theinput AC supply.

A.Three phase AC supply:

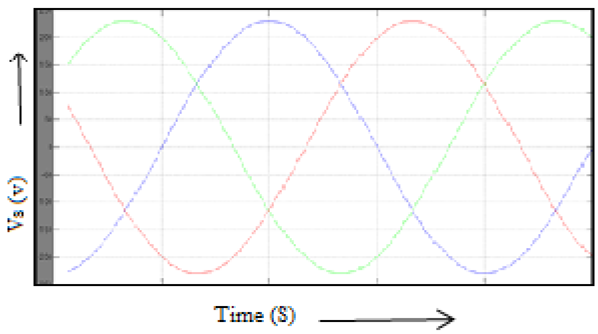

Figure. 6 Three phase AC supply

The given three phase AC supply is rotating A, B, C phases which is converted into stationary d,qcoordinates by park's transformation technique. Then the voltages Vd,,Vq is been converted into complex and then to magnitude and angle. The magnitude is to determine the switching period for each sector. And angle is used to determine the sector as shown in the following figure 7.

B. sector separation corresponding to the angle:

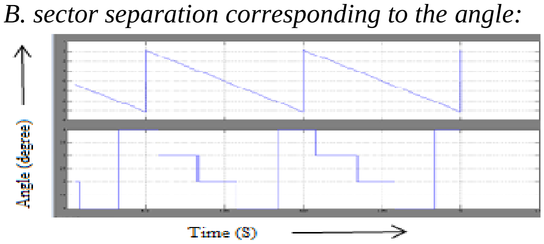

Figure.7 sector corresponding to the angle

As the sectors are divided, the time period for each sector is calculated and the gate pulses are generated as shown in figure7

As the time periods are calculated , the pre-determined stator flux is formed, which is supposed to be sinusoidal wave but the actual wave contain harmonics and get suppressed as shown in figure 8.

C. Stator flux:

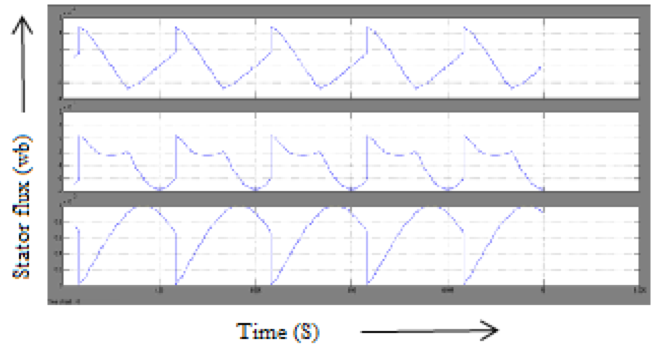

Figure. 8 stator flux of the induction motor

D. Sine triangular PWM:

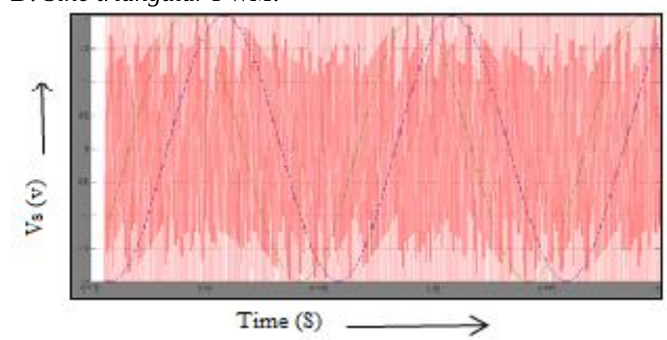

Figure. 9 Sine triangular PWM

The harmonic content of the stator flux can be eliminated by comparing the fundamental sine wave with the carrier triangular wave. So that the output voltage can be smoothed and ripple content will be reduced. And also the output voltage get boosted.

E. Gate pulse generation

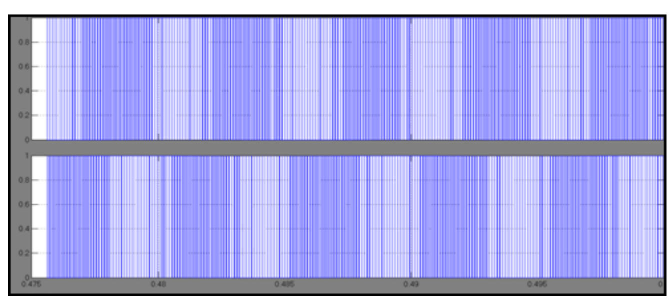

Figure. 10 Gate pulse generation

After the gate pulses are generated and given to the two leg inverter switches, the induction motor start running. The output parameters of the three phase induction motor can be obtained as follows.

F. Output voltage:

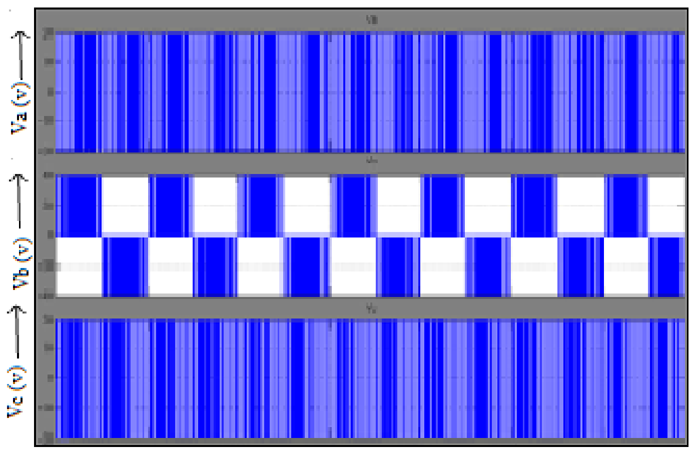

Figure. 11 output voltage of a 3 phase Induction Motor

G. Stator current:

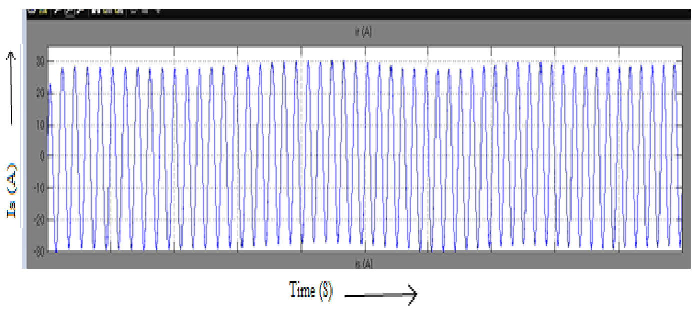

Figure. 12 Stator current of a 3 phase Induction Motor

H. Rotor current:

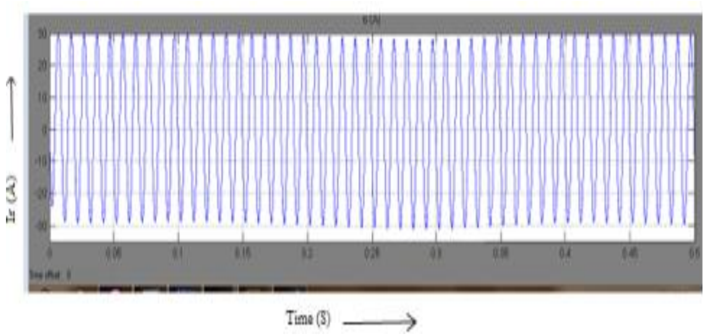

Figure. 13 Rotor current of a 3 phase Induction Motor

I. Electromagnetic torque:

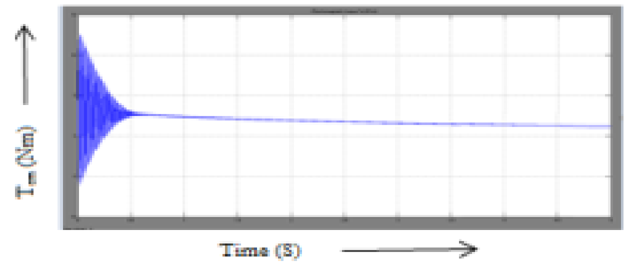

Figure. 14 Electromagnetic torque of the induction motor

J. Speed

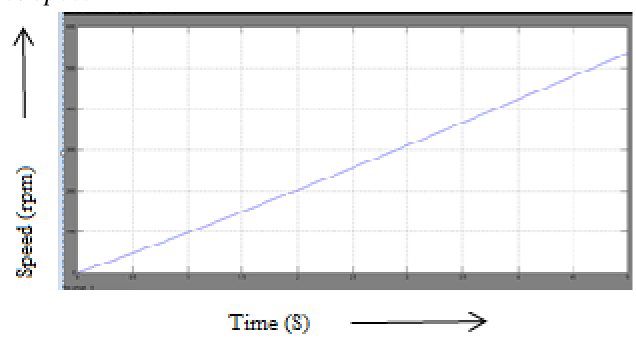

Figure 15 Speed of the induction motor

V. CONCLUSION

Conventionally, the direct torque control can be achieved in the single phase induction motor using four switches and in three phase induction motor using six switches. In this paper, we have achieved the direct torque control of three phase induction motor just by using four switches. There by the fast switching can be achieved. The overall efficiency can be improved. The complexity of the circuit is reduced by reducing the driver circuit .it is more economical than the conventional one. The switching losses will be reduced by reducing the number of switches. The limitation of paper, fast turn on and turn off switches should be used. Future scope of this module can be used in the hybrid electric vehicles or electric vehicle where the variable speed drive is essential.

REFERENCES

[1] Takahashi, and T. Noguchi, “A new quick-response and high-efficiency control strategy of an induction motor,” IEEE Trans. Ind. Appl., vol. 22, no. 5, pp. 820-827, 1986.

[2] F. Khoucha, S. M. Lagoun, K. Marouani, A. Kheloui, and M. E. H. Benbouzid, “Hybrid cascaded h-bridge multilevel-inverter induction-motordrive direct torque control for automotive applications,” IEEE Trans. Ind. Electron., vol. 57, no. 3, pp. 892-899, 2010.

[3] A. Dey, B. Singh, D. Chandra, and B. Dwivedi, “A novel approach to minimize torque ripples in DTC induction motor drive,” Proc. IEEE Int. Conf. Power, Control and Embedded

Systems (ICPCES'10), pp. 1-6, Allahabad, India, November-December, 2010.

[4] L. Gao, J. E. Fletcher, and L. Zheng, "Low-speed control improvements for a two-level five-phase inverter-fed induction machine using classic direct torque control," IEEE Trans. Ind. Electron., vol. 58, no. 7, pp. 2744-2754, 2011.

[5] A. Jidin, N. R. N. Idris, A. H. M. Yatim, T. Sutikno, and M. E. Elbuluk, "An optimized switching strategy for quick dynamic torque control in DTC-hysteresis-based induction machines," IEEE Trans. Ind. Electron., vol. 58, no. 8, pp. 3391-3400, 2011.

[6] C. Patel, P. P. Rajeevan , A. Dey, R. Ramchand, K. Gopakumar, and M. P. Kazmierkowski, "Fast direct torque control of an open-end induction motor drive using 12-sided polygonal voltage space vectors," IEEE Trans. Power Electron., vol. 27, no. 1, pp. 400-410, 2012.

[7] B. Bouzidi, B. El Badsi, and A. Masmoudi, "Investigation of the performance of a DTC strategy dedicated to the control of B4 fed induction motor drives," Computation and Mathematics in Electrical and Electronic Engineering (COMPEL), vol. 31, no. 1, pp. 224-236, 2012.

[8] K. B. Lee, an d F. Blaabjerg, "An improved DTC-SVM method for sensorless matrix converter drives using an overmodulation strategy and a simple nonlinearity compensation," IEEE Trans. Ind. Electron., vol. 54, no. 6, pp. 3155-3166, 2007.

[9] M. Hajian, J. Soltani, G. A. Markadeh, and S. Hosseinnia, "Adaptive nonlinear direct torque control of sensorless IM drives with efficiency optimization," IEEE Trans. Ind. Electron., vol. 57, no. 3, pp. 975-985,2010.

[10] S. A. Zaid, O. A. Mahgoub, and K. A. E. Metwally, "Implementation of a new fast direct torque control algorithm for induction motor drives," IET Electr. Power Appl., vol. 4, no. 5, pp. 305-313, 2010.

[11] Z. Zhifeng, T. Renyuyan, B. Boadong, and X. Dexin, "Novel direct torque control based on space vector modulation with adaptative stator flux observer for induction motors," IEEE Trans. on Magnetics, vol. 48, no. 8, pp. 3133-3136, 2010.

[12] K. K. Shyu, J. K. Lin, V. T. Pham, M. J. Yang, and T. W. Wang, "Global minimum torque ripple design for direct torque control of induction motor drives," IEEE Trans. Ind. Electron., vol. 57, no. 9, pp. 3148-3156, 2010.

[13] A. Jidin, N. R. N. Idris, A. H. M. Yatim, T. Sutikno, and M. E. Elbuluk, "Simple dynamic overmodulation strategy for fast torque control in DTC of induction machines with constant-switching-frequency controller,"IEEE Trans. Ind. Appl., vol. 47, no. 5, pp. 2283-2291, 2011.

[14] Y. Zhang, J. Zhu, W. Xu, and Y. Guo, "A simple method to reduce torque ripple in direct torque-controlled permanent-magnet synchronousmotor by using vectors with variable amplitude and angle," IEEE Trans. Ind. Electron., vol. 58, no. 7, pp. 2848-2859, 2011.

[15] Y. Zhang, and J. Zhu, "A novel duty cycle control strategy to reduce both torque and flux ripples for DTC of permanent magnet synchronous motor drives with switching frequency reduction," IEEE Trans. Power Electron.,vol. 26, no. 10, pp. 3055-3067, 2011.

[16] B. El Badsi, "Space-vector pulse-width modulation strategies devoted to the control of reduced structure inverter-fed induction motor drives," ELECTROMOTION, vol. 17, no. 3, pp. 209-219, 2010.

[17] M. M. Renge, and H. M. Suryawanshi, "Three-dimensional space-vector modulation to reduce common-mode voltage for multilevel inverter,"IEEE Trans. Ind. Electron., vol. 57, no. 7, pp. 2324-2331, 2010.

[18] J. Prieto, M. Jones, F. Barrero, E. Levi, and S. Toral, "Comparative analysis of discontinuous and continuous PWM techniques in VSI-fed five-phase induction motor," IEEE Trans. Ind. Electron., vol. 58, no. 12,pp. 5324-5335, 2011.

[19] S. Das, and G. Narayanan, "Novel switching sequences for a spacevector- modulated three-level inverter," IEEE Trans. Ind. Electron., vol. 59, no. 3, pp. 1477-1487, 2012.

[20] G. Narayanan, H. K. Krishnamurthy, D. Zhao, and R. Ayyanar, "Advanced bus-clamping PWM techniques based on space vector approach,"IEEE Trans. Power Electron., vol. 21, no. 4, pp. 974-984, 2006.

[21] G. Narayanan, D. Zhao, H. K. Krishnamurthy, R. Ayyanar, and V. T.Ranganathan, "Space vector based hybrid PWM techniques for reduced current ripple," IEEE Trans. Ind. Electron., vol. 55, no. 4, pp. 1614-1626,2008.

[22] T. Bhavsar, and G. Narayanan, "Harmonic analysis of advanced busclamping PWM techniques," IEEE Trans. Power Electron., vol. 24, no.10, pp. 2347-2352, 2009.

[23] K. S. Gowri, T. B. Reddy, and C. S. Babu, "Switching loss characteristics of advanced DPWM methods using space vector based double switching clamping sequences," Proc. IEEE Symp. Ind. Elect. and Appl. (ISIEA'09), vol. 2, pp. 818-822, Kuala Lumpur, Malaysia, October, 2009.

[24] K. Basu, J. S. S. Prasad, G. Narayanan, H. K. Krishnamurthy, and R.Ayyanar, "Reduction of torque ripple in induction motor drives using an advanced hybrid PWM technique," IEEE Trans. Ind. Electron., vol. 57,no. 6, pp. 2085-2091, 2010.

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