Academic Science

**International Journal of Electronics, Electrical and Computational System**
**IJEECS**
**ISSN 2348-117X**
**Volume 6, Issue 8**
**August 2017**

# SVM-DTC Scheme for Multilevel Inverter Fed Induction Motor Drive

**Dr. Nisha G. K[1]**
[1]Associate Professor, Dept of EEE,
Mar Baselios College of Engineering and Technology, Trivandrum, Kerala, India.

**Praveen O[2]**
[2] PG Scholar, Dept of EEE,
Mar Baselios College of Engineering and Technology, Trivandrum, Kerala, India.

***Abstract**: This paper proposes a space vector based Direct torque controlscheme for multilevel inverter fed induction motor drive. Space Vector Modulation is one of the best modulation schemes for switching of the inverter for the generation of the load line voltages, here the advantage is that the harmonics are reduced. The Multilevel inverter used in this paper is a three level Neutral Point Clamped inverter which the best topology for the drive application scheme. Direct torque control used in the paper is control strategy for controlling the induction motor, it is a decoupled torque and flux control and PI controllers for both torque and flux control. The simulations are done using MATLAB/SIMULINK software and the results are presented.*

***Keywords:Direct Torque Control DTC, Neutral Point Clamped Inverter, Space Vector Modulation, Induction Motor, AC filters.***

## 1. INTRODUCTION

The Electric Drive used in the industries are mostly adjustable speed drives for various purposes so speed control and ripple free torque are most needed among all the machines and the machine should be low cost, rugged and should have low maintenance. So most commonly used machine is the three phase induction motor which has high reliability and good performance among all other machines. The other factors which allow using this machine its parameters such as speed, torque and flux can be easily controllable. For such controlling of machine there are various methods such as Field Oriented Control, V/F control and Direct Torque Control. Among them DTC is one of the most efficient and effective control. It uses a decoupled control of torque and stator flux.

The inverter used in this paper to supply the AC voltage to the machine is three level Neutral Point Clamped inverterare an emerging technology and are commonly applied to highpower motion drives instead of the standard two-level voltagesource inverters (VSI). For the switching scheme here used is three level Space Vector Modulation which will generate the gating pulse for the switches and corresponding load line voltages are generated .

## 2. NEUTRAL POINT CLAMPED INVERTER

The neutral point clamped inverter provides multiple voltage levels through connection of thephases to a series bank of capacitors. According to the original invention, the concept can be extended to any number of levels by increasing the number of capacitors [1]-[2]. The additional level was the neutral point of the dc bus, so the terminology neutral point clamped inverter was introduced. However, with an even number of voltage levels, the neutral point is not accessible, and the term Multiple Point Clamped (MPC) is sometimes applied [3].Early descriptions of this topology were limited to three-levels where two capacitors are connected across the dc bus resulting in one additional level [4]. Due to capacitor voltage balancing issues, the diode-clamped inverter implementation has been mostly limited to the three-level. Because of industrial developments over the past several years, the three-level inverter is now used extensively in industry applications. Although most applications are medium-voltage, a three-level inverter for 480V is on the market.

Although the structure is more complicated than the two-level inverter, the operation is straightforward and well known. Each phase node can be connected to any node in the capacitor bank [5]-[7].Connection of the a-phase to junctions can be accomplished by switching transistors $S_{A1}$ and $S_{A2}$ both off or both on respectively as shown in Fig. 1.

These states are the same as the two-level inverter yielding a line-to-groundvoltage of zero or the dc voltage.

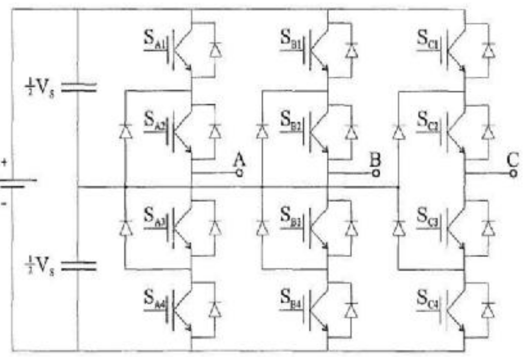



Fig.1Three level neutral clamped multilevel inverter.

### 3. THREE LEVEL SVM

Space Vector Modulation is quite different from the other PWM methods. With PWMs, the inverter can be thought of as three separate push-pull driver stages which create each phase waveform independently. SVM however treats the inverter as a single unit. Specifically the inverter can be driven to eight unique states. Modulation is accomplished by switching the state of inverter [8]-[10].

In α-β coordinate axis, the space vectors corresponding tothe 27 working states are shown in Fig.3. Due to the redundancy states the 27 switching states are reallycorresponding to 19 different space vectors. And they separate Fig.2 into 6 sectors A,B,C,D,E,Fwith 4 equilateral triangles in each sector. Fig.3 shows that through the calculations of theamplitude and phase angle, where the referred vectors locate can be decided [11]-[13]. For their symmetry, here only gives an exampleof sector A to describe how the referred ones integrated bybasic vectors. No matter where *V*refis, it can be expressed by

$$VrefTs=(T_1V_1+T_2V_2+T_3V_3) \qquad (1)$$

$$T_1+T_2+T_3=T_s \qquad (2)$$

where

$V_1$, $V_2$, $V_3$ - vectors that define the triangle region in which Vrefis located.

$T_1$,$T_2$,$T_3$ – corresponding vector durations.

Ts - sampling time.

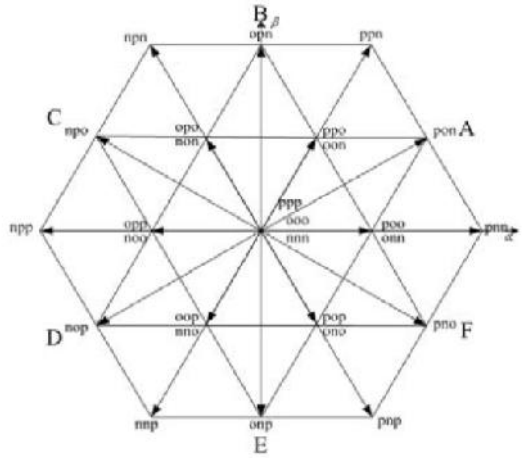



Fig.2 The space vectors corresponding to the 27 working state

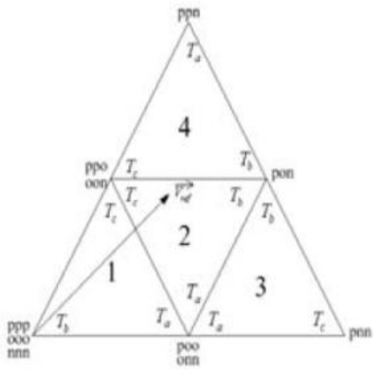



Fig.3 The integration of *V*ref

Of all the 19 basic space vectors, there is one phaseconnected with zero curves at least except long vectors, andforms the closed circuit with the plus or minus. As aresult, the capacitors charge and discharge frequently, whichcauses the ripple of the neutral voltage. To make sure that thethree-level circuit working under the normal condition, it isnecessary to control the neutral voltage ripples acceptable. So itneeds to consider about the influences reacting on it.The redundant small vectors separately exert plus and minusoffset on the neutral voltage. For this reason, their acting timecan be adjusted to keep the balance of the neutral voltages.

### 4. INDUCTION MOTOR

The induction motor has a very wide range of industrial applications because of simple construction, ruggedness & low cost. These advantages are superseded by control problems when using in industrial drives with high

performance demands. The dynamic model is used to for getting the transient and steady state behavior of induction motor [11]-[13].

The dynamic behavior of Induction Motor can be with described with the equation of induction motor. A 3-phase winding can be reduced to 2-phase winding set by using this method. With the magnetic axis being formed in quadrature. The stator and rotor variable (voltage, current, and flux linkages) of an induction motor may rotate at an angular velocity or remain stationary, when transferred to a reference frame [14]-[16].

This frame of reference is generally called as arbitrary reference frame in generalized machine analysis. Direct Torque Control (DTC) and Field Oriented Control (FOC) have emerged as standard industrial solutions for high dynamic performance operation of these machines [17]-[19].

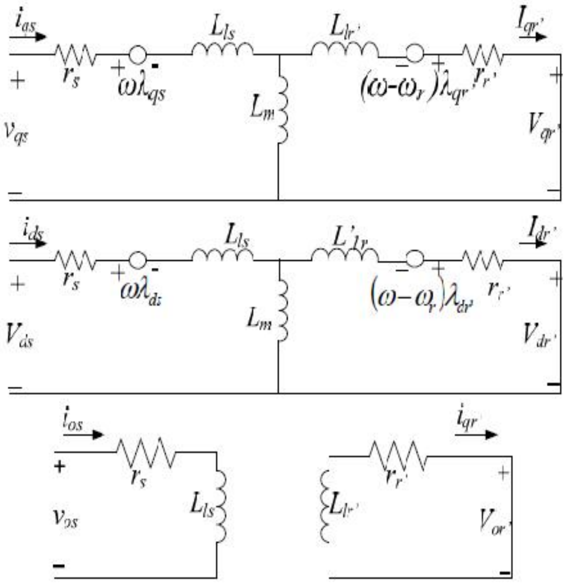


Fig.4. Equivalent Circuit diagram of induction motor in dqo

## 5. DIRECT TORQUE CONTROL

Direct torque control with space vector modulation is proposed in order to improve the classical DTC. The SVM-DTC strategies had the advantage that they can operate at a constant switching frequency. In the control part, space vector modulation SVM is used. This type of SVM-DTC strategy depends on the applied flux and torque control technique. The controllers calculate the required stator voltage vector to feed the machine and then it is realized by space vector modulation [20]-[22].

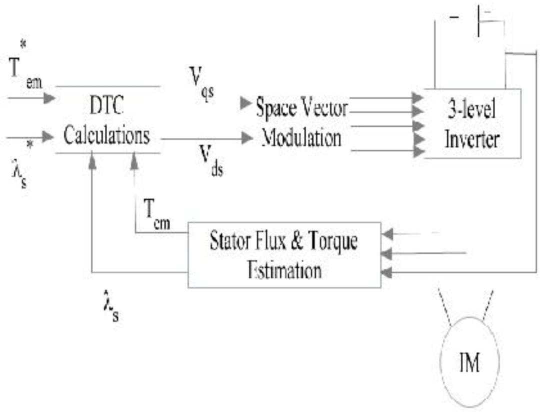



Fig.5. DTC using space vector modulation block diagram

The principle of direct torque control of induction motor drive is to control the flux linkage and electromagnetic torque directly by the selecting proper inverter switching state. The conventional DTC includes two level and three level hysteresis controllers, three levels for torque and two levels for flux linkage. It has many advantages like no feedback control, no traditional PWM algorithm, no vector transformation, it has some drawbacks like variable switching frequency, inherent steady state torque and flux ripple. Due to hysteresis band controller, steady state torque and flux ripple is more in direct torque control of induction motor which is undesirable from smooth response point of view [23]. Direct Flux and Torque Control with Space Vector Modulation (SVM-DTC) schemes are proposed in order to improve the classical DTC of Induction motor.The inverter is controlled by the space vector modulation technique instead of voltage sector selection block as used in classical DTC. The SVM-DTC strategy depends on the applied flux and torque estimation block. The controllers calculate the required stator voltage vector and then it is realized by space vector modulation technique [24]. In this scheme there are two proportional integral (PI) type controllers instead of hysteresis band to regulate the torque and the magnitude of flux. By controlling torque and flux amplitude, a gate signal for inverter is generated [25].

$$Te=\frac{3}{2}\frac{p}{2}\frac{L}{L\,.L}\psi\ *\psi \quad (3)$$

p-no of poles, Lm-mutual inductance, Ls-stator inductance, Lr-rotor inductance, ψs, ψr- stator and rotor flux linkages.

Academic Science

International Journal of Electronics, Electrical and Computational System
IJEECS
ISSN 2348-117X
Volume 6, Issue 8
August 2017

## 6. FILTER DESIGN

A filter is required to obtain an approximate sine wave for the load, since the output of multilevel inverter is not sinusoidal. We have to design a filter. The filter is designed as per the equation

$$fc=\sqrt{f\ .f} \quad (4)$$

fc- corner frequency

fr-reference frequency

fs-switching frequency

$$fc=\frac{1}{2\pi\sqrt{L}} \quad (5)$$

from the above equation inductor and capacitor value are obtained for filter design.

## 7. RESULTS AND DISCUSSIONS

An induction motor speed control was studied using SVM-DTC fed three level neutral clamped inverter scheme the controlling is done by using two PI controllers for both torque and flux in this paper. This has been verified using MATLAB/SIMULINK. The torque ripple has been reduced to 91.04%.

Fig 6 represents the overall proposed SVM-DTC scheme, Fig 7, represents the output voltage from NPC-MLI.Fig 8 shows the (a)Flux controller block, (b) torque controller block, (c) Speed controller block of DTC schemeFig 9 represents the corresponding torqueand speed of induction motor Fig 10(a) shows the torque ripple in open loop system and (b) SVM-DTC scheme.

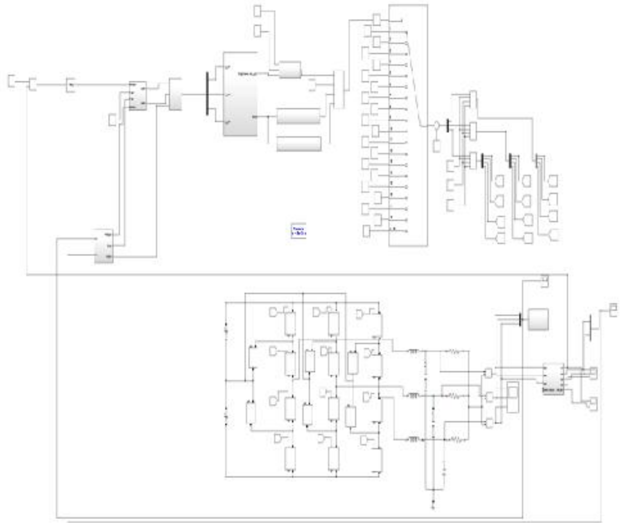


Fig 6 The overall proposed SVM-DTC scheme

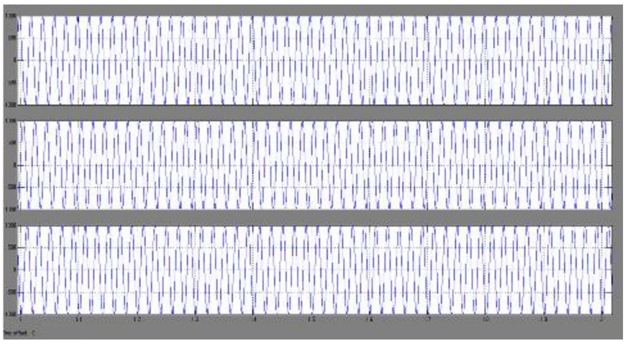
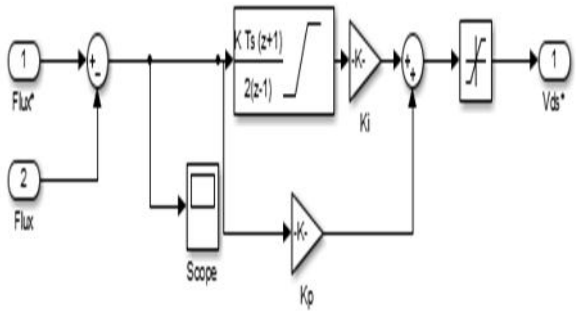
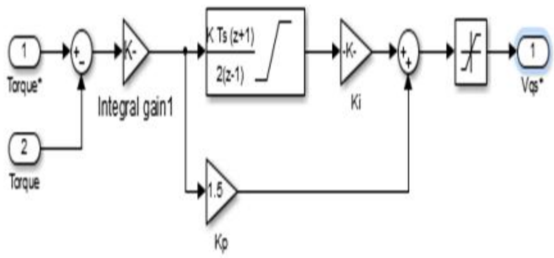


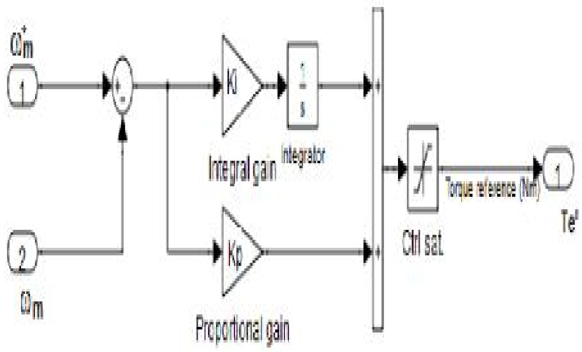
Fig 7.The magnified output voltage




(a)




(b)




(c)

Fig 8 shows the (a) Flux controller block, (b) torque controller block, (c) Speed controller block of DTC scheme

Academic Science

International Journal of Electronics, Electrical and Computational System
IJEECS
ISSN 2348-117X
Volume 6, Issue 8
August 2017

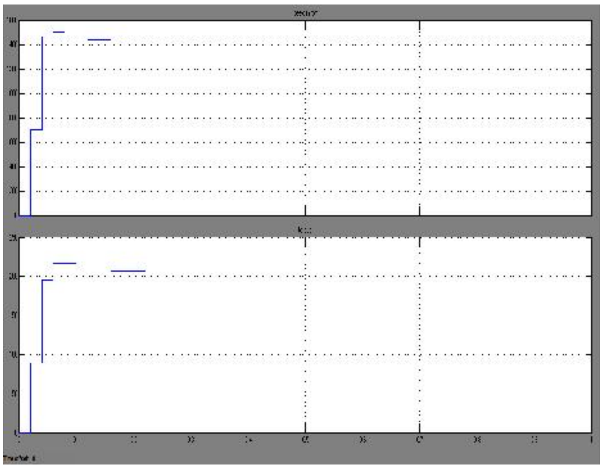
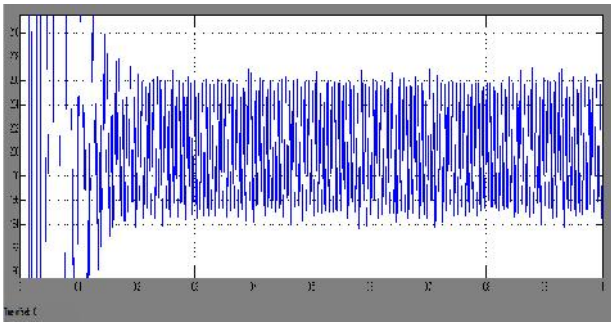
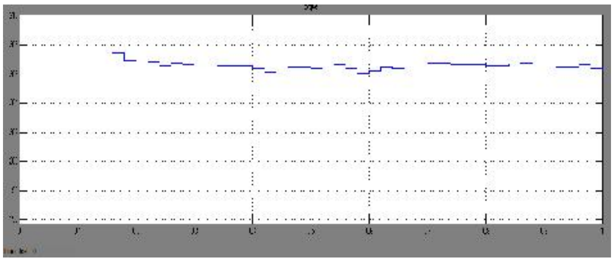


Fig 9The corresponding torque and speed of induction motor



(a) Torque ripple in open loop control of induction motor is 5.44%



(b)Torque ripple in closed loop control of induction motor is 0.487%

Fig 10 (a) shows the torque ripple in open loop system and (b) SVM-DTC scheme.

## 8. CONCLUSION

The simulation of SVM-DTC scheme was done for the multilevel inverter fed induction motor drive. The performance of the inverter and induction motor has been done using MATLAB/SIMULINK. From the results it is obtained that in the open loop control of the system the torque ripple was found to be 5.44% and the SVM-DTC scheme the torque ripple was found to be 0.487%.Thetorque ripple has been reduced by 91.04% by using the SVM-DTC scheme thus produce an effective and efficient drive performance by the induction machine.

## REFERENCES

[1] J. Rodriguez, S. Bernet, B. Wu, J. O. Pontt, S. Kouro, “Multilevelvoltage-source-converter topologies for industrial medium-voltage drives”, *IEEE Transactions on Industrial Electronics*, vol. 54, no. 6, pp.2930-2945,July 2007.

[2] Akhila. A, Manju Ann Mathews, Nisha G .K, “Comparative Analysis of Flying Capacitor and Diode Clamped Multilevel Inverters Using SPWM,” *International Journal of Innovative Science, Engineering and Technology (IJISET)*, vol. 3, no.8, pp.387-393,August2016.

[3] Y. Zhang, Z. Zhao, “Study on capacitor voltage balance for multilevelinverter based on a fast SVM algorithm”, Proceeding of the CSEE(inChinese), vol. 26, no. 18, pp. 71-76, May 2006.

[4] G. K. Nisha, S. Ushakumari and Z. V. Lakaparampil “CFT Based Optimal PWM Strategy for Three Phase Inverter,” *IEEE International conference on Power, Control and Embedded Systems (ICPCES’12)*, Allahabad, India,pp. 1-6, 17-19 December 2012.

[5] A Gupta, A. M. Khambadkone, “A space vector PWM scheme formultilevel inverters based on two-level space vector PWM”, *IEEE Transactions on Industrial Electronics*, vol. 53, no. 5, pp. 1631–1639, February 2006.

[6] G. K. Nisha, S. Ushakumari and Z. V. Lakaparampil “Online Harmonic Elimination of SVPWM for Three Phase Inverter and a Systematic Method for Practical Implementation,” *IAENG International Journal of Computer Science*, vol. 39, no. 2, pp. 220-230, May 2012.

[7] A. Sapin, P. K. Steamer, J. J. Simond, “ Modeling simulation and test ofa three-level voltage-source-inverter with output LC filter and directtorque control”, *IEEE Transactions on Industry Applications*, vol. 43, no. 2, pp.469-475,April 2007.

[8] G. K. Nisha, S. Ushakumari and Z. V. Lakaparampil "Harmonic Elimination of Space Vector Modulated Three Phase Inverter," *Lecture Notes in Engineering and Computer Science: Proceedings of the International Multi-conference of Engineers and Computer Scientists, (IMECS 2012)*, Hong Kong, pp.1109-1115, 14-16 March 2012.

[9] L. Dalessandro, S. D. Round, J. W. Kolar,"Center-point voltagebalancing of hysteresis current controlled three-level PWM rectifiers",*IEEE Transactions on Power Electronics*, vol. 23, no. 5, pp. 2477-2488, September 2008.

[10] Akhila.A, Lekshmi.K.R, Nisha .G.K, "Analysis and Comparison of Flying Capacitor and Modular Multilevel Converters Using SPWM,"International Journal of Innovative Research and AdvancedStudies (IJIRAS),vol.3, no.8, pp.352-357,July. 2016.

[11] G. K. Nisha, Z. V. Lakaparampil and S. Ushakumari, "Performance Study of Field Oriented Controlled Induction Machine in Field Weakening using SPWM and SVM fed Inverters," *International Review of Modeling and Simulations*, vol. 6, no. 3, pp. 741-752, June 2013.

[12] Jih-Sheng Lai, Fang ZhengPeng, "Multilevel Converters a New Breed of Power Converters," *IEEE Transaction on Industrial Applications*, vol. 32, no. 3, pp. 509-517,May/June 1996.

[13] Jose Rodriguez, Leopoldo.G. Franquelo, SamirKouro,Jose.I.Leon,Ramon.C.Portil"Multilevel Converters an Enabling Technology for High power Applications,"*IEEE Transaction on Industrial Applications*, vol. 97, no. 11, pp. 1786-1816, November 2009.

[14] G. K. Nisha, Z. V. Lakaparampil and S. Ushakumari, "FFT Analysis for Field Oriented Control of SPWM and SVPWM Inverter fed Induction Machine with and without Sensor," *International journal of Advanced Electrical Engineering*, vol. 2, no. 4, pp. 151-160, June 2013.

[15] G. K. Nisha, S. Ushakumari and Z. V. Lakaparampil "Method to Eliminate Harmonics in PWM: A Study for Single Phase and Three Phase," *International conference on Emerging Technology, Trends on Advanced Engineering Research*, Kollam, India, pp. 598-604, 20-21 February 2012.

[16] KalleIlves,Antonios Antonopoulos, StaffanNorrga, Hans-Peter Nee, "A New Modulation method for the Modular Multilevel Converter Allowing Fundamental Switching frequency," *IEEE Transaction on Industrial Applications*, vol. 27, no. 8, pp. 3482-3494,August 2012.

[17] G. K. Nisha, Z. V. Lakaparampil and S. Ushakumari, "FFT Analysis for Field Oriented Control of SPWM and SVPWM Inverter fed Induction Machine with and without Sensor," *International conference on Advance Engineering Technology(ICAET'13)*, Mysore, India, pp. 34-43, 27 January 2013.

[18] Akhila A, Nisha G .K, "Comparative Analysis of Flying Capacitor and Cascaded Multilevel Inverters Using SPWM," *International Journal of Engineering Trends and Technology*,vol.4,.no.1,pp.6-10,October 2016.

[19] Tolbert. L. M and Pend. F. Z, "Multilevel Converter as a Utility Interface for Renewable Energy Systems," *IEEE Power Engineering Society Meeting*, vol. 2, pp. 1271-1274, March 2000.

[20] I. Takahashi and T. Noguchi, "A new quick-response and high efficiency control strategy of Induction Motor," IEEE Transactions on Industry Applications, vol. 22, no. 5, pp. 820– 827, 1986.

[21] M. Depenbrock, "Direct self-control (DSC) of inverter-fed induction machine," IEEE Transactions on Power Electronics, vol. 3, no. 4, pp. 420–429, 1988.

[22]G. S. Buja and M. P. Kazmierkowski, "Direct torque control of PWM inverter-fed AC motors—a survey," IEEE Transactions on Industrial Electronics, vol. 51, no. 4, pp. 744–757, 2004.

[23] E. D. Mitronikas and A. N. Safacas, "An improved sensorless vector-control method for an induction motor drive," IEEE Transactions on Industrial Electronics, vol. 52, no. 6, pp. 1660– 1668, 2005.

[24] G. Buja and R. Menis, "Steady-state performance degradation of a DTC IM drive under parameter and transduction errors," IEEE Transactions on Industrial Electronics, vol. 55, no. 4, pp. 1749–1760, 2008.

[25]M. Bertoluzzo, G. Buja, and R. Menis, "A direct torque control scheme for induction motor drives using the current model flux estimation," in Proceedings of the IEEE International Symposium on Diagnostics for Electric Machines, Power Electronics and Drives (SDEMPED '07), pp. 185–190, September 2007.