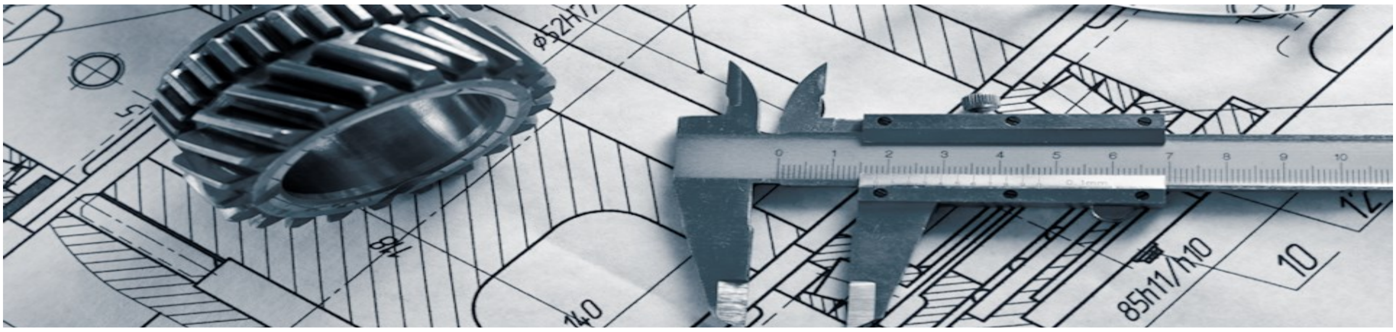
OPEN LOOP CONTROL OF NPC MULTILEVEL INVERTER USING SVPWM INDUCTION MOTOR DRIVE FOR ELECTRIC VEHICLE APPLICATION



Original Research Article

ISSN CODE: 2456-1045 (Online)
(ICV-EE/Impact Value): 3.08
(GIF) Impact Factor: 2.174

Journal Code: ARJMD/EE/V-10.0/I-1/C-7/FEB-2017
Category : ELECTRICAL ENGINEERING
Volume : 10.0 / Chapter- VII / Issue -1(FEBRUARY-2017)
Website: www.journalresearchijf.com
Received: 03.03.2017
Accepted: 08.03.2017
Date of Publication: 10-03-2017
Page: 34-38

Name of the Authors:

PRAVEEN O[1]

DR. NISHA G. K[2]

[1]*PG Scholar, Dept of EEE,*
Mar Baselios College of Engineering and Technology,
Trivandrum, Kerala, India.
praveentherealindian@gmail.com

[2]*Associate Professor, Dept of EEE,*
Mar Baselios College of Engineering and Technology,
Trivandrum, Kerala, India.
nishacharu@gmail.com

Citation of the Article

Praveen O. & Dr. Nisha G. K. (2017, February). Open Loop Control of NPC Multilevel Inverter Using SVPWM Induction Motor Drive for Electric Vehicle Application, Advance Research Journal of Multidisciplinary Discoveries.10.0,C-7(2017) 34-38 ISSN-2456-1045. http://www.journalresearchijf.com

ABSTRACT

This paper presents an efficient AC Drive for an Electric Vehicle (EV) using an induction motor. In this the use of induction motor requires implementing of multilevel inverter supplied by DC voltage source and switched using three level space vector PWM. In this paper a technique is implemented for a better control for electric vehicle using induction motor drives. Multilevel inverter have less distortion and Total Harmonic Distortion (THD) of output voltages compared to other inverters. SVPWM generates the required gate drive waveform for each PWM cycle. The inverter is treated as one single unit and can combine different switching states (number of switching states depends on levels). The model of the multilevel inverter system is fed with SVM method to control the induction motor for electric vehicle applications.The simulations are performed using MATLAB/SIMULINK software and the results are presented.

Keywords:

Drive system,
Electric vehicle,
Induction motor Multilevel inverter,
Neutral Point Clamped Inverter NPC,
Space Vector Pulse Width Modulation.

INTRODUCTION

The Induction Motor (IM) is best suited for the EV application because it has many advantage over other types of electric motors. For example, it is more reliable due to the absence of brushes, it is more rugged due to its inherent one piece rotor shaft, it is much safer when used in hazardous environments, and it presents a very low cost solution and has replaced the dc motor drives in industries.

The multilevel inverter MLI is one of the most promising converter topologies suitable for EV applications. The MLI has very interesting properties such less distortion and low total harmonic distortion on the output waveforms. It is also used for high and medium voltage power drives.

Selection of suitable switching schemes are needed for power electronic converter which is difficult in the area of ac drives. While using Pulse Width Modulation (PWM) for the control of the power electronic converter, duty ratio input should be in a specific range or it will create stability issues. Thus, the power conversion stage is playing a pivot role. So Space vector pulse width modulation is one of the recent techniques used for the switching of the power electronic circuits.

In this paper, a neutral point clamped MLI which is fed to induction motor powering an electric vehicle drive system is done. A three level space vector is used to generate switching pulses for the neutral point clamped MLI. The performance of overall proposed system is done for various operating conditions.

II. NEUTRAL POINT CLAMPED INVERTER

The three-level NPC inverter features higher operating voltage without devices in series, better output voltage THD, and lower electromagnetic interference (EMI). Therefore, it is increasingly used in high power applications. In the original invention, the concept can be extended to any number of levels by increasing the number of capacitors in the design [1]-[2]. The additional level is the neutral point of the dc bus, so the name neutral point clamped inverter was introduced [3].Early this topology were limited to three-levels where two capacitors are connected across the dc bus which resulted in one additional level [4]. Due to industrial developments over the past 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.

Since the structure is more complicated than that of two-level inverter, the operation is straight forward. 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_1 and S_2 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-ground voltage of zero or the dc voltage.

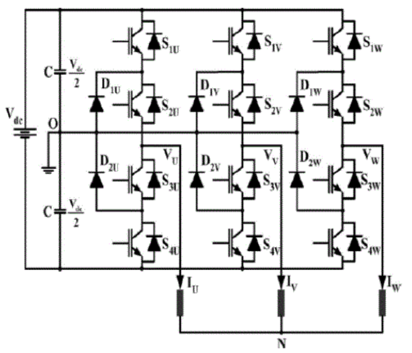


Fig.1 : Three level neutral clamped multilevel inverter.

III. THREE LEVEL SVPWM

Space vector pulse width modulation is much different from the PWM methods. With PWMs, the inverter can be considered as three separate push-pull driver stages which create each phase waveform independently. But, SVM treats the inverter as a single unit. More specifically the inverter can be driven to eight unique states. Modulation is accomplished by switching the state of inverter [8]-[10].

SVM is a digital modulation technique where the objective is to generate PWM load line voltages. This is done in each sampling period by properly selecting the switching states of inverter and calculation of the appropriate time period for each state [11]-[12].

3.1 Switching States

For a three-level three-phase inverter there are 27 switching states. It is requested to generate five levels of outputs, so the three-level can be created. These levels are $2V_{DC}$, V_{DC}, 0, -V_{DC} and -$2V_{DC}$ (for the line-to-line voltage).

Fig. 2 shows space vector diagram for a three-level inverter demonstrating 19 voltage vectors and 27 switching states.

But for the two-level inverter the reference vector is given with the help from three voltage vectors. For the three-level converter each sector also is divided into 4 regions, specifying the output even more.

Table 1 shows voltage vector. Based on the magnitude the voltage vectors can be defined as:

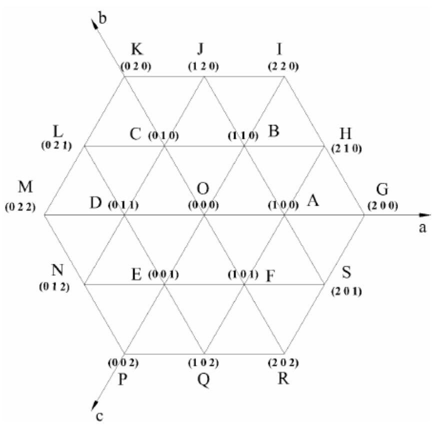


Fig. 2 : Space vector diagram for a three-level inverter demonstrating 19 voltage vectorsand 27 switching states.

Value of voltage vectors	Reduntant switching states
Zero Voltage Vectors (ZVV)	V=0
Small Voltage Vectors (SVV)	V1, 4,7,10,13,16
Medium Voltage Vectors (MVV)	V3, 6,9,12,15,18
Large Voltage Vectors (LVV)	V2, 5,8,11,14,17

Table 1 Voltage vectors

The principle of SVPWM method is that the command voltage vector is approximately calculated by using three adjacent vectors [13]-[15]. The duration of each voltage vectors obtained by vector calculations;

$$V^*Ts=(T_1V_1+T_2V_2+T_3V_3) \quad (1)$$

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

Where V_1, V_2, V_3 - vectors that define the triangle region in which V* is located. T_1,T_2,T_3 – corresponding vector durations. Ts - sampling time.

In a three-level inverter similar to a two-level inverter, each space vector diagram is divided into 6 sectors. Forsimplicity here only the switching patterns for Sector A will be defined so that calculation technique for the other sectors will be similar [16]. Sector A is divided into 4 regions as shown in Fig. 3, where all the possible switching states for each region are given as well. SVPWM for three-level inverters can be implemented by using the steps of sector determination, determination of the region in the sector, calculating the switching times, T_1, T_2, T_3 and finding the switching states[16].

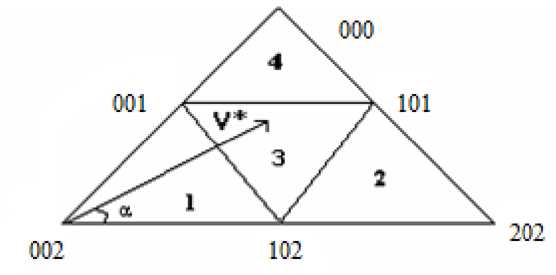


Fig. 3 Sector and its switching states for three-level inverter

3.2Determining the sector

The sector in which the command vector V* as shown in Table 2.

α	V* in sector
0° ≤ α < 60°	A
60° ≤ α < 120°	B
120° ≤ α < 180°	C
180° ≤ α < 240°	D
240° ≤ α < 300°	E
300° ≤ α < 360	F

Table 2 Sector selection

3.3 Determining the region in the sector

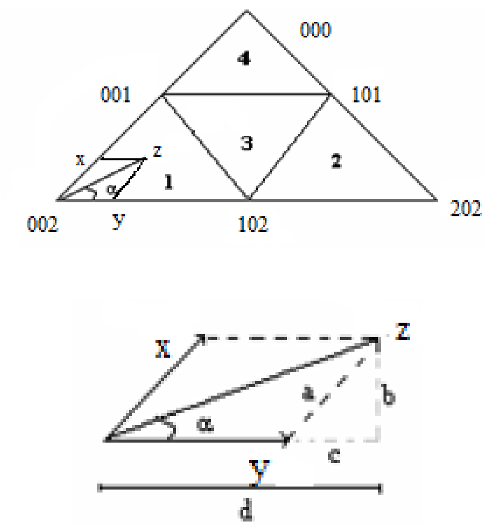


Fig. 4 Calculation of x and y

Table 4 shows value m_1 and m_2. The m_1 and $m_2$can be calculated as:

$$a = y = \frac{b}{\sin\frac{\pi}{3}} = \frac{2}{\sqrt{3}}b = \frac{2}{\sqrt{3}}z.\sin\alpha \qquad (3)$$

$$x = z.\cos\alpha - \left(\frac{2}{\sqrt{3}}\, z.\sin\alpha\right).\cos\left(\frac{\pi}{3}\right)$$

$$x = z.\left(\cos\alpha - \frac{\sin\alpha}{\sqrt{3}}\right) \qquad (4)$$

Value of x, y	V* Region
x+y>0.5	1
x> 0.5	2
y> 0.5	3
x and y< 0.5	4

Table 4 Value of x and y

3.4 Calculating the switching times, T_1, T_2, T_3

Table 5 shows the switching times T_1, T_2, T_3 for Sector A.

	Region I	Region II
T_1	1.1*m*T_s*sin((π/3)-α)	T_s* (1-1.1*m*sin(α+π/3))
T_2	T_s/2* (1-(2*1.1*sin(α+π/3))	1.1*T_s*m*sinα
T_3	1.1*T_s*sinα	T_s/2((2*1.1*m* sin(π/3-α))-1)
	Region III	**Region IV**
T_1	T_s/2* (1-2*1.1*m*sinα)	T_s/2* (2*1.1*m*sin(α)-1)
T_2	T_s/2* (2*1.1*m*sin(π/3+α)-1)	1.1*m*T_s* sin((π/3)-α)
T_3	T_s/2* (1+2*1.1*m*sin(α-π/3))	T_s* (1-1.1*m*sin(α+π/3))

Table 5 Switching time of T_1,T_2,T_3

IV. 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 [17]. The dynamic model is used to for getting the transient and steady state behaviour of induction motor.

The dynamic behaviour 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 [18]-[19].

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 [20]-[24].

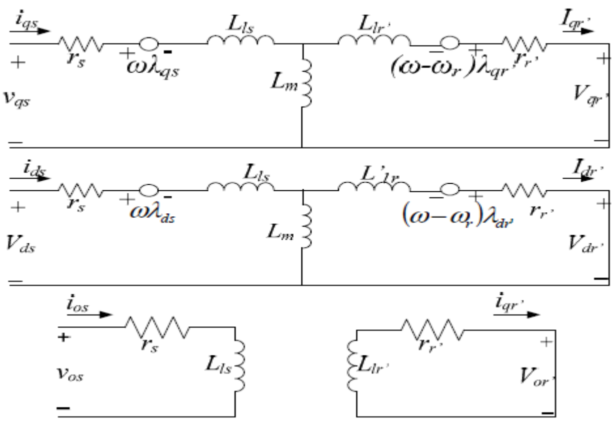


Fig.5. Equivalent Circuit diagram of induction motor in dqo.

V. DRIVE SYSTEM

The mechanism that transmits the power developed by the motor of automobile to the driving wheels is called the transmission system (or power train). In automobiles the differential allows the outer drive wheel to rotate faster than the inner drive wheel during a turn. A clutch is a mechanism which enables the rotary motion of one shaft to be transmitted at will to second shaft, whose axis is coincident with that of first. A gear is a rotating part having cut teeth which mesh with another toothed part to transmit torque. Geared devices can change the speed, torque, and direction of a power source.

VI. RESULTS AND DISCUSSIONS

An induction motor drive for electric vehicle was discussed in the paper using NPC multilevel inverter with space vector modulation. This has been done using MATLAB/SIMULINK. When the induction motor torque reaches to 200 Nm then only the Electric vehicle starts to move and as torque values reduces the speed of electric vehicle increases to the 155 Km/hr.

Fig 6 represents the overall proposed system, Fig 7,8,9 represents the output voltage from inverter, stator current of induction, and Torque and Speed of induction motor. Fig 10 shows the simulation of drive system and Fig 11 shows the speed characteristics of electric vehicle.

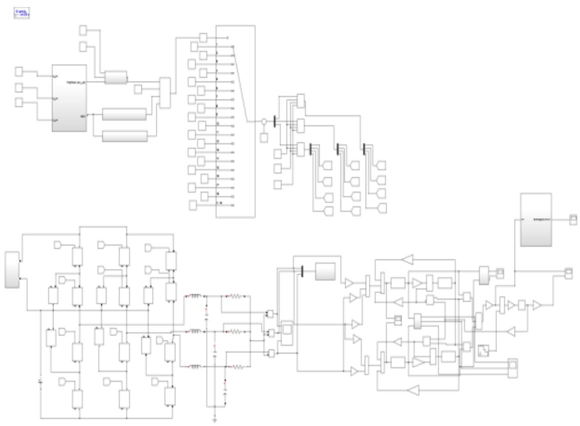


Fig 6 Overall proposed system

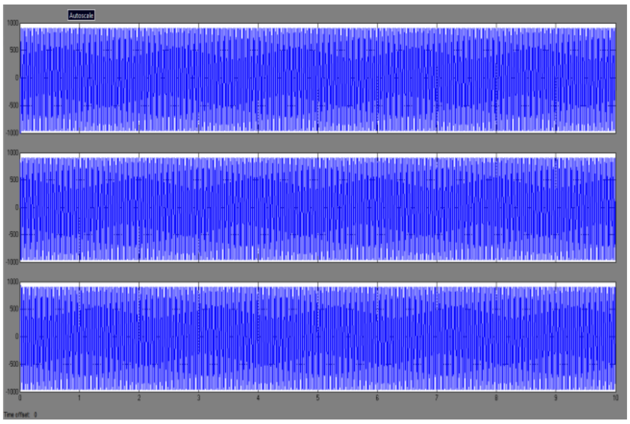


Fig 7 output voltage from inverter

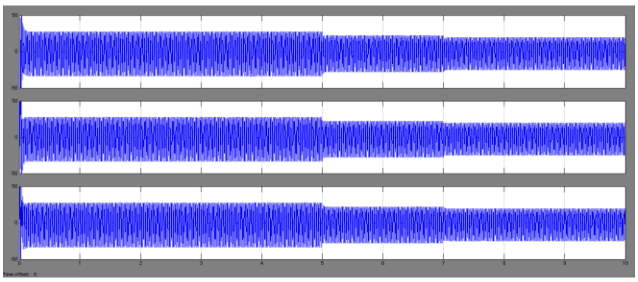


Fig 8 stator current of induction

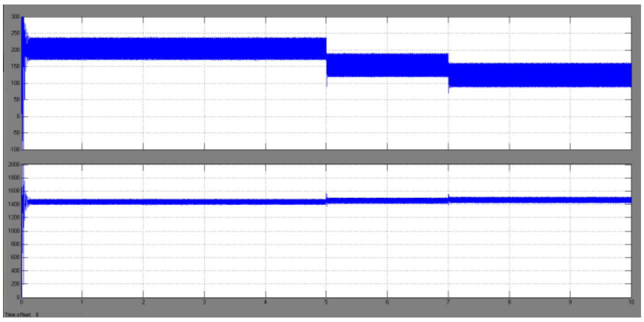


Fig 9 Torque and Speed of induction motor

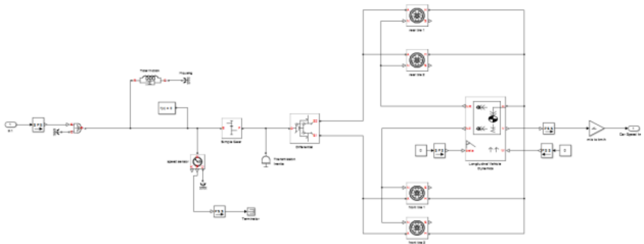


Fig 10 Simulation of Drive system

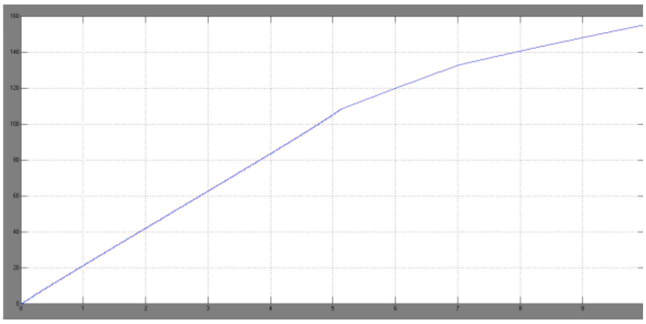


Fig 11 Speed characteristics (km/hr) of Electric vehicle

VII. CONCLUSION

The simulation of three level Neutral clamped multilevel inverter fed induction motor was carried out using space vector pulse width modulation for electric vehicle application. The performance of the inverter and induction motor has been done using MATLAB/SIMULINK. From the results it is obtained as when starting torque is high then only vehicle will start to move and the torque of induction motor decreases the vehicle speed increases.

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 Capacitor clamped multilevel and Diode Clamped Multilevel Inverters Using SPWM,” *International Journal of Innovative Science, Engineering and Technology(IJISET),* vol. 3, no.8, pp.387-393,August 2016.

[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 of a 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 Capacitor clamped multilevel 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 Zheng Peng, "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, Samir Kouro, 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] Kalle Ilves, Antonios Antonopoulos, Staffan Norrga, 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 Capacitor clamped multilevel 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] 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.

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

[22] G. K. Nisha, Z. V. Lakaparampil and S. Ushakumari, "Effect of Leakage inductance on Torque Capability of Field Oriented Controlled Induction Machine in Field Weakening Region," International Conference on Advances in Engineering and Technology (ICAET'2014), Singapore, 29-30 March 2014

[23] G. K. Nisha, Z. V. Lakaparampil and S. Ushakumari, "Sensorless Field Oriented Control of SVM inverter fed Induction Machine in Field Weakening Region using Sliding Mode Observer," 7th *World Congress oF Engineering (WCE'2013),* Imperial College, London, U.K., pp. 1174-1181, 3-5 July 2013.

[24] G. K. Nisha, Z. V. Lakaparampil and S. Ushakumari, "Four-quadrant Operation of Sensorless FOC Induction Machine in Field Weakening Region Using MRAS-Sliding Mode Observer," IEEE International Conference on Control Communication and Computing (ICCC'2013), Thiruvananthapuram, pp. 33-38, 13-15 December 2013.