ISSN 2348 – 9928
IJAICT Volume 6, Issue 2, February 2019 Doi:01.0401/ijaict.2015.05.05 Published on 05 (2) 2019

RANDOM PWM BASED OPEN END WINDING INDUCTION MOTOR DRIVE

Ms. K. Hema Gowthami, Ms. V. Anantha Lakshmi, Mr. G. Satheesh
Department of EEE,
G.Pulla Reddy Engineering College,
Kurnool, Andhra Pradesh, India.

Abstract—This paper proposes a simplified space vector based Random Pulse Width Modulation scheme for open end winding induction motor drive. In this paper randomization is achieved by placing effective vector randomly in the switching time period.The offset time is obtained from the instantaneous reference phase voltages. The proposed scheme uses no sector identification. No external circuitry is required for generating switching vectors.The proprsed scheme is not having any compelex calculations like angle calculations.

Keywords— Open-end winding, RPWM, SVPWM, Space vector based RPWM

I. INTRODUCTION

The multilevel inverters have the advantages of low output distortion, reduced stress on power switches and lower common mode voltage [1], [4]. In the field of medium and high power applications, multilevel inverters have merged as an attractive option. Several multi level inverter topologies have been proposed in [1]-[5] major among the proposed topologies are diode clamped, flying capacitor, cascaded and open end winding induction motor based multilevel inverter.

There are different drawbacks like acoustic noise, vibration and electromagnetic interference due to the concentration of power at harmonics of switching frequency in deterministic pulse width modulation that are proposed in [10]. In order to reduce these effects random PWM (RPWM) techniques have been proposed in [6]-[16]. The main principle of random PWM is to spread harmonic spectrum by introducing randomness to PWM switching signal. Three major techniques for random modulation have been proposed in [10]. They are random switching, random pulse position and random switching frequency. Random switching frequency and constant switching frequency techniques have been proposed in [7]-[9] among these two constant switching frequency methods are attractive due to easiness in implementation.

Many RPWM schemes that used carrier based modulation techniques are proposed in [6]-[9], [11]-[13], [16]. But there are few SVPWM implementations proposed in [6], [12], [11] that ensured easy digital implementation and better utilization of dc bus where as general SVPWM has many drawbacks. Recently RPWM techniques are extended for 3-level inverters proposed in [13]-[16]. In this paper 3-level inverter based on open-end winding induction motor is proposed.

This paper proposes a fixed switching frequency space vector based random PWM scheme, which combines the advantages of both topology and modulation scheme. In this proposed scheme, randomization is introduced by placing the effective vectors randomly in every switching period. The switching vector is automatically obtained from the instantaneous reference phase voltages. The proposed scheme requires no sector identification. There is no need of look up tables for generation of switching vector.

II. DUAL INVERTER FED OPEN-END WINDING CONFIGURATION

Fig. 1 shows a 3-level inverter structure realized by feeding an open-end winding induction motor with two 2-level inverters from both ends. The open-end winding induction motor is obtained by opening the neutral point of the star windings of conventional three phase induction motor and feeding the motor from either end using inverters. The inverters use isolated DC links of ½ v_{dc} each. The pole voltage of individual inverter can achieve two levels viz. ½ v_{dc} and 0. Depending upon the pole voltages of inverter-1 and inverter-2, the phase voltage of 3-phase induction motor can have three levels viz. -½ v_{dc} , 0 , ½ v_{dc}. The switching vectors of two level inverter when applied from the both ends of an open-end winding induction motor, produces space vector locations equivalent to that of a 3-level inverter as shown in fig. 2.As each inverter is capable of assuming 8 states independently of the other, a total of 64 space vector combinations are possible with this circuit configuration. It is a hexagonal structure with inner one sub hexagon and six outer sub hexagons. The 64 locations for all space vector combinations and 24 sectors of the two inverters are shown in Fig. 2.

ISSN 2348 – 9928
Doi:01.0401/ijaict.2015.05.05 Published on 05 (2) 2019

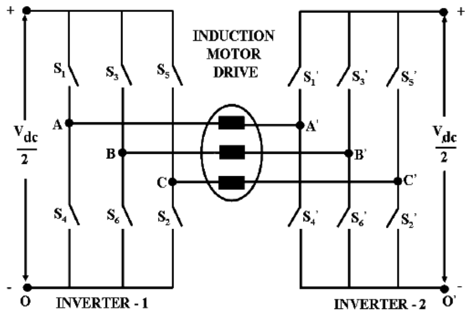


Fig 1 : Dual inverter fed 3-phase induction motor

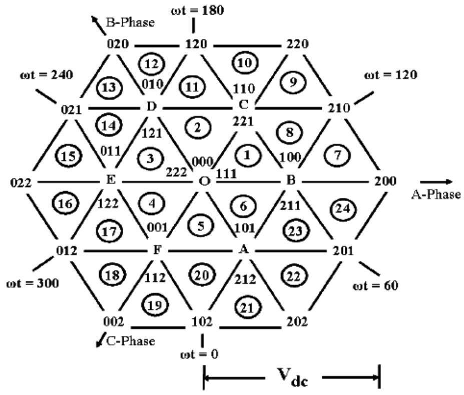


Fig 2 : Space vector diagram for 3-level inverter

Six hexagons can be identified with their centers located at A, B, C, D, E, and F respectively. In addition there is one inner hexagon with its center 0.

III. SVPWM AND RPWM

3.1 SVPWM

Fig. 5 shows the space vector diagram for 3-level inverter with reference space vector OT as shown. In the following figure, vector OT is located in sector 9 (in the triangle CJI). It is resolved into two components OC and CT. Since the reference vector OT can be viewed as sum of these two vectors. The sub hexagon center near to the tip of reference vector is realized by switching Inverter-1 from one side of motor, and CT is realized by feeding opposite vector of CT from the other side of motor from Inverter-2.Their is no need of any translational circuitry for generating gating signal for Inverter-1.This process is discussed to explain the principle of operation, but the center of sub hexagon, which contains the tip of OT, can be identified directly from the instantaneous amplitudes of 3-phase reference voltages.

From the Fig. 3, we can see that there are two layers L_1 and L_2 which are in two different shades [17]. The position of reference vector can be found out by projecting three instantaneous reference phase voltages into three axes j_a, j_b, and j_c as shown in figure. Let v_{jmax} be the maximum magnitude among all projections, depending upon the ($|v_{jmax}|$) is less than or greater than the$\sqrt{3}*V_{dc}/4$, position of reference vector is identified. If the reference vector lies in L_1 there is no requirement of mapping. If reference vector lies in L_2 the center of sub hexagon is determined from the instantaneous magnitudes of 3-phase reference signal. Fig.5 illustrates the scheme of finding sub hexagon center. If the magnitude of Si/ne wave is positive it is taken as “1”, and if the magnitude is negative then it is taken as “0” [18][16].From the normalized instantaneous voltages figure, it may be noted that from *wt=60* to *wt=120*,we can see that v_a is more positive, and B is the nearest sub hexagonal center as recognized.

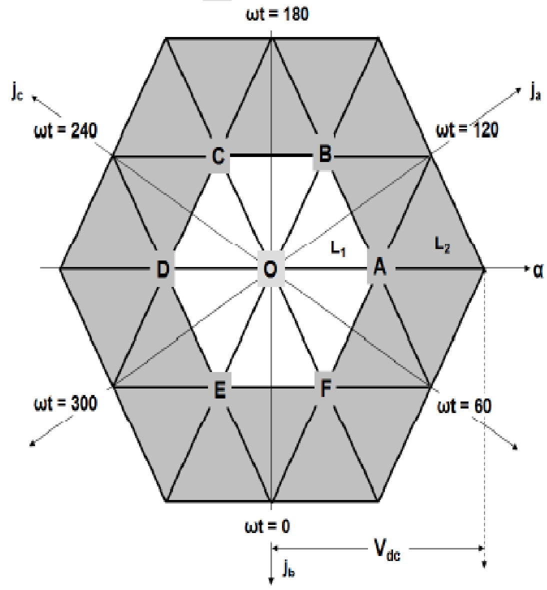


Fig 3 : Space vector diagram of a 3-level inverter, with layers L_1 and L_2 indicated

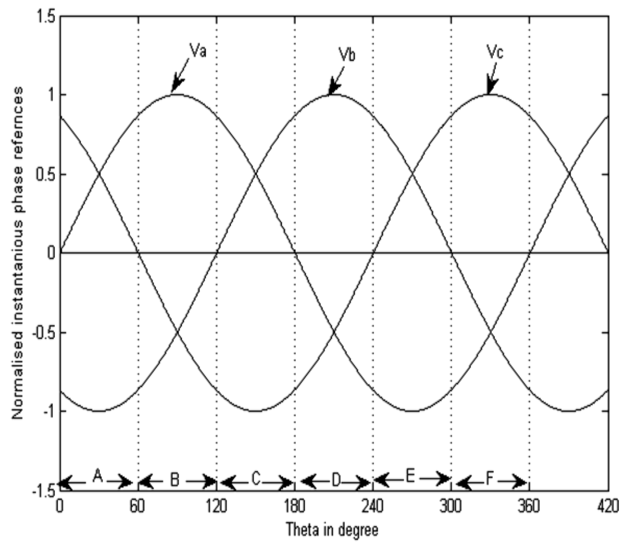


Fig. 4.: 3-Phase reference signal and sub hexagon centers

Thus it is clear that by finding the maximum value amongst these quantities, one can determine the nearest sub hexagonal center. sub hexagon centre vector can be used for driving Inverter-1.

ISSN 2348 – 9928
Doi:01.0401/ijaict.2015.05.05 Published on 05 (2) 2019

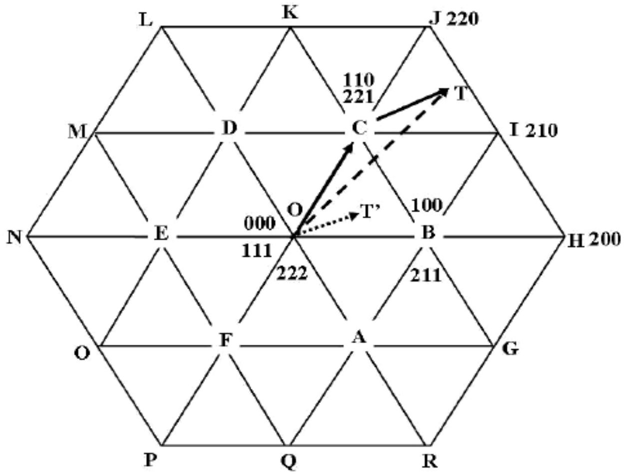


Fig. 5 : Space vector diagram of3-level inverter, indicating Reference vector OT and mapped reference vector OT'

.

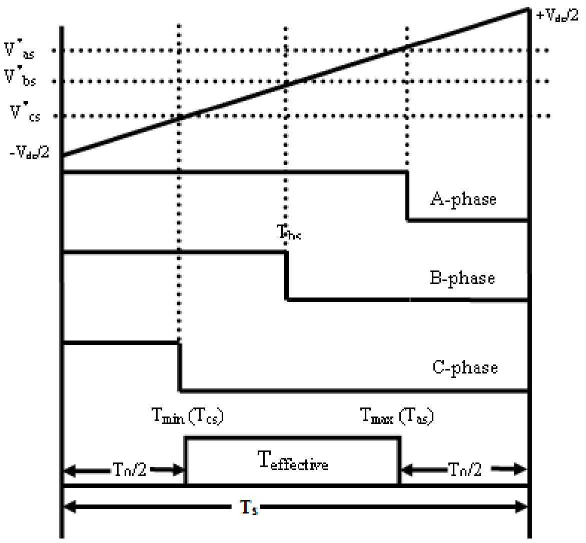


Fig. 6 : Instantaneous mapped reference signals, corresponding gating pulses and effective switching time[18]

After identification of sub hexagon center (α, β); the coordinates of sub hexagon center are calculated (v_α, v_β), that is near tip of the reference vector OT as shown in Fig. 5. The (α, β) coordinates of mapped reference vector OT' are obtained from subtracting the (α, β) coordinates of tip of OT. From the Fig. 5 we can observe that OT' lying in sector1. By using a simple method we can determine the switching time of two level inverter [19]. It is calculated by relation between switching time of inverter legs and amplitudes of reference signals. This process is simple by considering unified voltage modulation. Where there is proportionality between time and voltage it is given by (where *x*ϵ *a, b, c)*

$$T_{xs} = \left(\frac{T_s}{V_{dc}}\right) V_{xs} \qquad (1)$$

The switching time could be negative in case where negative phase voltage is required, where it is called as "imaginary time". From Fig. 6 we can see that; when the switching starts of each phase become 0 from 1 at different times during one sampling interval, an effective voltage (T_{eff}) is applied on load side.

$$T_{eff} = T_{\max} - T_{\min} \qquad (2)$$

Time shift is applied to imaginary times and added with the offset time in order to obtain the actual gating signals.

$$T_{gx} = T_{xs} + T_{offset} \qquad (3)$$

In SVPWM, centralized pulses are obtained by relocating effective vector at the center of sampling period by adding an offset given by

$$T_{offset} = \frac{T_o}{2} - T_{\min} \qquad (4)$$

Where $T_o = T_s - T_{eff}$

In order to generate a symmetrical pulse pattern within two sampling intervals, the actual switching signals will be replaced by subtracting value with sampling time [19].

$$T_{gx} = T_s - T_{gx} \qquad (5)$$

3.2 *RPWM*

Random pulse width modulation techniques are used to achieve spread spectrum characteristics in the output voltage spectrum of VSI. RPWM based multilevel inverters have less acoustic noise and reduced electromagnetic interference [2]. Recently RPWM techniques are extended for 3-level inverters also [13]-[16].Decoupled random modulation technique is adopted for 3-level inverters in order to achieve spread spectrum characteristics of output voltage. RPWM scheme with weighted switching decision achieves many advantages. Random frequency space vector based RPWM; with the concept voltage balancing in case of linked capacitors improves the unbalancing in input voltage in capacitors and also reduces the mechanical stress.

IV. PROPOSED PWM TECHNIQUE

4.1 *Space Vector based RPWM*

Fig.8 shows the gating signals for the proposed scheme and SVPWM. The gating signal T_{ga} is smoothly varying for SVPWM therefore we can see a clear signal, T_{ga} signal shows the abrupt variations in amplitudes in case of proposed scheme which is due to random placement of active vectors.

4.2 *Process of Randomization*

The process of randomization for 2-level inverter is done by switching zero vector and effective vectors with effective randomly placed in sampling time period. The random offset time and T_{ran} should be in limits in order to ensure the positioning of effective vectors within the sampling time.Fig.9

ISSN 2348 – 9928
Doi:01.0401/ijaict.2015.05.05 Published on 05 (2) 2019

shows the placement of vectors for middle, medium and maximum values of offset.

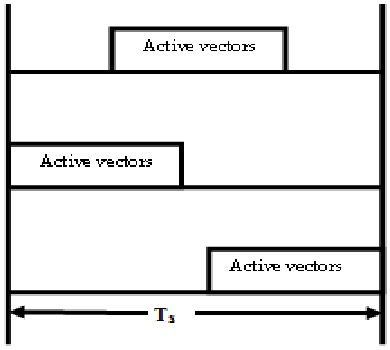


Fig. 7 : Placement of active vectors for middle, minimum and maximum values of offset

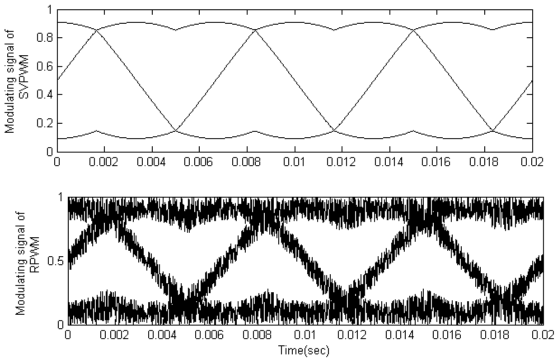


Fig. 8. : Modulating signals of SVPWM and RPWM

$$T_{off\,\min} = -T_{\min}$$

$$T_{off\,\max} = T_S - T_{\max}$$

Random offset is obtained by subtraction of T_{offmax} from T_{offmin} with uniform distributed random number which varies between 0 and 1; and is added to $T_{offmin.}$

$$(T_s - T_{max} + T_{offmax})Ran - T_{offmin} + T_{xs} = T_{gx} \quad (6)$$

V. SIMULATION RESULTS

In order to analyze the proposed PWM schemes, computer simulations are carried out using MATLAB. The DC source voltage of 270 volts is given to each inverter and switching frequency is kept at 1.5KHZ. From Fig. 9. we can see that synthesized 3-level voltage waveform using open end winding induction motor with 2-level inverters. Fig.9. and Fig.10 show the voltage waveforms for both SVPWM and RPWM.

Figs.11. and 12 show the speed, torque and current waveforms at transient and steady state for SVPWM and proposed PWM scheme.

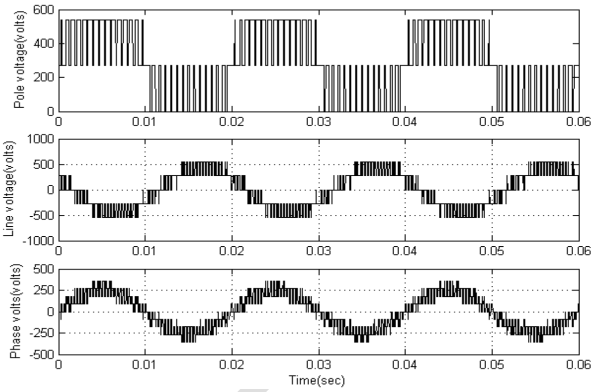


Fig. 9 : Simulation waveform of output voltage for SVPWM

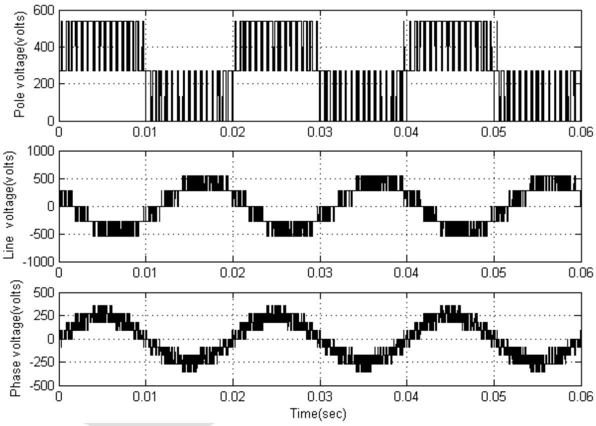
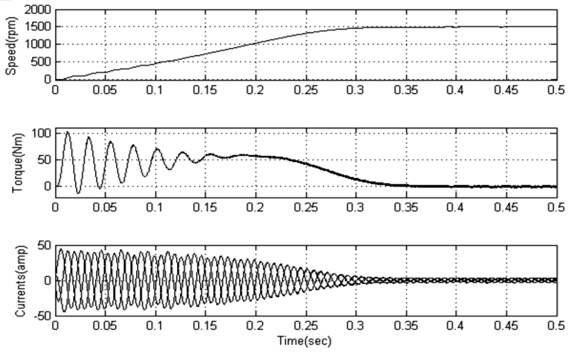
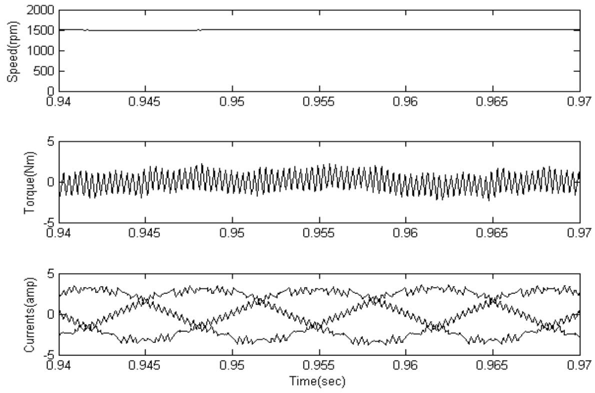


Fig. 10 : Simulation waveform of output voltage for RPWM



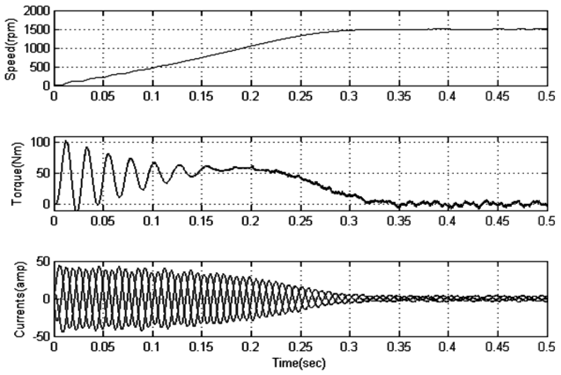
(a)



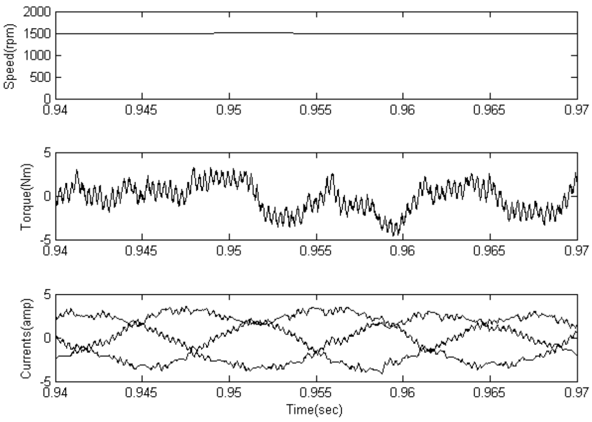
(b)

Fig 11 :(a) Simulation waveform of speed, torque and current of induction motor with SVPWM(b) at steady state

ISSN 2348 – 9928
Doi:01.0401/ijaict.2015.05.05 Published on 05 (2) 2019

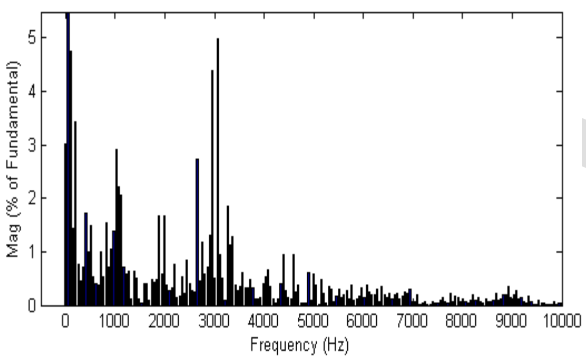


(a)

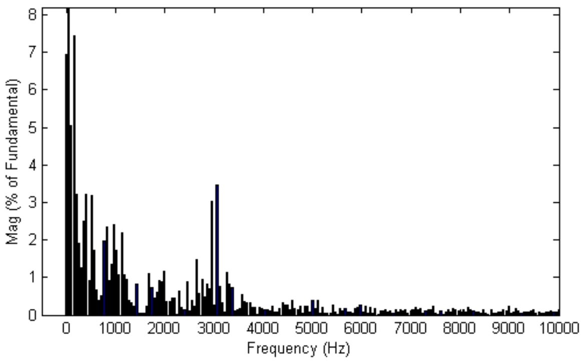


(b)

Fig. 12 : .(a) Simulation waveform of speed, torque and current for induction motor with RPWM (b)at steady state



(a)



(b)

Fig.13. Normalized FFT for (a) SVPWM (b) RPWM

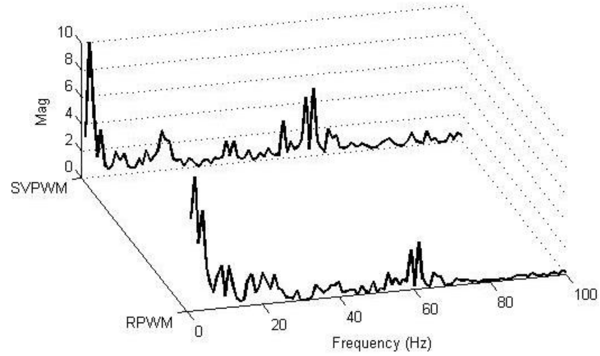


Fig. 14. Comparison of magnitude of THD for SVPWM and RPWM

Figs.13.(a) and (b)shows the magnitude of harmonics for SVPWM and proposed technique. It is clear that there is reduction of magnitude of harmonics at switching frequency around 3.5 to 4 in case of proposed scheme, where as in SVPWM it ranges from 4.5 to 5 and also we can see spread spectrum of harmonics.. Fig. 14. shows the spread of harmonic spectra for both SVPWM and RPWM which is less in case of proposed RPWM scheme. Reduction of harmonic effect decreases the acoustic noise, temperature effect and increases the performance of induction motor.

VI. CONCLUSION

In this paper a space vector based random PWM scheme for open end winding induction motor drive is presented. The switching vectors for dual inverters are generated without using any lookup tables .The proposed method does not involve in complex computations like sector identification and angle calculations. The process of randomization is achieved by random placement of effective vectors in the switching period. The offset is calculated from instantaneous values 3-phase reference signal. The reduction of magnitude of THD and a spread spectrum is achieved in this proposed technique when compared to the conventional SVPWM. This proposed scheme can also implimented in real time also because it is operated at low frequencies compared with conventional 3-level inverter circuit.

References

[1] Rodrígue, Jih-Sheng Lai, and Fang Zheng Peng, “Multilevel Inverters: A Survey of Topologies, Controls, and Applications,” IEEE transactions on industrial electronics, vol. 49, no. 4, August 2002.

[2] Shivakumar, E.G., Gopakumar, K., Sinha, S.K., Pittet, A., and Ranganathan, V.T, “Space vector PWM control of dual inverter fed open-end winding induction motor drive,” EPEJ. 2002 12, (1) pp. 9-18

[3] Stemmler H, and Guggenbach P. “Configurations of High Power Voltage Source Inverter drives,” EPE Conf. Brighton UK 1993 pp 7-12

[4] Baiju, M.R., Mohapatra, K.K., and Gopakumar, K., “PWM signal generation for dual inverter fed open-end winding induction motor drive using only the instantaneous reference phase amplitudes,” The Fifth

ISSN 2348 – 9928
Doi:01.0401/ijaict.2015.05.05 Published on 05 (2) 2019

International Conference on Power Electronics and Drive Systems, 2003 Volume 1, pp. 450 - 455

[5] Samir Kouro, Mariusz Malinowski, K. Gopakumar, Josep Pou, Leopoldo G. Franquelo, BinWu, Jose Rodriguez, Marcelo A. Pérez, and Jose I. Leon, "Recent Advances and Industrial Applications of Multilevel Converters," IEEE Trans. Industry Elecl. Vol 57, No.8, pp 2553- 2579 Aug. 2010

[6] Hamid Khan, Youssef Touzani, and Khalil El Khamlichi Drissi, "Random Space Vector Modulation for Electric Drives: A Digital Approach," 14th International Power Electronics and Motion Control Conference, EPE-PEMC pp 20-24, 2010

[7] Victor Adrian, Joseph S. Chang, and Bah-Hwee Gwee, "A ramdomized wrapped-around Pulse Position Modulation Scheme for DC-DC converters," IEEE Trans. On Circuits and Systems. Vol. 57, No.9, pp 2320-2333 Sept. 2010

[8] Trzynadlowski, A.M. Borisov K., Yuan Li, and Ling Qin, "A novel random PWM technique with low computational overhead and constant sampling frequency for high-volume, low-cost applications," IEEE Trans. Power Electronics. Vol 20, issue 1, pp 116- 122, 2005.

[9] M. M. Bech, F. Blaabjerg, and J. K. Pedersen, "Random modulation techniques with fixed switching frequency for three phase power converters," IEEE Trans. On Power Electronics, vol 15, pp 753 – 761, 2000

[10] Andrzej M. Trzynadlowski, Frede Blaabjerg, John K. Pedersen, R Lynn Kirlin, and Stanislaw Legowski, "Random Pulse Width Modulation Techniques for Converter-Fed Drive Systems- A review," IEEE Transactions on Industry Applications, vol. 30, pp. 1166-1175, September / October 1994

[11] AS de oliveira, ER da Silva, C B Jacobina, and AMN Lima, "Random Space Vector Modulation for 3-Level Power inverters and Induction Motor Drives Current Control", PESC, pp 987 – 993, 2005

[12] C.K. Lee, S.Y.R. Hui, and H.S.H. Chung, "A randomized voltage vector switching scheme for 3-level power inverters," PESC 2000, vol. 1, pp. 27-32

[13] Shrivastava,Y, and Hui, S.Y. "Analysis of random PWM switching methods for three-level power inverters," IEEE Transactions on Power Electronics, Volume 14, Issue 6, pp.1156 – 1163 Nov. 1999

[14] L Mathe, F. Lunguanu, PO Ramuseen, and John K. Pedersen, "Asymetric Carrier Random PWM," IEEE International Symposium on Industrial Electronics (ISIE), pp 1218 – 1223, 2010.

[15] Ki-Seon Kim, Young-Gook Jung, and Young-Cheol Lim," A New Hybrid Random PWM Scheme", IEEE Trans. Power Electronics. Vol 24, issue 1, pp 192-200, 2009

[16] Shiny G., Baiju, M.R.," Space Vector PWM scheme without sector identification for an open-end winding induction motor based 3-level inverter," IECON 2009, pp 1310 – 1315

[17] Aneesh Mohamed A. S., Anish Gopinath, and M. R. Baiju, "A Simple Space Vector PWM Generation Scheme for Any General n-Level Inverter," IEEE Trans. on Ind. Electronics, Volume 56, Issue 5, pp.1649 – 1656 May 2009.

[18] P.F. Seixas, M.A. Severo Mendes, P. Donoso Garcia, and A.M.N. Lima, "A space-vector PWM method for three-level voltage source inverters," in Proc. IEEE APEC, 2000, vol. 1, pp. 549-555

[19] D W Chung, J S Kim, Seung-Ki Sul "Unified voltage modulation technique for real Time Three Phase power Conversion," IEEE Trans. On Industry Applications, Volume 34, No.2, pp. 374-380, March/April 1998.

[20] H. W. Van Der Broeck, H.-C. Skudenly, and G. V. Stanke, "Analysis and realization of a pulsewidth modulator based on voltage space vectors," IEEE Trans. Ind. Appl., vol. 24, no. 1, pp. 142–150, Jan./ Feb. 1988

[21] David Solomon George, M. R. Baiju," Decoupled Random modulation technique for an open-end winding induction motor based 3-level Inverter," IEEE Symposium on Industrial Electronics and Applications (ISIEA) pp 1022-1027, 2009

Corresponding Author: Ms. K. Hema Gowthami, G. Pulla Reddy Engineering College, Kurnool, India.