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Decoupled Space Vector PWM for Dual inverter fed Open End winding Induction motor drive

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Abstract— An open-end winding induction motor, fed by two 2-level inverters connected at either end produces space vector locations, identical to those of a conventional 3-level inverter. In this paper, a switching algorithm is proposed to implement space vector PWM for the dual inverter scheme. The proposed algorithm does not employ any look-up tables. The time consuming task of sector identification is altogether avoided in both these algorithm. The proposed algorithm employs only the instantaneous reference phase voltages for the implementation of the space vector PWM. The harmonic content of the three phase currents in the motor are analyzed with an appropriate variation in its modulation index in both the proposed algorithm and two level inverter fed induction motor compared simultaneously. Thus the performance in terms of harmonic analysis is carried out using MATLAB/SIMULINK for an open end induction motor drive.

Index Terms— Cascaded Inverters, Decoupled PWM strategy, Dual-inverter, Open-end winding induction motor, Space vector modulation, V/f Control.

1 Introduction

VARIOUS PWM schemes are presented for the two-level inverters and their effects on the load are also continuously investigated. Thrive to get improved performance is on the anvil employing suitable PWM techniques [1]-[6] or using multi-level inverters. Multi-level inverters are finding increasing research opportunities and it is clearly evident in the past few years. This is due to the reduced total harmonic distortion (THD) in the output voltage and genesis of higher voltage with use of series connections of lower voltage rating switching devices. Various derivative of this power circuit and the associated PWM schemes are also reported in the recent past [6]-[14]. Two space vector modulation techniques are suggested, which obviate the need for the sector identification. Also these PWM schemes do not employ any look-up table, thus reducing the memory requirement. Fig.1 shows the basic open-end winding induction motor drive operated with a single power supply. The symbols vao, vbo and vco denote the pole voltages of the inverter-1.Similarly, the symbols va'o, vb'o and vc'o ' denote the pole voltages of inverter-2.

The space vector locations from individual inverters are shown in Fig.2. The numbers 1 to 8 denote the states assumed by inverter-1 and the numbers1" through 8" denote the states assumed by inverter-2[1-5]. Table-1 summarizes the switching state of the switching devices for both the inverters in all the states. In Table-1,a „+" indicates that the top switch in a leg of a given inverter is turned on and a „-" indicates that the bottom switch in a leg of a given inverter is turned on. 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 .The space vector locations for all space vector combinations of the two inverters are shown in Fig.3. InFig.3, |OA| represents the DC-link voltage of individual inverters, and is equal to Vdc/2 while |OG| represents the DC-link voltage of an equivalent single inverter drive, and is equal to *Vdc*.

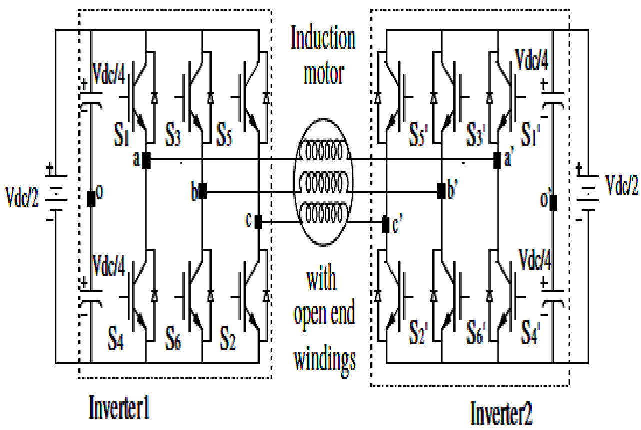

Fig.1: Power circuit configuration of dual two-level inver-

2 Decoupled PWM scheme

The reference voltage vector to be realized by the dual inverter is shown as Vref in Fig.2. It can be resolved into two equal and opposite half components as Vref /2 and −Vref /2. The vector addition of the later and the former results in the generation of actual reference vector as:

$$Vref = Vref/2 - (-Vref/2) \quad (1)$$

These individual reference voltages are synthesized sepa-

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TABLE 1
SWITCHING STATES OF THE INDIVIDUAL INVERTERS

state of inverter 1	Switches turned on	State of Inverter-2	Switches turned on
1 (+ - -)	S6, S1, S2	1' (+ - -)	S6', S1', S2'
2 (+ + -)	S1, S2, S3	2' (+ + -)	S1', S2', S3'
3 (- + -)	S2, S3, S4	3' (- + -)	S2', S3', S4'
4 (- + +)	S3, S4, S5	4' (- + +)	S3', S4', S5
5 (- - +)	S4, S5, S6	5' (- - +)	S4', S5', S6'
6 (+ - +)	S5, S6, S1	6' (+ - +)	S5', S6', S1'
7 (+ + +)	S1, S3, S5	7' (+ + +)	S1', S3', S5'
8 (- - -)	S2, S4, S6	8' (- - -)	S2', S4', S6'

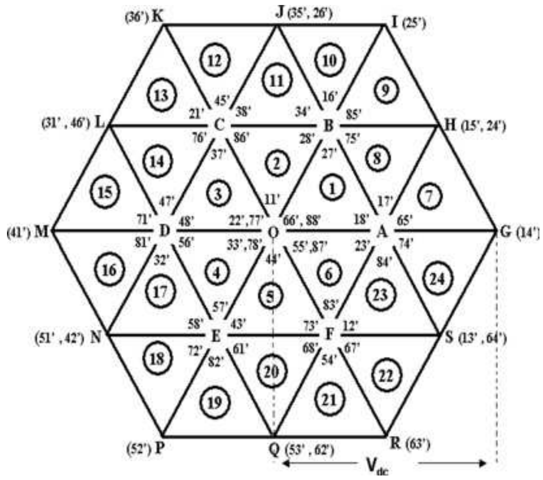


Fig.2: Space vector locations of dual two-level inverter

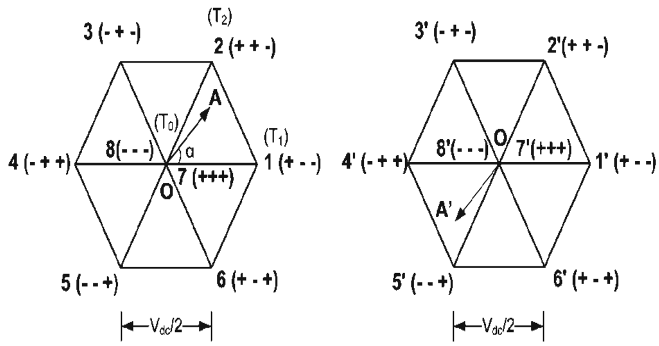


Fig. 3: space vector locations of the two inverters

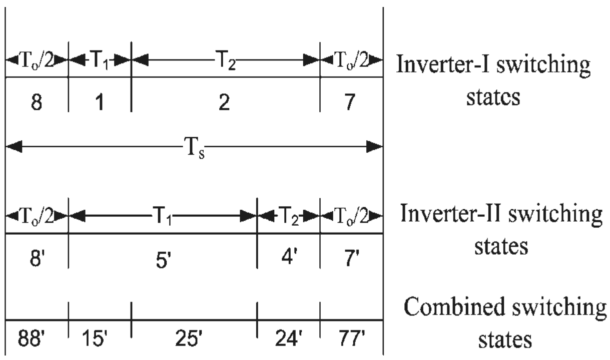


Fig .4: Timing distribution of the switching states for two inverters in one sampling interval

rately by the two two-level inverters using SVPWM and are depicted in Fig.2 The resultant voltage can be

$$Vo\angle\theta=Vo1\angle\theta-Vo2\angle\,(180+\theta) \qquad (2)$$

The voltage vector Vo1 is synthesized by inverter-1 and Vo2 by inverter-2 respectively and are given as:

$$Vo1=va0ej0+vb0ej2\pi3+vc0ej4\pi3 \qquad (3)$$
$$Vo2=va'0ej0+vb'0ej2\pi3+vc'0ej4\pi3 \qquad (4)$$

where vao, vbo, vco are three-phase pole voltages of inverter-1 and va'o, vb'o ,vc'o are three-phase pole voltages of inverter-2 The actual vector can now obtained using the vectors defined in eqns (3) & (4) as:

$$Vo=Vaa'ej0+Vbb'ej2\pi3+Vcc'ej4\pi3 \qquad (5)$$
$$Vaa'=Vao-Va'o \qquad (6)$$
$$Vbb'=Vbo-Vb'o \qquad (7)$$
$$Vcc'=Vco-Vc'o \qquad (8)$$

Where vaa', vbb', vcc' are the three-phase phase voltages of the dual-inverter fed induction motor drive.

3 PROPOSED SVPWM ALGORITHM

The inverter-I and inverter II are operated with a reference voltage space vector of Vref/2 and –Vref/2. Therefore, both the inverters will generate a same fundamental phase voltage with a phase shift of 180˚. So both the winding coils will see the same fundamental voltage. Since the stator windings are magnetically coupled, the induction motor will see a voltage space vector with a magnitude of Vref, and the resultant voltage space vector will result in a three level inverter structure. The common mode voltage will be present between the terminals A2A3, but the common mode current will not get any path to flow.

For example, considering one sampling period (Ts), the reference vector OA (|Vref/2|<180+α) shown in fig .3 can be generated with a sequence of switching states 8-1-2-7 for inverter-I and 8′-5′-4′-7′ for inverter-II. The resultant switching sequence is 88′-15′-25′-24′-77′ as shown in fig 5. Note that the presence of switching states 15′,25′ and 24′ in fig 5 implies that space vector locations on a three level structure is being utilized. In the present work the reference waveforms for two-level inverters are 180˚ phase shifted. But the resultant flux produced in the air-gap of the machine by the two groups gets added because of the winding arrangement of the drive (fig .1)

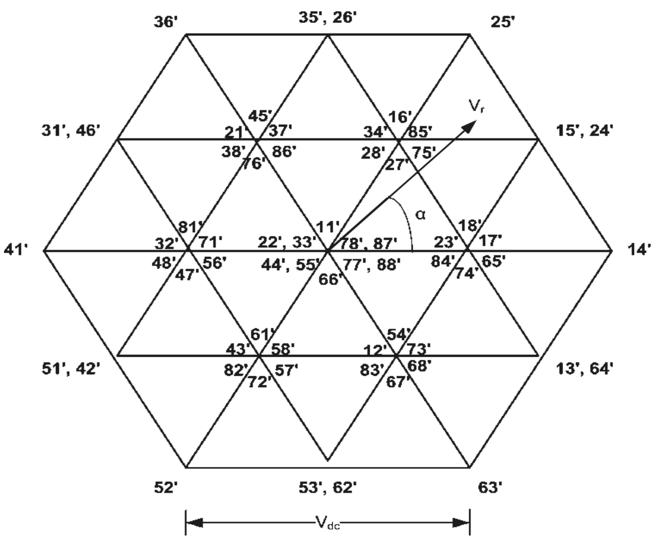


Fig .5 Space vector location of open-end winding three-level inverter

Moreover, in a carrier based PWM scheme, in which the modulating waveforms are 180˚ phase shifted, results in the addition of the fundamental waveforms and the cancellation of the first centre band at carrier frequency and its side bands. Now the high amplitude harmonics will appear at the side bands of twice the carrier frequency. This can be effectively utilized for reducing the switching frequency of the inverters nearly to half, when compared to a conventional scheme where the first high amplitude harmonics appear at the carrier frequency and at its side bands. The above scheme presented in this paper doesn't require any special design for the induction machine. It is sufficient to take the pole pair phase belt winding tapping from the conventional four pole induction machine. All the schemes can be realized with half the DC link voltage compared to a conventional scheme.

Hence the three level voltage space vector has been generated with the help of open end winding induction motor with dual two level inverters.

4 Simulated Results and Discussion

To validate the proposed PWM method, simulation studies have been carried out using MATLAB-SIMULINK. For the simulation, the simulation parameters have been taken as ode4 (Runge -Kutta) with Step size of 1 µsec fixed step. The

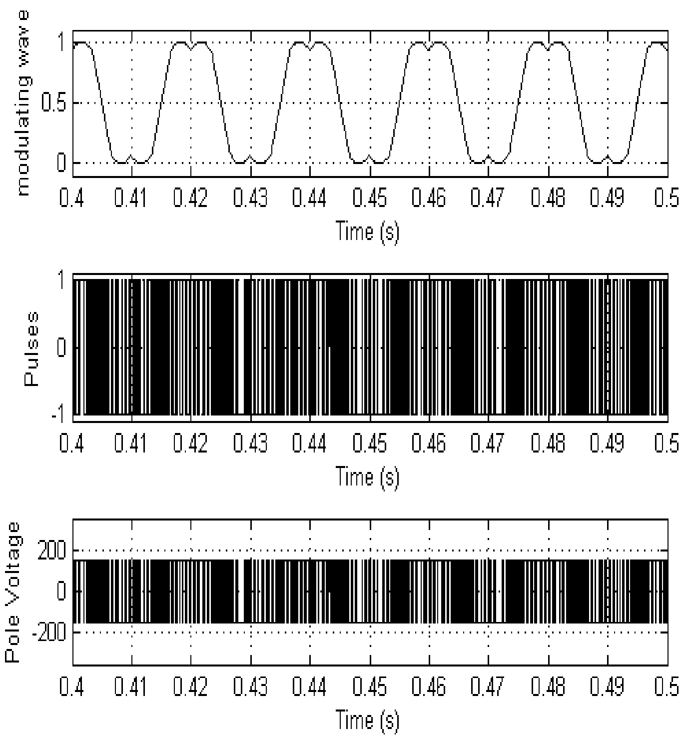


Fig. 6 simulation results of inverter-1 at a supply frequency of 50Hz.

induction motor considered in this thesis is a 400 Volts, 4 kW, 4-pole, 1470 RPM, 50 Hz, rated torque = 30 N-m with parameters as follows:

R_s =1.57 ohm, R_r = 1.21 ohm, L_m = 0.165 H, L_s = 0.17 H, L_r = 0.17 H, J = 0.089 Kg - m^2

For the simulation studies the switching frequency of the inverter is taken as 3 kHz and DC link voltage of the inverter is taken as 600V.

The simulation results of dual inverter fed open-end winding induction motor drive are shown in From Fig .6 to Fig .15.

From Fig 11 and Fig 13, it can be observed that the SVPWM algorithm for a conventional two level inverter gives reduced total harmonic distortion (THD) at lower frequencies. And from the simulation results, and the harmonic spectra analysis it can be observed that the proposed algorithm for Open End Winding Induction Motor gives reduced THD when

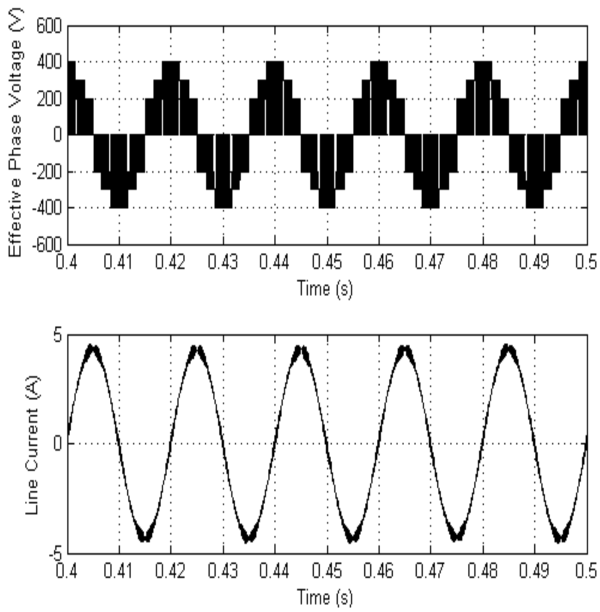


Fig. 7 effective phase voltage and line current of open-end winding induction motor at 50Hz

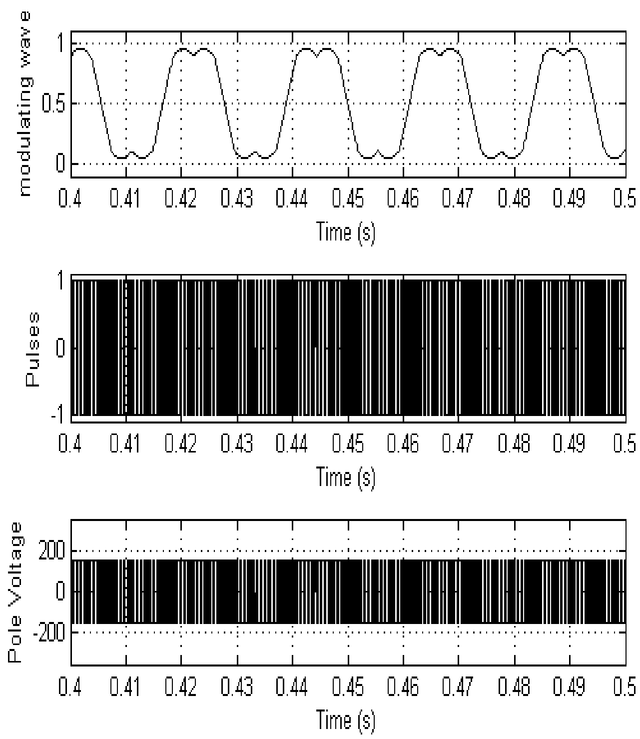


Fig. 8 simulation results of inverter-1 at a supply frequency of 45Hz.

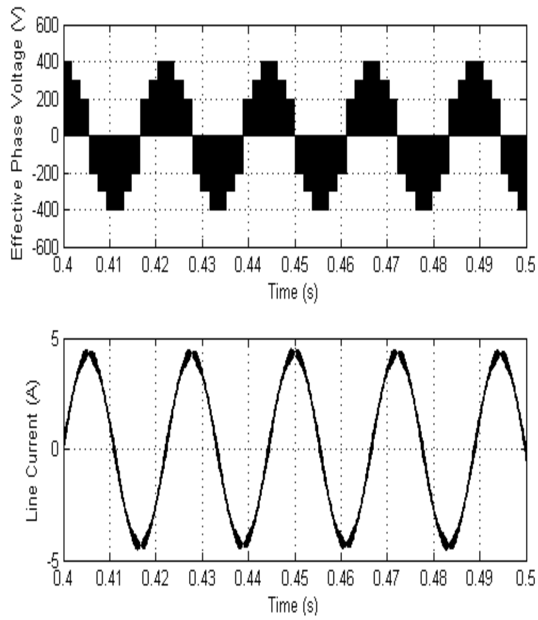


Fig. 9 effective phase voltage and line current of open-end winding induction motor at 45Hz.

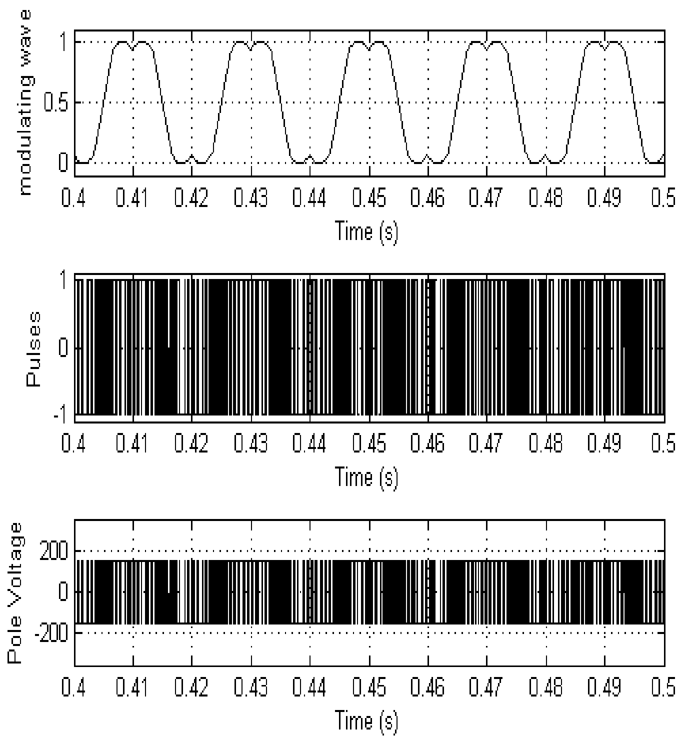


Fig. 10 simulation results of inverter-2 at a supply frequency of 50Hz.

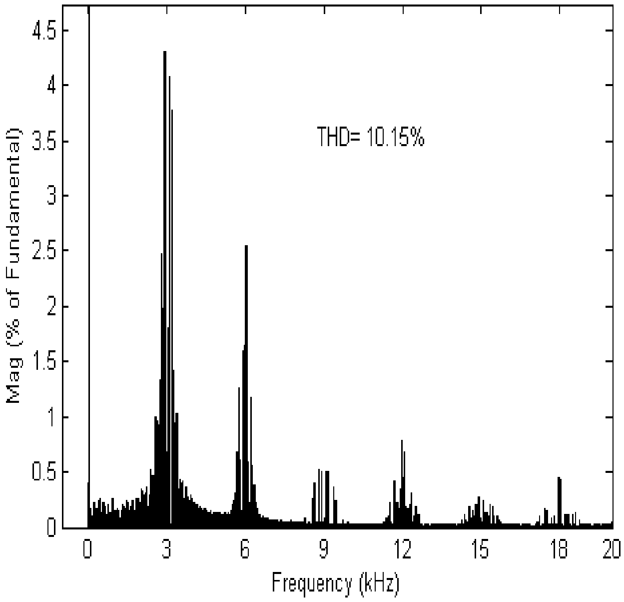
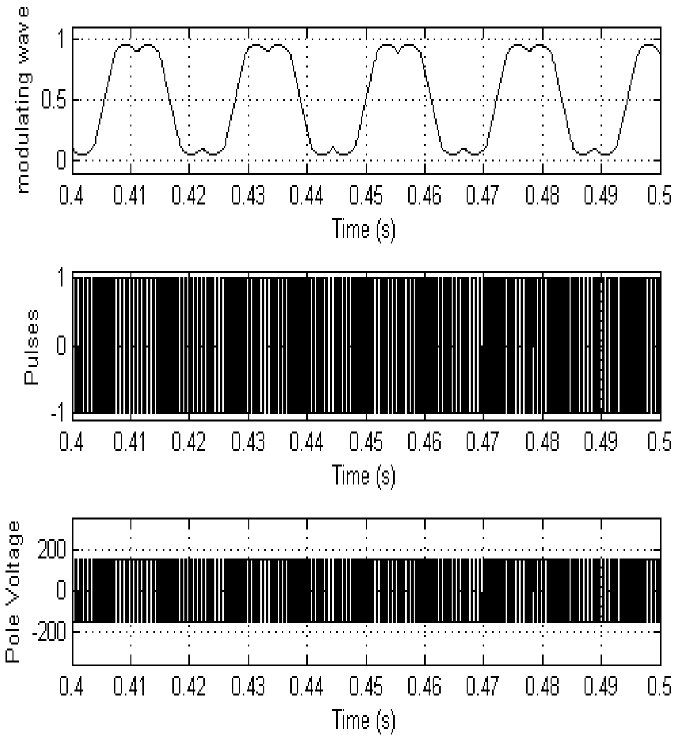


Fig. 11 Harmonic spectra of line current at 45Hz for a conventional 2 level inverter.



. Fig. 12 Simulation results of inverter-2 at a supply frequency of 45Hz.

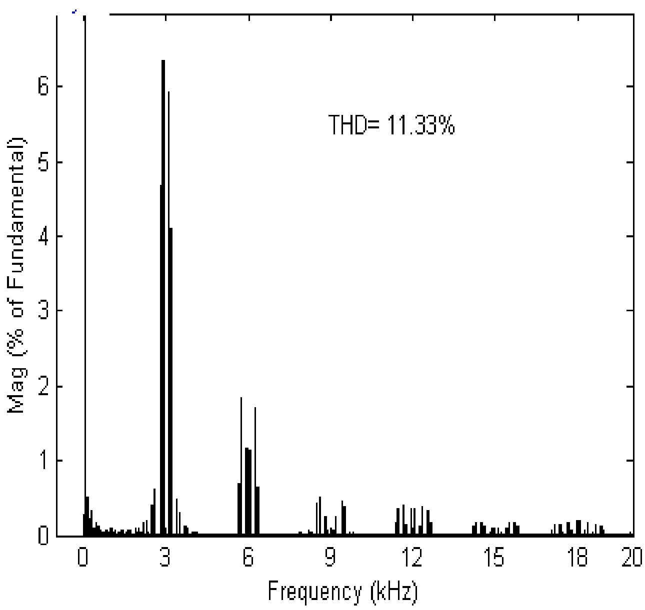


Fig. 13 Harmonic spectra of line current at 50Hz for a conventional 2 level inverter.

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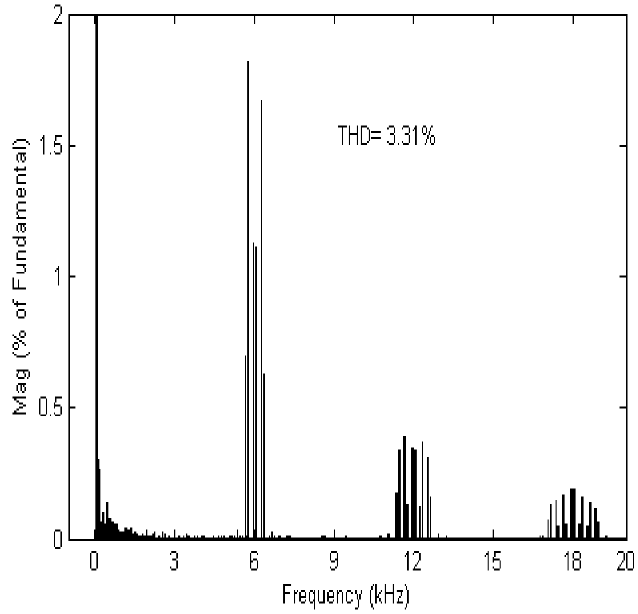

Fig 14 Harmonic spectra of line current at 50Hz supply frequency

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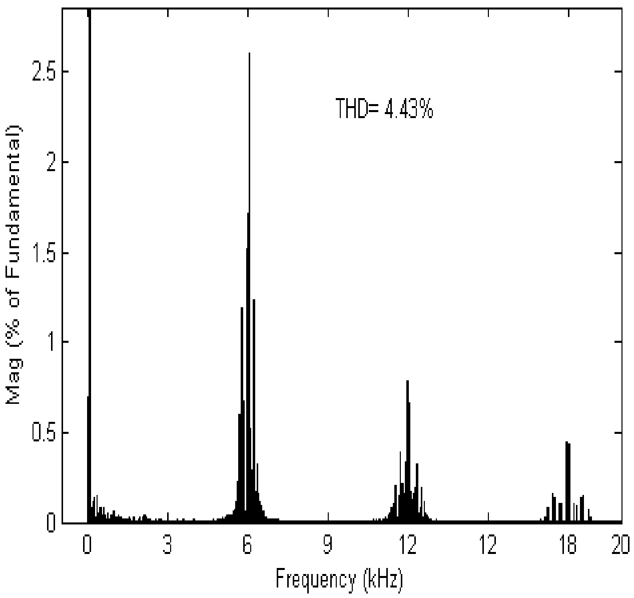

Fig 15 Harmonic spectra of line current at 45 Hz supply frequncey

compared with the two-level inverter fed induction motor drive.

4 Conclusion

In the conventional SVPWM algorithm, the angle and sector information is used to calculate the switching times of the devices. Hence, the complexity involved is more. Hence to reduce the computational burden involved in conventional approach, this thesis presents the concept of imaginary switching times which involves the calculation of offset and effective times. And also three-level inverter topology is realized by feeding an open-end winding induction motor with two two-level inverters. In this method reference waveforms are 180˚ phase shifted and three level voltage space vector is generated. The present scheme will give fundamental flux profile in the motor identical to that produced by conventional three-level inverter structure. The implementation of the proposed scheme does not necessitate any special design requirements for the induction motor and no new algorithm is required to generate PWM pulses to the inverter. With this topology we can observe that the Total Harmonic Distortion (THD) has been reduced.

References

[1] R.M. Green and J.T. Boys, "Implementation of Pulse width Modulated Inverter Modulation Strategies", IEEETrans. On nd. Appl.Vol.IA-18, No.2, Mar/Apr.1982, pp. 138 - 145.

[2] J. Holtz, "Pulse width modulation- A survey", IEEE Trans. on Industrial Electronics, Vol. 30, No. 5, Dec 1992, pp. 410-420.

[3] D. G. Holmes, "The significance of Zero-Space Vector placement for Carrier-based PWM schemes", IEEE Trans. on Ind. Appl., vol.32, No.5, Sept-Oct 1996, pp. 1122-1129.

[4] Vladimir Blasko, "Analysis of a Hybrid PWM based on Modified Space-Vector and Triangle-Comparison Methods",IEEE Trans. on Ind. Appl., Vol.33, No.3, May/June, 1997, pp. 756-764.

[5] G. Narayanan, Di Zhao and Harish K.krishnamurthy, "Space vector based hybrid PWM technique for reduced current ripple", on Ind. Electronics, Vol.55, No.4, April 2008, pp.1614 - 1627.

[6] E.G. Shivakumar, K. Gopakumar, S.K. Sinha, Andre Pittet, V.T. Ranganathan, "Space Vector Control of Dual Inverter Fed Open-End Winding Induction Motor Drive", EPE Journal, Vol. 12, No. 1, February 2002, pp. 9-18.

[7] V.T. Somasekhar, K. Gopakumar, "Three-Level Inverter Configuration Cascading Two Two-Level Inverters", IEEE Proc. Electr. Power Appl., Vol. 150, No. 3, May 2003, pp. 245-254.

[8] V.T. Somasekhar, K. Gopakumar, A. Pittet and V.T. Ranganathan, "PWM Inverter Switching Strategy for Dual Two-Level Inverter Fed Open End Winding Induction Motor Drive with a Switched Neutral", IEE Proc. Of Electr. Power Appl., Vol. 149, No, 2, March 2002, pp. 152-160.

[9] V.T. Somasekhar, K. Gopakumar, M.R. Baiju, K.K. Mohapatra and L. Umanand, "A Multilevel Inverter System for an Open End Winding Induction Motor with Open-End Windings," IEEE transactions on Industrial Electronics,Vol. 52, No. 3, June 2005, pp. 824-836.

[10] V.T. Somasekhar, K. Gopakumar, E.G. Shivakumar, S.K. Sinha, "A Space Vector Modulation Scheme for Dual TwoLevel Inverter Fed an Open-End Winding Induction Motor Drive for the Elimination of Zero Sequence Current", EPE Journal, Vol. 12, No. 2, May 2002, pp. 26-36.

[11] V.T. Somasekhar, M.R. Baiju and K. Gopakumar, "Dual Two Level Inverter Scheme for an Open- End Winding Induction Motor Drive with a Single DC Power Supply and Improved DC Bus Utilization", IEE Proc.of Electr. Power.Appl., Vol. 151, No. 2, March 2004, pp. 230-238.

[12] M. B. Baiju, K.K. Mohapatra, R.S. Kanchan and K. Gopakumar, "A Dual Two-Level Inverter Scheme with Common Mode Voltage Elimination for an Induction Motor Drive", IEEE Transactions on Powe Electronics Vol. 19, No. 3, May 2004, pp. 794-805.

[13] V. Oleschuk, B.K. Bose, A.M. Stankovic, "Phase-Shift-Based Synchronous Modulation of Dual- Inverter for an Open-End Winding Induction Motor Drive with Elimination of Zero Sequence Currents", Conf. Proc. IEEE-PEDS-2005, pp. 325-330.

[14] V. Oleschuk, F. Profumo, A. Tenconi and R. Bojoi,"Synchronized Pulse_Width Modulation Control of Inverter-Fed Open-End Winding Motor Drives", EPE Conf.Proc., Pelincec, 2005, Paper-ID: 94.