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A Simplified SVPWM Control for Five Level Asymmetrical Dual Inverter Fed Induction Motor Drive

Usha N*, Venkata Prasad P** and Ramesh Reddy K***

Many of the Adjustable speed drives are inverter based motor drives. There are various PWM techniques to control the inverter. This paper presents modified control strategy for five level asymmetrical dual inverter fed induction motor drive. The control method for the inverter improves the performance of the drive. The characteristics of the drive at different modulation indices were observed and found that at higher modulation index the total harmonic distortion of line currents is less. The time response of speed is better at modulation index greater than 0.75.The simulation based analysis and design is carried out in MATLAB™ software.

Keywords: *Dual inverter, Space vector pulse width modulation, Induction motor drive.*

1.0 INTRODUCTION

Power electronic converters, especially DC to AC converters (VSI) have been extending their range of use in industry because, they provide reduced energy consumption, better system efficiency, improved quality of product, good maintenance and so on. But most of the loads used in industrial drive applications are Induction motor loads which are supplied through these VSIs. When only one inverter is used, the output voltage of voltage source inverters contains harmonics. So, there is every necessity to improve the performance characteristics of these inverters since they have adverse effect on the load. The performance characteristics include reduction in switching losses, reduction in harmonics, reduction in common mode voltages etc.

To obtain a pure sinusoidal input without harmonics, there are three methods, High frequency PWM technique, Multi Level inverter (MLI) with low frequency PWM Technique and Open end winding with dual inverter[2]. High frequency PWM has disadvantages as less utilization of DC link and high switching losses. By using MLI, a pure sinusoidal wave is produced at the output of VSI. This is done by increasing the number of operating levels of MLIs. As the number of levels increases, the harmonic content in the output voltage gets reduced, improving the performance characteristics of the inverter. But as the number of levels increases, complexity of the circuit increases and has its own disadvantages such as having more number of diodes, flying capacitors and sources[3].

A simple circuit configuration with induction motor being fed from dual inverter as shown in Figure1 is considered to improve the performance characteristics of inverter[1]. This configuration reduces the usage of number of diodes, number of flying capacitors and number of sources too, thereby reducing the cost involved. In this configuration, stator windings of induction motor are opened and connected to two inverters on either side. DC supply is provided to both the inverters and resultant AC output from inverters

*Research Scholar , JNTUH. GNITS,Hyderabad-500104. usha0578@gmail.com, Ph no: +91-9296303619
**Professor, CBIT. Gandipet, Hyderabad-500075. pvp_reddy@yahoo.co.uk, Ph no: +91-9848753742
***Professor,GNITS. Shaikpet, Hyderabad-500104. kollirameshreddy@yahoo.com, Ph no: +91-9849422460

is given to the induction motor connected between both the inverters. If the DC input to the inverters is same, then the configuration is called symmetrical dual inverter fed induction motor drive. If the DC input to the inverters is different, then the configuration is called asymmetrical dual inverter fed induction motor drive[3]. To increase the number of levels in the output voltage, the input DC voltage to the inverters is so adjusted to increase the number of levels, thus, reducing the cost and complexity in the circuit[5].

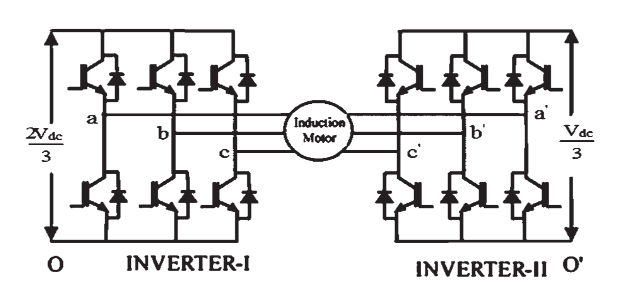

FIG. 1. DUAL INVERTER FED INDUCTION MOTOR

In this paper, dual inverter fed induction motor drive is employed to improve the performance characteristics with third harmonic injection SVPWM control. The configuration is studied for 4 different modulation indices. Their performance characteristics of speed are studied for each case.

2.0 SIMPLIFIED SVPWM TECHNIQUE

The switching sequence is obtained by considering six switch operation, dividing each inverter into two parts as upper and lower part. The upper part consists of switches S_1, S_3 & S_5 and lower part consists of switches S_4, S_6 & S_2. The switching states can be two either ON or OFF. Therefore the possible switching states are 2^3=8. In the 8 switching states, two of them are completely On and OFF which is not applicable. Considering the six switching states, the switching pattern is represented as hexagon . This approach depends on the angle and reference magnitude calculation which is complex and time consuming [12]. In order to avoid complexity, a simplified SVPWM is obtained by adding reference voltages with a zero sequence voltage.

$V^*_{ref} = V_{ref} + V_{zs}$

where $V_{zs} = V_{DC}/2\ (2a_0 - 1) = a_0\ V_{max} + (a_0 - 1)$ ...(1)

A SVPWM technique can be carried out in carrier based modulation approach wherein the carrier is compared with the N-1 triangles with reference modulating wave to generate N-level output voltages. The peak amplitude of modulating wave lies between 0 and 1. To generate 5 level output voltage 4 triangles have to be compared with the modulating wave. Depending on the peak amplitude of modulating wave,modulation index will vary. In this work ,analysis is done for 4 different modulation index range.

3.0 FIVE LEVEL VOLTAGE SOURCE INVERTER

If the modulating wave is present in lower triangular region as shown as in Figure 2 only inverter–II is in operation and generates an output voltage of (0,V_{dc}/3) which is considered as two-level output voltage

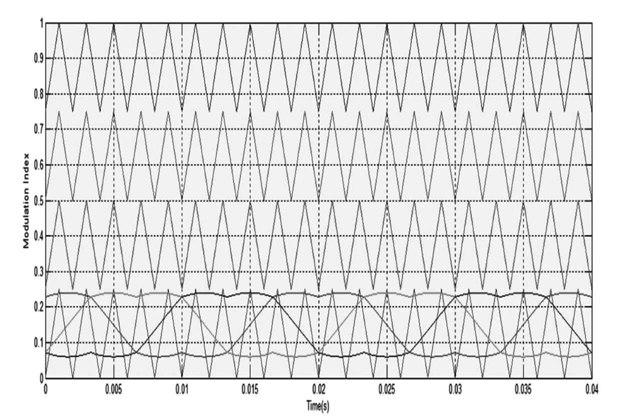

FIG. 2. CARRIER BASED MODULATION APPROACH FOR TWO-LEVEL OPERATION (M<0.25)

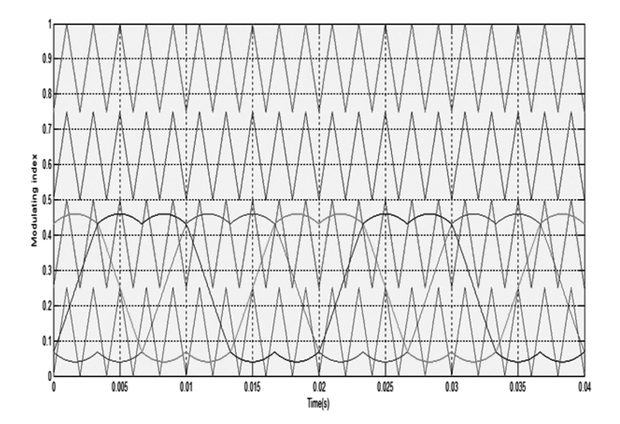

FIG. 3. CARRIER BASED MODULATION APPROACH FOR THREE-LEVEL OPERATION (0.25<M<0.5)

If the modulating wave is present in lower two triangular region as shown as in Figure 3 both inverter-I & inverter –II are in operation and produces an output voltage of ($-V_{dc}/3, 0, V_{dc}/3$) which is considered as three-level output voltage

If the modulating wave is present in lower three triangular region as shown as in Figure 4 both inverter-I & inverter –II are in operation and produces an output voltage of ($-V_{dc}/3$, $0, V_{dc}/3$, $2V_{dc}/3$) which is considered as four-level output voltage

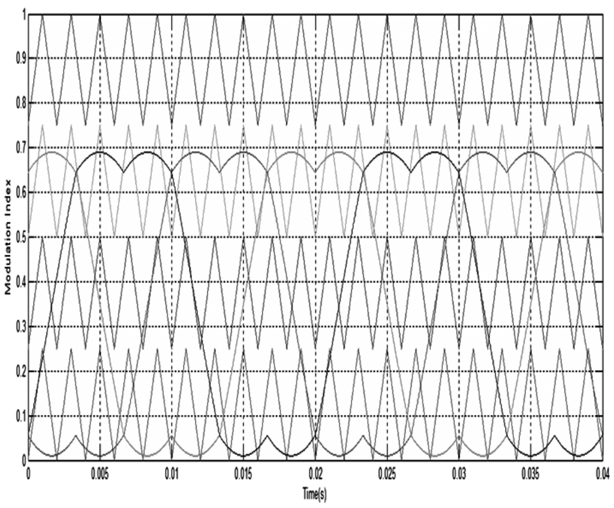

FIG. 4. CARRIER BASED MODULATION APPROACH FOR FOUR-LEVEL OPERATION (0.5<M<0.75)

If the modulating wave is present in all triangular region as shown as in Figure 5 both inverter-I & inverter –II are in operation and produces an output voltage of ($-2V_{dc}/3, -V_{dc}/3, 0, V_{dc}/3$, $2V_{dc}/3$) which is considered as five-level output voltage

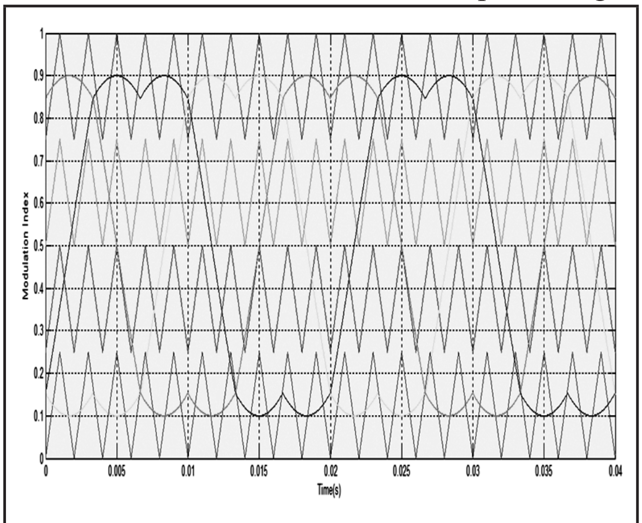

FIG. 5. CARRIER BASED MODULATION APPROACH FOR FIVE-LEVEL OPERATION (0.75<M<0.9)

4.0 SIMULATION RESULTS AND DISCUSSION

The analysis of control strategy is carried out in MATLAB / SIMULINK™. The parameters of the induction motor used in the simulation are given in Table 1. The simulation results at different modulation indices are shown in Figure 6 to Figure 9.

TABLE 1

INDUCTION MOTOR PARAMETERS

Power	5 HP	Rotor resistance	0.156 Ω
Rated speed	1440 RPM	Inverter input DC Voltage	540 V
Frequency	50 Hz	Mutual inductance	0.041 H
Stator resistance	0.294 Ω	Stator and Rotor Inductance	1.4/mH

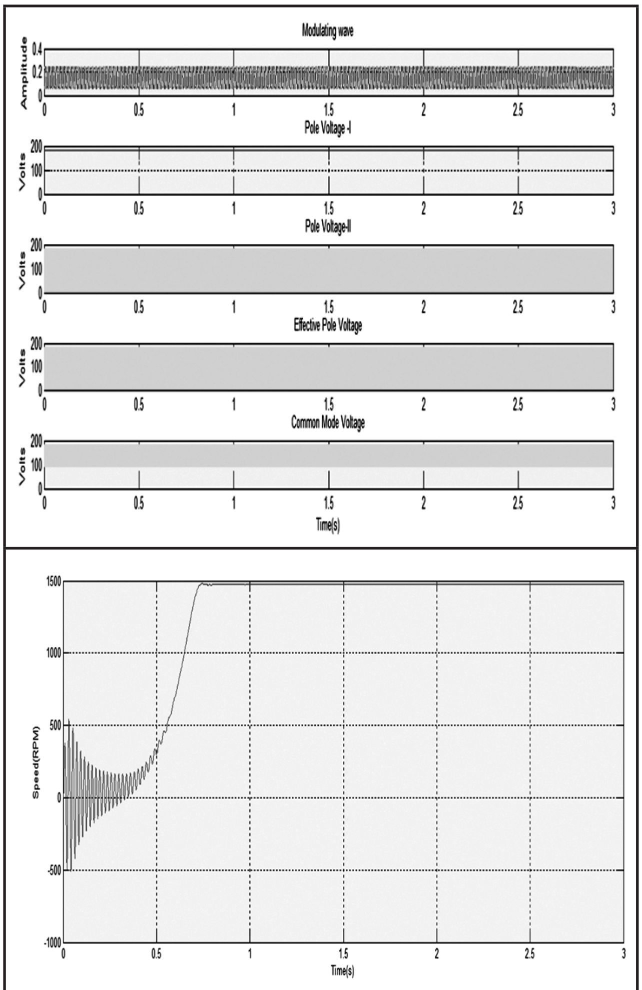

FIG. 6 VOLTAGE AND SPEED PLOTS AT M<0.25

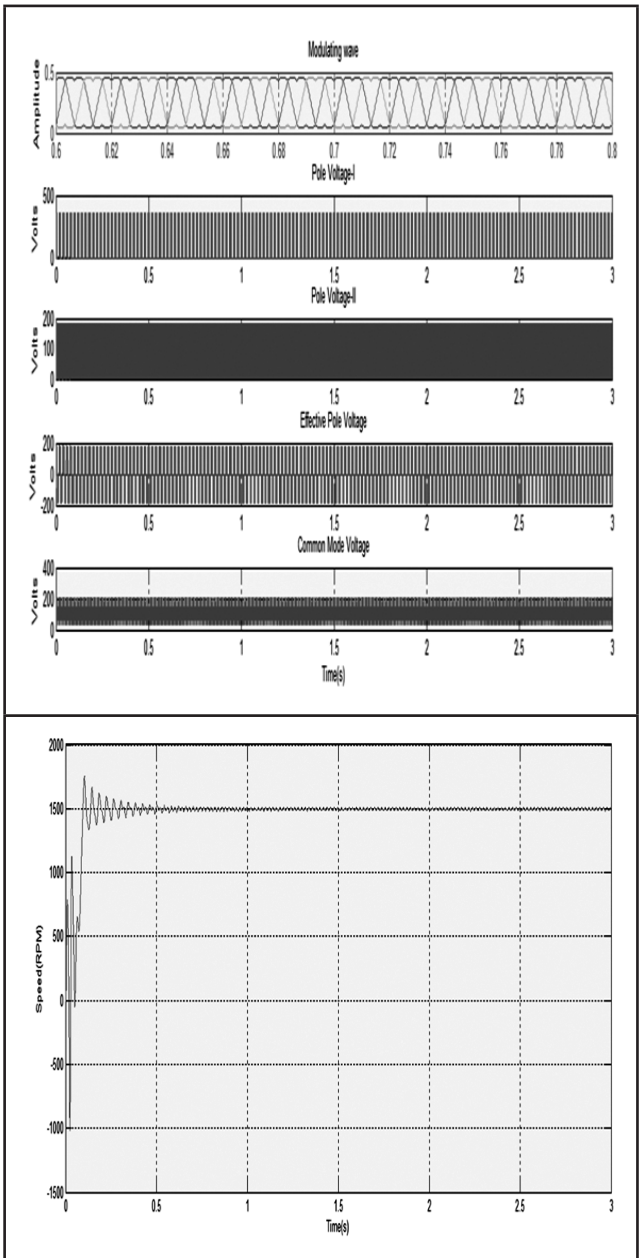

FIG. 7 VOLTAGE AND SPEED PLOTS FOR 0.25< M<0.5

With modulation index less than 0.25, only one inverter is in operation so switching losses are less but the speed response is sluggish as in Figure 6. For the modulation index in the range of 0.25 to 0.5 both inverters are in operation and the effective pole voltage varies has three levels with better speed response than that of lower modulation index as shown above in Figure 7. To obtain the four level output voltage, modulation index can be between 0.5 to 0.75 wherein the speed response is oscillatory as shown in Figure 8. It was observed from above results that with higher modulation index the speed response is fast with less peak overshoot and settling time.

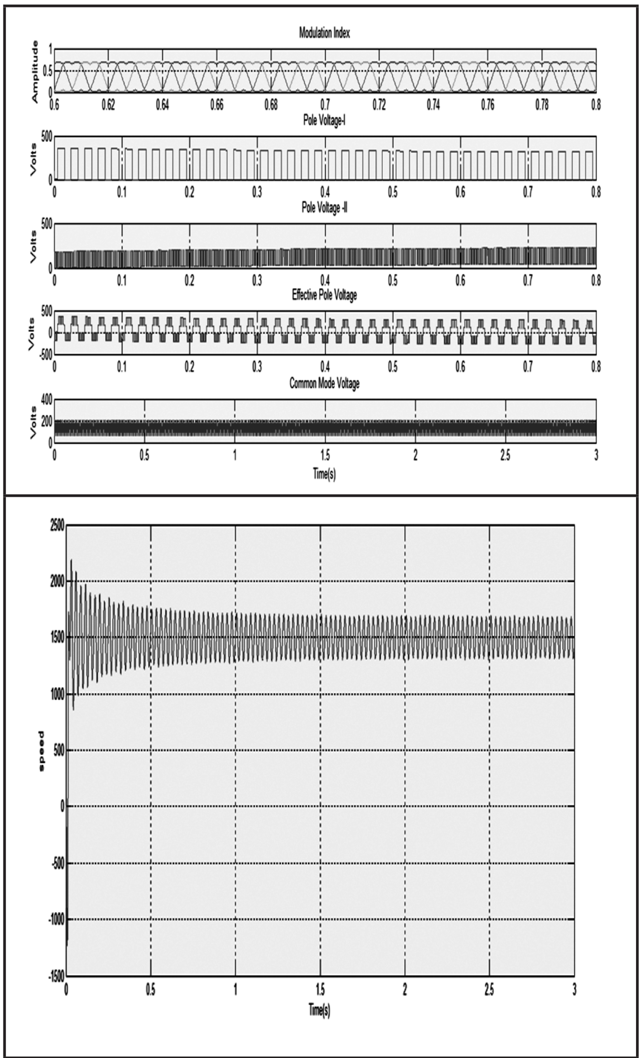

FIG. 8 VOLTAGE AND SPEED PLOTS FOR 0.5< M<0.75

Along with better performance of the load the current ripple is also reduced with the proposed control strategy. The THD's are tabulated in the table II

TABLE 2

COMPARISON OF THD'S

Modulation Index(M)	Current THD for four level inverter [1]	Current THD for five level inverter
0.27	4.17	0.34
0.45	3.4	0.32
0.63	2.9	0.28
0.81	2.9	0.24

The total harmonic distortion of line current at different modulation indices with two different inverters are given in table III and it was observed that as the modulation index are increasing the harmonic content in the current is reduced and also performance of the drive is better .

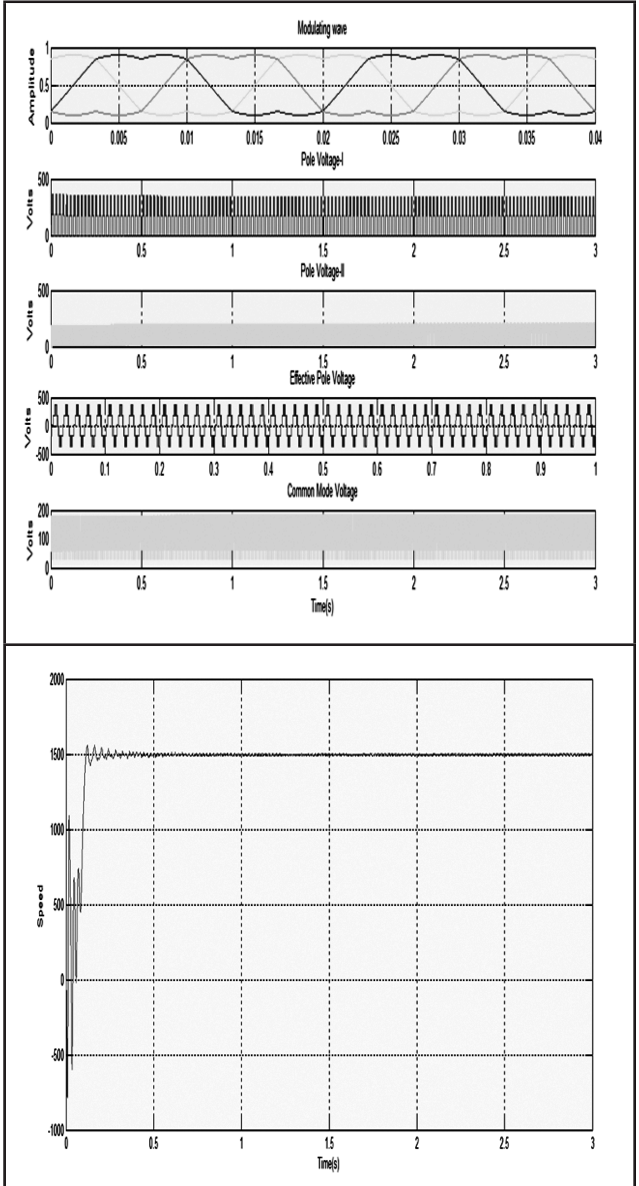

FIG. 9 VOLTAGE AND SPEED PLOTS FOR 0.75< M<0.9

5.0 CONCLUSION

The asymmetrical dual inverter is less complex in comparison with multilevel inverter. With lower modulation index (M<0.25) switching losses are reduced as only one inverter is in operation. In modulation index range 0.25 to 0.75 the speed response is oscillatory in nature.

At high modulation index the current harmonics are reduced with improved speed response.

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