Performance Evaluation of Induction Motor for Unipolar and Bipolar Pulse Width Modulation Techniques

T. Murali Krishna, K. Krishna Veni, G. Suresh Babu, D. Sushma, C. Harish

Abstract*: Inverter is an interface device between a dc source and ac loads which converts DC voltage to a variable voltage, variable frequency AC voltage. While converting, it introduces harmonics in the output of the system which results in additional heating of induction motors. Hence in order to diminish these harmonics, different techniques are introduced viz. external and internal control techniques in which the latter is more efficient. Out of the all proposed methods, the internal control of inverter which is also called as Pulse Width Modulation (PWM) can be achieved either using unipolar modulation technique or bipolar modulation technique. In this paper, the control circuitry to model unipolar and bipolar modulation methods is simulated and their performance is checked on an induction motor and compared in MATLAB Simulink environment.

***Keywords*: Unipolar modulation, bipolar modulation, induction motor, total harmonic distortion, lower order harmonics.**

I. INTRODUCTION

Now-a-days in industries there is a dire need of flexible operation of induction motor to meet various types of applications which require a smooth variable ac voltage from the fixed supply. To provide variable voltage to induction motor, inverters are given due importance in converting the dc voltage to variable ac voltage of required frequency using suitable electronic circuit. In the process of realization of inverters various parameters like efficiency, size, cost etc. are to be considered, however, the basic conventional two-level inverter supplies an ac output voltage of desired magnitude and frequency in which the output voltage is not a pure sinusoid. In order to achieve controlled ac voltage at the output terminals of the inverter different techniques are proposed. They are external control and internal voltage control techniques in which internal voltage control technique is more efficient and economic compared to external control technique, because it is more rugged and complex. Internal voltage control can be achieved by controlling the conduction period of the switching elements in the inverter, which is also called as Pulse Width Modulation. In majority of the inverters, most commonly employed harmonic reduction method is Pulse Width Modulation (PWM)[1-2]. To deliver controlled voltage at the inverter output terminals, the switches must be ON and OFF with high frequency, hence fully controlled switches like IGBTs are considered for many medium voltage applications. This PWM requires a reference signal which is to be compared with a high frequency triangular carrier signal in order to generate driving pulses to the switching elements of the inverter. The basic PWM techniques are classified into two types based on their switching frequency; they are i) fundamental frequency technique ii) High frequency switching technique. The former is used for selective harmonic elimination whereas the latter is carried either by using space vector or carrier based PWM techniques. Out of these, the simplest and cost-effective method is carrier based pulse width modulation technique[3-4] . In pulse width modulated technique, a sine wave is used as a reference signal, whose frequency is same as that of inverter frequency is compared with high frequency triangular wave form called carrier signal to generate the pulses for the switches in the inverter circuit. In order to change the output voltage, vary the magnitude of the reference signal. This variation is indicated as amplitude modulation index (m_a) and to change the switching frequency vary the frequency of the carrier signal called frequency modulation index (m_f) [5-6].There are different PWM techniques based on reference wave, conventional and advanced PWM techniques to cater a variable voltage, variable frequency for the speed control of induction motor for different topologies like Unipolar and bipolar.

Manuscript published on 30 August 2019.
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II. CONVENTIONAL INVERTER

Conventional inverter is a basic model which consists of four switches (IGBT) for single phase inverter and six switches for three phase inverter with anti-parallel diode are connected as shown in Fig.1. The two-level inverters are mainly used to obtain controllable voltage. A conventional two-level inverter consists sources and many switches for controlling voltage or current though it has controllable voltage has some limitations at high frequency due to high switching losses and constraints of power device rating. Due to the presence of sources and switches it has high power losses. A group of switches that provide positive half cycle are called as positive group switches and the other which provides negative half cycle are called as negative group switches.

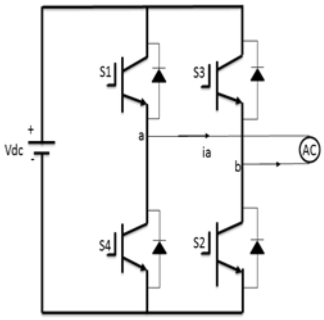

Fig.1 Conventional Inverter

When the both the switches S_1 ,S_2 are ON and S_3,S_4 are OFF then the output voltage is V and when the switches S_3, S_4 are ON and S_1,S_2 are OFF the output voltage is –V. Here all switches are IGBT/ Thyristors, so that we can generate three levels (V, 0, -V) in the output voltage waveform. As seen in figure1 four semiconductor switches S1, S2, S3, S4 are arranged with the load connected at the mid points of the two legs. Hence circuit seems like the letter H, so it is also named as H-Bridge inverter [3].

III. UNIPOLAR PULSE WIDTH MODULATION

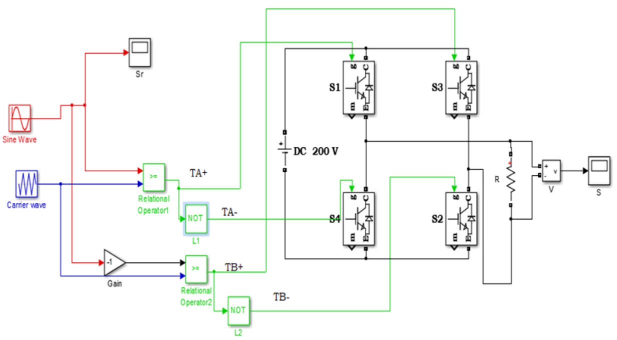

Fig .2 Simulink Model For Unipolar PWM

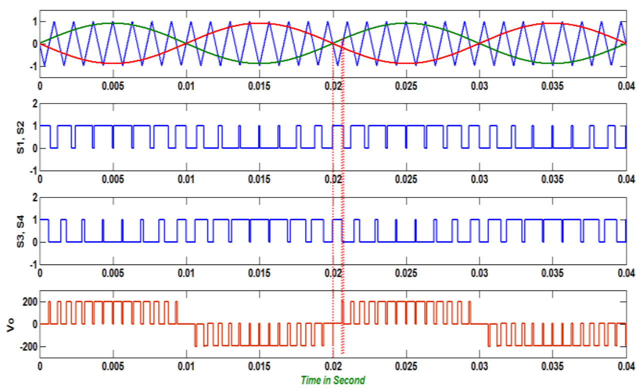

Fig.3 Gate pulses and output voltage in Unipolar PWM

In unipolar PWM, the output voltage switches either from 0 to +V or 0 to –V, hence the name. In this method two phase shifted reference signals are compared with a triangular carrier wave or two phase shifted carrier waves are compared with a reference signal in order to generate the control signals to the switches in the inverter. The above Fig.2 shows the Simulink model of unipolar PWM for a single phase H-bridge inverter in which the sinusoidal wave is phase shifted and compared with a high frequency triangular signal to drive the switches to generate controlled voltage.The resultant gate pulses and corresponding output voltage using unipolar PWM are depicted in Fig 3. From the voltage waveform it is observed that the output voltage is switched between either 0 to +V or from 0 to -V, hence there are three levels in the output voltage.

IV. BIPOLAR PULSE WIDTH MODULATION

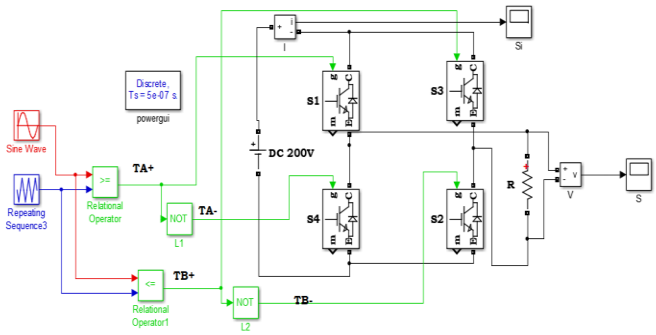

Fig .4 Simulink model for Bipolar PWM

In bipolar PWM, the output voltage switches either from -V to +V or +V to –V, hence the name. In this method one sinusoidal reference signal is compared with a triangular carrier wave in order to generate the control signals to the switches in the inverter. The above Fig.4 shows the Simulink model of bipolar PWM for a single phase H-bridge inverter.

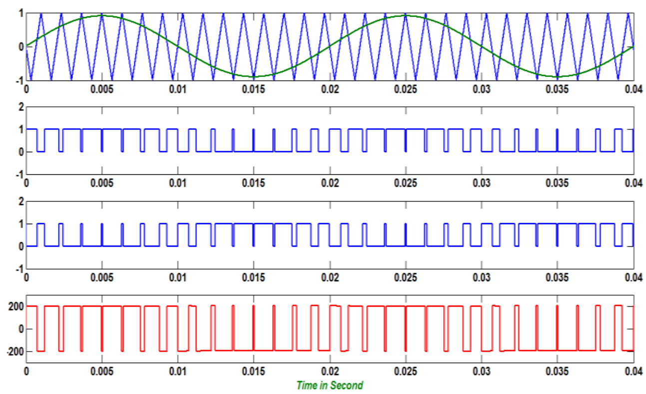

Fig .5 Gate Pulses And Output Voltage In Unipolar PWM

The resultant gate pulses and corresponding output voltage using bipolar PWM are depicted in Fig 5. From the voltage waveform it is observed that the output voltage is switched between -V to +V or from +V to -V, hence there are only two levels in the output voltage.

V. RESULTS

A single phase H-bridge inverter in MATLAB Simulink environment is developed to compare performances of both modulation techniques and then this output is connected to a single phase induction motor to examine its performance.

Retrieval Number: J97930881019/19©BEIESP
DOI: 10.35940/ijitee.J9793.0881019
Journal Website: www.ijitee.org

Published By:
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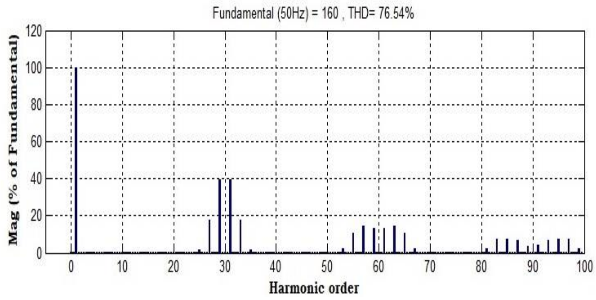

Fig.6 THD of output voltage using Unipolar PWM

The harmonic content and fundamental peak at the output voltage are obtained by Fast Fourier Transform (FFT) of the waveform which is shown in figure 6 for an amplitude modulation index of 0.8 and a frequency modulation index of 15. From the FFT it is observed that the Lower Order Harmonic up to 25th harmonic is absent. In the frequency spectrum of the output voltage it is also observed that, as the frequency modulation index is 15, its odd multiples and their side bands are eliminated, hence only even multiples and their side bands($2m_f \pm n$) are only present.

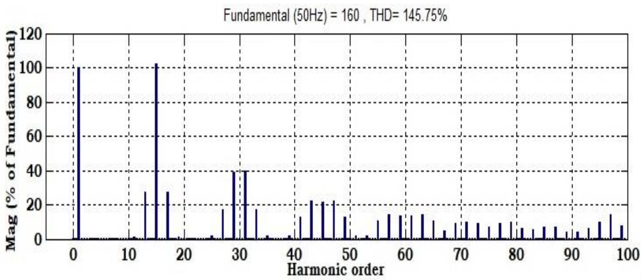

Fig.7 THD of output voltage using Bipolar PWM

The harmonic content and fundamental peak at the output voltage are obtained by Fast Fourier Transform (FFT) of the waveform which is shown in figure 7 for an amplitude modulation index of 0.8 and a frequency modulation index of 15. From the FFT it is observed that the Lower Order Harmonic up to 11th harmonic is absent. In the frequency spectrum of the output voltage it is also observed that, as the frequency modulation index is 15, its multiples and their side bands are ($m_f \pm n$) are present. Hence as compared to that of unipolar modulation, bipolar modulation introduces more harmonic contents in the output voltage of the inverter.

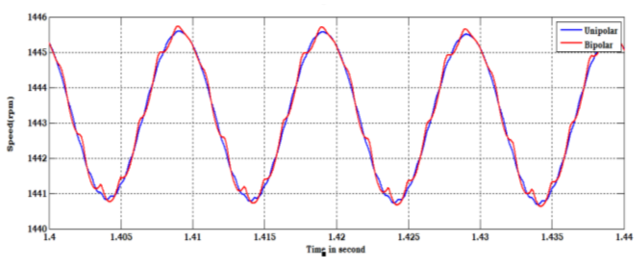

Fig.8 Speed Of The Induction Motor

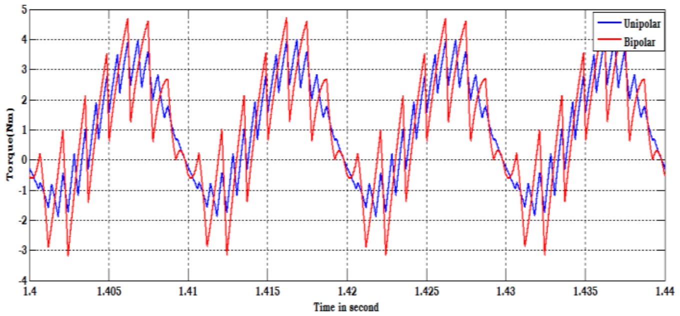

Fig.9 Torque of the induction motor

The speed and torque of the induction motor are depicted in figure 8 and figure 9 respectively using both unipolar and bipolar PWM techniques. It is observed that the unipolar PWM provides less ripple in speed and torque than bipolar PWM.

VI. CONCLUSION

The THD is less in Unipolar technique compared to bipolar technique. Hence the requirement of large filter circuit for bipolar technique to reduce the harmonic content in current and voltage compared to Unipolar PWM. The switching losses are more in bipolar as a switch should conduct not only during positive half cycle but also during negative half cycle. But in unipolar PWM technique the switch utilization factor is poor.

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DOI: 10.35940/ijitee.J9793.0881019
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