Unipolar and Bipolar PWM Inverter

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Abstract

Inverter is basically an interface between DC source like photovoltaic cell and AC networks. There are many inverter topologies but output current distortion and efficiency are the two main parameters for the selection of inverters. Two such topologies are described herein. In this paper, the SPWM (Sinusoidal Pulse Width Modulation) technique of unipolar and bipolar inverters is presented and the models are simulated in MATLAB – Simulink. The H-Bridge inverter topologies (both unipolar and bipolar) are made up of power electronic switches and are fed with constant amplitude pulses with varying duty cycle for each period. The SPWM pulses are generated by comparison of two waves- a carrier wave, which is triangular in this case and a modulating reference wave whose frequency is the desired frequency, which is sinusoidal in this case. This pulse width modulation inverter is characterized by simple circuitry and rugged control scheme that is SPWM technique to obtain inverter output voltage control and to reduce its harmonic content.
Keywords: Bipolar, Inverter, Over Modulation, PWM, Unipolar.

I. INTRODUCTION

The basic inverter circuits performs the task of converting DC input power to AC output power. Inverter can be widely classified based on many parameters but considering one of them based on the arrangement of the power electronic switches are – Half Bridge Inverter and Full bridge inverter. A Full bridge inverter has two legs consisting of two semiconductor switches in each of them with the load connected at the center points of the two legs.
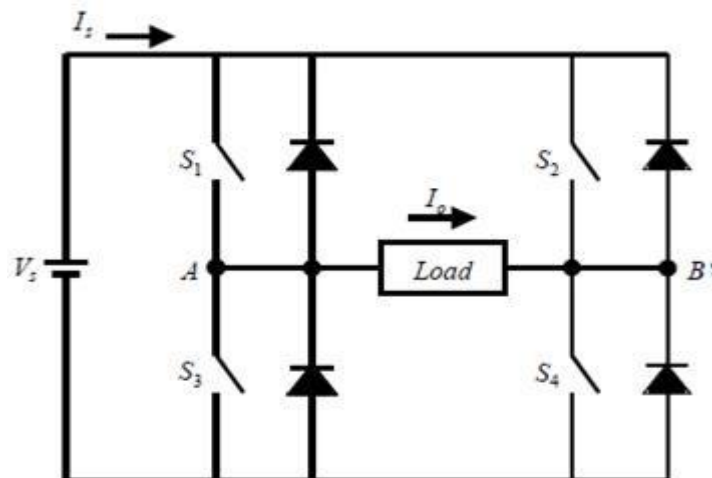

Fig. 1: Full- Bridge Inverter Circuit

As seen in Figure1 four semiconductor switches S1, S2, S3, S4 are arranged with the load connected at the midpoints of the two legs hence forming the letter H, so is the name H-Bridge inverter. Feedback diodes are provided for all the switches. DC source Vs is supplied to H-Bridge. The switches s1, S2, S3, S4 can be switched in three different sequences

– When S1 and S4 are turned on +Vs is obtained at the output
– When S2nand S3 are turned on –Vs is obtained at the output
– When S1 and S2 or S3 and S4 are turned on together zero voltage is obtained at the output

II. PULSE WIDTH MODULATION

Variation of duty cycle of the PWM signal provides a voltages across the load in a specific pattern will appear to the load as AC signal. A pure sin wave is obtained after passing the signal through a low pass filter. The pattern at which the duty cycle of a PWM signal varies can be implemented using simple analogue components or a digital microcontroller. Either of the two basic topologies generate sinusoidal PWM that controls the output of the inverter.

PWM signals find a wide application in modern electronics. Some of these reasons are:

- Reduced Power Loss – switched circuits tend to have lower power consumption because the switching devices are almost always off (low current means low power) or hard-on (low voltage drop means low power).
- Easy to Generate – PWM signals are quite easy to generate. Many modern microcontrollers include PWM hardware within the chip; using this hardware often takes very little attention from the microprocessor and it can run in the background without interfering with executing code.
- Digital to Analogue Conversion – The fact that the duty cycle of a PWM signal can be accurately controlled by simple counting procedures is one of the reasons why PWM signals can be used to accomplish digital-to-analogue conversion.

The desired PWM technique should have the following characteristics:

- Good utilization of DC supplies voltage possibly a high voltage gain.
- Linearity of voltage control.
- Low amplitude of low order harmonic of output voltage to minimize the harmonic content of output currents.
- Low switching losses in inverter switches.
- Sufficient time allowance for proper operation of the inverter switches and control system.

In SPWM (Sinusoidal Pulse Width Modulation) two signals are compared. The Modulating reference signal is sinusoidal and the carrier wave is triangular. Gating pulses are produce by comparing the two signals and the width of each pulse is varied is proportion to the amplitude of the sine wave . The frequency of the reference signal determines the inverter output frequency and the reference peak amplitude controls the modulation index and the RMS value of the output voltage.
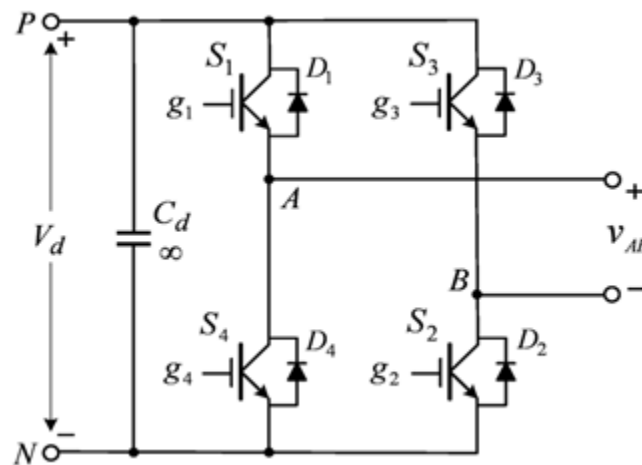

Fig. 2: Single Phase H-Bridge Inverter

The basic H bridge inverter circuit for both the schemes remains same. Consider the H bridge circuit comprising of IGBT switches as shown in Figure2 for both unipolar and bipolar inverter

III. BIPOLAR PWM INVERTER

The upper and the lower switches in the same inverter leg work in a complementary manner with one switch turned on and other turned off. Thus we need to consider only two independent gating signals v_{g1} and v_{g3} which are generated by comparing sinusoidal modulating wave v_m and triangular carrier wave v_{cr}. The inverter terminal voltages are obtained denoted by V_{AN} and V_{BN} and the inverter output voltage $V_{AB} = V_{AN}-V_{BN}$. Since the waveform of VAB switches between positive and negative dc voltages this scheme is called bipolar PWM.
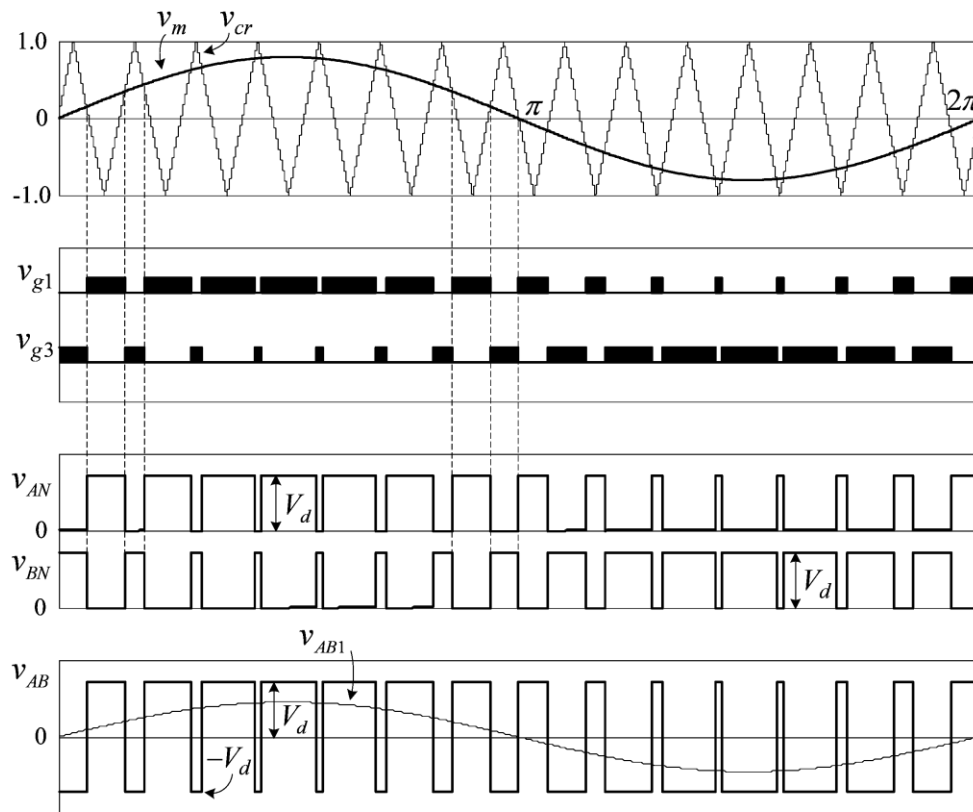
Fig. 3: Waveforms of Bipolar Modulation Scheme

IV. UNIPOLAR PWM INVERTER

The unipolar modulation normally requires two sinusoidal modulating waves v_m and v_m- which are of same magnitude and frequency but 180^0 out of phase. The two modulating wave are compared with a common triangular carrier wave v_{cr} generating two gating signals v_{g1} and v_{g3} for the upper two switches S_1 and S_3. It can be observed that the upper two devices do not switch simultaneously, which is distinguished from the bipolar PWM where all the four devices are switched at the same time. The inverter output voltage switches between either between zero and $+V_d$ during positive half cycle or between zero and $-V_d$ during negative half cycle of the fundamental frequency thus this scheme is called unipolar modulation. The unipolar switched inverter offers reduced switching losses and generates less EMI. On efficiency grounds, it appears that the unipolar switched inverter has an advantage.

Overmodulation occurs when amplitude modulation index ma is greater than unity. It causes a reduction in number of pulses in the line to line voltage waveform leading to emergence of lower order harmonics. Moreover the notch and pulse widths near the center of positive and negative half cycle tend to vanish. To complete the switching operations of the device, minimum notch and pulse widths must be maintained. When minimum width notches and pulses are dropped, there will be some transient jump of load current.
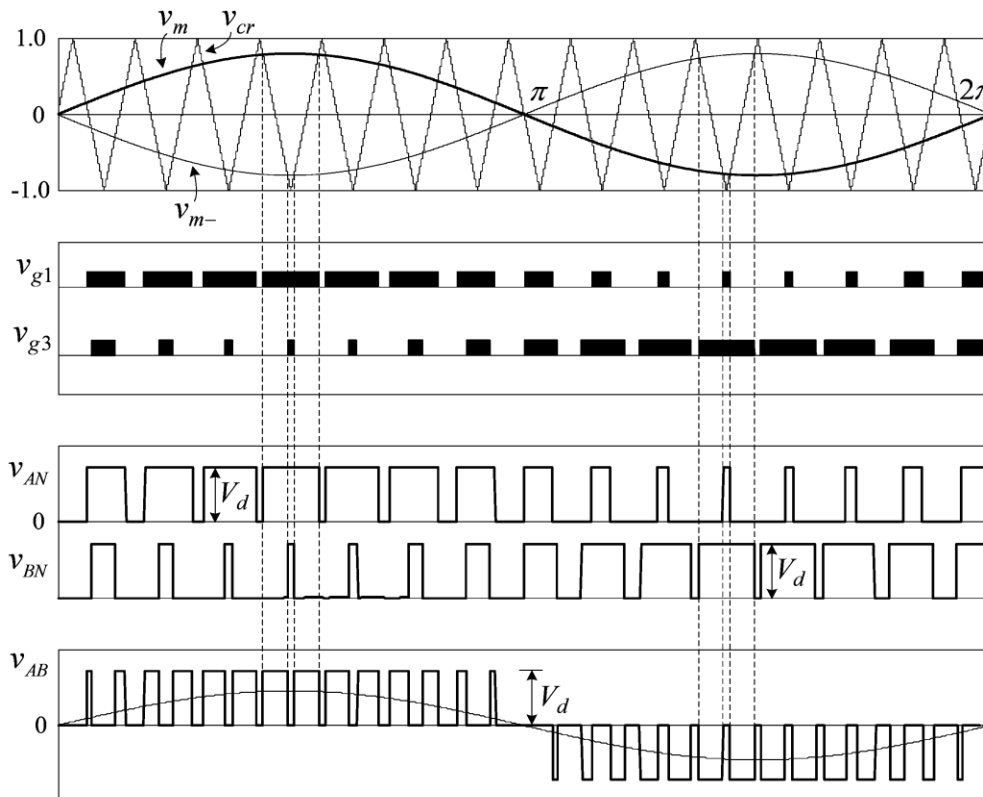
Fig. 4: Waveforms of Unipolar Modulation Scheme

V. MATLAB SIMULATION

The MATLAB- Simulink model of the unipolar inverter is as shown Figure 5 and for bipolar inverter is as shown in Figure 7. A triangular generator and a sine wave generator are used for generating the carrier wave and the modulating wave respectively. The carrier frequency is $11H_z$ and the reference wave frequency is $1H_z$. The modulation index can be varied by changing the amplitude of sinusoidal modulating wave. The waveforms are for modulation index of 1.0
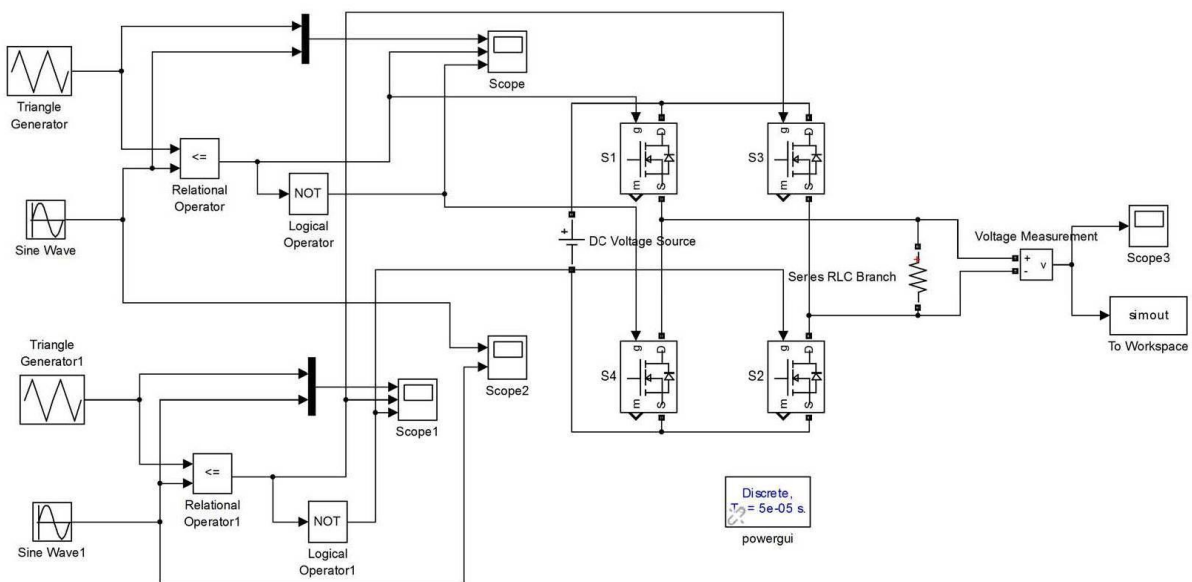
Fig. 5: Simulink Model of Unipolar PWM Inverter
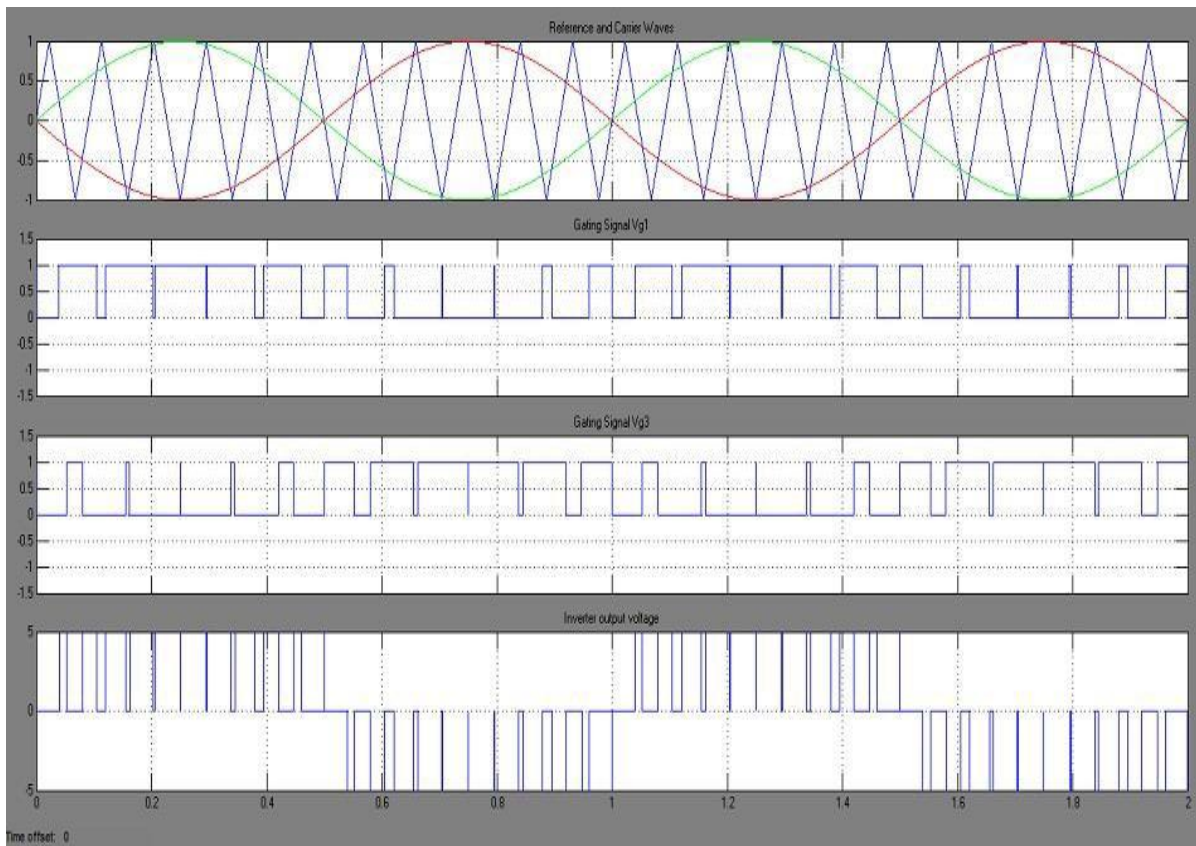
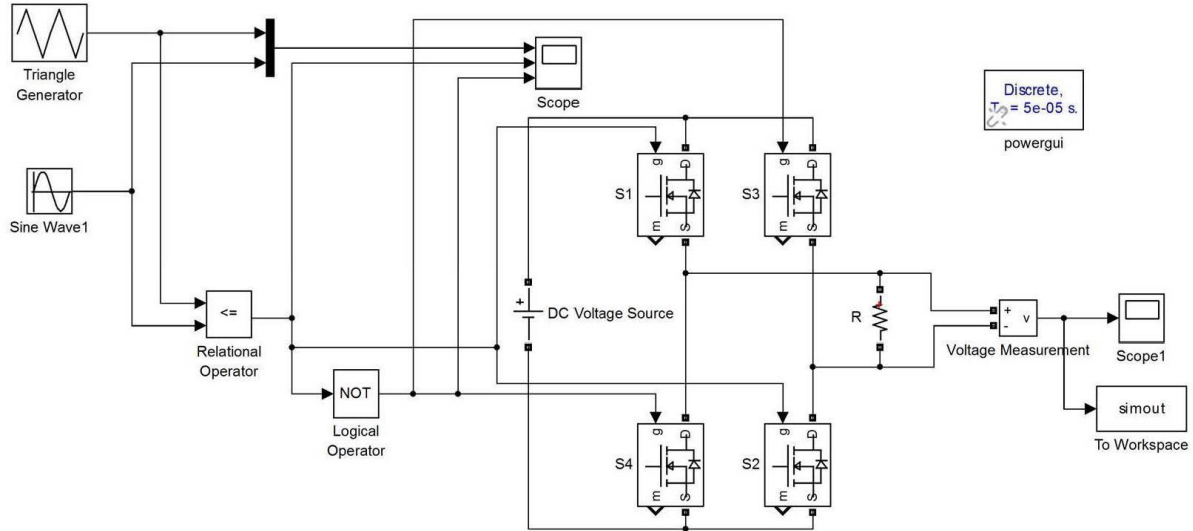Fig. 6: Unipolar PWM Waveforms, Gating Signals And Output Voltage
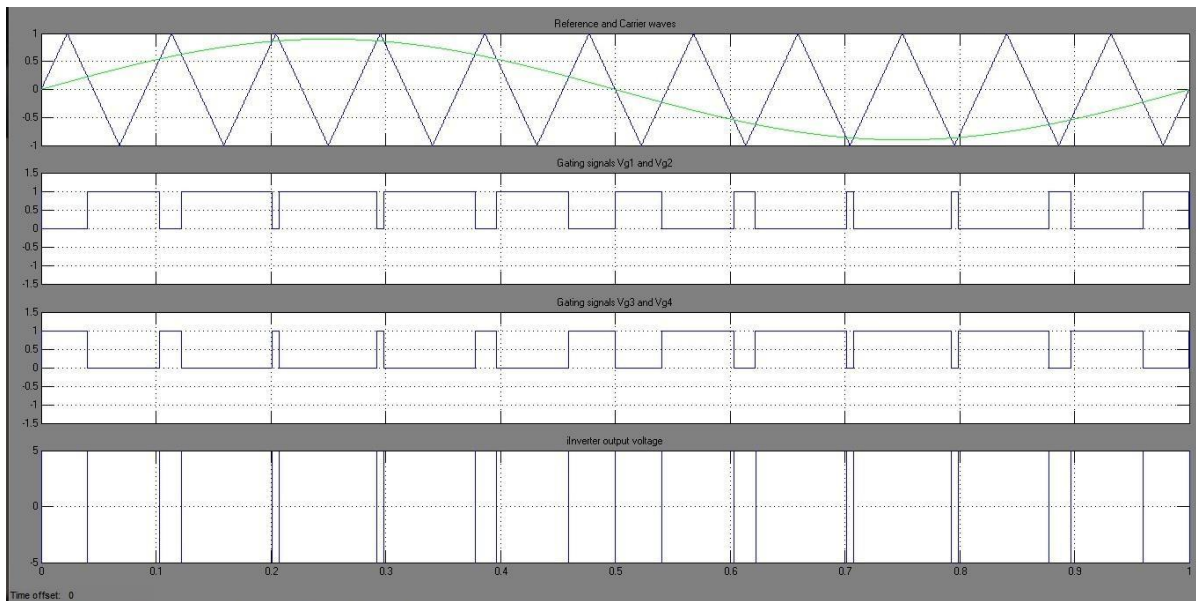

Fig. 7: Simulink Model of Bipolar Inverter

Fig. 8: Bipolar PWM Waveforms, Gating Signals And Output Voltage

The FFT analysis of the unipolar PWM inverter for modulation index 1.0 and for 1.2 ; which is a case of over modulation are as shown in Figure 9 and Figure 10.
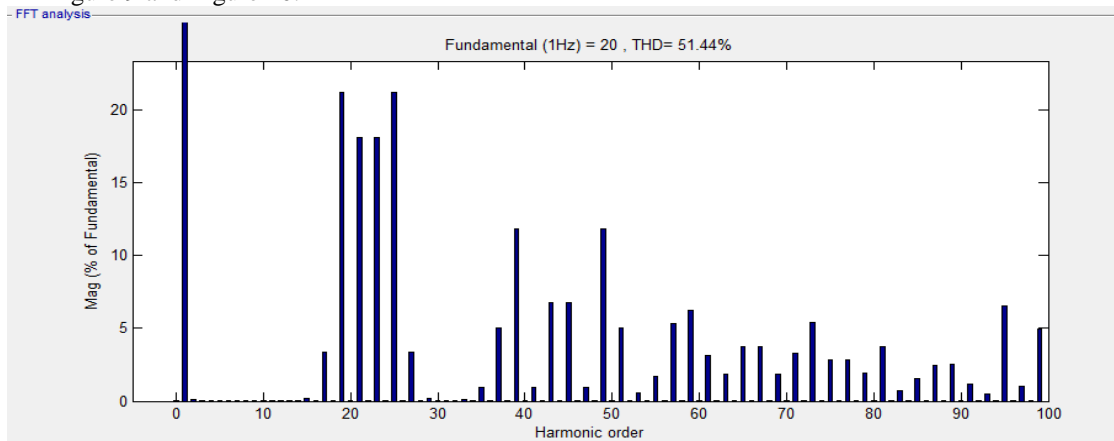

Fig. 9: FFT Analysis of Unipolar Inverter With Modulation Index 1.0(Without Filter Circuit)
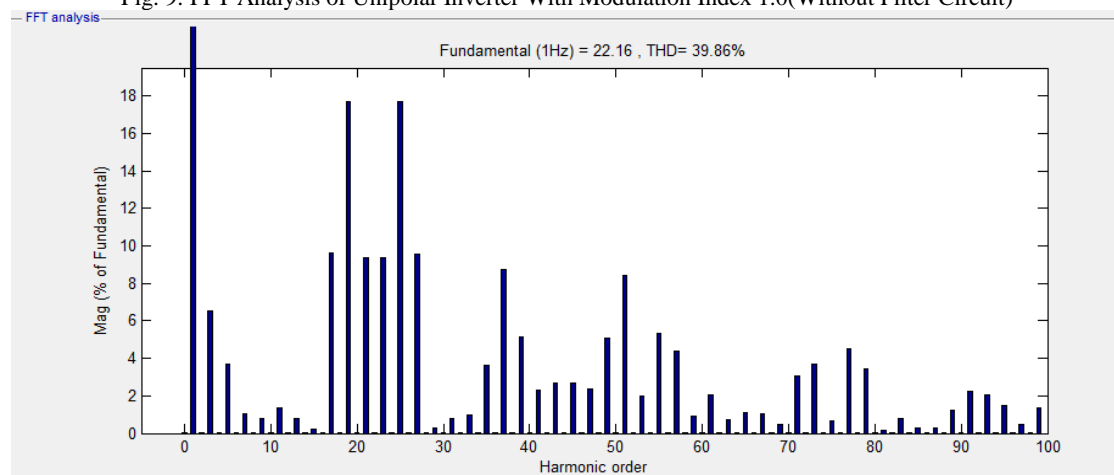

Fig. 10: FFT Analysis of Unipolar Inverter With Modulation Index 1.2(Without Filter Circuit)

Similarly for bipolar inverter the FFT analysis for modulation index 1.0 and overmodulation witn modulation index 1.2 are as shown. It can be clearly concluded that unipolar PWM inverters are better in terms of efficiency and lower THD(TOTAL Harmonic Distortion) as compared to bipolar PWM inverter.
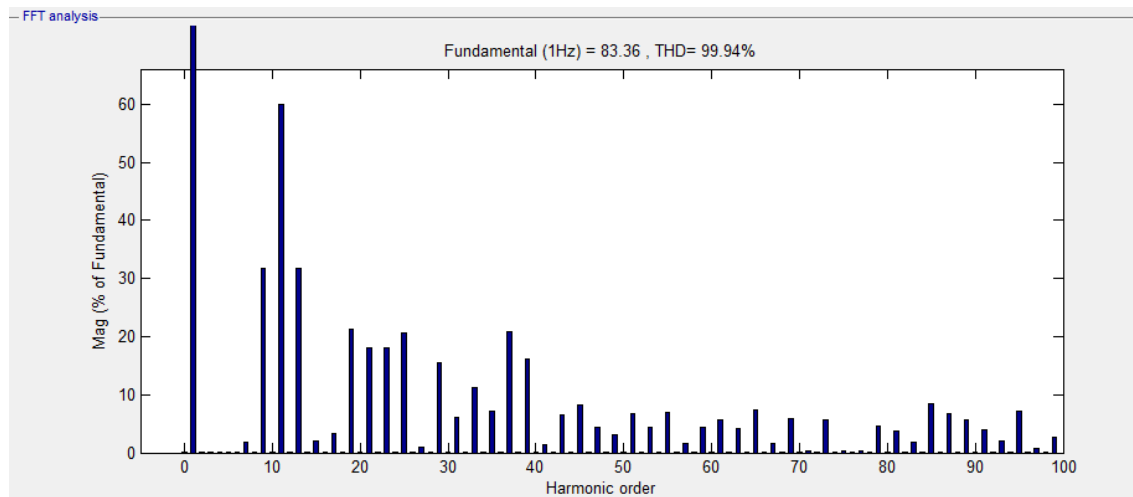
Fig. 11: FFT Analysis of Bipolar Inverter With Modulation Index 1.0(Without Filter Circuit)
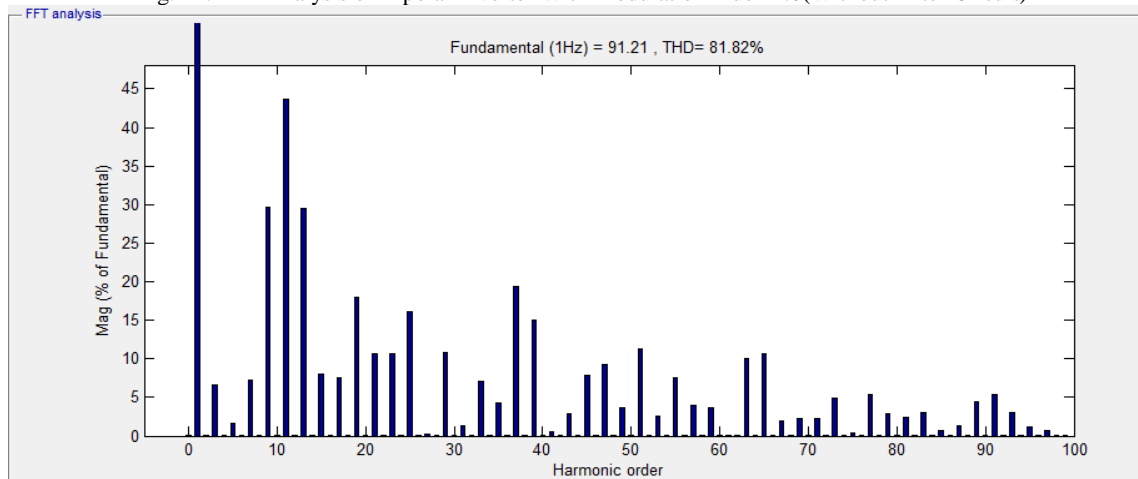

Fig. 12: FFT Analysis of Bipolar Inverter With Modulation Index 1.2(Without Filter Circuit)

VI. CONCLUSION

Pure sine wave DC/AC conversion will introduce the least amount of harmonics into an electrical device, but are also the most expensive method. Since the AC sine wave must come from a DC source, switching must still take place. However, switching takes place with logic so that the energy delivered to a load approaches that of a pure sine wave. It can be derived from the waveform that a unipolar inverter with a filter circuit will give better sinusoidal output waveform compared to bipolar inverter.

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