Comparative Analysis On Modulation Techiniques HCCPWM,SPWM and MSPWM For a Single Phase Full- Bridge Inverter

Kingsley A. Ogudo and Josiah Makhubele

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***Abstract*: Fundamental basics of modulation techniques applied in inverter circuits for AC drives. This study investigate the comparative analysis of modulation techniques applied on the single-phase full bridge inverter topology. Simulink / MATLAB software was used to implement three modulation techniques such as SPWM, HCCPWM and MSPWM. The waveforms characteristics were analyzed based on their amplitude, frequency, and Total harmonic distortion (THD). Bipolar topology was used as a basic PWM generator on SPWM and MSPWM. MSPWM generated output waveforms for both current and voltage was having low THD and its output waveforms for both current and voltage to be pure sinusoidal. Therefore, this technique has been proved to be the best modulation technique compared to the SPWM and HCCPWM and can be used for AC drives application. All the modulation techniques have been implemented using the same parameters. As shown from the SPWM and HCC they have high values of THD and switching losses which results in the inverter having poor efficiency and less reliability. There are also other factors which plays a role in the harmonic contents presence such as modulation index. Inverter losses has been discussed and ways to improve the performance of the inverter.**

Keywords—Sinusoidal Pulse Width (SPWM), Hysteresis-band Current Control (HCCPWM), Space Vector Pulse Width (SVPWM), Selective Harmonic Elimination (SHE),Phase Shifted Carrier PWM (PSCPWM) and Pulse Width Modulation (PWM), Switching Frequency (Fs),Fundamental frequency (Fr), Direct Current (D.C.), Alternating Current (A.C.) Voltage Source Inverter (VSI)

I. INTRODUCTION

The study of inverters in the field of Power electronics is a very broad topic which comprises of more research work. There are so many industrial problems associated with inverters which requires solutions. Electronic devices that are involved in the conversion of D.C. power to AC are called inverters. There are variety of inverter types such as 2-level and multi-level inverters. An overall control, in the output voltage and frequency of the VSI is obtained from the gate firing pulses that are generated by a power electronic device [1&2]. Pulse width Modulation (PWM) has its normal application lying on control in power conversion and motion. There are variety of modulation techniques methods available such as PWM have variety of Modulation Techniques such as SPWM, SVPWM, HCCPWM, SHE-PWM, PSCPWM, Third Harmonic Injection (THIPWM), and Multi Pulse Width Modulation (MPWM) Technique, Modified SPWM, etc. [1-14]. SPWM is one of the popular PWM techniques in industrial applications with SVPWM known for wave shaping [3-7] Total Harmonic Distortion (THD) is very important selective criteria for practical implementation of a PWM generator, because THD is directly proportional to harmonic contents [3]. Modified SPWM is used in hybrid multilevel inverters [8]. HCC PWM switching frequency does not remain constant and therefore optimal design of the input filter become impossible [4&11]. In this paper only three modulation techniques will be implemented and analyzed using Simulink/MATLAB software. The modulation techniques include SPWM, HCCPWM and the modified SPWM and waveform characteristics will be demonstrated. THD and waveform characteristics will be analyzed for less harmonic contents, efficiency and reliability. Therefore, these are the key performance indicators to be used in this study.

II. SIMULATION RESULTS

A. *Hysteresis –Band Current Control Pulse Width Modulation (HCCPWM)*

Parameters used in all the three simulations includes a single-phase full bridge inverter, line inductance and resistance of 0.001H&0.001Ω (ohms), load resistance of 100Ω (ohms) with a capacitance of 1000 µF (micro Farad). Supply voltage is DC and is 100V at 50 Hz Fr and1kHz Fs. Gain factor is set to be 1 and modulation index of 0.1.

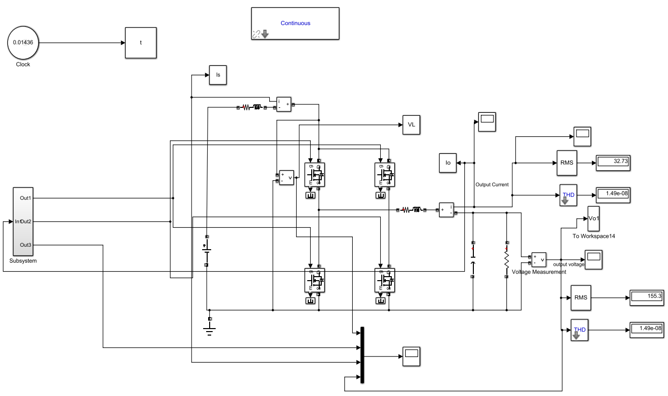

Figure 1: Single phase Hysteresis Current controller Simulink model

Hysteresis Current Controller Pulse Width Modulation technique is as shown in Figure 2. This method is defined to be the simple or easiest method of PWM to implement. It does not require complex circuits or complex mathematics. This control circuit generates sinusoidal reference current at a desired size and frequency, and it is then compared with the actual phase current wave. It takes the error signal with the assistance from the comparator and keeps it at an imposed band. Operation takes place by means of switching power transistors Q1, Q4 and Q2, Q3 input current forced to track or follow a reference shape. There are advantages associated with this method such as provision of dynamic response and high performance. Switching frequency of the HCC changes according to variations of the operating conditions and load parameters. When the load is changed then the switching frequency amplitude changes. It results in switching losses to be high and it is restricted to lower power level application. This serves as its main disadvantage.is defined as a simple method of current control feedback of the Pulse width Modulation (PWM), where the control current follows a reference current within the hysteresis band [12 &17]. HCC always play a role of controlling the switching frequency.

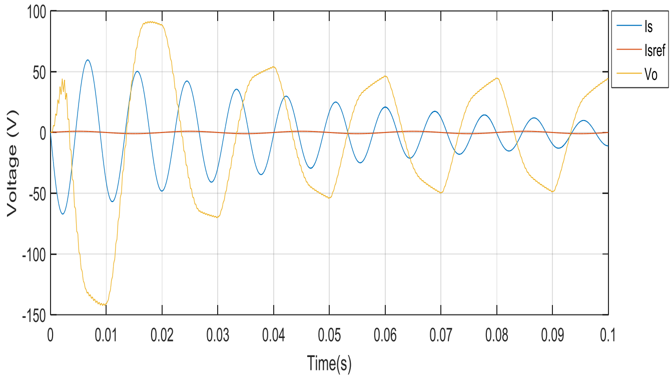

Figure 1.1: Simulated performance of HCC

It can be observed in Figure 1.1 the reference current (Isref), supply current (Is), load voltage (Vl) and the output voltage (Vo). Control signals are generated by comparison between the actual and reference current at desired frequency and magnitude. When current exceeds a prescribed hysteresis band the upper switch gets turned off and lower switch turns on and vice versa. As a result, output current transition is between +0.5 Vd and -0.5Vd and then current starts to decay. The actual current is force to follow the sine reference current within the band [8]. Switching frequency is changed with the variation of the load parameters. This affects the performance of this method and the losses are limited by the semiconductor switch characteristics.

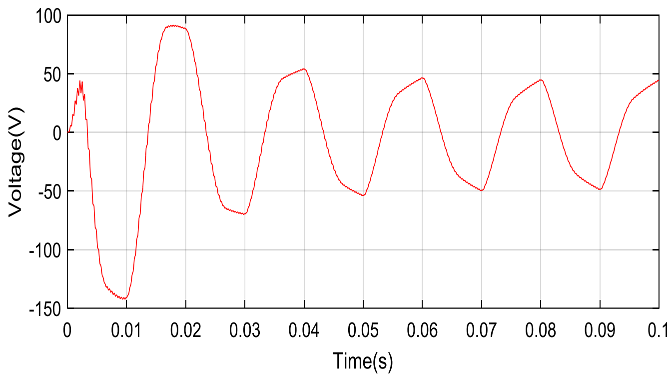

Figure 1.2: Simulated performance of HCC PWM inverter output voltage (Vo) (fs=1kz).

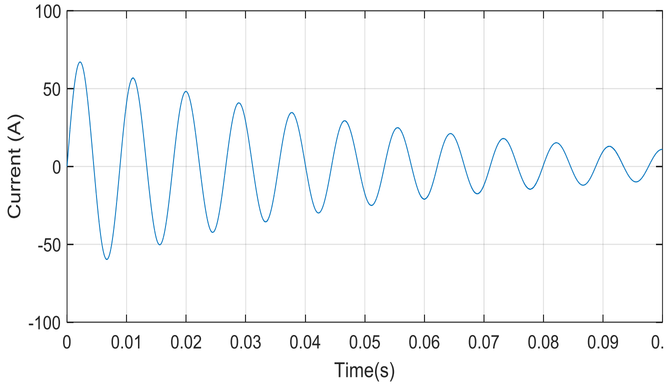

Figure 1.3: Simulated performance of HCC PWM inverter output current (Io) (fs=1kz).

As shown in Figure 1.2 &1.3 output current and voltage are sinusoidal in shape. Output voltage amplitude of the waveform start to change as noticed from0.05 seconds. It remains sinusoidal and the peak voltage slightly changes. With the increase in frequency the are more harmonics present and results in high loss in the inverter. The load variations have a negative impact in the switching frequency and performance of the inverter. Losses are limited by the characteristics of the Insulated Gate Bipolar Transistor (IGBT) or Metal Oxide Semiconductor Field Effect Transistor (MOSFET) and other secondary elements [11].

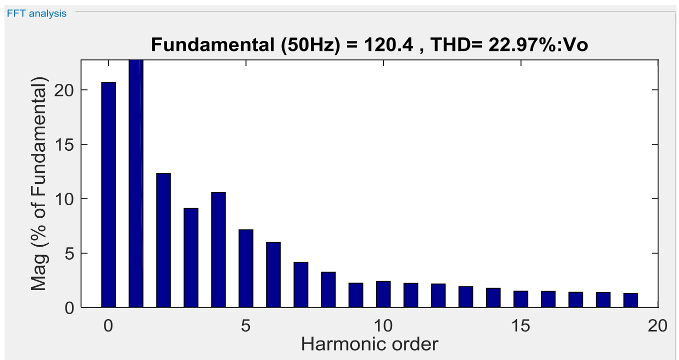

Figure 1.4: FFT result of Output voltage of Bipolar HCCPWM inverter

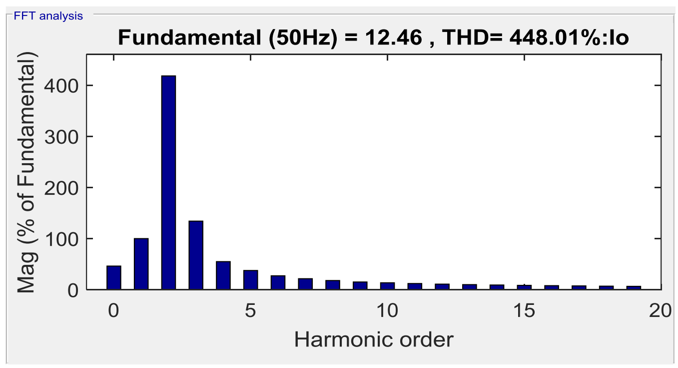

Figure 1.5: FFT result of Output current of Bipolar HCCPWM inverter

It has been shown in the Figure 1.4 & 1.5 the THD of output current and voltage waveforms of the Hysteresis current control pulse width modulation technique. FFT analysis as shown in Figure 1.4, output voltage has THD of 22.97%. This waveform characteristic is sinusoidal and with less distortion from high harmonic order and low order harmonics are more. Output current has 448.01%THD as shown by the FFT analysis. There low order harmonics present than high order harmonics. Both the output waveforms have same magnitude and frequencies.

B. Sinusoidal Pulse Width Modulation(SPWM)

Parameters used for all the three simulations includes a single-phase full bridge inverter, line inductance and resistance of 0.001H&0.001 Ω, load resistance of 100 Ω with a capacitance of 1000 µF. Supply voltage is DC and is 100V at 50 Hz Fr and 1kHz Fs. Gain factor is set to be 1 and modulation index of 0.1.

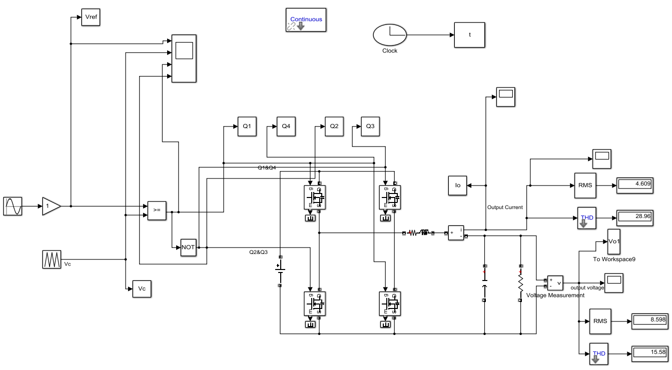

Figure 2: Single phase SPWM Simulink model

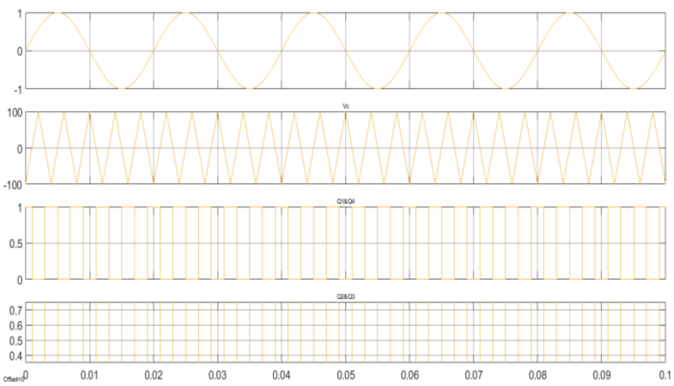

Figure 2.1: Simulated Performance of Bipolar PWM Inverter (Fs=1kHZ)

A Bipolar SPWM switching signals is shown in Figure 2. This scheme has its advantages and disadvantages as like other switching methods of the inverter. Output signals are generated by the comparison between the sinusoidal reference signal and the carrier triangular signal [1]. Reference signal has a fundamental frequency which controls the output frequency of the inverter. Carrier signal is known for its high frequency switching signal and determines the number of pulses per half cycle. The output voltage transforms from positive and negative direct current (DC) voltages hence its called bipolar PWM as shown in Figure 2.1 [9]. Output signals are generated by switching (on/off) of Q1, Q4 and Q3, Q2 switches. When the amplitude of a reference signal is higher than the amplitude of a carrier signal then output pulse is high. When the carrier is higher than the reference then the output is low, and carries on that way generating output pulses. There are time delays which are important in the creation of error voltages. There is error voltage pulse in each carrier cycle.

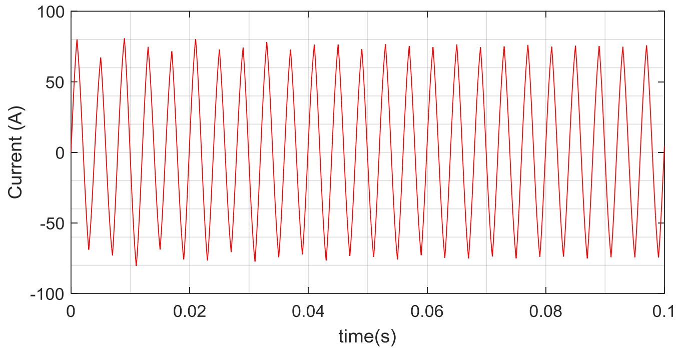

Figure 2.2: Output current of Bipolar PWM inverter

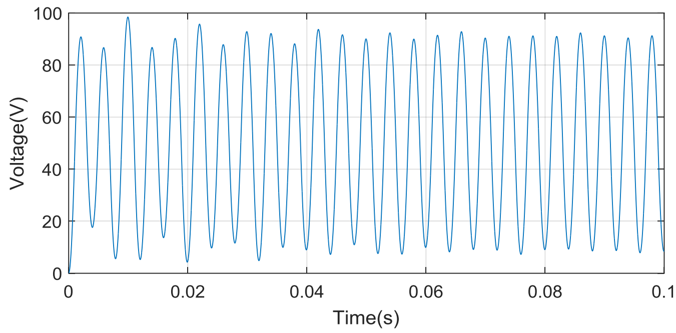

Figure 2.3: Output voltage of Bipolar PWM inverter

Performance of output current and voltage waveforms from the simulation has been illustrated in Figure 2.2 & 2.3. Both waveforms are sinusoidal in shape. It can be seen that the waveforms are unstable from 0 to 0.03 seconds from both waveforms. This results from harmonic contents present in the waveform. Minimum losses and the variation of load does not affect the switching frequency. High switching frequencies are associated with odd harmonic orders. The modulation index plays a very important role in the design by changing the amplitude of the output voltage. When PWM is designed with a proper modulation index minimum harmonic will be present from the output wave [1].

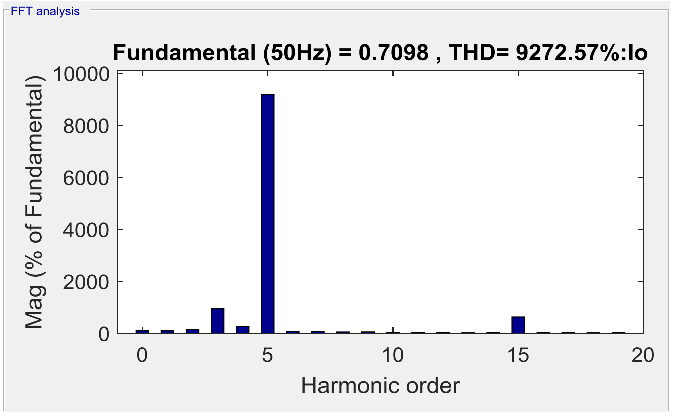

Figure 2.4: FFT result of Output current of Bipolar SPWM inverter

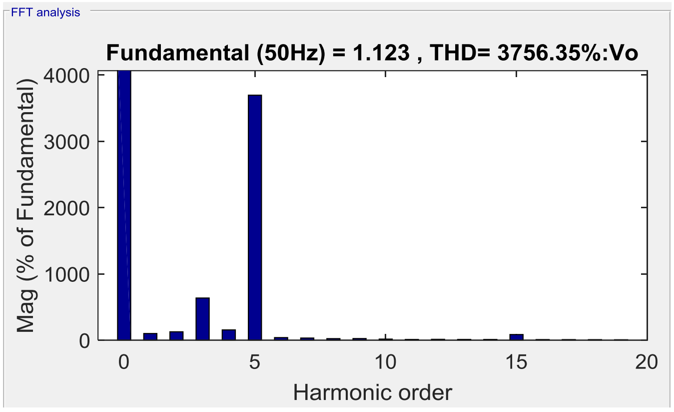

Figure 2.5: FFT result of Output voltage of Bipolar SPWM inverter

FFT analysis of Bipolar SPWM output current and voltage has been shown in Figure 2.4 &2.5. Output current show the THD of 9272.57%. There are 1st order harmonics during switching and the 5th order harmonic is also present. There are 11th, 15th etc. present as shown in Figure 2.5 that have less harmonic distortion. As shown from Figure 2.5, the THD value is 3756.35%. This means that there are more harmonics and the losses during switching is also high. As a result, from FFT analysis it shows clearly that output voltage and currents need a harmonic filter to obtain a pure sine wave with less harmonic contents.

C. *Modified Sinusoidal Pulse Width Modulation(MSPWM)*

Parameters used for all the three simulations includes a single-phase full bridge inverter, line inductance and resistance of 0.001H&0.001 Ω, load resistance of 100 Ω with a capacitance of 1000 µF. Supply voltage is DC and is 100V at 50 Hz Fr and 1kHz Fs. Gain factor is set to be 1 and modulation index of 0.1.

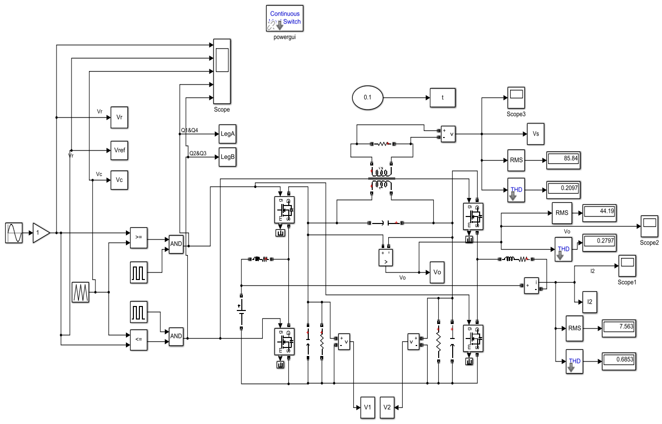
Figure 3: Single phase Bipolar MSPWM Simulink model

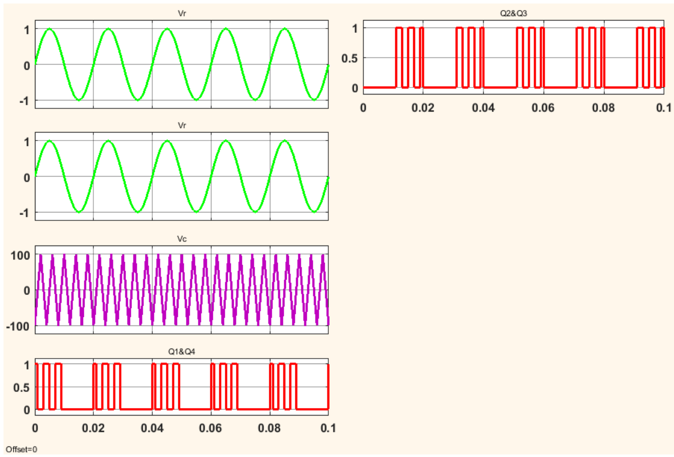

Figure 3.1: Simulated Performance of MSPWM Inverter (Fs=1kHZ)

Modified Sinusoidal Pulse Width Modulation technique is as shown in Figure 3. This method has been derived from standard SPWM controller. The characteristics of the controller is similar to the standard SPWM technique. This controller has been modified so that carrier signal can be applied during the first and last 60 degrees interval per half cycle [5-8]. The improvement of harmonic contents increases the fundamental component. This technique has some advantages such as improved harmonic characteristics, reduced number of switching power devices, and decreased switching losses. The performance characteristics for generating the output pulses is as shown in Figure 3.1. There are two sine reference voltages which have same magnitude and frequency. The reference is compared with the carrier triangular signal of high frequency to generate the pulses to the gate of the inverter. The switching of transistors varies with time and the switches can not be turned on at the same time as it can result in short circuit and damage the device. When you turn on next switch the other is delayed. As it is observed in Figure 3.2, output pulses of Q1, Q4 and Q2, Q3. There is a delay in the switching angles and phase shift.

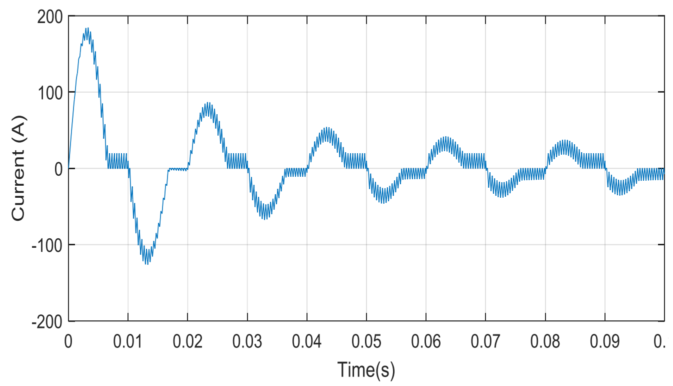

Figure 3.2: Output current of Bipolar MSPWM inverter

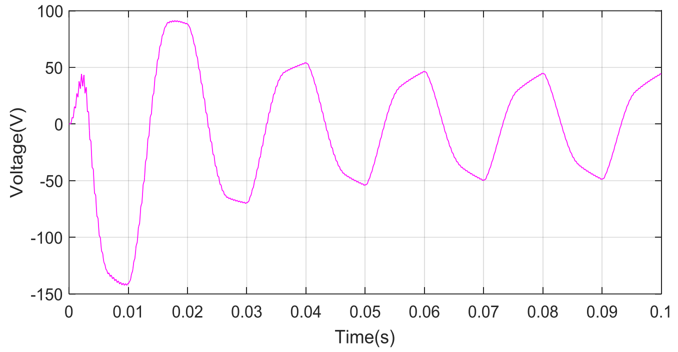

Figure 3.3: Output voltage of Bipolar MSPWM inverter

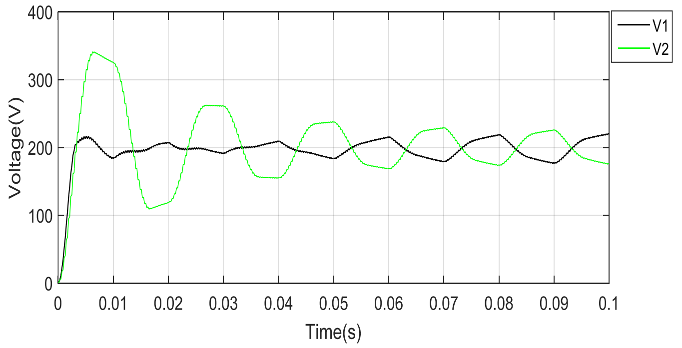

Figure 3.4: Inductor voltages (V1 & V2) of Bipolar MSPWM inverter

As shown in Figure 3.3 &3.4 the simulation current and voltage waveforms. Output voltage of bipolar MSPWM have an overshoot from 0 to 0.03 seconds. As time increases the amplitude becomes constant and its shape get to be more sinusoid. Inductor voltages V1 and V2 results from inductor switching on/off. The inductors charges and discharges, therefore there is voltage induced in the circuit. Both voltage waveforms as pure sine waves and with less harmonic content present.

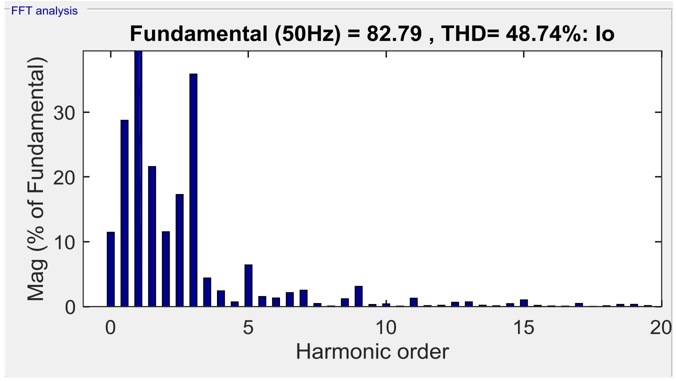

Figure 3.5: FFT result of Output current of Bipolar MSPWM inverter

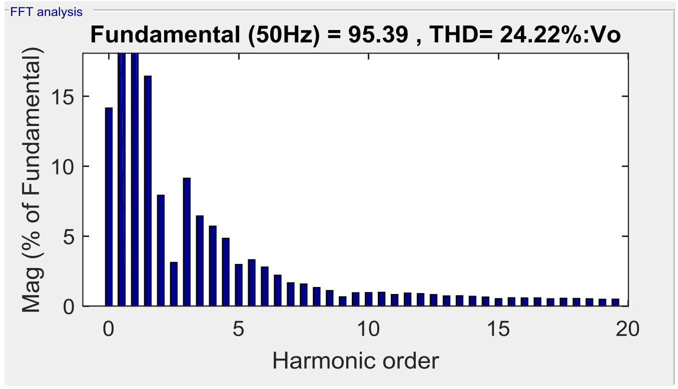

Figure 3.6: FFT result of Output current of Bipolar MSPWM inverter

FFT analysis of Bipolar MSPWM output current and voltage has been shown in Figure 3.5 &3.6. Output current show the THD of 48.74 %. low order harmonics are high and less high harmonic order. The output voltage THD is 24.22 % which is low compared to current output. During switching there are more low order harmonics present in the waveform. This performance is fairly good and its fundamental frequency is 50Hz similar to the output current. The parameters used in the inverter circuit are the same for all the modulation techniques used.

III. CONCLUSION

Performance analysis of harmonic content present in the AC drives remains the core study of inverters in Power Electronics. The switching losses, and presence of harmonics have been studied using different modulation techniques. Three modulation techniques have been implemented and simulated on the single-phase full bridge inverter using Simulink/MATLAB software. The performance of the Sinusoidal PWM technique being the common method applied in single phase inverter yielded 9272.57%. & 3756.35% THD results for both output current and voltage respectively. The HCCPWM for both output voltage and current has 22.97% & 448.01% THD values as shown in Figure 1.4, 1.5, 2.5 & 2.6. This performance analysis carried in MSPWM techniques show to be the best modulation technique with low values of 48.74 %

& 24.22 % THD on both output waveforms. These results show this modulation technique is the best suitable method for PWM applications, from the comparative analysis performed. There is also a room for improvement to minimize the harmonic content and performance of the inverter. More research work needs to be conducted to have output voltage and currents signals of the inverter with negligible harmonic content and switching losses as to improve the efficiency and reliability of inverters in AC Drives.

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