Abstract- In this paper, a simulation of SPWM (Unipolar) strategy is presented for single phase full bridge inverter. The simulation of the single-phase unipolar voltage switching inverter device model is simulated in Matlab/Simulink. The modulation ratio change from 0.4 to 0.9 by varying amplitude of modulating signal. The outputs voltage and current %THD waveforms for variable AC voltages and modulation index are observed on scope, and also see the THD. SPWM techniques are characterized by constant amplitude pulses with different duty cycle for each period. The width of these pulses are modulated in order to obtain inverter output voltage control and to reduce its harmonic content. Sinusoidal pulse width modulation or SPWM is the most common method in motor control and inverter application. Conventionally, to generate the signal, triangle wave as a carrier signal is compared with the sinusoidal wave, whose frequency is the desired frequency. In next the hardware design for unipolar voltage switching for inverter for fixed modulation index and is tested for different resistive loads.

Keywords-Sinusoidal pulse width modulation (SPWM), Bipolar, Total Harmonic distortion (THD). Pulse Width Modulation (PWM), UPS (uninterruptible power supplies).

I. INTRODUCTION

An inverter is basically a device that converts electrical energy of DC form into that of AC. The purpose of DC-AC inverter is to take DC power from a battery source and converts it to AC. The inverter receives DC supply from 12V battery and then inverter converts it to 230V AC with a desirable frequency of 50Hz. These DC-AC inverters have been widely used for industrial applications such as uninterruptible power supply (UPS), AC motor drives. In addition to this, the control strategies used in the inverters are also similar to those in DC-DC converters. Both current-mode control and voltage-mode control are employed in practical applications.

A voltage source inverter employing thyristor as switches, some type of forced commutation is required, while the VSI made up of using GTOs, power transistors, power MOSFETs or IGBTs. A standard single-phase voltage or current source inverter can be in the half-bridge or full-bridge configuration. Some industrial applications of inverters are for adjustable-speed ac drives, UPS (uninterruptible power supplies) for computers, HVDC transmission lines, induction heating, standby aircraft power supplies etc.

II. PULSE WIDTH MODULATION (PWM) TECHNIQUE IN INVERTER

The Modulation Process is Included in Inverter for Switching. A basic of Pulse Width Modulation (PWM) Technique is as. There are many forms of modulation used for communicating information. When a high frequency signal has amplitude varied in response to a lower frequency signal we have AM (amplitude modulation). When the signal frequency is varied in response to the modulating signal we have FM (frequency modulation). These signals are used for radio modulation because the high frequency carrier signal is needs for efficient radiation of the signal. When communication by pulses was introduced, the amplitude, frequency and pulse width become possible modulation options. In many power electronic converters where the output voltage can be one of two values, the only option is modulation of average conduction time.

The Pulse Width Modulation (PWM) is a technique which is characterized by the generation of constant amplitude pulse by modulating the pulse duration by modulating the duty cycle. Analog PWM control requires the generation of both reference and carrier signals that are feed into the comparator and based on some logical output, the final output is generated. The reference signal is the desired signal output maybe sinusoidal or square wave, while the carrier signal is either a saw tooth or triangular wave at a frequency significantly greater than the reference.

In many industrial applications, it’s often required to control the output voltage of inverters for the following reasons

- To cope with the variations of DC input voltage.
- For voltage regulation of inverters.
- For the constant volts/frequency control requirement.
There are various techniques to vary the inverter gain. The most efficient method of controlling the gain (and output voltage) is to integrate pulse width modulation (PWM) control within the inverters. The commonly used techniques are. There are five basic PWM techniques:

1. Linear modulation
2. Sawtooth PWM
3. Single Pulse Width Modulation
4. Multiple Pulse Width Modulation
5. Sinusoidal Pulse Width Modulation

III. SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

Instead of maintaining the width of all pulses of same as in case of multiple pulse width modulation, the width of each pulse is varied in proportion to the amplitude of a sine wave evaluated at the centre of the same pulse. The distortion factor and lower order harmonics are reduced significantly. The gating signals are generated by comparing a sinusoidal reference signal with a triangular carrier wave of frequency $F_c$. The frequency of reference signal $F_r$ determines the inverter output frequency and its peak amplitude $A_r$, controls the modulation index $M$, and $V_{rms}$ output voltage $V_O$. The number of pulses per half cycle depends on carrier frequency.

Inverters that use PWM switching techniques have a DC input voltage that is usually constant in magnitude. The inverters job is to take this input voltage and output ac where the magnitude and frequency can be controlled. There are many different ways that pulse-width modulation can be implemented to shape the output to be AC power. A common technique called sinusoidal-PWM will be explained. In order to output a sinusoidal waveform at a specific frequency a sinusoidal control signal at the specific frequency is compared with a triangular waveform. The inverter then uses the frequency of the triangle wave as the switching frequency. This is usually kept constant.

The triangle waveform, $V_{tri}$, is at switching frequency $f_s$; this frequency controls the speed at which the inverter switches are turned off and on. The control signal, $V_{control}$, is used to modulate the switch duty ratio and has a frequency $f_1$. This is the fundamental frequency of the inverter voltage output. Since the output of the inverter is affected by the switching frequency it will contain harmonics at the switching frequency. The duty cycle of the one of the inverter switches is called the amplitude modulation ratio, $m_a$.

![Fig.2 Desired Frequency is compared with a Triangular Waveform.](image1)

![Fig.3 Pulse-width Modulation (PWM)](image2)

$$V_{control} < V_{tri}$$

$T_{A_+}$ on, $T_{A_-}$ off

$$m_a = \frac{V_{control}}{V_{tri}}$$

Where $V_{control}$ is the peak amplitude of the control signal

$$V_{control} > V_{tri}$$

$T_{A_+}$ pos is on, $T_{A_-}$ off

$$v_A = \frac{V_d}{2}$$

$$m = \frac{f}{f_s}$$

The $V_{control} < V_{tri}$

$T_{A_{neg}}$ is on, $v_A = -\frac{V_d}{2}$

switches $T_{A+}$ and $T_{A-}$ are controlled based on the comparison of
\[ V_{\text{control}} \text{ and } V_{\text{sine}} \text{. The two switches are never off at the same time which results in the output voltage fluctuating between } +/- V_d/2. \]

In order to fulfill the requirement, the new switching technique had been analyzed and recommended in this paper, namely SPWM which is generated by PIC microcontroller. The various frequency triangular carriers with different amplitude modulation ratio SPWM signal had been programmed and tested in single phase inverter circuit in order to find the best switching signal in simulink.

- Switching Losses.
- Utilization of DC power supply that is to deliver a higher output voltage with the same DC supply.
- Linearity in voltage and current control.
- Harmonics contents in the voltage and current.

IV. PWM Switching Techniques

The PWM switching can be divided into two switching scheme which are PWM with Bipolar voltage switching and PWM with Unipolar voltage switching

1. PWM with Bipolar voltage switching
2. PWM with Unipolar voltage switching

Power inverter converts DC power to AC. There are several methods to do this. The two main ways, which use switched mode inverters, are square wave and pulse width modulation. The DC input voltage is adjusted to control the AC output magnitude of a square wave inverter. The switching frequency is adjusted to control the frequency. However, the methods used for a square wave inverter differ for a pulse width modulated inverter. In PWM, the controller adjusts both the magnitude and frequency. The difference in switching causes the harmonics to appear at different locations. Although the square wave signals are simpler, the harmonics exist mostly in the lower frequencies, which are close to the output frequency. In a PWM inverter, the harmonics are at multiples of the fundamental frequency, and thus are easier to filter. As a result, the output sinusoid has less distortion. Unfortunately, a PWM hold a major disadvantage in requiring complex switching circuitry as well as increased switching loss.

V. PWM with Unipolar Voltage Switching

The two types of pulse width modulation inverters are bipolar and unipolar switching. Each unique switching technique creates either a unipolar or bipolar output at the load. The control signals depend on comparing a reference signal and carrier signal. A PWM requires a sinusoidal reference signal and triangular carrier signal.

There are two types of unipolar switching. Type one operates both switches pairs at a high frequency. Type two uses a high frequency for one pair and a low frequency for the other pair of switches. We will be building a type two unipolar PWM inverter because it is simpler than type one. Fig.6 shows the output voltage switching characteristics for type two unipolar switching. The switching conditions are shown in Fig.6 (a) where Vsine and Vtri are the sine wave and triangular wave control signals respectively.

![Fig.6 Waveform for SPWM with Unipolar voltage switching](image-url)
In this scheme, the triangular carrier waveform is compared with two reference signals, which are positive and negative signal. The basic idea to produce SPWM with unipolar voltage switching is shown in Fig.6 (a). The difference between the Bipolar SPWM generators is that the generator uses another comparator to compare between the inverse reference waveform−Vr. The process of comparing these two signals to produce the unipolar voltage-switching signal. In Unipolar voltage switching the output voltage switches between 0 and Vdc, or switching event is halved in the Unipolar case from 2Vdc to Vdc. The effective switching frequency is seen by the load is doubled and the voltage pulse amplitude is halved. Due to this, the harmonic content of the output voltage waveform is reduced compared to bipolar switching. In Unipolar voltage switching scheme also, the amplitude of the significant harmonics and its sidebands is much lower for all modulation indexes thus making filtering easier, and with its size being significantly smaller. Between 0 and −Vdc. This is in contrast to the bipolar switching strategy in which the output swings between Vdc and −Vdc. As a result, the change in output voltage at each.

(a) Comparison between reference waveform and triangular waveform
(b) Gating pulses for S11 and S22
(c) Gating pulses for S12 and S21
(d) Output waveform.

In this scheme, the devices in one leg are turned on or off based on the comparison of the modulation signal Vr with a high frequency triangular wave. The devices in the other leg are turned on or off by the comparison of the modulation signal −Vr with the same high frequency triangular wave.

The logic behind the switching of the devices in the leg connected to ‘a’ is given as,

\[ Vr > Vc \quad S11 \text{ is on} \quad \Rightarrow \quad V_an = \frac{V_d}{2} \]
\[ Vr < Vc \quad S12 \text{ is on} \quad \Rightarrow \quad V_an = -\frac{V_d}{2} \]

and that in the leg connected to ‘b’ is given as

\[ -Vr > Vc \quad S11 \text{ is on} \quad \Rightarrow \quad V_{bn} = \frac{V_d}{2} \]
\[ -Vr < Vc \quad S11 \text{ is on} \quad \Rightarrow \quad V_{bn} = -\frac{V_d}{2} \]

In Unipolar switching scheme the output voltage level changes between either 0 to −Vd or from 0 to +Vd. This scheme ‘effectively’ has the effect of doubling the switching frequency as far as the output harmonics are concerned, compared to the bipolar switching scheme.

VI. SOFTWARE SYSTEM DEVELOPMENT USING MATLAB

In looking at the components selected and the simulations created before the actual construction of the inverter, everything was built in mind for the purpose of efficiency and keeping power losses to a minimum. Nowadays in so many applications desire controlled A.C. for controlling speed of machines like Induction Motor, Brushless D.C. Motor etc. For getting controlled A.C. nowadays inverter is used. Inverter is converting uncontrolled D.C. in to controlled A.C. There are so many types of inverter like two level, three level and five level etc. This is a very simple technique for harmonic reduction. In this technique pulse magnitude will be constant and only pulse time (width) can be changed. In this pure sine wave is compared with carrier (triangular) wave and producing gate pulses. Sine wave has fundamental frequency and carrier wave can be taken more than fundamental frequency. This is a very simple technique for harmonic reduction. In this technique pulse magnitude will be constant and only pulse time (width) can be changed. In this pure sine wave is compared with carrier (triangular) wave and producing gate pulses. Sine wave has fundamental frequency and carrier wave can be taken more than fundamental frequency. In this simulation development of two level inverter has discussed and output voltage and current waveforms, and its harmonics reduction by varying the modulation index.

VII. BLOCK DIAGRAM OF THE SPWM SYSTEM

Fig. 7 Block Diagram of the SPWM Inverter
a) Ideal DC Voltage Source
   The DC Voltage Source block implements an ideal DC voltage source. The positive terminal is represented by a plus sign on one port. You can modify the voltage at any time during the simulation.

b) MOSFET Inverter Bridge Section
   It consists of two or Four semiconductor switches, according to Configuration either half or full bridge. Here we use four MOSFET’s which are connected to form a full bridge circuit. The input to the bridge is the output of the filtered rectified DC voltage. The gates of the MOSFET’s are triggered using the PWM pulses.

c) Discrete PWM Generator
   This Discrete block generates pulses for Carrier-based PWM (Pulse Width Modulation) depending on the number of arms in the selected mode parameter, the blocks can be used either for single-phase or three-phase PWM Control.

d) Filter and Load Circuit
   The last block is filter and load circuit. The branch resistance, in ohms (Ω (100Ohm) acts as a load. In next the outputs from the MOSFET’s have some harmonics. The harmonics can be filtered using filter circuit.

VIII. SIMULINK MODEL OF UNIPOLAR AND BIPOLAR VOLTAGE SWITCHING

The Simulation diagram for single phase inverter drawn using MATLAB SIMULINK is shown in Fig.8, the simulation model diagram consists of the following blocks.

- DC Supply (Vdc2)
- MOSFET Bridge Section(s1,s2,s3,s4)
- PWM Pulse Generator
- Filter and Load Circuit

MOSFET INVERTER BRIDGE SECTION

The metal-oxide semiconductor field-effect transistor (MOSFET) is a semiconductor device controllable by the gate signal (g > 0). The MOSFET device is connected in parallel with an internal diode that turns on when the MOSFET device is reverse biased (Vds < 0) and no gate signal is applied (g=0). The model is simulated by an ideal switch controlled by a logical signal (g > 0 or g = 0), with a diode connected in parallel; here we use four MOSFET’s which are connected to form a bridge circuit. The input to the bridge is the output of the filtered rectified DC voltage. The gates of the MOSFET’s are triggered using the PWM pulses. The parameters are given below.

IX. PWM PULSE GENERATOR FOR UNIPOLAR VOLTAGE SWITCHING

The output pulses are a vector (with values=0 or 1). Depending on the selected "Generator Mode", the output vector contains: For a 1-arm bridge: Two pulses. Pulse 1 is for the upper switch and pulse 2 is for the lower switch. For a 2-Arm Bridge: Four pulses. Pulses 1 and 3 are respectively for the upper switches of the first and second arm. Pulses 2 and 4 are for the lower switches. For a 3-arm bridge: Six pulses. Pulses 1,3 and 5 are respectively for the upper switches of the first, second and third arm. Pulses 2, 4 and 6 are for the lower switches. For double 3-arm bridges: Twelve pulses. The first six pulses (pulses 1 to 6) must be sent to the first 3-arm bridge and the last six (pulses 7 to 12) to the second 3-arm bridge.

By selecting "Internal generation" you can control the modulation index m, frequency and phase of the output voltage from the
internal parameters (m, Freq and Phase). Otherwise, external signals are used for pulse generation. The width of the input vector must be 1 for single phase bridges (1-arm or 2-arm) and 3 for 3-phase bridges (single or double bridge).

Figure 9 shows SPWM Pulse Generator Circuit in that we use two sine wave signal (reference signal) has phase opposite to each other. It is compared with triangular wave (switching signal). In comparator gives switching pulses to the MOSFETs.

X. GATE PULSES GENERATION FOR UNIPOLAR VOLTAGE SWITCHING

The PWM pulse generator block generates the four PWM pulses and these pulses are given to the gates of the MOSFETs for turning on and turn off.
XIII. CONCLUSION

The electronic devices is smaller, therefore the efficiency of power supply used in electronic devices should be improved from time to time. The different switching techniques and switching elements were used in single phase inverter also considered when inverters become the best power supply for converting DC power to AC power. Based on studied, SPWM techniques is a common method used in single phase inverter circuit are Unipolar and Bipolar voltage Switching. The simulation of the single-phase Unipolar voltage switching inverter device model is simulated in Matlab/Simulink.

XIV. REFERENCES


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