MATLAB simulation of three phase inverter & study of harmonic analysis by using SPWM technique

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Abstract- This project deals with study of a Sinusoidal Pulse Width Modulated Inverter and techniques used to reduce the harmonics in the output voltage of the inverter along with improved efficiency. The project is carried out with a basic understanding of the circuitry of the SPWM Inverter and its operation. SPWM techniques are characterized by constant amplitude pulses with different duty cycle for each period. The width of these pulses are modulated to obtain inverter output voltage control and to reduce its harmonic content. In this development a unipolar and bipolar SPWM voltage modulation type is selected because this method offers the advantage of effectively doubling the switching frequency of the inverter voltage, thus making the output filter smaller, cheaper and easier to implement. Our attempt will be to observe the output for three phase SPWM inverter and analyze its parameters used to get a pure sinusoidal output waveform and fewer harmonic in its output voltage waveform. It will be attempted to simulate a model circuit on MATLAB simulating software and analyze the output waveforms for various values of the elements used in the circuit and hence observe the waveform distortion.

Keywords*-IGBT, inverter, conduction modes, SPWM technique, unipolar-bipolar switching.*

1.INTRODUCTION

Devices that convert dc power to ac power are called inverters. The purpose of an inverter is to change a DC input voltage to AC output voltage which will be symmetric and will have desired magnitude and frequency. Inverters can be broadly classified into two types, voltage source and current source inverters. A voltage–fed inverter (VFI) or more generally a voltage–source inverter (VSI) is one in which the dc source has small or negligible impedance. The voltage at the input terminals is constant. A current–source inverter (CSI) is fed with adjustable current from the dc source of high impedance that is from a constant dc source.

For voltage source inverter employing thyristor as switches, some type of forced commutation is required. The VSI made up of using GTOs, power transistors, power MOSFETs or IGBTs, self commutation with base or gate drive signals can be used for their controlled turn-on and turn-off. A standard single-phase voltage or current source inverter can be in the half-bridge or full bridge configuration. The single-phase units can be joined to have three-phase multiphase topologies. Some industrial applications of inverters are for adjustable-speed ac drives, induction heating, standby aircraft power supplies, UPS (uninterruptible power supplies) for computers, HVDC transmission lines, etc Generally PWM control is used to obtain ac output voltage of desired frequency and magnitude.

For providing adjustable frequency power to industrial application, three phase inverters are more common than single phase inverters. Three phase inverters, like single phase inverters, take their DC supply from a battery or more usually from a rectifier. A basic three phase inverter is a six step bridge inverter . it uses minimum six IGBTs. In inverter terminology ,a step is defined as a change in firing from one IGBT to next IGBT in proper sequence. Foe one cycle of 360^0,each step would be of 60^0 interval. This means that IGBTs would be gated at regular interval of 60^0 in proper sequence so that a three phase ac voltage is synthesized at the output terminal of six step inverter. . A large capacitor is connected at the input terminal tends to make the input dc voltage constant, this also suppresses the harmonics fed back to the source.

2. METHODOLOGY

There are two possible patters on getting the IGBTs. In one pattern each IGBT conducts for 180^0 and in the other , each IGBT conducts for 120^0. But in both these patterns, getting signal are applied and removed at 60^0 intervals of the output voltage waveform. Therefore, both these modes requires a six step bridge inverter.

180^0 mode of operation:

Each transistor conducts for a period of 180^0. Three of the transistors remain on at any instant of time. When Ta+ is switched on, terminal a is connected to positive terminal of dc input voltage. When Ta- is switched on, terminal a is brought to negative terminal of dc input. There are six modes of operation in a cycle and duration of each mode is 60^0.

The load can be connected in either Y or Δ. Switches of any leg of the inverter cannot be switched on at the same time since this would result in a short circuit across the dc link voltage supply. Similarly to avoid undefined states and thus undefined ac output line voltage, the switches of any leg of the inverter may not be switched off simultaneously since this can result in voltages that depend on respective line current polarity

For practical applications, 180^0 mode of conduction is preferred since each IGBT is better utilized in case of 180^0 mode of conduction as compared to 120^0 mode of operation for similar load conditions. Nevertheless, the analysis of the output waveforms of the inverter will not vary much for 120^0 since only the amplitude will vary for the two modes and not the vital characteristics. So, for our purpose, it will suffice to proceed with 120^0 mode of conduction.

120^0 mode of operation:

In this type of control, each IGBT conducts for 120^0 Only two IGBTs conduct simultaneously. The IGBTs conduct in a sequence 61,12,23,34,45,56,61. So there are three modes of operation in one half cycle .

In the 180^0 mode inverter, when gate signal ig1 is cut off to turn OFF IGBT-1 at wt=180^0, getting signal ig4 simultaneously applied to turn ON IGBT-4 in the same leg. In practice, a commutation interval must exist between the removal of ig1 and application of ig4, because otherwise DC source would experience a direct short circuit through IGBT-1 & IGBT- 4 in the same leg.

This difficulties overcome considerably in 120^0 mode inverter . In this inverter, there is a 60^0 interval between the turning off of IGBT-1 & turning on of IGBT-4.during this 60^0 interval, IGBT-1 can be commutated safely. in general, this angular interval of 600 exist between the turning off of one device and turning off of the complimentary device in the same leg. This 60^0 period provide sufficient time for the outgoing IGBT to regain forward blocking capability.

3. PULSE WIDTH MODULATION

This is a method in which fixed dc input voltage is given to an inverter and the output is a controlled ac voltage. This is done by adjusting the on and off periods of the inverter components.

A. Single pulse width modulation

In this control, there’s only one pulse per half cycle and the width of the pulse is varied to control the inverter output. The gating signals are generated by comparing a rectangular reference signal of the amplitude Ar with triangular carrier wave of amplitude Ac, the frequency of the carrier wave determines the fundamental frequency of output voltage. By varying Ar from 0 to Ac, the pulse width can be varied from 0 to 100 percent. The ratio of Ar to Ac is the control variable and defined as the modulation index.

B. Multiple pulse width modulation

The harmonic content can be reduced by using several pulses in each half cycle of output voltage. The generation of gating signals for turning ON and OFF transistors by comparing a reference signal with a triangular carrier wave. The frequency Fc, determines the number of pulses per half cycle. The modulation index controls the output voltage. This type of modulation is also known as uniform pulse width modulation (UPWM).

C. 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 Fc. The frequency of reference signal Fr ,determines the inverter output frequency and its peak amplitude Ar, 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 fs; 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 f1. 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.

SPWM Switching Techniques:

1. PWM with bipolar voltage switching

2. PWM with unipolar voltage switching

SPWM with Bipolar Switching:

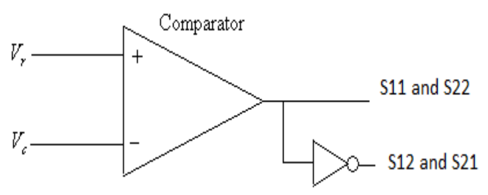


Fig 1. Comparator of bipolar switching

The basic idea to produce PWM Bipolar voltage switching signal is shown in Fig. 4 . It comprises of a comparator used to compare between the reference voltage waveform V_r with the triangular carrier signal V_c and produces the bipolar switching signal. If this scheme is applied to the full bridge single phase inverter as shown in Fig., all the switch S11, S21, S12 and S22 are turned on and off at the same time. The output of leg A is equal and opposite to the output of leg B.

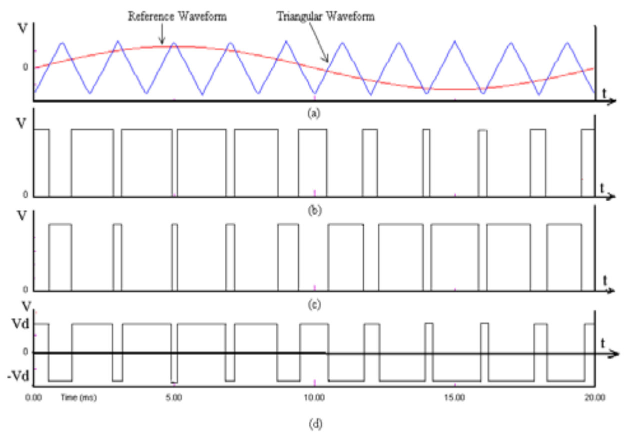


Fig.2 Waveform for SPWM with bipolar voltage switching

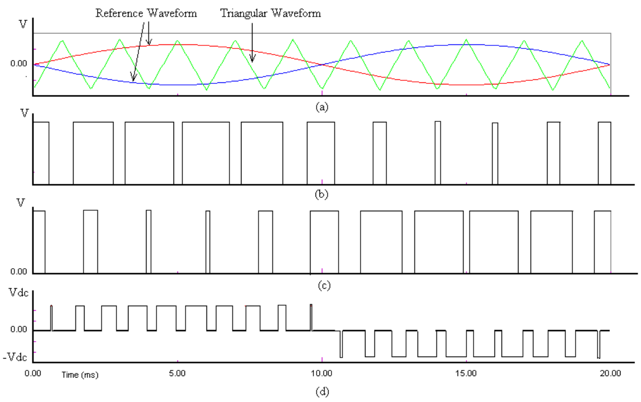
(a) Comparison between reference waveform and triangular waveform

The output voltage is determined by comparing the reference signal, V_r *and* the triangular carrier signal, V_c. In this scheme the diagonally opposite transistors S 11, S21, and S12 , S22 are turned on or turned off at the same time. The output of leg A is equal and opposite to the output of leg B. The output voltage is determined by comparing the control signal, V_r and the triangular signal, V_c as shown in Fig. 5 to get the switching pulses for the devices, and the switching pattern and output waveforms as follows.

SPWM with Unipolar Switching:

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. The different 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. The switching pattern and output waveform is as follows in Fig. 7. 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.[2], [6],[8]



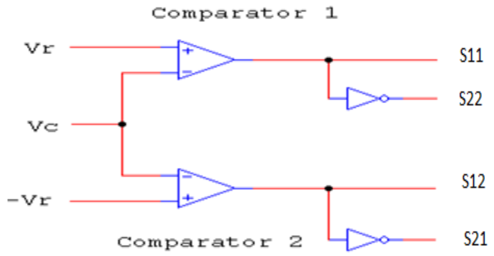
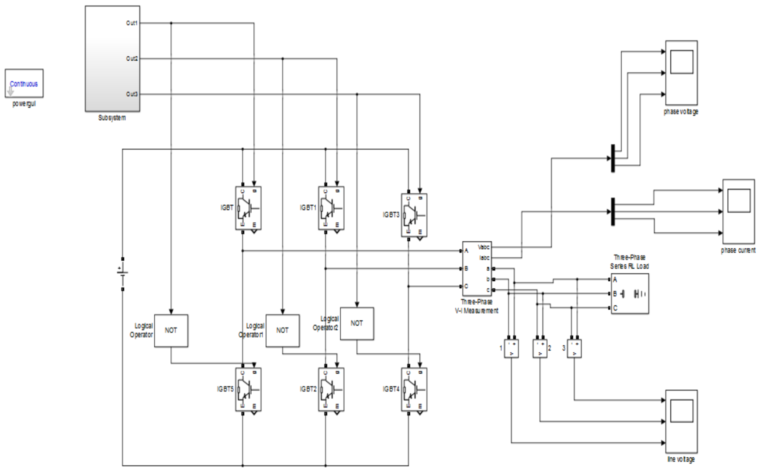


Fig 3. Comparator of unipolar switching

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

Fig. 4 Waveform for SPWM with unipolar voltage switching

MATLAB Simulation of SPWM:-



(a) Comparison between reference waveform and triangular waveform (b) Gating pulses for S1 and S4 (c) Gating pulses for S2 and S3 (d) Output waveform

4.SIMULATION RESULT

The model of three phase inverter by SPWM technique is simulated in the MATLAB as shown in the fig. the objective of this paper is to generate the gate pulses for the IGBT used in the VSI. The gate pulses are generated by SPWM method. In this method triangular wave is compared with the three phase sinusoidal wave when we compares the two wave with unipolar switching six output are generated which are used to control the vsi.

The output waveforms are as shown in fig.

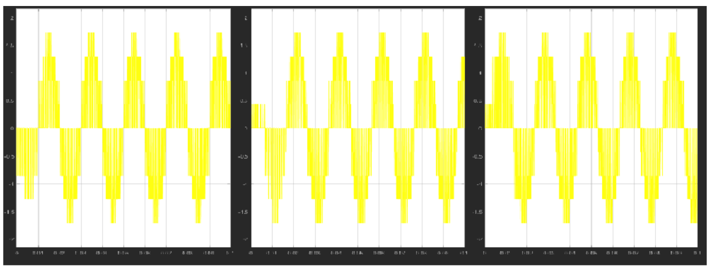


Fig 5. output voltage(three phase)

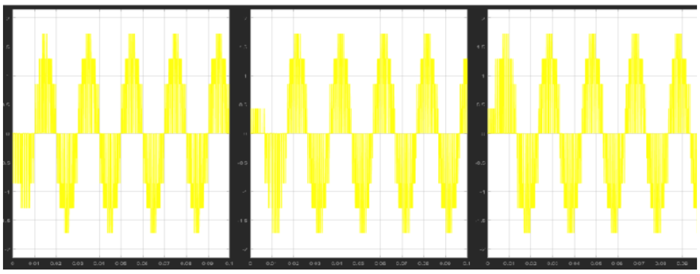


Fig 6. output current(three phase)

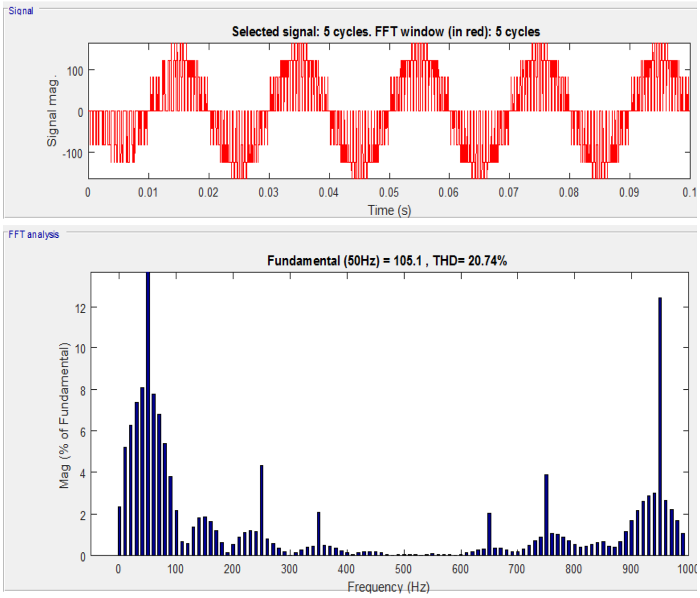


Fig 7. THD of output current at 1kw

5.CONCLUSION

We studied the basic circuitry of three phase inverter and different conduction modes, which are used for getting the IGBT on/off. We are also studied the harmonic reduction of three phase inverter by SPWM technique. By using this method, harmonic voltages of 5th, 7th and other odd multiples of fundamental frequency can be eliminate and the output waveform contain only higher order harmonics, which can be easily filtered out using filter circuit. We also observed output waveform of current and voltages which contain reduced harmonics. We are also analyze the total harmonic distortion of the output current waveform. we observed that THD at 1kw is 20.74%, which further can be reduced by increasing career frequency. also we can use filter circuit to reduced the total harmonic distortion.

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