Simulation and Analysis of Five Level SPWM Inverter

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Abstract:- *This project deals with the simulation of single phase multilevel inverter by sine wave pulse width modulation (SPWM) using single H bridge inverter in the Simulink MATLAB R2016a. The circuit is divided into three parts i.e., Gate Driver Circuit (control circuit), Inverter Circuit and external voltage control circuit. Inverter circuit consists of 4 IGBT connected in H bridge fashion, control circuit or gate driver circuit gets its signals by comparing carrier signal (triangular wave) and reference signal (sine wave), and the voltage control circuit consist of combination of IGBT and voltage sources which varies the collector to emitter voltage by triggering the IGBT's with the help of pulse generators.*

Key Words: AC Power, DC Source, Gate Driver, H bridge inverter, IGBT,

1. INTRODUCTION

Most of the domestic electrical loads operate with an AC power supply of 230V, 50Hz frequency in India. It is normally available from plug point/power point in our houses. But in case of power cut-off due to fault or any other reason AC power can be obtained from stored DC power in Batteries. Hence as AC power can't be stored it has to be converted from DC. The converter that converts DC to AC is known as an Inverter. The Inverter does not produce any power the power is provided by the DC source.

There is a huge scope of inverters in the automotive industry also as there is a increase of e-vehicles, as many of e-automobiles use induction motors and there speed control is done by using v/f method. And variable frequency can be obtained by using variable frequency inverters.

Types of SPWM inverters:-

1. Bipolar Inverters
2. Unipolar Inverters

In this project we would be dealing with the unipolar inverter.

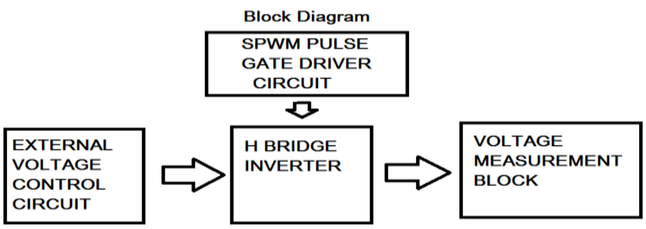

Fig -1: Block diagram of inverter

Table 1: Comparison between MOSFET and IGBT

Sr No.	MOSFET	IGBT
1	Voltage controlled device	Voltage controlled device
2	Fast Switching	Slow Switching, but faster as compared to BJT
3	Conduction Losses are high	Conduction losses are low
4	Majority charge carriers	Minority Charge carriers
5	Unipolar Device	Bipolar Device
6	Preferred for high voltage and low frequency applications	Preferred for low voltage and high frequency applications

As from the above comparison it's clear that at low frequency and high voltage application like at solar power plants, IGBT will be having less losses and hence better operation will be obtained.

2. Sinusoidal Pulse Width Modulation

Pulse width modulation is a technique in which a dc voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting, the on and off periods of the inverter components. This is most popular method of controlling the output voltage and this method is termed as pulse width modulation technique. There are number of PWM methods for variable frequency voltage-sourced inverters. A suitable PWM technique is employed in order to obtain the required output voltage in the line side of the inverter. A Sinusoidal Pulse Width Modulation technique is also known as the triangulation, sub oscillation, sub harmonic method is very popular in industrial applications. In this technique a high frequency triangular carrier wave is compared with the sinusoidal reference wave determines the switching instant. When the modulating signal is a sinusoidal of amplitude Am, and the amplitude of triangular carrier wave is Ac, then the ratio m=Am/Ac, is known as the modulation index. When m<1, it's defined as under modulation, and in this method under modulation is used. The frequency of the triangular carrier signal is kept more than the frequency of the modulating signal (sine wave).

A comparator is used to compare modulating signal (sine wave) and triangular carrier wave. Whenever magnitude of the modulating signal (sine wave) is more than the triangular carrier wave the comparator produces a high signal and else low. A string of comparison produces a signal which is fed to the IGBT's. This is done for the positive half cycle and for the negative half cycle, modulating signal (sine wave) is shifted by 180 degree.

A not logical operator is used to avoid short circuit of the dc source. The output of the comparison and its logical not is fed to the gate of the IGBT. The potential between the output terminals produces sine wave pulse width modulated output.

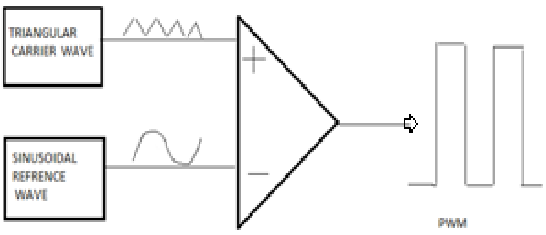

Fig -2: SPWM Generation using comparator

3. Single Level SPWM Inverter

Single level SPWM inverter output is obtained by using single dc voltage source. The voltage source is applied across collector and emitter of the IGBT.

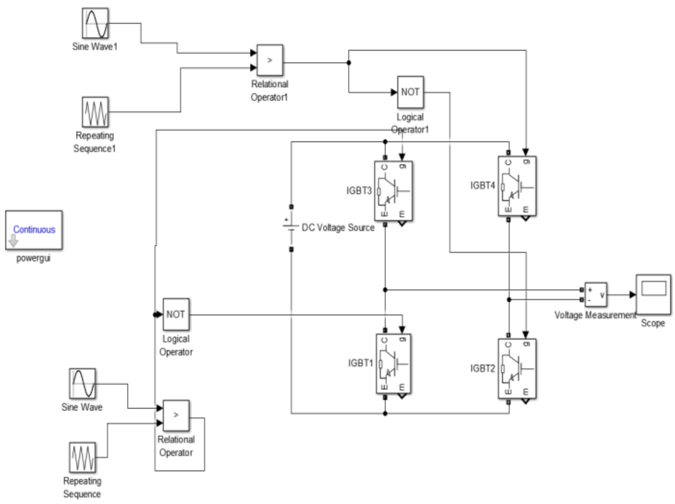

Fig -3: SPWM single level inverter

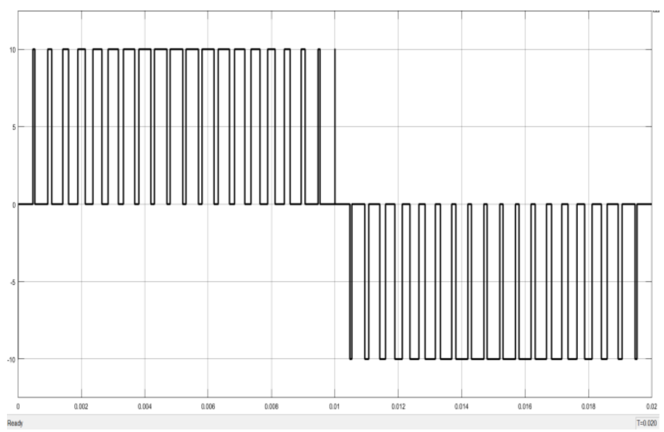

Fig -4: Single level SPWM inverter output (t=0.02 sec) (V vs T)

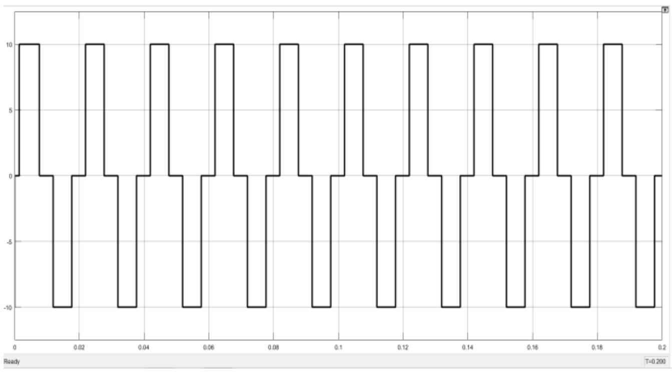

Fig -5: Single level SPWM inverter output (t=0.2 sec) (V vs T)

4. Five Level SPWM Inverter

In this project, 5 level inverter is made by externally controlling the collector to emitter voltage with the use of IGBT'S and different DC voltage sources. DC voltage sources gets switched through the IGBT's with the help of pulse generator, this type of results can also be achieved by using digital to analog converter(DAC) interfaced with microcontrollers like arduino.

Voltage is varied in the following manner:-

Table 2: Time Period of different voltage levels

Voltage Level(volts) (DC Source)	Voltage Obtained in the ouput waveform	Time Period of operation(sec)
12	9	0.0045-0.0055
9	6	0.003-0.0045 , 0.0055-0.007
6	4.5	0-0.003 , 0.001-0.01
-6	-4.5	0.01-0.013, 0.011-0.02
-9	-6	0.013-0.0145, 0.0155-0.017
-12	-9	0.0145-0.0155

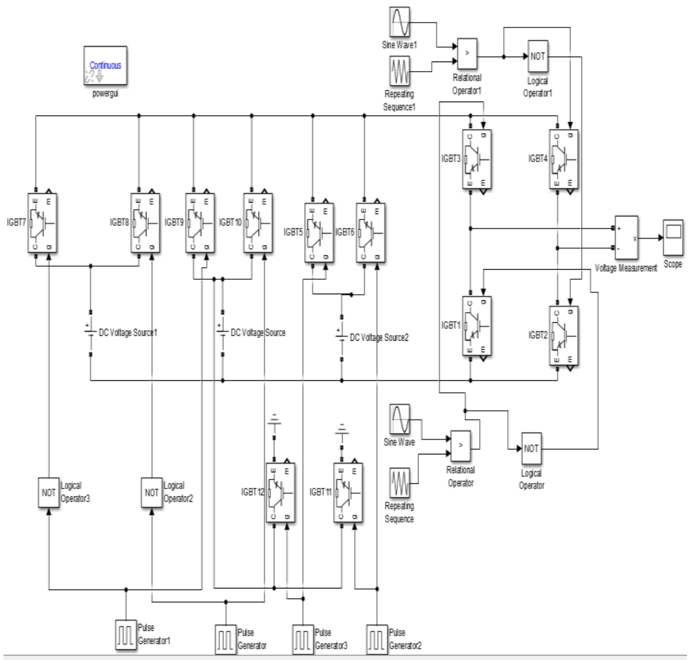

Fig -6: 5 Level SPWM Inverter Circuit

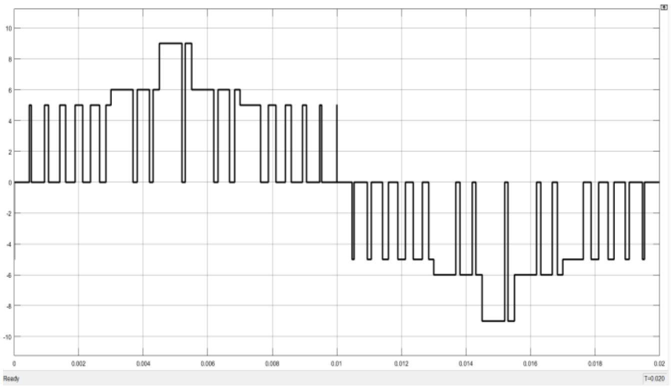

Fig -7: Five level SPWM inverter output (t=0.02 sec) (V vs T)

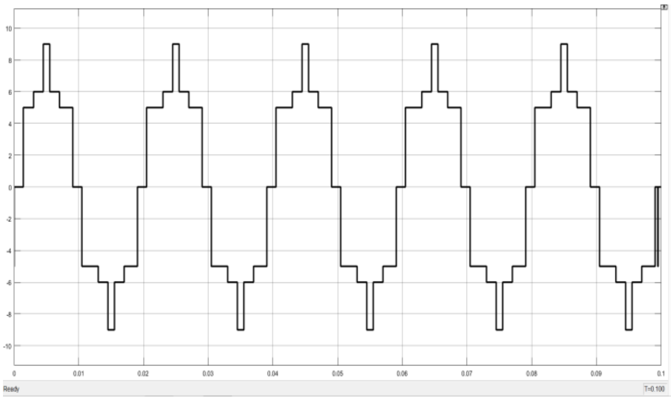

Fig -8: 5 Level SPWM Inverter output (t=0.1sec) (V vs T)

The general Fourier series expansion of 5 level inverter is given by

$$V(\omega t) = \sum_{n=1,3,5\ldots}^{\infty} \frac{4V_{dc}}{n\pi}\left(Cos(n\theta_1) + Cos(n\theta_2)\right) Sin(n\omega t)$$

5. Fast Fourier Transform Analysis

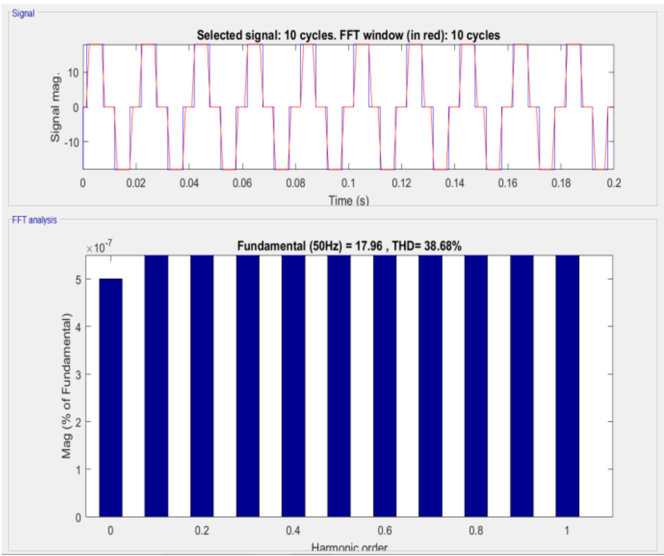

Fig 9: Single Level SPWM Inverter FFT Analysis

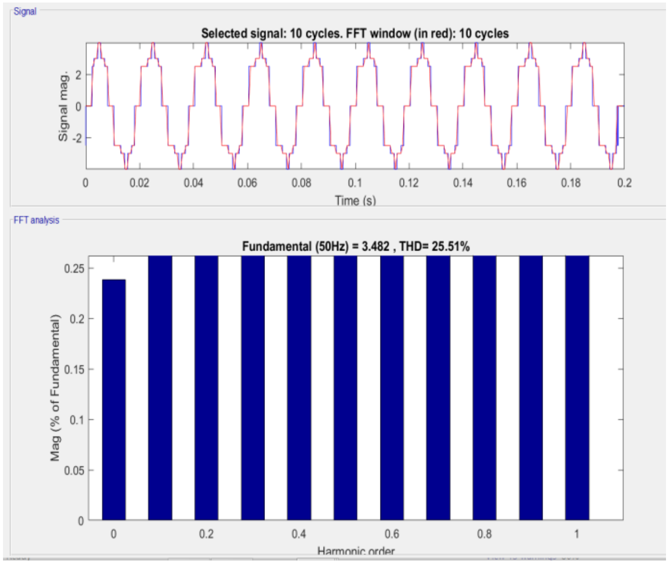

Fig 10: Five Level SPWM Inverter FFT Analysis

Fast Fourier transform analysis shows that total harmonic distortion (THD) of single level inverter is 38.68% and of five level inverter is 25.52%.

6. Conclusion

It can be concluded from the above Fast Fourier transform analysis that, as the level of the inverter increases total harmonic distortion (THD) decreases. Therefore higher level inverters (7 levels, 9 levels and so on) which can be designed using the same methods will have less total harmonic distortion.

Table 3: Time Period of different voltage levels

Multilevel Inverter	No. Of Battery source	No. Of Switches	THD(%)
1	1	4	38.68
5	3	12	25.51

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