Design of Single-Phase Sine PWM Inverter

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Abstract - The primary objective of designing this project is to minimize the harmonic reduction of the inverter output voltage. A microcontroller based on an advanced technology to generate a sine wave with fewer harmonics, less cost and a simpler design. The technique used is the sinusoidal pulse width modulation signal (SPWM) which is generated by microcontroller(Arduino).The designed inverter is tested on various AC loads and is essentially focused upon low power electronic applications such as a lamp, a fan and chargers etc. This project is designed and simulation of single-phase inverter using sinusoidal pulse width modulation (SPWM) unipolar technique. The circuit has been designed and simulated using the Matlab/Simulink program. Metal Oxide Semiconductor Field Effect Transistor (MOSFET) has been used as a switch. The project aims to use the Matlab/Simulink program to design, analyze and control switching for inverter circuits.

Key Words: *Inverter, SPWM, MOSFET,*

1. INTRODUCTION

A large amount of switching loss occurs in the inverter. From this point of view, an inverter design should be optimized for which size and cost will be minimum along with increasing efficiency [1]. A voltage source inverter is commonly used to supply a three-phase induction motor with variable frequency and variable voltage for variable speed applications [2]. A microcontroller based advanced technique of generating sine wave with minimized harmonics is implemented in this paper [3]. Sinusoidal pulse width modulation is widely used in power electronics to digitize the power so that a sequence of voltage pulses can be generated by the on and off of the power switches. The pulse width modulation inverter has been the main choice in power electronic for decades, because of its circuit simplicity and rugged control scheme SPWM switching technique is commonly used in industrial applications SPWM techniques are characterized by constant amplitude pulses with different duty cycle for each period. The width of this pulses are modulated to obtain inverter output voltage control and to reduce its harmonic content. Sinusoidal pulse width modulation or SPWM is the mostly used method in motor control and inverter application [4]. The main goal of this design is to generate a sine wave with fewer harmonics, while keeping the cost and complexity of the circuit low [5]. The designed inverter has undergone testing with different AC loads and is primarily intended for low-power applications, as lamps, fans, and chargers. This design aims to provide a reliable and efficient inverter solution for these specific applications [6]. This paper presents the development of control circuit for single phase inverter using a pulse width modulation (PWM) IC. The attractiveness of this configuration is the elimination of a complex circuitry to generate oscillation pulses for transistor switches [7].

An inverter is basically a device that converts electrical energy of DC source into that of AC source. The purpose of DC-AC inverter is to take DC power from a battery source and converts it to AC. For example, the household inverter receives DC supply from 12V or 24V battery and then inverter converts it to 230V AC with a desirable frequency of 50Hz or 60Hz. These DC-AC inverters have been widely used for industrial applications such as uninterruptible power supply (UPS), AC motor drives. Recently, the inverters are also playing an important role in various renewable energy applications as these are used for grid connection of Wind Energy System or Photovoltaic System and in electric vehicle. Both current-mode control and voltage-mode control are employed in practical applications. The DC-AC inverters usually operate on Pulse Width Modulation (PWM) technique. The PWM is a very advance and useful technique in which width of the Gate pulses are controlled by various mechanisms. PWM inverter is used to keep the output voltage of the inverter at the rated voltage (depending on the user's choice) irrespective of the output load. In a conventional inverter the output voltage changes according to the changes in the load. To nullify this effect of the changing loads, the PWM inverter correct the output voltage by changing the width of the pulses and the output AC depends on the switching frequency and pulse width which is adjusted according to the value of the load connected at the output so as to provide constant rated output. The inverters usually operate in a pulse width modulated (PWM) way and switch between different circuit topologies, which means that the inverter is a nonlinear, specifically piecewise smooth system. In the last decade, studies of complex behavior in switching power converters have gained increasingly more attention from both the academic community and industry.

2.1 Block Diagram

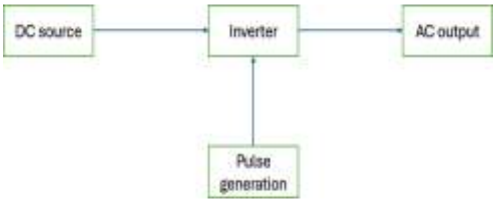

Fig-1: Block diagram of an inverter

2.2 Single Phase Full wave Bridge Inverter

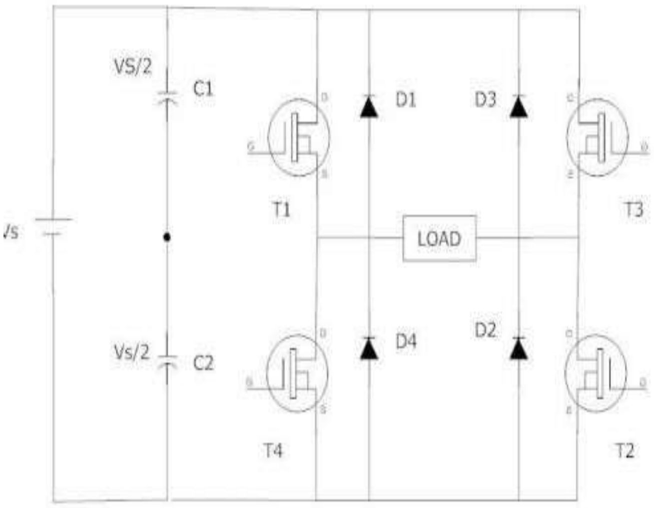

Fig- 2: Single Phase Full Bridge Inverter

It consists of two arms with a two semiconductor switches on both arms with antiparallel freewheeling diodes for discharging the reverse current. In case of resistive-inductive load, the reverse load current flow through these diodes. These diodes provide an alternate path to inductive current which continue so flow during the Turn OFF condition. The switches are T1, T2, T3 and T4. The switch in each branch is operated alternatively so that they are not in same mode (ON /OFF) simultaneously. In practice they are both OFF for short period of time called blanking time , to avoid short circuiting. The switches T1 and T2 or T3 and T4 should operate in a pair to get the output. These bridges legs are switched such that the output voltage is shifted from one to another and hence the change in polarity occurs in voltage waveform. If the shift angle is zero, the output voltage is also zero and maximal when shift angle is π.

Table -1: Switching States for Full Bridge Inverter

T1	T2	T3	T4	Va	Vb	Vab
ON	ON	OFF	OFF	+Vs/2	+Vs/2	+Vs
OFF	OFF	ON	ON	-Vs/2	Vs/2	-Vs
ON	OFF	ON	OFF	+Vs/2	-Vs/2	0
OFF	ON	OFF	ON	-Vs/2	+Vs/2	0

2.3 Sinusoidal Pulse Width Modulation

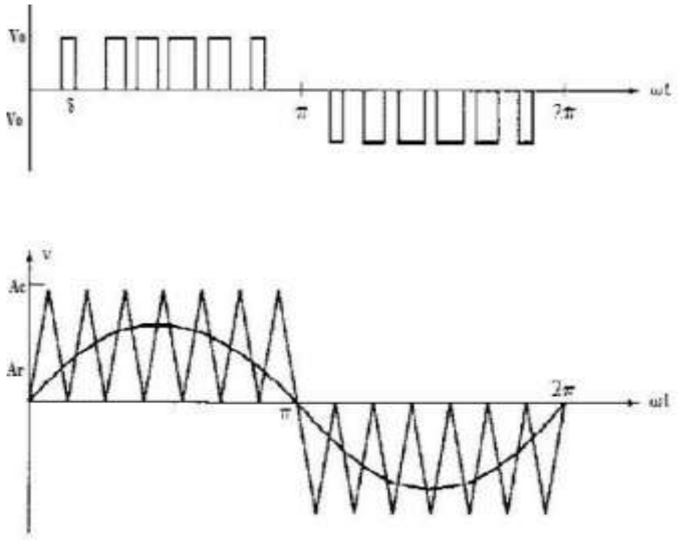

Fig-3: SPWM

In this modulation technique are multiple numbers of output pulse per half cycle and pulses are of different width. The width of each pulse is varying in proportion to the amplitude of a sine wave evaluated at the centre of the same pulse. The gating signals are generated by comparing a sinusoidal reference with a high frequency triangular signal.

- Lowering harmonic interference and raising system efficiency.
- use of a sine wave reference to alter the

1) Pulse widths
2) SPWM minimizes harmonic distortion and yields a smoother output.

2.4 General Simulation Data

The inverter circuit used in the simulations is a voltage source inverter in full bridge or H-bridge topology .The input is DC voltage source. The inverter uses four MOSFET switches for the switching function, in order to produce an AC output signal. The simulation design use pulse generator for the square wave inverter design and SPWM technique is used for PWM generation in sine PWM inverter design. The parameters in the PWM controller for the SPWM are as follows: modulation index (m_i) =1; frequency (f) = 50Hz; Switching frequency for the triangular carrier waves (f_s)=10kHz. The input DC Voltage is 12 V. Output Voltage is measured using voltage measurement with rms block via a display block and Output Current is measured using current measurement with rms block via a display block. THD is measure using THD block and FFT analysis tool. The Output waveforms are obtained through the scope.

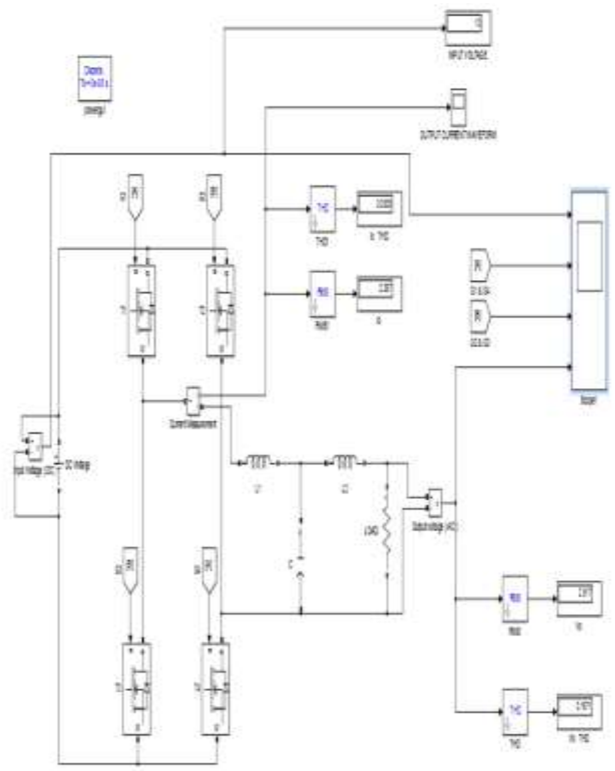

Fig-4: Simulation Diagram of Single Phase Inverter R - LOAD with LCL Filter

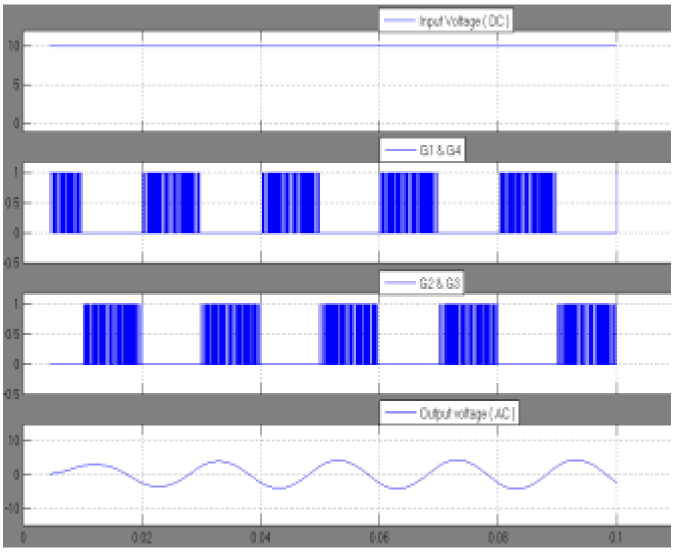

Fig-5: Input and Output Waveform of Single Phase Inverter R – LOAD With LCL Filter

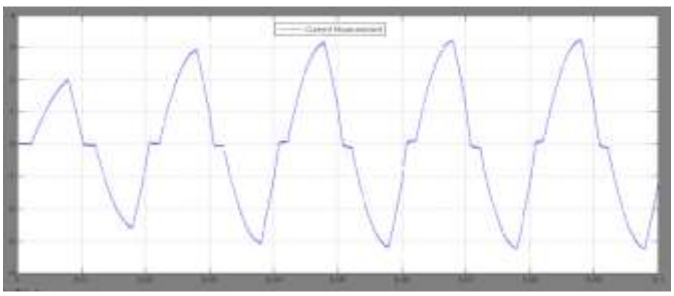

Fig-6: Output Current Waveform

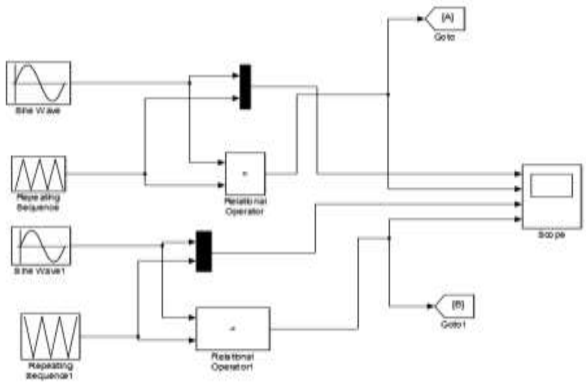

Fig-7: Simulation Diagram of SINE Wave PWM

Table - 2: Results for R load

R (ohms)	Vo (V)	Io (I)	THD of V (%)	THD of I (%)
3	7.955	2.652	49.22	49.22
5	8.15	1.632	49.22	49.22
7	8.25	1.179	49.22	49.22
10	8.31	0.8319	49.22	49.22

2.6 Design of LCL Filter

Constant K Low Pass Filter:-

Formula:

Shunt Capacitance, $C = \frac{1}{\pi f_c K}$

Series Inductance, $L = \frac{K}{\pi f_c}$

Design Calculation:

Load Resistance, K = 0.6,

Lower Cutoff frequency, f_c = 50 Hz,

Power, P_o = 60 watts

Input Voltage, V_{in} = 10v

Output Voltage, V_o = 6v

$I_o = \frac{P_o}{V_o}$; $I_o = \frac{60}{6}$; I_o = 6 amps

$R = \frac{V_o}{I}$; $R = \frac{6}{10}$; R = 0.6 ohms

Shunt Capacitance, $C = \frac{1}{\pi f_c K}$; $C = \frac{1}{\pi X 50 X 0.6}$;

C = 10.6 milli farads

Series Inductance, $L = \frac{K}{\pi f_c}$;$L = \frac{0.6}{\pi X 50}$;

L = 3.819 milli Henry

$L_1 = \frac{L}{2}$; $L_1 = \frac{1.91 X 10^{-3}}{2}$;L_1 = 1.91 milli Henry

$L_2 = \frac{L}{2}$; $L_2 = \frac{1.91 X 10^{-3}}{2}$; L_2 = 1.91 milli Henry

Switching Frequency, Fsw = 10 KHz,

Reference frequency, Fr = 50 Hz

Amplitude of Reference Frequency = 0.8

Amplitude of Switching Frequency = 1

Modulation Index, $m_i = \frac{A_r}{A_c}$

2.5 Hardware Implementation

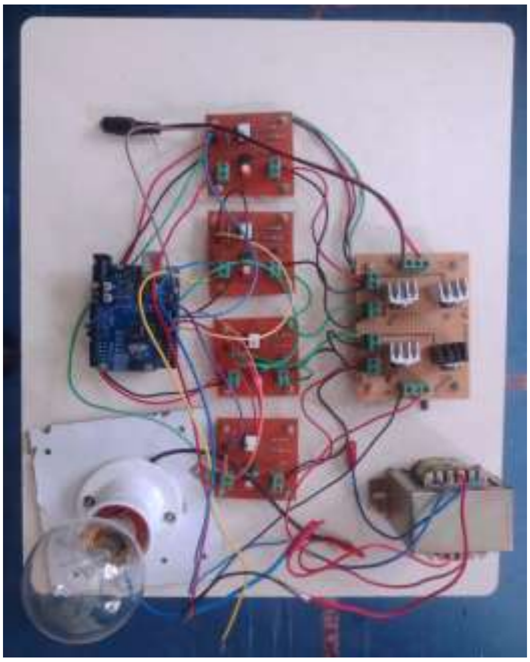

Fig-8: Power circuit

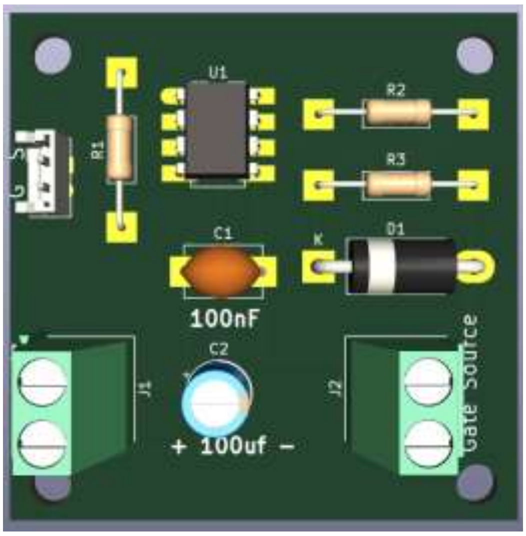

Fig-9: Gate Drive Circuit

3. CONCLUSION

This project deals with Harmonics reduction of single-phase inverter with Sine PWM techniques. The SIMULINK model of single-phase sine PWM inverter has been studied and stimulated in MATLAB/SIMULINK software. The THD values of output voltage and current have been studied along with the output voltage and current graphs. The SPWM technique is implemented for hardware. The future work includes improving the stability of the system and also to study various instability in PWM with harmonic analysis in three phase and ways to eliminate it and to design an actual household PWM-VSI with a better controller design.

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