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Research Paper

COMPARATIVE STUDY OF SINGLE PHASE INVERTER-BASED ON UNIPOLAR PWM TECHNIQUES

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Performance of a single phase unipolar PWM inverter is compared based on circuit configurations. A part of main switches are connected to high frequency arm and the remaining switches to low frequency arm. All main switches of high frequency arm operate at Zero Voltage Switching (ZVS) turn on and all the main switches of low frequency arm operate at 50 Hz to reduce switching losses. The main purpose of using Unipolar PWM inverter is to reduce output voltage harmonics.

Keywords: Soft-switching, Unipolar Pulse width Modulation (PWM) inverter, Zero Voltage Switching (ZVS), Electromagnetic Interference (EMI)

INTRODUCTION

As the demands for high-quality power sources increases, a pulse-width modulated (PWM) inverter has been used as a key element for a high performance power conversion system such as Uninterruptible Power Supplies (UPS), medical equipment and communication systems [2]. The DC to AC converters based on PWM technology is superior when compared to other inverters designed using conventional technologies.

PWM or Pulse width Modulation is necessary to maintain the output voltage of the inverter at the rated voltage irrespective of the output load. In a conventional inverter the output voltage changes as the changes in the load occur. To nullify the effect caused by the changing loads, the PWM inverter is used to correct the output voltage according to the value of the load connected at the output. This can be achieved by changing the width of the switching frequency. The AC voltage at the output depends on the width of the switching pulse.

PWM inverters require high-speed switching devices to achieve high performance in term of dynamic response, size, and weight. This results in switching stresses on the power devices, switching loss, and generation of electromagnetic interference (EMI). To

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overcome these problems soft switching techniques have been introduced [3]-[6].

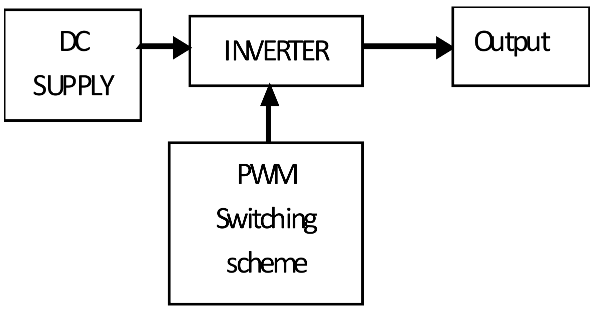
In the proposed inverter all main switches of high-frequency arm operate at Zero-Voltage-Switching (ZVS) turn-on and all the main switches of low frequency arm operate at 50 Hz to reduce switching losses. The main purpose of using Unipolar PWM scheme is to reduce the output voltage Harmonics. The Simulink model of proposed inverter is simulated in Matlab.

PROPOSED INVERTER

System Configuration

The block diagram of proposed inverter is shown in Figure 1.

Figure 1: Block Diagram



Power circuit consists of DC input, full bridge inverter and PWM switching scheme.

The inverter consists of arm A and B arm. The B arm is switched at Low Frequency to achieve low switching losses and the A arm is switched at high Frequency for the better output regulation. Proposed scheme uses Unipolar switching scheme. The soft-switching of the main switches can be achieved using ZVS technique.

The circuit configuration for Unipolar PWM inverter is shown in Figures 2 and 3.

Figure 2: Configuration 1

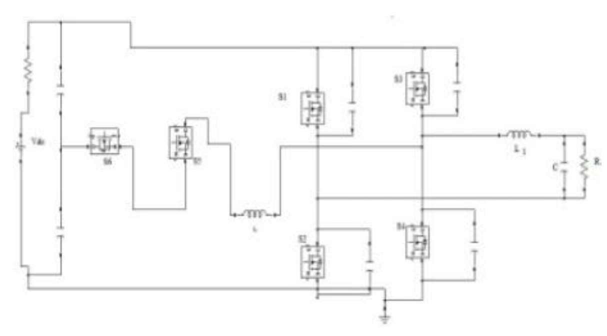
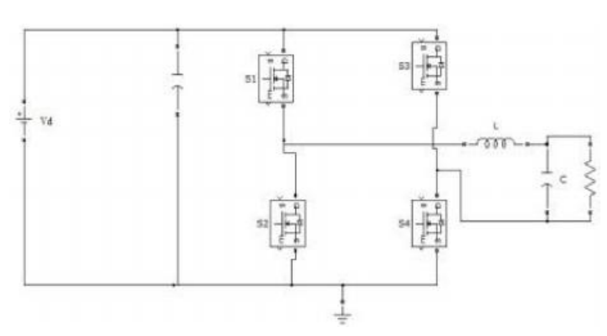


Figure 3: Configuration 2



Single Phase Unipolar PWM Inverter

Inverters are those which convert DC into AC. The source can be either current source or voltage source corresponding to a Current Source Inverter (CSI) or a Voltage Source Inverter (VSI) respectively [7].

There are two different types of voltage source inverter

- Half Bridge topology
- Full Bridge topology

Full bridge topology consists of 4 switching devices connected in the form of bridge. Pulse width modulation techniques provide current and voltage shaping modifications under specific needs of applications. PWM techniques also minimize switching stress present on the switching devices [8].

PWM signal is usually generated by comparing sinusoidal waveform with triangular waveform.

PWM inverters are two types

- Unipolar inverter
- Bipolar inverter

The Unipolar inverter always requires two reference signals ($Vref^+$ and $Vref^-$) which must be same magnitude and frequency but are out of phase. This reference wave is then compared with triangular wave [8].

In the Unipolar switching scheme the output voltage changes from positive voltage (+V) to zero during positive half cycle or from Zero to negative voltage (–V) during negative half cycle, Whereas in Bipolar switching Scheme the output voltage switches between positive voltage and negative voltage levels [1].

The Unipolar switching scheme has the advantage of doubling the switching frequency compared to bipolar switching scheme. As a result the output harmonics is reduced in unipolar switching scheme than bipolar switching scheme [7].Efficiency of unipolar switched inverter is better compared to bipolar switched device.

For a full bridge inverter the root mean square (RMS) output voltage can be found from

$$V_o = (2/T_o \int_0^{To/2} V_s^2 \, dt)1/2 \quad ...(1)$$

$$V_o = V_s \quad ...(2)$$

Design of Output Filter

The ripples in PWM output voltage is filtered using a low pass filter. The cut-off frequency of output filter can be obtained by selecting the values of C and L.

$$f_c = 1/(2*®*\sqrt{LC}) \quad ...(3)$$

By selecting C = 25 μF and L = 1 mH the cut-off frequency Obtained is f_c = 1 kHz.

SOFT-SWITCHING

Hard Switching Occurs when there is overlap between the voltage and current when the Switching device is turned on and off. Because of this, overlap energy losses increases and as a result electromagnetic interference (EMI) is generated. These problems can be overcome using Soft Switching refer Figures 4 and 5.

Switching transitions occur when device voltage or current is Zero. Soft switching has following advantages

- Reduced Switching losses
- Reduced switch stress

Figure 4: Hard Switching

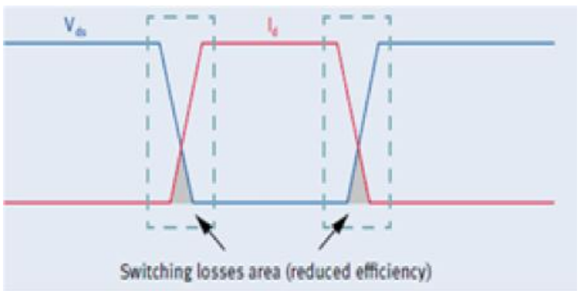
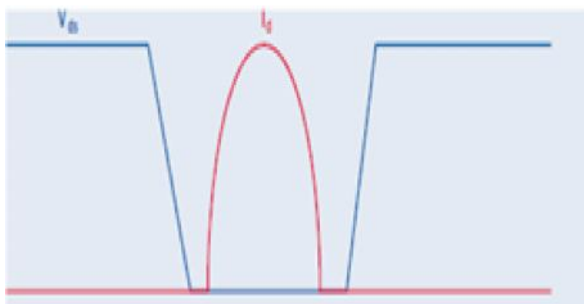


Figure 5: Soft Switching



- Low EMI
- Easier Thermal management

SIMULATION RESULT

The Unipolar PWM inverter is simulated using MATLAB Simulik and the following results are noted below for different circuit configuration. The parameters for the proposed inverter are as follows:

Input Voltage V_{dc} = 12 V

Output Voltage V_o = 10 V

Filter Inductor L = 1 mH

Filter Capacitor C = 25 µF

Configuration 1: This configuration is shown in Figure 2. Before the main switches of high frequency arm are turned on (S3 and S4) drain voltages have been decreased to zero. Hence these switches are turned on at ZVS. The simulation result is shown in Figure 6 and Figure 7. From the result it is found that switching losses for the inverter proposed in configuration 1are reduced.

Configuration 2: This configuration is shown in Figure 2. It consists of switches S1, S2, S3,

Table 1: Comparative Study

Performance Parameter	Configuration 1	Configuration 2
THD	Reduced (10.03%)	More (41.08%)
Switching loss	Less	More
EMI	Low	High

Figure 6: Simulation of Inverter Proposed in Configuration 1

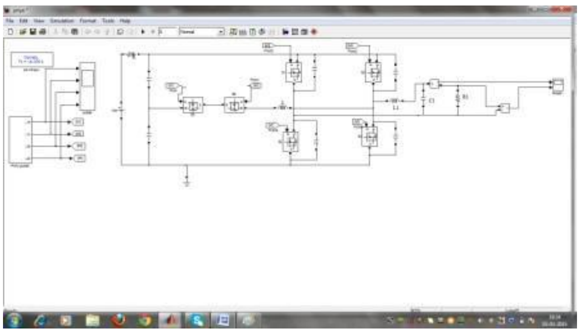


Figure 7: Simulation Result of Inverter Proposed in Configuration 1

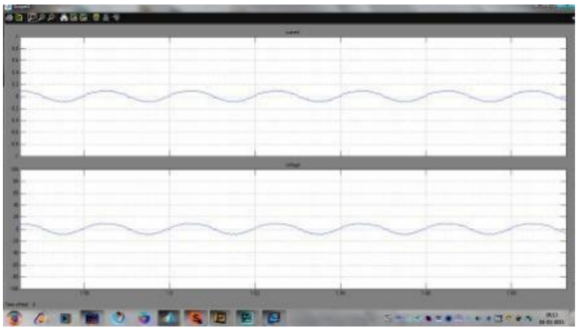


Figure 8: Simulation of Inverter Proposed in Configuration 2

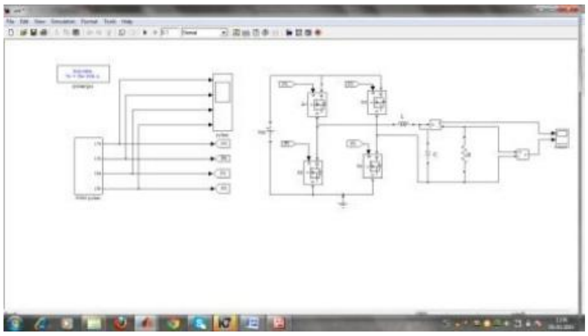
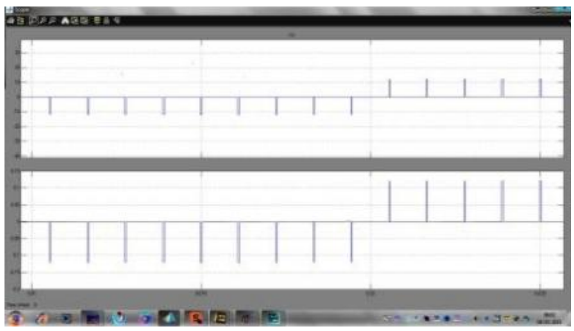


Figure 9: Simulation Result of Inverter Proposed in Configuration 2



S4 and output LC filter which forms a conventional hard switching PWM inverter. The simulation result is shown in Figure 8 and Figure 9.

Harmonic Analysis of Configuration 1 and Configuration 2: FFT analysis is performed to determine the total harmonic distortion for configuration 1 and configuration 2. It is shown in Figure 10 and Figure 11. Total Harmonic Distortion (THD) is a measure of closeness in shape between a waveform and its fundamental component. The Comparison is shown in Table 1.

$$THD = 1/V_{o1}\left(\sum_{n=2,3}^{\infty} V_{on}^{2}\right)^{2} \quad ...(4)$$

Figure 10: FFT Analysis of Configuration 1

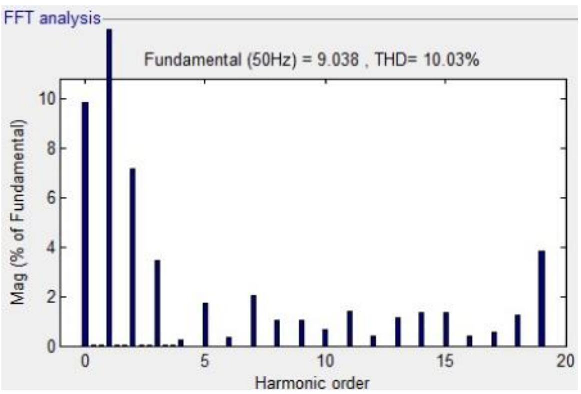
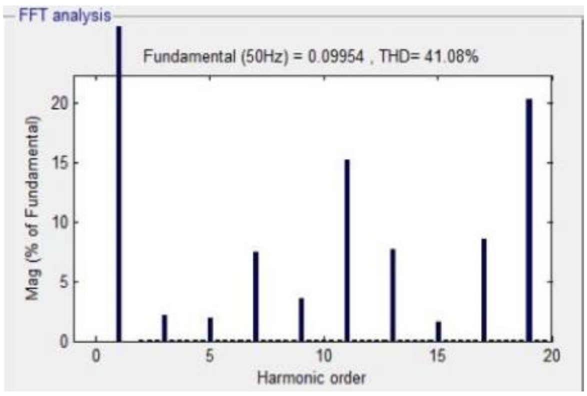


Figure 11: FFT Analysis of Configuration 2



CONCLUSION

Single phase Unipolar PWM inverter has been compared using different configuration. Configuration 1 is a soft-switching inverter consists of high frequency arm and low frequency arm. All the main switches of high frequency arm operate at ZVS turn on. Configuration 2 is an conventional hard switching PWM inverter. Unipolar PWM scheme is used to reduce output voltage harmonics. The single phase inverter is simulated in both the configurations and results are obtained according to the parameters and it was found that performance is better in soft switching inverter compared to conventional hard switching PWM inverter.

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