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Unipolar and Bipolar SPWM Voltage Modulation Type inverter for Improved Switching Frequencies

Amit Kumar Sharma *, Ashok Kumar Sharma & Nidhi Vijay
Department of Electrical Engineering, University College of Engineering, Kota, India
amy.sharma21@gmail.com

Abstract

This paper attempts an in-depth analysis of switching loss, waveform quality and voltage linearity characteristics of the modern PWM methods. SPWM or sinusoidal pulse width modulation is widely used in power electronics to initialize the power so that a sequence of voltage pulses can be generated by the on and off of the power switches. 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. In SPWM a unipolar and bipolar SPWM voltage modulation type is selected because these types of methods offers the advantage of effectively doubling the switching frequency of the inverter voltage, thus making the output filter smaller, cheaper and easier to implement.

Keywords: Modelling, Simulation, SPWM, Voltage profile

Introduction

Of all the modern power electronics converters, the Voltage Source Inverter (VSI) is perhaps the most widely utilized device with 3 power ratings ranging from fractions of a kilowatt to megawatt level. 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 [1], [2], [3]. The VSI consists of six power semiconductor switches with anti-parallel feedback diodes. It converts a fixed DC voltage to three phase AC voltages with controllable frequency and magnitude. Since the VSI has discrete circuit modes for each set of switch states, generating an output voltage with correct frequency and magnitude requires an averaging approach. In the widely utilized Pulse Width Modulation (PWM) methods, the inverter output voltage approximates the reference value through high frequency switching. In AC motor drive applications, typically a rectifier device converts the AC three phase line voltages to DC voltage. Following the rectifier voltage passive filtering stage, the PWM-VSI interfaces the DC source with the AC motor to control the shaft speed/position/torque. 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 [1],[4]. When utilized in such applications, the device is often termed as converter (opposite of inverter), hence PWM-VSC.

In all cases, power flow is controlled by the inverter switching device gate signals in a manner to obtain high performance, improved efficiency, and reliable operation. Although its main circuit topology is quite simple, a modern PWM-VSI drive involves an overwhelming level of technology and intelligence. From the semiconductor power switching devices such as Insulated Gate Bipolar Transistors (IGBTs) operating at frequencies as high as many tens of kilohertz to the microcontrollers and Digital Signal Processors (DSPs) that process the control signals at speeds beyond many tens of megahertz, most components of a state of the art PWM-VSI drive involve advanced technologies. The costumer's increasing demand for multifunctionality, precision performance, efficiency, and reliability and user friendliness has motivated engineers to build a significant amount of intelligence into the microcontrollers and DSPs of the PWM-VSI drives. Load parameter estimation, fault diagnostics, high performance vector control, observer based shaft encoder less speed control, energy efficiency optimization etc. algorithms have been developed and built into the modern PWM-VSI drives. With their

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global production rate above millions per year, the power ratings ranging from fractions of a kilowatt to megawatts, and the applications ranging from simple house appliances such as air-conditioning units to heavy industries such as steel mills, PWM-VSI drives are modern technology devices which have been experiencing a rapid progress over the last three decades. This rapid progress is partially due to the great effort of many academic and industrial researchers' attempts to respond to the costumers demand for increasing efficiency, reliability, and enhanced performance. And, it is partially due to the substantial progress in the enabling technologies, such as the semiconductor micro and macro electronics technology.

Voltage Source Inverters are one in which the DC source has small or negligible impedance. In Other words VSI has stiff DC voltage source at its input terminals. A current source inverter is fed with adjustable current from a DC source of high impedance, i.e. from a stiff DC current source. In a CSI fed with stiff current source, output current waves are not affected by the load. From view point of connections of semiconductor devices, inverters are classified as under [1],[2]

- Bridge Inverters
- Series Inverters
- Parallel Inverter

Bridge Inverters are classified as Half bridge & Full bridge A single-phase inverter in the full bridge topology is as shown in Fig.1 which consists of four switching devices, two of them on each leg. The full-bridge inverter can produce an output power twice that of the half-bridge inverter with the same input voltage. The SPWM switching schemes are discussed in this section, which improve the characteristics of the inverter. The objective is to add a zero sequence voltage to the modulation signals in such a way to ensure the clamping of the devices to either the positive or negative dc rail; in the process of which the voltage gain is improved, leading to an increased load fundamental voltage, reduction in total current distortion and increased load power factor. In Fig.1 the top devices are assigned to be S_{11} and S_{21} while the bottom devices as S_{12} and S_{22}.

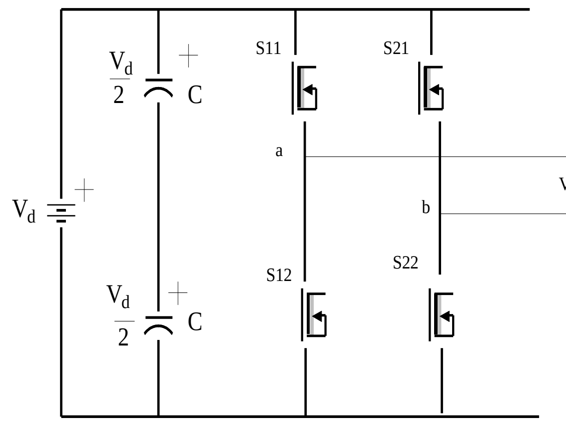

Fig. 1: Schematic of a Single Phase Full- Bridge Inverter

The voltage equations for this converter are as given in the following equations. [1]-[6].

$$\frac{V_d}{2}(S_{11} - S_{12}) = V_{an} + V_{no} = V_{ao} \quad (1)$$

$$\frac{V_d}{2}(S_{21} - S_{22}) = V_{bn} + V_{no} = V_{bo} \quad (2)$$

$$V_{ab} = V_{an} - V_{bn} \quad (3)$$

The voltages V_{an} and V_{bn} are the output voltages from phases A and B to an arbitrary point n, V_{no} is the neutral voltage between point n and the mid-point of the DC source. The switching function of the devices can be approximated by the Fourier series to be equal to 1/2 * M. Where M is the modulation signal which when compared with the triangular waveform yields the switching pulses Thus from Equations1, 2 and 3 the expression for the modulation signals are obtained as

$$M_{11} = \frac{2(V_{an} + V_{no})}{V_d} \quad (4)$$

$$M_{21} = \frac{2(V_{an} + V_{no})}{V_d} \quad (5)$$

Equations 4 and 5 give the general expression for the modulation signals for single-phase dc-ac converters. The various types of modulation schemes presented in the literature can be obtained from these equations using appropriate definition for V_{an}, V_{bn} & V_{no} [1].

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To generate signals, triangle wave as a carrier signal is compared with the sinusoidal wave, whose frequency is the desired frequency. In this paper single-phase inverters and their operating principles are analyzed in detail. The concept of sinusoidal Pulse Width Modulation (PWM) for inverters is described with analyses extended to different kinds of SPWM strategies. Finally the simulation results for a single-phase inverter (Bipolar) using the SPWM strategies described are presented [1],[2],[5].This project deals with implementing the basic theory of a Sinusoidal Pulse Width Modulated Inverter (SPWM) technique for Bipolar voltage switching , its simulink modeling, estimating various designing parameters. The project will be commenced by a basic understanding of the circuitry of the SPWM Inverter, the components used in its design and the reason for choosing such components in this circuitry. After this, it will be attempted to simulate a model circuit on any simulating software MATLAB.

SPWM Switching Techniques

PWM with bipolar switching

The basic idea to produce PWM Bipolar voltage switching signal is shown in Fig. 2. 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 S_{11}, S_{21}, S_{12} and S_{22} are turned on and off at the same time. The output of leg A is equal and opposite to the output of leg B [3].

The output voltage is determined by comparing the reference signal, V_r *and* the triangular carrier signal, V_c 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 waveform is as follows.[2]

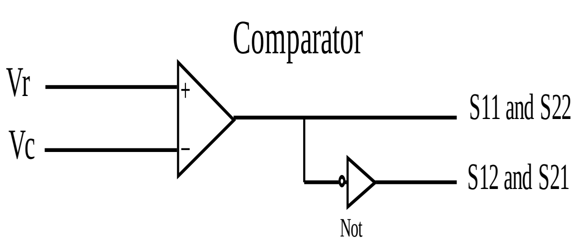

Fig 2: Bipolar PWM Generator

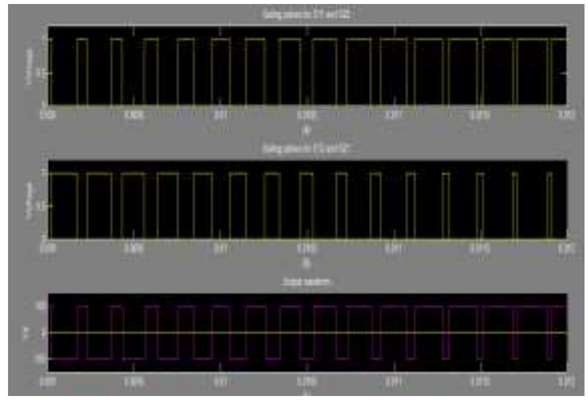

Fig 3:Waveform for SPWM with Bipolar voltage switching (a) Gating pulses for S11 and S22 (b) Gating pulses for S12 and S21 (c) Output waveform

PWM 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. 4. The different between the Bipolar SPWM generators is that the generator uses another comparator to compare between the inverse reference waveform$-V_r$. 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. 5. In Unipolar voltage switching the output voltage switches between 0 and Vd*c*, 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], [3], [4].

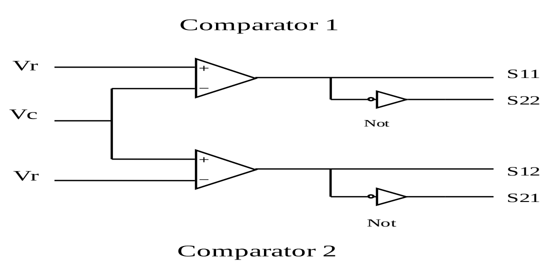

Fig 4: Unipolar PWM generator

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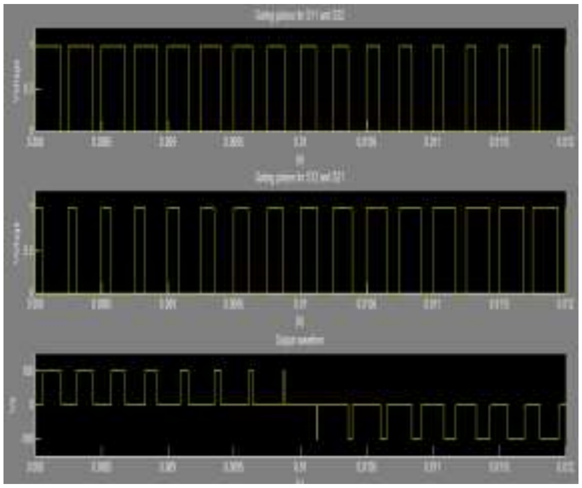

Fig 5: Waveform for SPWM with Unipolar voltage switching (a) Gating pulses for S11 and S22 (b) Gating pulses for S12 and S21 (c) Output waveform.

Simulation of Inverter Circuit

Here we Design and Test Bipolar Voltage Switching for and also simulate in MATLAB.

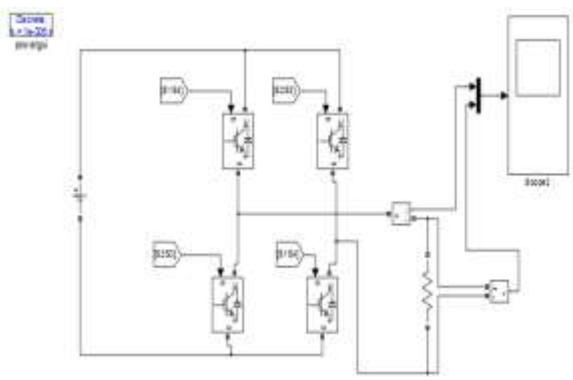

Fig 6: Simulink Model Bipolar Voltage Switching

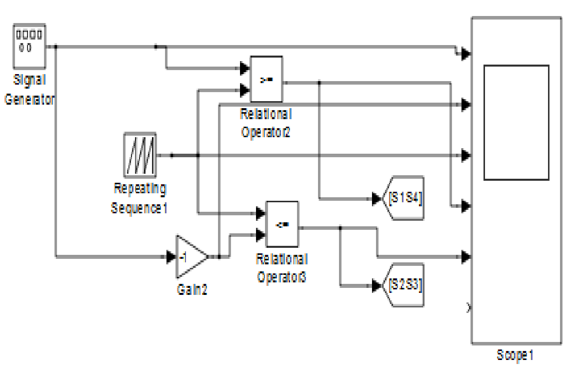

Fig 7: Simulink model for SPWN inverter

Conclusion

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. The width of this pulses are modulated to obtain inverter output voltage control and to reduce its harmonic content.

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Author Biblography

	**Amit Kumar Sharma** was born in Jaipur, India on January 19, 1988. He received his B. Tech. degree in Electrical Engineering from Govt. Engineering College Ajmer, India in 2011.Now he is pursuing Masters with specialization in Power Systems from University College of Engineering-Rajasthan Technical University, Kota, Rajasthan, India. His research interests include Power Electronics, Electric Drives and Electric Machines. Email: amy.sharma21@gmail.com
	**Ashok Kumar Sharma** was born in , India on July 10, 1962 .He received his BE degree (Hons.) in Electrical Engineering from M.B.M Engineering College Jodhpur, J.N.V University, Jodhpur India in 1986 and Master of Engineering with specialization in Power Apparatus & Electric Drives from Indian Institute of Technology, Roorkee, India in 1993. He is presently Associate Professor in University College of Engineering, Rajasthan Technical University, Kota, Rajasthan, India. Prof. Sharma has published about 60 papers in National and International Journals and Conferences. He is a Fellow of the Institution of Engineers (IE India) and a Life Member of the Indian Society of Technical Education (ISTE) and Indian Society of Lighting Engineers (ISLE). His fields of interest include power electronics, electrical drives, static var compensation, optimization and renewable energy. Email: aksharma_eck@hotmail.com
	**Nidhi Vijay** was born in Jaipur, India on June 25, 1990. She received her B. Tech. degree in Electrical Engineering from Gyan Vihar College Jaipur, India in 2011. Now she is pursuing Masters with specialization in Power Systems from University College of Engineering-Rajasthan Technical University, Kota, Rajasthan, India. Her research interests include FACTS, Power System Protection and Electric Machines. Email: Nidhi.vijay25@yahoo.com