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Analysis of Voltage Source Inverter and its Applications

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Abstract: In growing number of industrial market. Voltage source inverters have proven to be more efficient, has greater reliability and higher dynamic response. Pulse Width Modulation (PWM) techniques are increasingly applied in industrial applications for variable speed drives. In this we are using different switching techniques for analysis of voltage source inverter such as uni polar and bipolar PWM and Sine Pulse Width Modulation method for a single-phase voltage source inverter. The PWM technique results in reduced Total Harmonic Distortion (THD) improving the spectral quality of the output. The parameters such as Weighted Total Harmonic Distortion (WTHD), Distortion factor (DF), Harmonic Spread Factor (HSF) and switching losses are computed. Voltage Source inverters (VSI) have been widely used in uninterruptible power supplies, unified power quality conditioners and distributed generations systems (DGS). Voltage source inverters are inherently efficient, compact and economical devices used to control power flow and provide quality supply.

Keywords— Voltage source inverter, Sine Pulse Width Modulation, Pulse Width Modulation, Weighted Total Harmonic Distortion, Distortion factor, Harmonic Spread Factor and switching losses.

I. INTRODUCTION

The word ‘inverter’ in the context of power-electronics denotes a class of power conversion (or power conditioning) circuits that operates from a dc voltage source or a dc current source and converts it into ac voltage or current. The ‘inverter’ does reverse of what ac-to-dc ‘converter’ does (refer to ac to dc converters). Even though input to an inverter circuit is a dc source, it is not uncommon to have this dc derived from an ac source such as utility ac supply. Thus, for example, the primary source of input power may be utility ac voltage supply that is ‘converted’ to dc by an ac to dc converter and then ‘inverted’ back to ac using an inverter. Here, the final ac output may be of a different frequency and magnitude than the input ac of the utility supply. Voltage Source Inverters are used to transfer real power from a DC power source to an AC load. Usually, the DC source voltage is nearly constant and the amplitude of AC output voltage is controlled by adapting a suitable control strategy. Areas where VSI’s are used include adjustable speed drives for AC motors, Electronic frequency changer circuits etc. VSI’s are also becoming widely adopted for other applications such as grid connection for renewable energy sources, where a variable voltage DC power source supplies power to an AC system with a nearly constant voltage. There are three main types of VSI’s namely Single Phase Half Bridge Inverter, single phase full bridge inverter and three phase voltage source inverter.

The harmonics generated by the nonlinear loads can have detrimental effects on the power systems. These harmonics cause the current to increase to higher values beyond the permissible limits, which in turn leads to temperature rise in conductors. They also increase the losses, thereby reducing the efficiency of the power converter. In order to minimize the Total Harmonic Distortion, unipolar and bipolar modulation are discussed. In this paper, the proposed modulation techniques are studied, simulated and applied to a single-phase voltage source inverter. This paper also presents the analysis of the single-phase inverter on its various Performance parameters.

II. SINGLE PHASE VOLTAGE SOURCE INVERTER

Voltage Source Inverters are used to transfer real power from a DC power source to an AC load. Usually, the DC source voltage is nearly constant and the amplitude of AC output voltage is controlled by adapting a suitable control strategy. Areas where VSI’s are used include adjustable speed drives for AC motors, Electronic frequency changer circuits etc. VSI’s are also becoming widely adopted for other applications such as grid connection for renewable energy sources, where a variable voltage DC power source supplies power to an AC system with a nearly constant voltage. There are three main types of VSI’s namely Single-Phase Half Bridge Inverter, single phase full bridge inverter and three phase voltage source inverters.

Figure1. Shows the power circuit diagram for single phase bridge voltage source inverter. In these four switches (in 2 legs) are used to generate the ac waveform at the output. Any semiconductor switch like IGBT, MOSFET or BJT can be used. Four switches are sufficient for resistive load because load current io is in phase with output voltage vo. However,

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this is not true in case of RL load where the io is not in phase with vo and diodes connected in anti-parallel with switch will allow the conduction of the current when the main switch is turned off. These diodes are called as Feedback Diodes since the energy is fed back to the dc source.

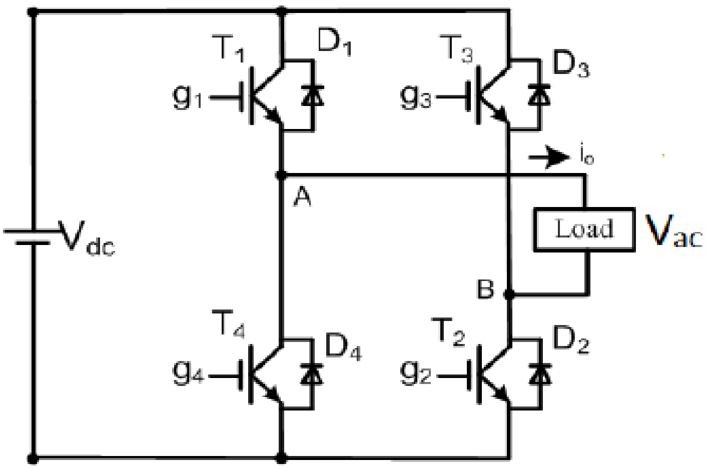

Figure-1: Full Bridge Inverter

III. MODULATION TECHNIQUES FOR VOLTAGE SOURCE INVERTERS

The main objective behind adopting control strategies is to generate good quality controllable AC voltage and to minimize the harmonic distortion, switching losses and the filtering requirements. Various modulation techniques for VSI are reported in the literature. The modulation strategy discussed in this paper is Pulse Width Modulation (PWM). The reason for adopting this technique are allowing flexible control over the AC power, reduced power loss, easy generation of gating signals. Pulse width modulation is the process of modifying the width of the pulses proportional to the control voltage. Greater the control voltage, wider the resulting pulses become. By modulating the relative time intervals corresponding to conduction and non-conduction periods, it is possible to spread the voltage during the period in such a way that the conduction time of the switching device becomes practically proportional to the instantaneous value of the fundamental. There are two types of switching for SPWM namely, bipolar and unipolar switching.

- **Bipolar Modulation**

The sampling of SPWM bipolar switching is that the reference sinusoidal waveform having magnitude Vref is compared with triangular carrier signal having amplitude Vcarrier. The upper and the lower switches in the same inverter leg work in a complimentary manner which means the gating signals are generated for only one of the switches in each leg and the compliment of the same is given to the other switch belonging to the same leg. The output voltage will swing between +Vdc and –Vdc.

The schematic for the simulation of bipolar modulation and the pulse pattern for the various switches under this modulation for the full bridge inverter is shown in Figure2.

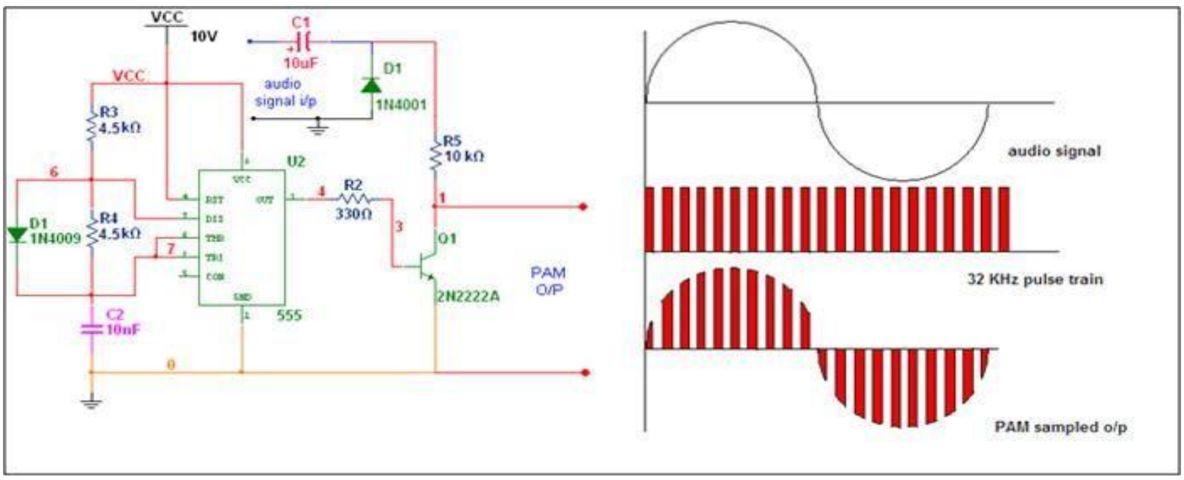

Figure- 2: Schematic for bipolar modulation and Carrier, Reference and Gating pattern for bipolar modulation.

- **Unipolar modulation**

The unipolar modulation normally requires two sinusoidal modulating waves Vref1 and Vref2 which are of same magnitude and frequency but 180 degree out of phase .The two modulating wave are compared through a common triangular carrier wave Vcarrier generating two gating signals Vg1 and Vg3 for the upper two switches S1 and S3. It can be observed that the upper two devices do not switch simultaneously, which is well-known from the bipolar PWM. The inverter output voltage switches either between zero and +Vdc during positive half cycle or between zero and –Vdc. during negative half cycle. This is referred as unipolar modulation. The schematic for simulation of unipolar modulation is shown in Figure 3. The Carrier wave, Reference wave and gating pattern for a full bridge inverter under this scheme is shown in Figure 3. The reference wave comprises two sinusoidal waves phase shifted by 180 ° from each other. The carrier wave is a high frequency triangular waveform. The gating pattern for S1 and S3 are shown. The gating pattern for S2 is the complement of S1 and that ofS4 is the complement of S3. Piezoelectric motors often must be individually handmade. Thus, the manufacturing process is labour intensive and expensive. In addition, it is difficult to produce large quantities because each motor is handmade. Furthermore, it is difficult to control the manufacturing process.

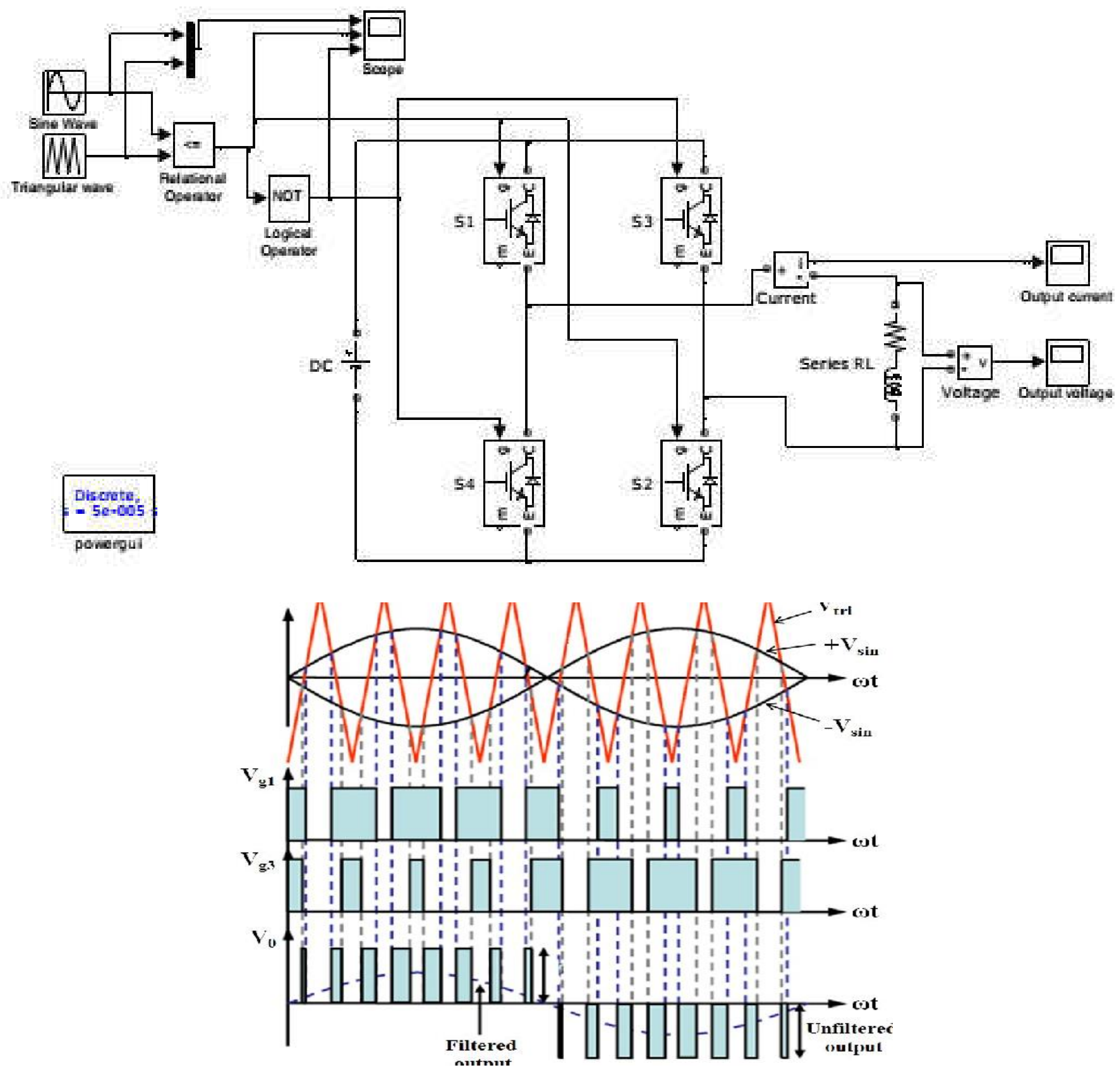

Figure- 3: Schematic for uipolar modulation and Carrier, Reference and Gating pattern for bipolar modulation.

IV. PERFORMANCE ANALYSIS

The quality of the inverter output is normally evaluated in terms of the performance parameters discussed below.

- **Harmonic Spread Factor**

An important parameter to indicate the generation of noise in the motor is the harmonic spread factor. It can be calculated for evaluating the quality of voltage spectrum of inverters.

Where, HSF= $s = \sqrt{\frac{\sum_{j=1}^{N}(X_j - \bar{X})^2}{N}}$

Hn - Value of nth harmonic
H0 -Average value of all N harmonics

- **Distortion Factor**

When Distortion factor indicates the amount of harmonic distortion that remains in a particular waveform even after being subjected to second order attenuation.

- **Weighted Total Harmonic Distortion**

This index gives a better measure of the harmonic pollution in the output voltage using the order of each harmonic component as its weight factor .

WTHD = $$THD_{voltage} = \sqrt{\sum_{n=2}^{n=n}\left(\frac{V_n}{V_1}\right)^2} \times 100$$

Where,
Vn – Voltage component of nth harmonic
V1 – Voltage of the fundamental component

- **Switching Losses**

The efficiency of voltage source inverters depends mainly on power losses that occur in semi-conductor elements. The switching losses are a function of the supply voltage, load current, operating frequency and on the dynamic parameters of the switching elements.

V. APPLICATIONS OF VOLTAGE SOURCE IVERTER

- **Power grid**

Grid-tied inverter are designed to feed into the electric power distribution system. They transfer synchronously with the line and have as little harmonic content as possible. They also need a means of detecting the presence of utility power for safety reasons, so as not to continue to dangerously feed power to the grid during a power outage. Synchronverters are inverters that are designed to simulate a rotating generator, and can be used to help stabilize grids. They can be designed to react faster than normal generators to changes in grid frequency, and can give conventional generators a chance to respond to very sudden changes in demand or production. Large inverters, rated at several hundred megawatts, are used to deliver power from high voltage direct current transmission systems to alternating current distribution systems.

- **Electric motor speed control**

Inverter circuits designed to produce a variable output voltage range are often used within motor speed controllers. The DC power for the inverter section can be derived from a normal AC wall outlet or some other source. Control and feedback circuitry is used to adjust the final output of the inverter section which will ultimately determine the speed of the motor operating under its mechanical load. Motor speed control needs are numerous and include things like: industrial motor driven equipment, electric vehicles, rail transport systems, and power tools. Switching states are developed for positive, negative and zero voltages as per the patterns given in the switching Table 1. The generated gate pulses are given to each switch in accordance with the developed pattern and thus the output is obtained.

- **Uninterruptible power supplies**

An uninterruptible power supply (UPS) uses batteries and an inverter to supply AC power when mains power is not available. When mains power is restored, a rectifier supplies DC power to recharge the batteries.

- **HVDC power transmission**

With HVDC power transmission, AC power is rectified and high voltage DC power is transmitted to another location. At the receiving location, an inverter in a static inverter plant converts the power back to AC. The inverter must be synchronized with grid frequency and phase and minimize harmonic generation.

VI. CONCLUSION

Inverters are static power converters that produce an ac output waveform from a dc power supply. If a dc input is a voltage source, then inverter is voltage source inverter. It is more reliable and ability to handle reactive load without freewheeling diode .it is more efficient and reliable and with help of PWM technique it is able to reduced total harmonic distortion and improved the spectral quality of output. it has been found that the Unipolar Modulation has lesser total harmonic distortion and better power quality. The various performance parameters of the VSI such as distortion factor, harmonic spread factor, weighted total harmonic distortion and switching losses have been analyzed.

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