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Three-Phase Inverter Performance Based on Sinusoidal Pulse Width Modulation

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Abstract- This study describes a novel type of sinusoidal PWM inverter that may be used with power MOSFETs. The suggested PWM inverter's output waveforms are examined theoretically and empirically. Compared to a traditional sine-wave inverter, the three-phase line-to-line voltage's basic component is raised by around 15%. One may regulate both the output voltage's frequency and magnitude using the sinusoidal PWM switching approach. Because of this, an unregulated, very constant dc voltage source serves as the PWM inverters' input. This switching approach produces harmonic voltage that is readily filtered out and falls within the switching frequency range and beyond. Several carrier-based modulation approaches for complete bridge inverters are proposed in this paper.

Keywords— *PWM Inverter, Three-Phase Inverter, Performance Based on Sinusoidal, Pulse Width Modulation.*

Introduction

These days, a great deal of applications call for regulated AC to regulate the speed of devices like brushless DC motors and induction motors, among others. These days, an inverter is employed to obtain regulated air conditioning. Uncontrolled D.C. is transformed into controlled A.C. via an inverter. There are several varieties of inverters, including two-, three-, and five-level models. A potential inverter structure for high voltage and high power applications is the multilayer inverter (MLI). This inverter creates a stepped staircase that resembles a pure sine waveform by synthesising several DC voltage levels. When compared to two-level inverters, this has better power quality waveforms, lower device voltage ratings, less harmonic distortion, lower switching frequency and losses, higher efficiency, less dv/dt stresses, and the ability to use low-speed semiconductors. The most often used MLI architecture is the Diode Clamp, Flying Capacitor, and Cascaded Multilevel Inverter (CMLI). Numerous MLI topologies and modulation techniques have been presented and thoroughly investigated. In this work, we employ a CMLI with unequal DC that consists of a few H-Bridge inverters. Asymmetric Cascaded Multilevel Inverter (ACMLI) is another name for it. It is most frequently used because inverters have simpler, more modular architecture and offer benefits beyond diode clamp and flying capacitor. This inverter may be controlled by a variety of modulation methods, including Carrier-Based PWM (CBPWM), Space Vector PWM (SVPWM), and Optimised Harmonic Stepped-Waveform (OHSW). The most popular of these modules for multilevel inverters is CBPWM because of its straightforward logic and ease of implementation. One may regulate both the output voltage's frequency and magnitude using the sinusoidal PWM switching approach. As a result, the PWM inverters' input is an unregulated, nearly continuous source of

DC voltage. Because multilevel inverter topologies have so many benefits over traditional two-level inverters, they have received particular attention in the last twenty years. Multilevel inverters provide several benefits over two-level inverters, including reduced dv/dt, less common mode voltages, lower power losses between switching components, and lower output voltage and current harmonics. As a result, a new class of multilayer inverters has surfaced as the answer for many uses, including medium voltage grids, transmissions, huge, powerful engine drivers, AC power supplies, and distribution systems. Several power conversion topologies have been put forth in an effort to lower control complexity while increasing efficiency and total harmonic distortion (THD). The most well-known are the neutral point clamped (NPC) inverter, packed U cell, flying-capacitors (FC) converter, and cascaded H-bridge (CHB) inverter. The NPC architecture is used in this work due to its benefits, which include low switching frequency, controllable reactive current, and DC-link capacitors shared by three phases. Because it uses a different DC supply of voltage than CHB inverters and performs better than FL inverters, the diode-clamped three level neutral-point clamped (NPC) architecture has been the most popular of all multilevel inverter topologies.

Application Of Spwm

(i) Concept of sine-modulated PWM inverter- The pole-voltage pulse lengths of a sine-wave PWM inverter fluctuate sinusoidal throughout the output cycle. In its most basic form, the system compares a sinusoidal modulating signal, which signifies the desired fundamental component of the voltage waveform, with a high frequency triangle carrier voltage. The modulating signal's peak magnitude must not exceed the carrier signal's peak magnitude. The high side and low side switches are then managed by the comparator output. Figure 1 displays an op-amp based comparator output with inputs that are typical triangular and sinusoidal waveforms. The triangular and sinusoidal signals are supplied to the inverting and non-inverting input terminals, respectively, of the comparator seen in Figure 1.

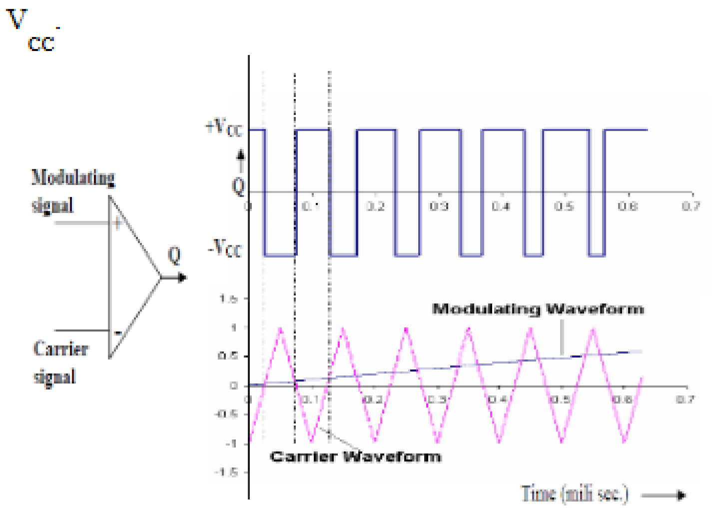

Figure 1- A schematic circuit for comparison of Modulating and Carrier signals

(ii) 2-Level Inverter- Pulse-width modulation is by far the most widely used and well-liked method of producing digital pure sine waves (PWM). Using the PWM approach, a digital waveform is created and its duty-cycle is adjusted so that the waveform's average voltage resembles a pure sine wave. Comparing a triangle wave to a low-power reference sine wave is the simplest method of creating a PWM signal. When these two signals are sent into a comparator, a 2-level PWM signal is produced as the result. (Figure 2). Switches attached to a high-voltage bus may then be controlled using this PWM signal, which will reproduce this signal at the proper voltage. This PWM signal will clean up into a near-sine wave when it is sent through a low pass filter. Despite producing a significantly cleaner source of AC power than square or modified sine waves, this approach nevertheless results in a truncated primary harmonic and a comparatively high quantity of higher level harmonics in the signal, according to the frequency analysis. By utilising a second-order low pass filter, this may be eliminated.

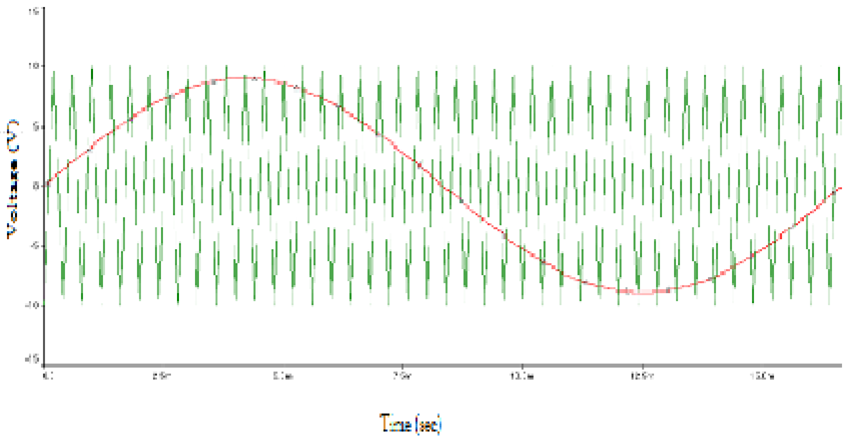

Figure 2- 2-Level PWM Comparison Signals

Three-Level Pwm Techniques

By using pulse width modulation (PWM) methods, the inverter's outputs may be adjusted. By modifying the INVERTER IGBTs' ON and OFF times, the PWM technique is applied in inverters. The SPWM approach is the best of all PWM techniques since it allows for direct control of the frequency and voltage of the inverter output, based on the sine functions that are applied. With this technique, the duty cycles vary with time, but the pulse amplitude stays constant. THD may be reduced and the inverter output voltage controlled by varying the pulse width. By comparing the triangle carrier signal of the cut off frequency (fc) with the sinusoidal reference signal, the pulse signal generation in the SPWM method is carried out. When the carrier triangle wave is less than the reference sinusoidal signals, the switching devices will turn on by adjusting the modulation signal's frequency and amplitude, the line side Fundamental component frequencies and magnitudes may be changed. Three sine waves are required as reference signals in this three-phase voltage source inverter. The sine waves are phase-shifted by 120° and taken at the desired output voltage frequency. The signals are contrasted with an extremely high frequency carrier signal. Figure 3 compares the waveforms of sine and triangle waves and also shows the creation of pulses.

(i) Space vector pulse width modulation- The foundation of SVPWM relies on temporal averaging of the two vectors generated by the inverter to create the reference voltage vector. The necessary command voltage that must be supplied in accordance with the application's requirements is known as the reference voltage vector. The rotating reference voltage space vector approximation is the foundation of the space vector PWM approach. The spatial vector sum of the three-phase voltage in the α-β space is represented by the rotating reference voltage vector. The instantaneous voltage readings may be used to calculate the vector's amplitude and the three-phase phase angle. The vector has constant amplitude and will rotate quickly in a set angular direction if the magnitudes are balanced and sinusoidal. When taking into account the inverter's three phases, there are 27 states that changeover.

(ii) Sinusoidal pulse width modulation technique- The sinusoidal carrier-based pulse width modulation (SPWM) technology works on the basis of comparing a sinusoidal control signal Vc at the required frequency with a high-frequency triangular carrier wave Vr. The modulated pulse's commutation and switching instants are determined by the junction of the Vc and Vr waves. Every comparison match point results in the generation of a PWM waveform transition. The PWM output is positive when the sine wave's magnitude is greater than the triangle wave's, and negative when Vc is less than Vr. The frequency of the triangle waveform Vc determines the inverter's switching frequency, fs. Amplitude modulation index can be used to regulate the inverter output voltage's fundamental frequency component.

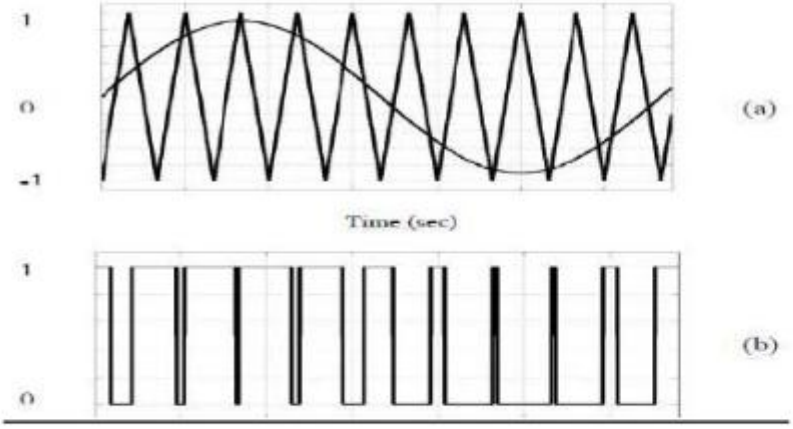

Figure 3-SPWM method: (a) Sinusoidal and triangular comparison; (b) Generation of switching pulses

Induction Motor

An insulated winding is used to carry current and magnetic flux in an induction motor, which also has a rotor and stator built of laminated silicon steel lamination to decrease hysteresis loss and Eddy current loss. The magnetic field and the housing for the stator windings are provided by the stator. The ac current flows through the stator winding of an induction motor when it is supplied a single phase alternating source. The alternating flux created by this flowing current is referred to as stator flux. The rotor conductor cuts the stator flux as a result of the produced flux linking with the rotor windings, causing an induced emf in the rotor winding.

(i) Working Principal- The stator windings produce a magnetic flux of constant magnitude and rotate at synchronous speed when the rated AC supply is connected to them. The flux travels via the stationary rotor conductors, the rotor surface, and the air gap. The rotor conductors experience an electromotive force (EMF) as a result of the relative speed differentials between the stationary conductors and spinning flux. The supply frequency and the induced EMF have the same frequency. The relative velocities of the conductors and the flux determine its magnitude. The rotor conductors experience a current due to the EMF created because the rotor bars are shorted at the ends.

(ii) Torque- speed characteristics of induction Motors- V/f control speed control method (regulation of frequency). This is one of the most used techniques, particularly for the Variable Frequency Drive (VFD) or Adjustable Speed Drive (ASD), which is primarily used to regulate the motor's speed. The magnetic field generated by the stator directly relates to the torque that the motor generates. Thus, the product of the stator flux and rotational velocity determines the voltage that is supplied to the stator. As a result, the stator's flux is proportionate to the relationship between the applied voltage and supply frequency. One may adjust the motor's speed by changing the frequency. Thus, flux and, thus, the torque may be changed by adjusting the voltage and frequency by the same ratio.

(iii) Total Harmonic Distortion (THD) effect in Induction Motor- Power electronics are being used more often as a result of improvements in regulated operation and more uses for controlled output voltages. One of the main causes of the system's generation of harmonics with varying orders is these power changes. All that exists is the periodic waveform's sine component, which has a frequency that is an integral multiple of the fundamental frequency. Fundamental frequency (f) represents the first order harmonic, 2f represents the second order harmonic, 3f represents the third order harmonic, and so on. Positive cycle = negative cycle cancels off the total distortion, automatically eliminating even harmonics in (Figure 4).

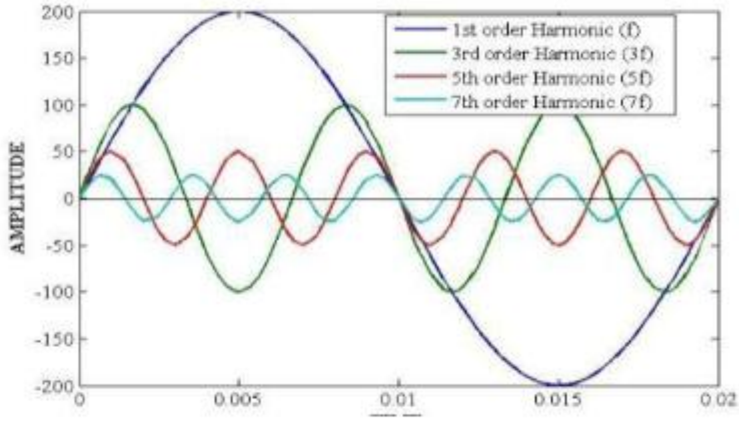

Figure 4 -THD Effect on Induction Motor

Conclusion

It is evident from all of the simulation results that the Op-Amp/Analog circuit controlled PWM inverter created for this purpose operates accurately. It satisfies every need necessary for a voltage source inverter. After filtering, there is less than 5% THD. The potentiometer's resistance may be changed to alter the inverter outputs. With independent inductive loads, the inverter responds more accurately. The power system will give electricity to the nearby standalone loads if there is insufficient power to power it. This research compares the sine-triangle SPWM scheme with a space vector based SVPWM strategy for an NPC three-level inverter. MATLAB/Simulink is used for the modelling and simulation of the three phase, three level diode-clamped inverter. The space vector pulse width modulation technology outperforms the traditional, classical method, according to the results (SPWM). When comparing the space vector pulse width modulation approach to the traditional PWM method, less harmonics are produced. Enhancing the carrier frequency to a sufficient extent will improve the filtering mechanism and reduce loss. However, the closed loop control system, also known as the feedback system, may be used to obtain better reaction. The feedback loop mechanism can be worked on in the future.

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