https://doi.org/10.46335/IJIES.2024.9.9.5 e-ISSN: 2456-3463
Vol. 9, No. 9, 2024, PP. 24-28

International Journal of Innovations in Engineering and Science, www.ijies.net

Performance Analysis of Three Phase Sinusoidal Pulse Width Modulation Inverter

Dr.Dinesh Wankhede , Dr. Chaitanya Jibhkate, Apurva Yesankar, Sahil Sable, Diksha Bhagat

St.Vincent Pallotti College of Engineering & TechnologyNagpur, RTMNU Nagpur University Nagpur, Maharashtra, India

dwankhede@stvincentngp.edu.in

***Received on**: 5 May,2024* ***Revised on**: 10 July,2024* ***Published on**: 12 July ,2024*

***Abstract-** Sinusoidal pulse width modulation (SPWM) is a technique in power electronics for generating high-quality sinusoidal waveforms with reduced harmonic content. This paper presents an extensive review and performance analysis of SPWM inverters, focusing on their characteristics and challenges across various applications. The review begins with an overview of principles of SPWM, highlighting its ability to generate sinusoidal waveforms by modulating the width of the pulses in the PWM waveform. The advantages of SPWM which includes low harmonic distortion, high efficiency, and improved voltage regulation, are discussed in detail, highlighting its suitability for the use of motor drives, renewable energy systems, and grid- connected inverters. Performance metrics such as Total Harmonic Distortion (THD), modulation index, output voltage regulation, and efficiency are analysed to assess the effectiveness of SPWM inverters. In conclusion, this comprehensive review and performance analysis provide valuable insights into the design, implementation, and optimization of SPWM inverters, facilitating their widespread adoption and deployment in various power electronics applications.*

Keywords- Inverter, sinusoidal pulse width modulation, total harmonic distortion.

I. INTRODUCTION

Inverter

Inverters are useful devices in modern power electronics systems, easing the conversion of DC direct current into AC alternating current. Their resilience and efficiency make them integral components in various applications, starting from renewable energy systems and motor drives, uninterruptible power supplies (UPS) system and grid tied inverters.

The basic principle of the inverters involves transforming the steady dc voltage input into an ac output waveform, typically sinusoidal, square, or modified sine wave, depending on the application requirements. This transformation enables the use of dc power sources, such as batteries or photovoltaic panels, to power ac loads or feed ac power into the grid.

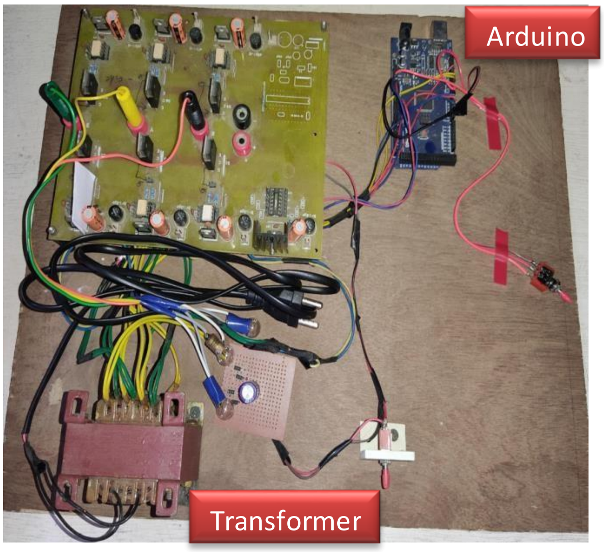


Figure 1: Hardware

https://doi.org/10.46335/IJIES.2024.9.9.5 e-ISSN: 2456-3463
Vol. 9, No. 9, 2024, PP. 24-28

International Journal of Innovations in Engineering and Science, www.ijies.net

II. Inverter with Sinusoidal Pulse Width Modulation

The SPWM in the inverter circuits is more complex than the PWM used in DC-DC converters. It has a sinusoidal waveform at the output of the inverter, with magnitude and frequency.

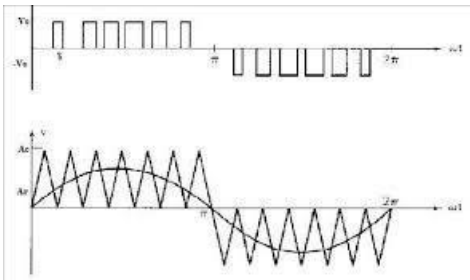


Figure 2: Sinusoidal pulse width modulation single phase inverter

Source: https://www.researchgate.net/figure/Sinusoidal-pulse-width-modulation-III-SINGLE-PHASE-SPWM-INVERTER_fig1_316432567

The foundation of Inverters with Sinusoidal Pulse Width Modulation rests upon the principle of modulating the width of the pulses within a Pulse Width Modulated (PWM) waveform to approximate a sinusoidal output waveform. By precisely controlling the width of these pulses in response to the instantaneous values of a reference sinusoidal waveform, SPWM achieves the objective of generating AC waveforms with minimal harmonic distortion and high fidelity to the desired sinusoidal waveform.

Modulation Index: The modulation index is defined as the ratio of change in the amplitude of carrier waveform to the amplitude of carrier waveform.

$$\mu = \frac{\text{change in amplitude of carrier waveform}}{\text{Amplitude of carrier waveform}}$$

Total Harmonics Distortions (THD): It is the ratio of the total harmonic component to the fundamental component. The formula of the THD is xpressed as, the numerator is the sum of the RMS values of each order starting from the second order and the denominator is the RMS value of the fundamental waveform.

$$THD = \frac{\sqrt{(1^{st}\ harmonic)^2 + (2^{nd}\ harmonic)^2}}{fundamental}$$

LITERATURE REVIEW

Pulse Width Modulation (PWM)

Pulse width modulation is abbreviated as PWM. It is a method which is used in electronics and digital communication to manage the amount of power delivered to the device by changing the width of pulses in a pulse train. In the pulse width modulation signal, the ratio of the duration of the high signal to the duration of the total period is changed to manage the power delivered.

PWM is commonly used in various operations which includes, speed control of the motors, regulating the intensity of LEDs, producing an analog signals, and controlling the power supplies. By modifying the duty cycle the average power which is delivered to the load can be controlled/managed efficiently. This allows for precise control of devices without dissipating much power as heat, making it an efficient method for controlling power.

Types of PWM Techniques

- **Single-Pulse Width Modulation:-** In SPWM, a series of pulses with variable widths are generated to approximate a sinusoidal waveform. This method is often used in motor control and power inverters for applications like variable-frequency drives (VFDs).
- **Multiple-Pulse Width Modulation:-** 'MPWM' is an extension of SPWM, where multiple pulses are used in each half-cycle to further approximate a sinusoidal waveform. This technique improves the quality of the output waveform compared to SPWM.
- **Sinusoidal Pulse Width Modulation (SPWM):-** 'SPWM' is abbreviated as Sinusoidal Pulse Width Modulation, which is a method used in inverters to control an output voltage and frequency of three-phase inverter. SPWM compares a sinusoidal ac voltage is a reference with a high-frequency triangular carrier waveform, which also determines the switching conditions for each pole in theinverter.
- **Selective Harmonic Elimination (SHE):-** 'SHE' is abbreviated as Selective Harmonics Elimination. It is method which eliminates the lower-order harmonics from a voltage or current waveform. SHE is also used in multilevel inverters (MLIs) to calculate switching angles that obtain the desired fundamental output voltage while eliminating the dominant low order harmonics.

https://doi.org/10.46335/IJIES.2024.9.9.5 e-ISSN: 2456-3463
Vol. 9, No. 9, 2024, PP. 24-28

SINUSOIDAL PULSE WIDTH MODULATION (SPWM) :-

Sinusoidal pulse width modulation is used for several reasons in the various applications, particularly in power electronics and motor control:

1. **Improved Output Quality**: SPWM generates a PWM waveform that closely resembles a sinusoidal waveform. This results in a cleaner output signal with reduced harmonic distortion compared to simpler PWM techniques like Square Wave PWM or Single Pulse Width Modulation (SPWM). The reduced harmonic content leads to smoother operation and better performance of the controlled system.

2. **Reduced Electromagnetic Interference (EMI)**: The sinusoidal nature of the output waveform produced by SPWM helps to reduce electromagnetic interference generated by the system. This is particularly important sensitive applications where EMI can interfere with other electronic devices or communication systems.

3. **Higher Efficiency**: SPWM can result in higher efficiency compared to simpler PWM techniques. By generating a waveform that closely matches the desired output signal, SPWM minimizes energy losses and improves the overall efficiency of the system, especially in applications such as motor drives and power inverters.

4. **Improved Motor Control**: SPWM is widely used in motor control applications, particularly in the variable frequency drives, where accurate control of speed of the motor and torque is required. The smooth, sinusoidal output waveform generated by SPWM helps to minimize torque ripple and improve the overall performance of the motor.

5. **Flexibility**: SPWM can be easily adjusted to meet specific requirements of different applications. By changing parameters such as modulation index, frequency, and phase angle, SPWM can accommodate a wide range of operating conditions and control objectives.

6. **Compatibility**: SPWM is compatible with a variety of power electronic devices, including MOSFETs, IGBTs, and power diodes. This compatibility makes it suitable for integration into existing systems and for use with a wide range of power conversion and control applications.

Overall, Sinusoidal Pulse Width Modulation offers improved output quality, reduced EMI, higher efficiency, and better motor control compared to simpler PWM techniques, making it a preferred choice in many power electronics and motor control applications.

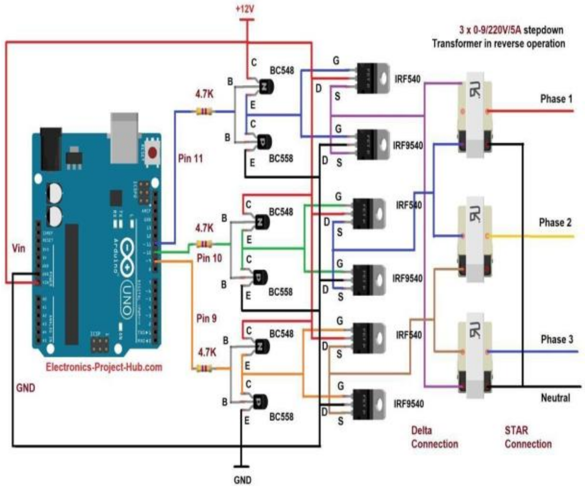


Figure 3: Three Phase Inverter Circuit Diagram
Source: *https://electronics-project-hub.com/three-phase-inverter-circuit-diagram/*

RESULTS OBTAINED

Voltage Waveforms of Original Frequency

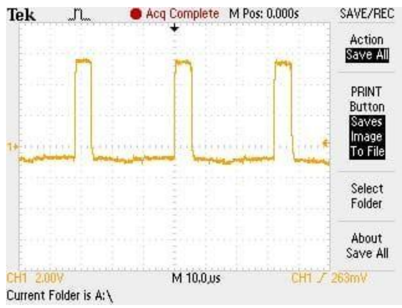


Figure 4.1: Phase 1 waveform

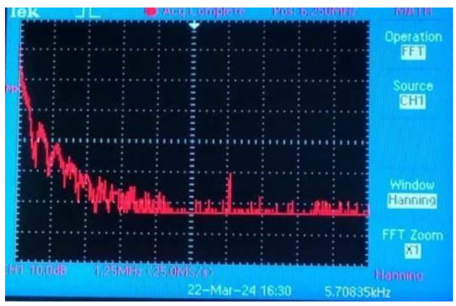


Figure 4.2: Phase 1 FFT waveform

https://doi.org/10.46335/IJIES.2024.9.9.5 e-ISSN: 2456-3463
Vol. 9, No. 9, 2024, PP. 24-28

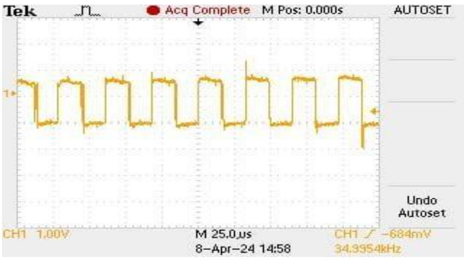


Figure 4.3: Phase 2 waveform

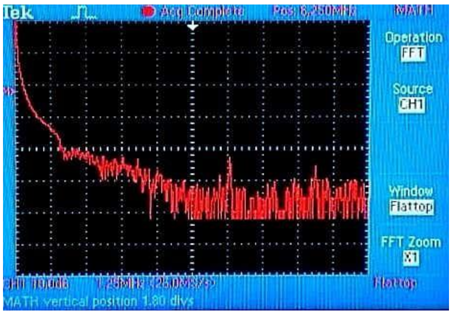


Figure 4.4: Phase 2 FFT waveform

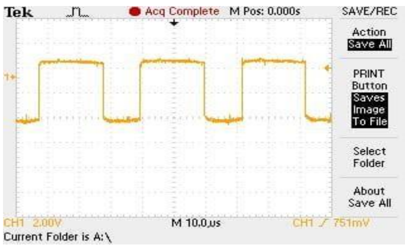


Figure 4.5: Phase 3 waveform

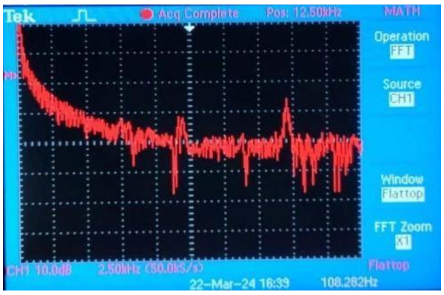


Figure 4.6: Phase 3 FFT waveform

Voltage Waveforms of Changed Frequency

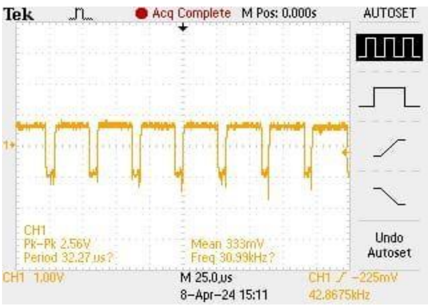


Figure5.1:Phase 1 Changed Frequency

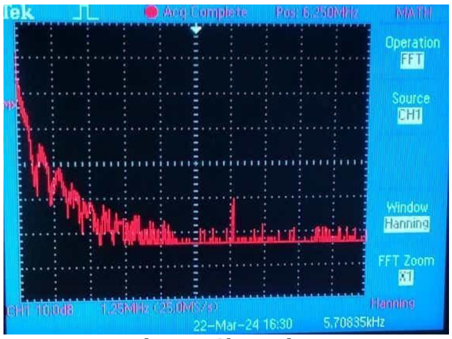


Figure5.2: Phase 1 Changed Frequency FFT

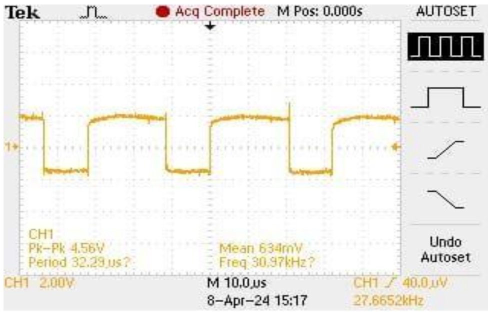


Figure 5.3:Phase 2 Changed Frequency

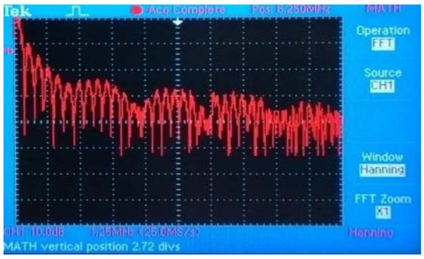


Figure5.4: Phase 2 Changed Frequency FFT

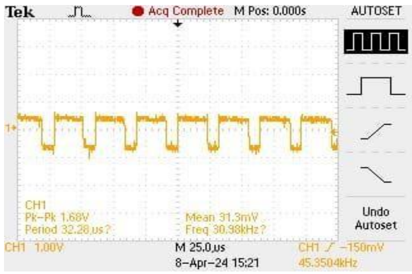


Figure 5.5: Phase 3 Changed Frequency

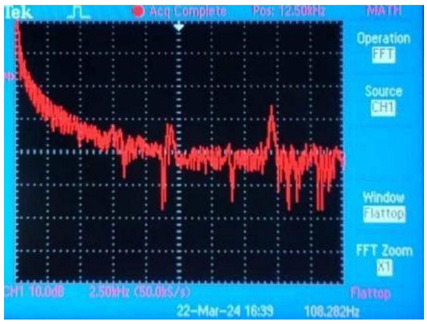


Figure 5.6 : Phase 3 Changed Frequency FFT

https://doi.org/10.46335/IJIES.2024.9.9.5 e-ISSN: 2456-3463
Vol. 9, No. 9, 2024, PP. 24-28

Output Waveforms of Original Frequency

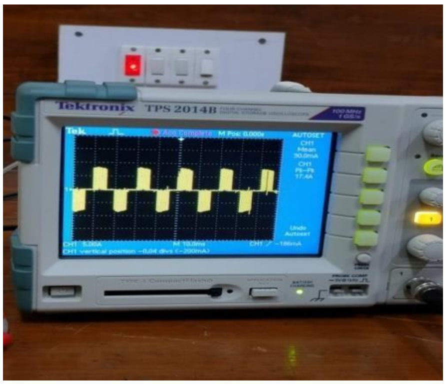


Figure 6.1: Output waveform

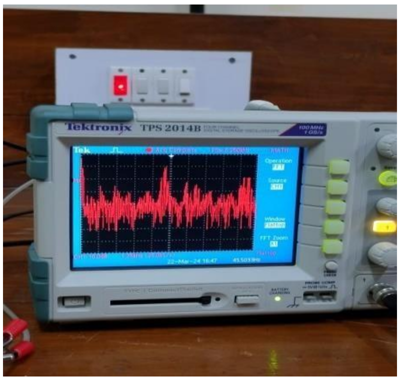


Figure 6.2: Output FFT waveform

Output Waveforms of Changed Frequency

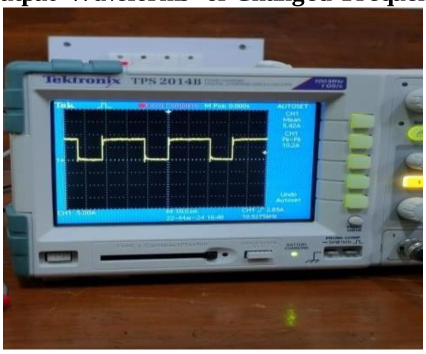
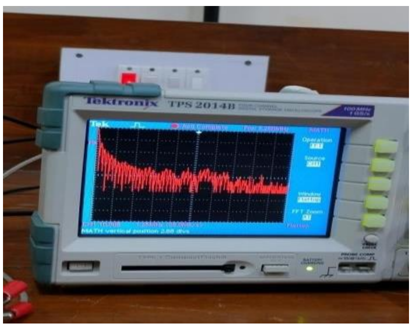


Figure7.1: Output waveform



CONCLUSION

This work provides a first introduction and a small guide to the topic of inverters, which is important to keep present in mind when designing. The parameters of the single-phase inverters are defined to extend it to the three-phase inverters. The simulations provide a clear example of the subject. The SPWM modulation has the advantage of managing the amplitude and the reduction of the harmonics in output voltage. These advantages, however, correspond to a complex control circuit. Through the simulation it can be seen the waveforms of the SPWM modulation as well as the output voltages present in the load. With the Fourier analysis the number of harmonics decreases with a high modulation index (within the linear range). The SPWM technique applied to the inverters presents several advantages, due the output signal has a main component and the other components are in carrier frequency, which eases the filtering of the output signal, therefore reducing the THD. In addition, an entire modulation index must be maintained; otherwise the output signal will have sub harmonics. It is recommended to expand the subject under the bibliography used.

REFERENCES

[1] M. H .Rashid, ‘Power Electronics’, Perentice-Hall of *India, New Delhi 1993.*

[2] *Dr. P. S. Bimbra, ‘Power Electronics’, Khanna Publishers, 2-B Nath Market, Nai Sarak, Delhi-110006.*

[3] *J. Holtz, “Pulse width modulation for electronic power conversion,” Proc. IEEE, Vol. 82, no. 8, pp. 1194–214, Aug.1994.*

[4] *Omar Alejandro Sosa, Electronic engineering UTN-FRC student National Technological University, Cordoba School, Argentina.*

[5] *Ali, A. I. M.; Takeshita, T.; Sayed, M.A. Three-Phase PWM Inverter for Isolated Grid-Connected Renewable Energy Applications. Energies 2021, 14, 3701.*

[6] *Racheel Anne, Three Phase Inverter Circuit Diagram, Published December 28,2021.*

[7] *https://www.researchgate.net/figure/Sinusoidal-pulse-width-modulation-III-*

[8] *SINGLE-PHASE-SPWM-INVERTER_fig1_316432567*

[9] *https://electronics-project-hub.com/three-phase-inverter-circuit-diagram/*