Enhanced SPWM Techniques for Harmonic Mitigation in Multilevel Inverters

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ABSTRACT

In the cutting edge period the electrical power framework faces a lack of petroleum derivative. Thus, to defeat this issue, nowadays more center is given to environmentally friendly power sources like sunlight based energy, wind energy and thermal power sources. There is additionally one more motivation to utilize environmentally friendly power sources to defeat an unnatural weather change and to decrease contamination by petroleum derivatives. So Photovoltaic (PV) exhibit or battery is utilized to give supply to the Staggered Inverter (MLI). The Sinusoidal pulse width modulation (SPWM) strategy is the most straightforward procedure than different kinds of PWM methods. The examination of result voltage waveforms is talked about with the diminished THD.

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1. INTRODUCTION

In this advanced age, the electrical grid is experiencing a deficit of fossil fuel-derived energy sources. To address this challenge, there is an increasing emphasis on sustainable energy sources such as solar power, wind energy, and geothermal resources. Additionally, transitioning to renewables is driven by the need to combat climate change and alleviate the pollution stemming from fossil fuels. The key issue in the electric area lies in meeting the escalating electricity demand daily due to limited resources available for renewable energy generation. One strategy involves employing various converters to integrate microsources, energy storage devices (ESD), and diverse loads onto a shared DC bus. In modern times, the electrical grid is facing a shortage of fossil fuel-derived energy sources. Hence, renewable energy sources are being deployed to address this concern. To achieve a sinusoidal waveform, the incorporation of Multilevel Inverters (MLI) is imperative. MLI technology ensures that the output waveform is sinusoidal and devoid of ripples. Furthermore, coupling MLI with an LC filter can effectively mitigate Total Harmonic Distortion (THD) [1-5].

2. PROPOSED METHOD

2.1 Designing of Solar Cell

The solar cell operates akin to a p-n junction diode. Its n-region is heavily doped and thin, facilitating easy passage of light. Conversely, the p-region is lightly doped, with most of the depletion region situated on the p-side. Solar cells play a vital role in solar chargers, where multiple cells are interconnected. Photovoltaic modules are crafted by linking numerous cells in parallel and series configurations. The commonly employed single diode model, illustrated in Fig. 1, is widely utilized. Electron-hole pairs (EHPs) are primarily created within the depletion region. Because of the inherent voltage and electric field, electrons migrate toward the n-region, while holes move toward the p-region. When a load is connected, electrons pass through the load to recombine with holes [6-10].

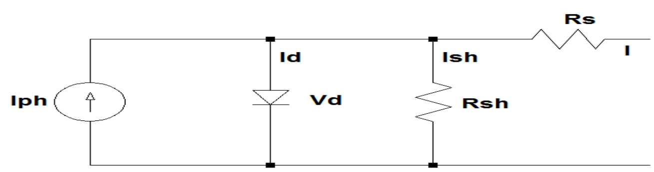


Figure 1. Single diode model

2.2. Effect due to Solar Irradiation

Solar irradiance values fluctuate with environmental conditions, including changes during the rainy and summer seasons. Embedded control mechanisms within the system can detect these variations and adjust the operation of the solar cell to meet the load demands. During periods of high solar irradiance, the solar cell receives increased input, leading to a distinct power output for the same voltage. As solar radiation intensifies, electrons within the solar cells gain more excitation energy, leading to increased electron mobility and higher power generation.

2.3. Effect due to Temperature

At the point when temperature increments other than sun-based cells then, at that point, power age limit will get decreased. Thus, these damages the activity of sunlight-based cells. The band gap of the material increases with rising temperatures.

3.MULTILEVEL INVETER (MLI)

3.1. Basics of Inverter

An electric device converts direct current (DC) into alternating current (AC). Two commonly used inverters for single-phase connections are the half-bridge inverter and the full-bridge inverter. The half-bridge inverter produces an output voltage half of the input voltage, while the full-bridge inverter yields an output voltage equivalent to the input voltage. Inverters are also utilized for emergency backup power when there is no grid supply available at home. In today's advancing technology landscape, many modern applications require high capacity to fulfill demand. Multilevel inverters (MLI) are employed in contemporary applications to achieve a pure sinusoidal waveform. Through the use of MLI, the Total Harmonic Distortion (THD) is reduced compared to conventional inverters. Here proficiency is additionally more. Three MLI geographies which are usually utilized.

- Diode clasped MLI
- Flying capacitor MLI
- Flowed H span MLI

3.2 Sinusoidal PWM (SPWM) Technique

Nowadays PWM inverters are turning out to be more famous among different sorts of inverters in certain ventures. PWM strategies are planned as equivalent abundancy beats. In Sinusoidal PWM (SPWM) utilization of more no. of heartbeats for a half cycle is there. Fig.2. describes types of Duty cycle [13-15].

$$N = \frac{f_c}{2f} \quad (1)$$

Where, N = no. of pulses, f_c = frequency of carrier wave, f = frequency of reference wave.

M = Vr/Vc, Here M = modulation index.

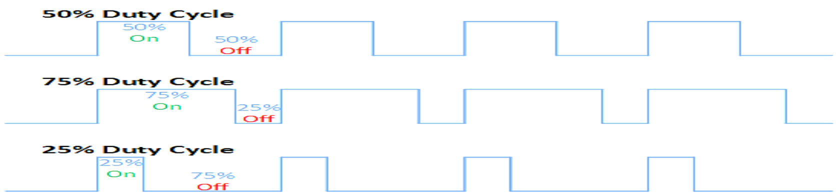


Fig.2. Types of Duty cycle

4.LC FILTER

In the LC filter, both the inductor and capacitor components are integrated. The configuration of the LC filter is illustrated in Figure 3. The impedance (Z) of the inductor element increases proportionally with the load, whereas it decreases inversely with the load in the capacitor component. As a result, when combined, the total impedance (Z) remains constant regardless of the load. The inductor provides greater impedance to AC components, allowing DC components to pass through. It is connected in series with the load [13-16].

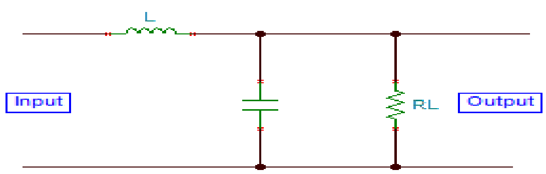


Figure 3. LC filter

5. SIMULATION RESULTS & ANALYSIS

In this configuration, a sinusoidal Pulse Width Modulation (PWM) based Multilevel Inverter (MLI) is devised. It is a three-phase MLI, as depicted in Fig. 4, with the Photovoltaic (PV) array serving as the primary source for the inverter. By implementing a filter, Total Harmonic Distortion (THD) is mitigated. Specific simulation parameters are outlined in Table 1.

Table 1. Simulation Parameters

Parameters	Values
L of filter	50 mH
Active power of the load	2 KW
Irradiance is given to the PV array	250 and 750 (W/m^2)
Temperature is given to the PV array	25^0 C
Capacitance across the PV array	1 mF
Parallel strings of PV array	1
Series-connected modules per string of PV array	14

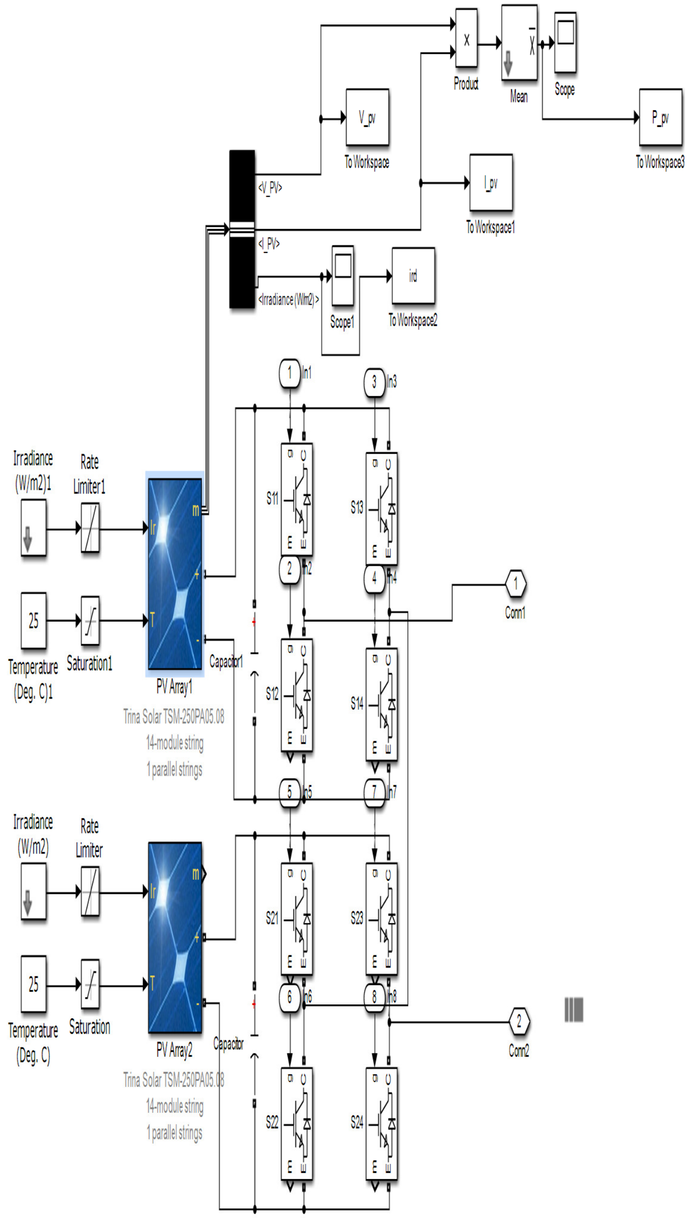
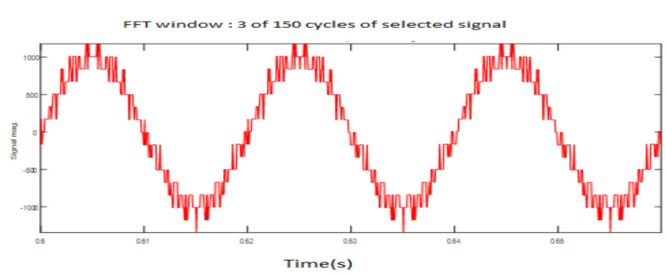
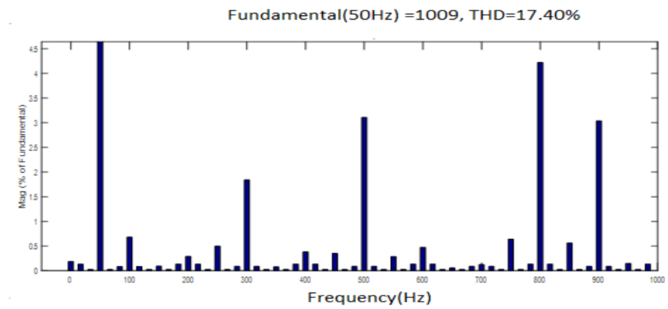


Figure 4. PV array as input to the ML

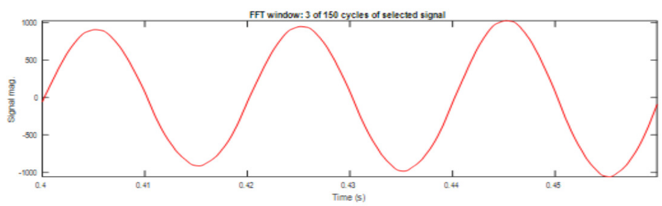


(a)

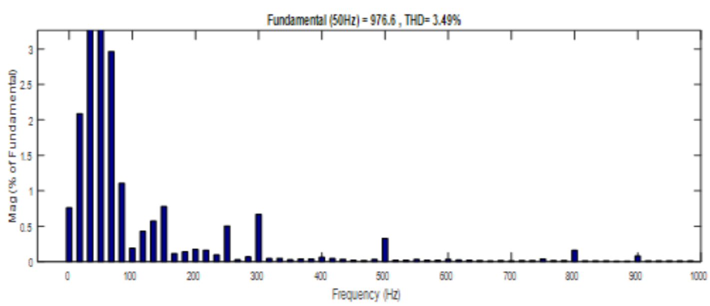


(b)

Figure 5. With no filter (a) signal magnitude (b) THD%



(a)



(b)

Figure 6. With filter (a) signal magnitude (b) THD%

Figure 5 illustrates the scenario without employing a filter, whereas Figure 6 depicts the scenario with a filter. Solar irradiance is visualized in Figure 7. The waveform of PV voltage is showcased in Figure 8. PV current is depicted in Figure 9, showcasing an increase from 0 to 4 seconds followed by a steady value thereafter. PV power variation over time is illustrated in Figure 10, showcasing how power fluctuates over time [17-25].

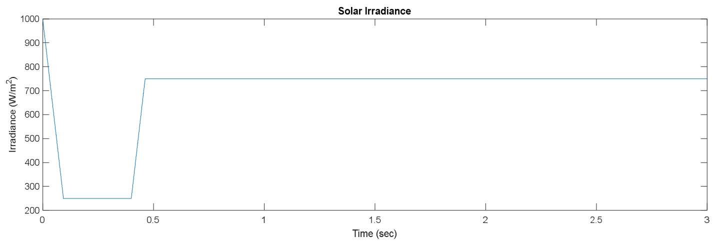


Figure 7. Solar irradiance variation

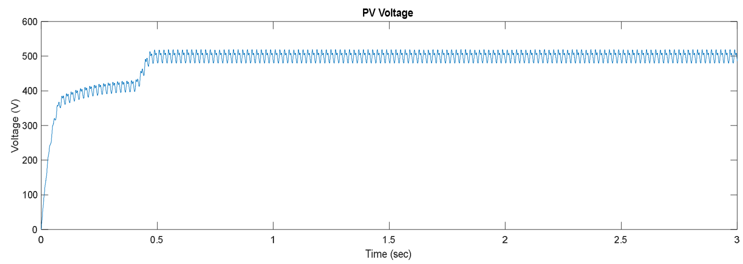


Figure 8. PV Voltage

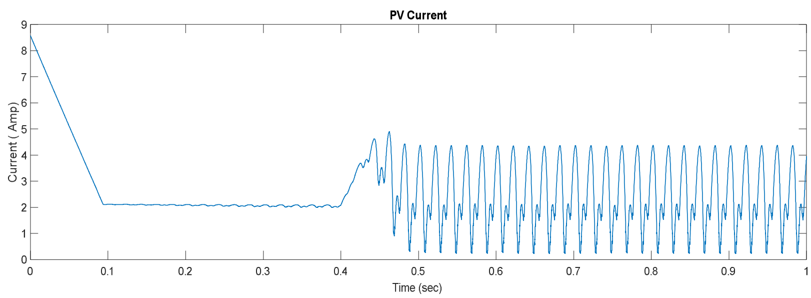


Figure 9. PV Current

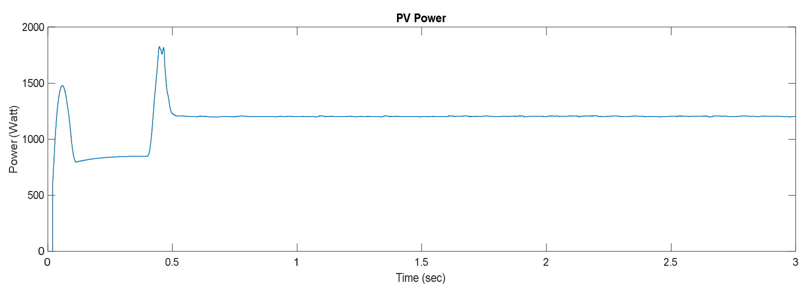


Figure 10. PV Power

6.**CONCLUSION**

The switching signals for the converter switches are determined using the Sinusoidal PWM technique, which is known for its simplicity among various PWM techniques. The model is developed and simulated using MATLAB. The current and voltage of the PV array are analyzed under different levels of irradiance and temperature variations. Fourier analysis is conducted to evaluate the Total Harmonic Distortion (THD). The THD of the output voltage waveform is measured to be 17.40% without employing any filter. However, upon implementing an LC filter, the THD is significantly reduced to 3.50%. To further improve the quality of power, techniques such as Selective Harmonic Elimination (SHE) can be utilized to generate higher-level output waveforms with reduced THD. Moreover, PV-based grid connection using the MLI can be explored, and hardware implementation of this system can be considered for future applications.

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