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ANALYSIS AND MINIMIZATION OF LEAKAGE CURRENT IN THE PV GRID CONNECTED CASCADED MULTI LEVEL INVERTER

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Abstract - *Common-mode voltage pulse width modulation techniques have been suggested recently to reduce the leakage current in single-phase transformer less photovoltaic (PV) systems. The majority of these studies, however, have ignored other aspects of PV system performance, including cost, voltage linearity, harmonic distortion, DC-link current ripples, and the reduction of leakage current. This paper focuses on a five-level inverter that doesn't need a transformer for gird integration and operates on a single phase. Modified Modulation method is suggested based on conventional pulse width modulation (PWM), and the five-level inverter design has been traditionally established for single-phase systems. In this study, MATLAB simulation to examine the performance of the suggested improved PWM with respect to harmonic distortion, leakage current, voltage linearity, output current ripples, and dc-link current ripples. The suggested architecture successfully lowers the leakage current without negatively impacting the system's overall performance.*

Key Words: Multilevel inverter, Solar PV system, Grid connected system, Leakage current, renewable energy sources

1.INTRODUCTION

Researchers are now focusing on photovoltaic (PV) energy as a solution to the problems caused by the ever-increasing demands of modern society. PV energy is renewable, sustainable, and never-ending [1]. As a result of technological advancements in power electronics and semiconductors, as well as government incentives and falling PV array costs, PV power systems have recently become ubiquitous.

There are two main varieties of electricity systems that are linked to the grid: those with and without transformers. On the alternating current side, the transformer might be a low-frequency model, or a high-frequency one [2]. In addition to increasing the input voltage, it prevents dc current injection into the grid and removes leakage current by galvanic isolation, which is a crucial safety feature. The transformers are costly, cumbersome, and hefty, however. Consequently, these problems are addressed by introducing transformer less PV systems. In addition to being more efficient, they are less expensive, lighter, and smaller [3].

The significant leakage current in transformer less PV systems, however, poses a major safety hazard. The PV leakage current might go directly to the grid if galvanic isolation is not used [4]. Stray capacitance is produced when the PV is grounded. A large amount of current leaks out because the stray capacitance charges and discharges due to the changing potential. In addition to posing a safety risk, a large leakage current will reduce the PV system's efficiency by amplifying losses, electromagnetic interference, and grid current ripples [5].

Because of its large leakage current, conventional pulse width modulation is unsuitable for grid-connected PV systems that do not use transformers. Various modulation approaches and conversion structures have been suggested in [6]-[8] as a means to decrease the leakage current to satisfy the standard's requirement. Constant voltage across the stray capacitance results in zero leakage current in [9] because the neutral of the grid is connected to the centre point of the dc-link. Unfortunately, the inductance in the neutral line is created by such a connection, therefore it is not practicable. A leakage current greater than the standard-recommended acceptable amount is caused by this inductance, which creates a high-frequency potential between the PV array and the ground [10].

The five-level topology has traditionally been designed for single-phase systems, hence in order to adapt it to single-phase systems, a matching single-phase modulation approach needs to be devised. This article so proposes a modified PWM that is based on the regular PWM. In terms of leakage current, dc-link current ripples, output current ripples, and the THD of the output current, the performance of the converter topology with the suggested modulation approaches is compared to other known PWM methods [11]-[13]. Discussions revolve on simulations conducted in Matlab/Simulink. For 230V (rms) grid systems, it has been shown that a five-level inverter structure coupled with the suggested modulation approaches provides the optimal overall performance for transformer less PV applications.

The structure of this paper is as follows: Section II presents the five-level inverter conversion structure with suggested modulation approaches. section III presents the suggested modulation methods and the operating principles. Section IV displays the simulation results that verify the performance of several topologies. Section V concludes by summarising the outcomes and findings.

2. FIVE LEVEL INVERTER WITH SOLAR PV INTEGRATED TO THE GRID

The idea behind a multilevel inverter is to provide a sinusoidal voltage output by linking H-bridge inverters in series. A full-bridge inverter is shown in Figure 2. Every cascading module adds two more voltage levels to the inverter; thus, a complete bridge is essentially a three-level cascaded H-bridge multilevel inverter. There are three voltages that may be generated by each full-bridge inverter: VDC, 0, and −VDC. Cascaded H-bridge multilevel inverters work by turning one full-bridge inverter switch ON and the other switch OFF in order to modify one voltage level.

Figure 1 shows the schematic circuit design of the five-level inverter that is suggested for the PV system. Two converters, Conv-1 and Conv-2, compose the provided setup. Both switches S_{x1} and S_{x2} combine up the half-bridge inverter known as Conv-1. S_{x3}–S_{x8} are the six switches that together make up the Conv-2's inverter arrangement, which is both efficient. Out of the six switches in Conv-2, an H-bridge circuit is made up of four of them (S_{x3} to S_{x6}). In Conv-2, the other two switches, S_{x7} and S_{x8}, may be turned on and off in both directions. The Conv-1's switches are responsible for producing the V_{PV} and $0.5V_{PV}$ voltage levels.

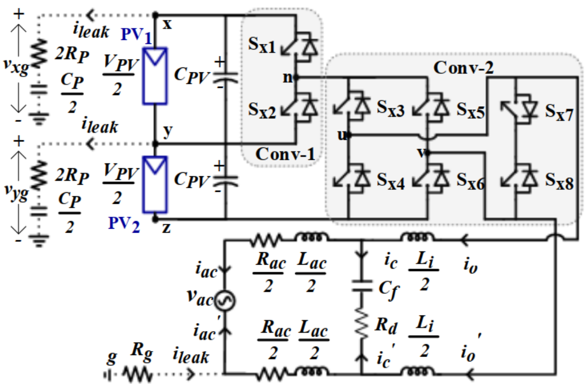
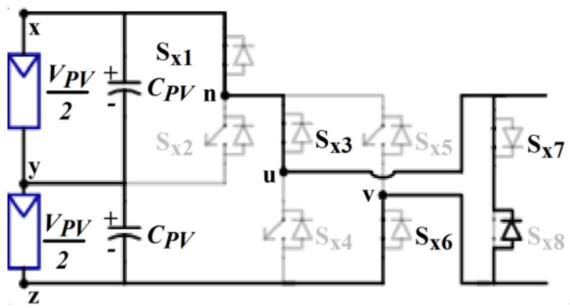
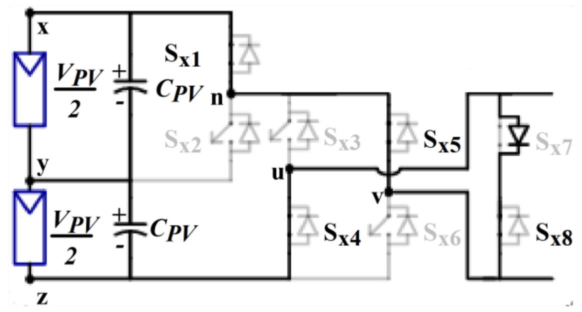


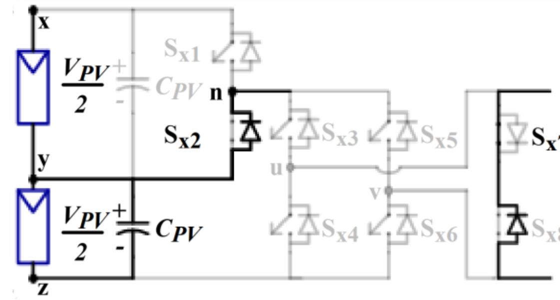
Fig -1: Five level inverter with solar PV integrated to the grid



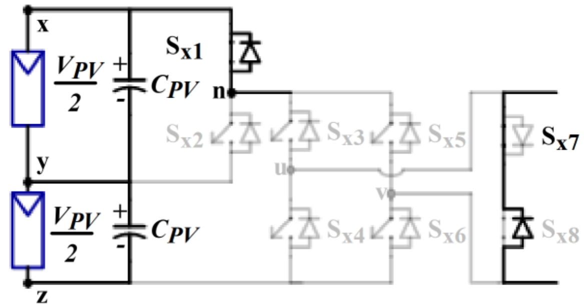
(a)+V_{PV}



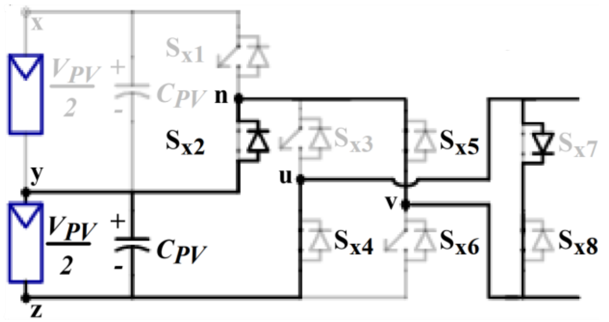
(b)+$V_{pv}/2$



(c)0V

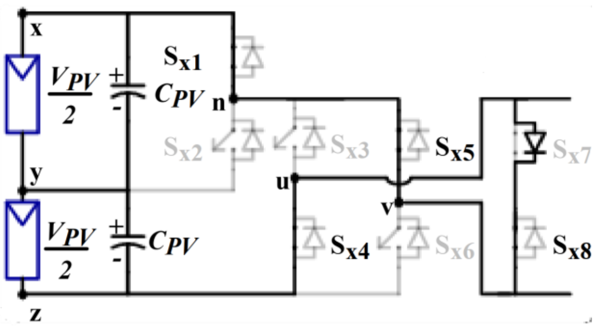


(d)0V



(e)-$V_{pv}/2$

The Five level inverter generates five level AC output voltage. The behavior of the inverter at each level as shown in Figure 2.



(f)-V_{pv}

Fig -2: Behavior of inverter at each level

3. CONTROL TECHNIQUE

Two separate PV sources are needed for the five-level output of the proposed system. Both symmetrical and asymmetrical configurations of the two PV sources are acceptable. As a result, as we'll see later on, the suggested PWM approach has to work in both symmetrical and asymmetrical setups for the two PV sources.

Using a multi-carrier modulation approach determines how well the multilevel inverter works. Multiple triangular carrier signals and a single reference signal are used to construct two-level to multilayer inverters. The created multilayer subharmonic PWM is presented in this work. Figure 3 demonstrate that modified PWM control technique for Five level inverter, it produces less harmonic distortion when utilizing symmetrical triangular carriers.

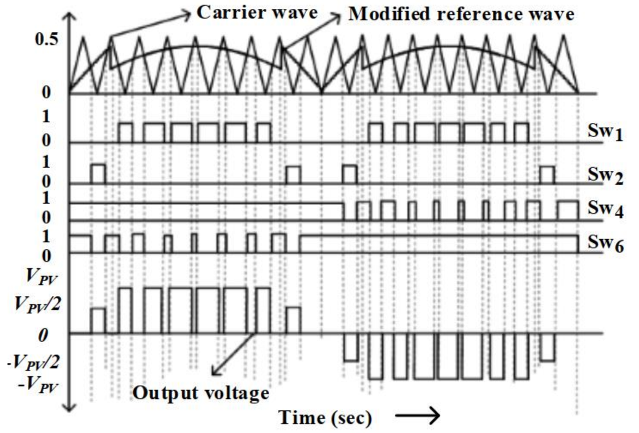


Fig -3: Modified PWM control technique for Five level inverter

As shown in Figure 4, a unit triangular carrier waveform multiplied by ratio x_2 will produce the necessary triangular wave. The output voltage reaches the level of '$V_{PV}/2$' when the instantaneous magnitude of '$v_{ref\_modified}$' is greater than the magnitude of the carrier wave, inside the positive half cycle and for phase angles ranging from 0 to 30 degrees or 150 to 180 degrees. To keep the fundamental output voltage's positive and negative cycles in perfect symmetry, the same sequence is used for the negative half cycle as well.

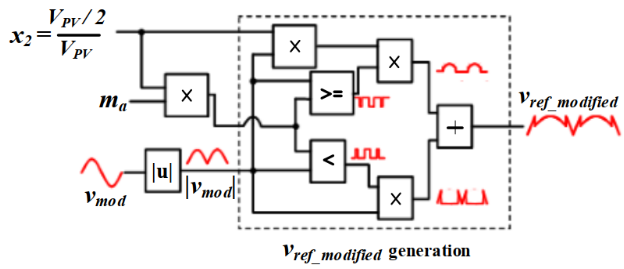


Fig -4: Control technique for production of modified reference wave

4. RESULT ANALYSIS

Figure 5 shows the five-level inverter simulation. Using MATLAB/SIMULINK software, we simulated a three-phase, five-level cascaded multilevel inverter model and found that the suggested PWM technique works. The five-level inverter arrangement was subjected to suggested PWM approaches. The grid requires the inverter to produce a voltage V_r with an angle δ_r in order to receive average active power P. In simulations, a system with P=5kW, V_r = 233V, and δ_r=0.158 rad was used. Cascaded five-level inverter simulation results with suggested PWM approaches are shown in Figure 6 to Figure 10. The output voltage of the five-level inverter after filter and the matching grid current "i_g" are shown in Figure 7. The related plots also displayed the Fast Fourier Transform of the five-level inverter output voltage and the associated grid current "i_g" are shown in Figure 11. When comparing the suggested PWM approach to the usual SPWM technique, it is noticeable that the inverter output voltage has somewhat greater magnitudes of higher order harmonics.

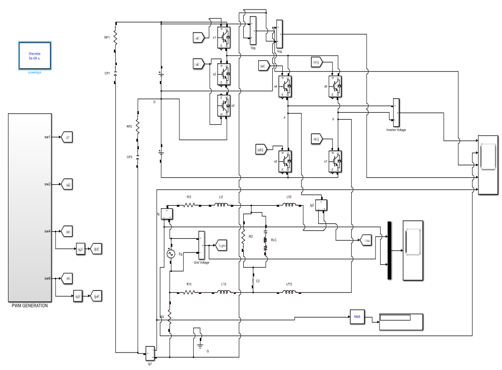


Fig -5: MATLAB-Simulink diagram of five level inverter with solar PV integrated to the grid

A well-designed filter, however, may eliminate these higher-order harmonics. The suggested PWM methods exhibit a predominance of harmonic components at frequencies in multiples of 25 kHz, as seen in Figure 12 (i) and (ii). Thus, with a cut-off frequency of 25 kHz, the filter's design parameters are same in both scenarios.

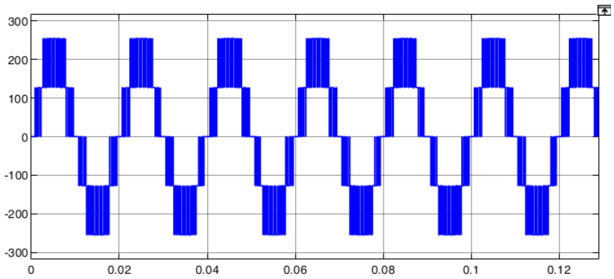


Fig -6: Five level output voltage

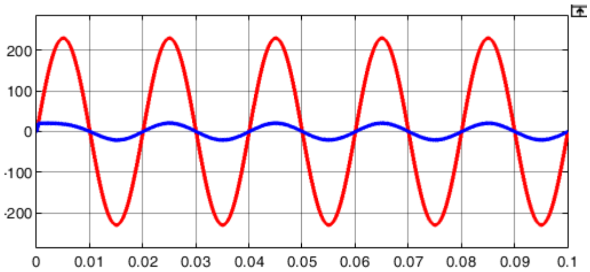


Fig -7: Name of the figure

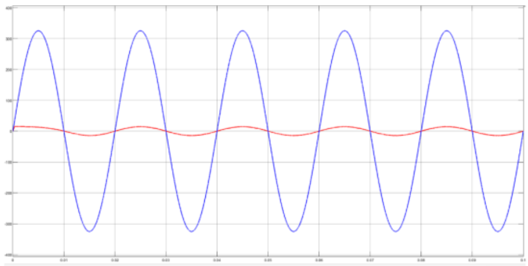


Fig -8: Grid Voltage and Current having 0° Phase Shift

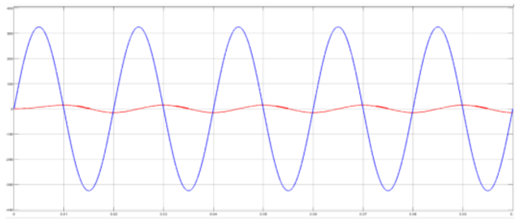


Fig -9: Grid Voltage and Current having 90° Phase Shift

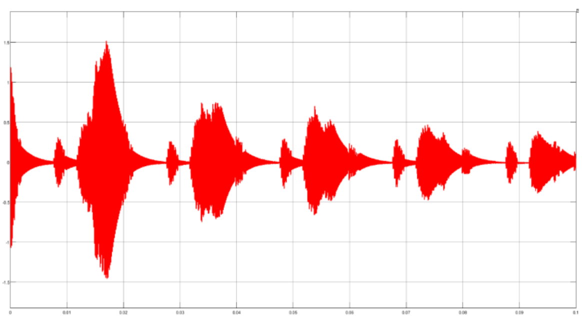


Fig -10: Leakage Current Waveform of 5-Level Cascaded H-Bridge Inverter Configuration

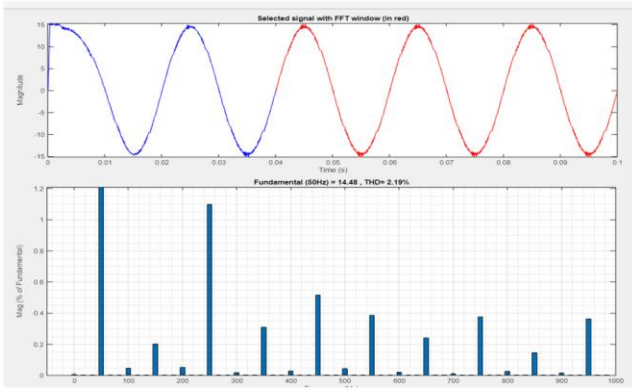


Fig -11: Name of the figure

Both the traditional SPWM method and the suggested PWM methodology exhibit the same Total Harmonic Distortion (THD) of the current waveform, which is readily verifiable. In both instances, the total harmonic distortion (THD) of the grid current is less than or equal to the amount required by IEEE 1547 standard [33]. According to plots of Fig. 10, another noteworthy finding is that, in the traditional SPWM, the common mode and terminal voltage waveforms exhibit high frequency voltage changes. As demonstrated in subplots (c), (d), and (f) of Fig. 10 (ii), the suggested PWM approach eliminates or eliminates these high frequency voltage shifts. The findings from the examination of the switching function are consistent with the terminal and common mode voltage waveforms (Fig. 9). The analysis was also justified by this. For the traditional SPWM method, zero sequence current flows because the common mode voltage has high frequency voltage changes. Grid current total harmonic distortion (THD) could rise as a result of this.

In addition, the waveform for the leakage current of the existing SPWM method and the suggested PWM method are shown in subplots (e) of Figure 10 (i) and (ii), respectively. The suggested PWM reduces the leakage current to less than 0.1A, in contrast to the traditional SPWM which has a value of around 0.2A. This is because the terminal voltages "vog" and "vpg" have a low frequency voltage waveform.

5. CONCLUSIONS

For the purpose of reducing leakage current, this research examines a single-phase transformer less PV inverter and the PWM approach that it employs. This paper proposes a modified PWM that builds on the standard PWM. In several studies, PWM was shown to outperform other methods in terms of total harmonic distortion (THD), ripples in the output current, and dc-link voltage. The large leakage current in transformer less PV systems, however, renders these qualities useless.

Leakage current has reduced the PV systems overall performances and introduced safety concerns. By doing away with zero voltage vector switching, the current solution—which employs modified PWM—reduces the CMV and hence eliminates leakage current. While these modified PWM methods do a good job of eliminating leakage current, they pay little attention to the PV systems overall performance. Problems including harmonic distortion, ripples in the output current and dc-link current, and voltage linearity have been compromised.

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