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# Harmonic Elimination of Three-Level Inverter Based on Hybrid PWM for PV Application: Analysis and Simulation Verification

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***Abstract*: In this paper, the envisaged system benefits from both components, reducing the harmonics and the catastrophic failure of the converter and improving the conversion stability of the system. At almost the same time probably, the SVPWM technique for simulating the proposed topology in the MATLAB / SIMULINK platform is used. In order to evaluate the performances of each set, a simple and straightforward distortion harmonic factor is termed that once again simply takes the first two most substantial harmonics present in the generated waveform into account. Two individual phase pattern removes all odd harmonics as well as 3-phase counterparts, which still eradicate non-triplen odd harmonics from the line-to-neutral pattern but instinctively remove such harmonics in line-to-line with the help of selective harmonic PWM elimination (SHEPWM). Thus, the hybrid PWM must ensure a smooth switch between space vector PWM methodologies and the selective harmonic removal PWM. The power quality of the grid under SVPWM and SHEPWM was assessed using the evolved simulation model in Matlab / Simulink. Photovoltaic system modelling includes SPV array modeling, inverter / convertor power electronics predicated on MATLAB / SIMULINK.***

***Index Terms*: Modulation Techniques, Power Converters, Selective Harmonic Elimination, Space Vector PWM**

## I. INTRODUCTION

Solar energy seems to be the world's largest yet most frequently distributed resource among renewable energies. Solar energy is efficiently consumed and converted into electricity with solar photovoltaic power generation advanced technology just using solar cells. The grid-connected inverter is the key component and important equipment in a grid-connected photovoltaic solar system. In the design of general inverters, which synthetically takes into consideration structural factors, the most used device is the insulated-gate bipolar transistor (IGBT). Furthermore, because the IGBT driving voltage decreases not linear, it does not increase substantially by increasing current, thereby guaranteeing that the inverter still has a relatively low loss and high efficiency at maximum charge. In comparison, partially due to both the MOSFET's linear tension drop, it affords a quiescent current drop for light loads. Given its outstanding vibrant features and high frequency of work, MOSFET would be the first decision for solar inverting [1].

The three-level inverters are broadly used in high-voltage medium-power rated AC drives for speed regulation, since the output of inverter has low harmonic content, better electromagnetic loss, low dv/dt switch stress, and other advantages. Moreover, it highly suffers from some key issues, such as enhancement of three-level algorithm, neural-point voltage controlling in over-modulation states and stability concerns. In view of above-mentioned issues, the proposed work controls the neutral-point voltage of DC-link capacitor and the realizations of proposed SVPWM technique.

The main contributions and organization of this paper are summarized as follows: In section 2 we describe background details of PWM mechanisms. The section 3 proposed work. The section 4 deliberates results and discussions. Finally in section 5 we concluded the paper.

## II. BACKGROUND WORK

As from the previous literature, such a particular form of PWM called space vector modulation (SVM) was advocated, claiming to give great individual performance, greater ease of implementation, and maximum possible transfer ratio benefits over completely natural and frequent random sample PWM [2]. The classic SVPWM strategy originally proposed by the authors in [3, 4], and by the authors in [5] is also quite prominent mostly because of its simplicity and its good operational properties. In this technique, it is combined into a single unit, which mostly depending mostly on the complex mix of its controlled switches, can presume a limited number of states. Combinations result in six active (non-zero) states and two zero states with a two-level converter. In the digital enactment of SVM, an adequate mixture of active and zero vectors is being sought in order to properly calculate the reference space vector (which refers to the reference voltage) [6]. The technology can also be used for three-tier inverters and is broadened to multiple levels [7, 8]. SVPWM is used to operate a variable speed electric drive in [9] and a switching sequence is suggested for a multi-level converter so that the number of switching's is reduced to a minimum. However one of the main problems in PWM systems is the reduction of harmonic content in inverter waveforms [10].

In the past three decades, a number of techniques have indeed been advocated to obtain the best switching strategy, such as Newton-Raphson iteration method [11], methodologies predicated mostly on the symmetric polynomial and the resultant theory [12, 14] and techniques predicated on the genetic algorithm [13]. The most common approach is the fundamental frequency selective harmonic elimination (SHE) technique under which metaphysical harmonic distortion are indeed remedied by the Newton-Raphson approach, in

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order to calculate optimum shifting angles.

The aim of this paper is to disclose total test results for both the single-phase and 3-phase SHEPWM techniques, where almost all odd harmonics and now the only non-triplen harmonics are removed. The researchers also found only where quarter and half-wave symmetry for the patterns exists. In addition, a harmonic distortion factor and the amplitude of the most crucial harmonic are examined to associate a potential significantly better unique solution, if available.

## III. PROPOSED CONFIGURATION

The figure.1 depicts the dual usage of the both space vector and selective harmonic elimination techniques to merge as one efficient structure to make it as hybrid approach for better outcome.

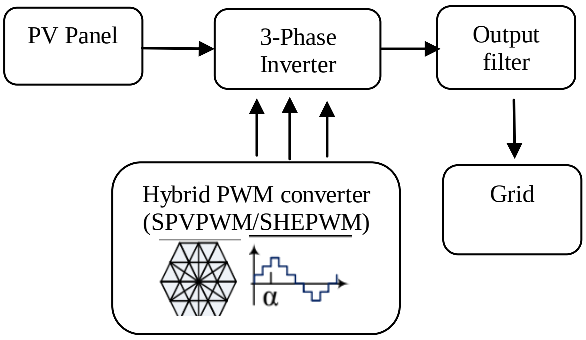


**Fig. 1: Block diagram of proposed method**

To work correctly the basic needs of proper operation is explained below

- For the both methods the application of reference voltage is similar angle as common vector.
- It is very clear that all the signal characteristic like amplitude (A), frequency (F) and phase (P) maintains constant output reference voltage when switching from one technique to another.
- The switching occurs during the half-period of sample time when the transition of SVPWM to the SHEPWM indefinitely.

### A. SVPWM Control Method

The theoretical basis of the SVPWM is the mean equivalent principle, that is, combining the fundamental voltage vectors in a switching cycle to make the average value equal to the given voltage vector. At a certain moment, the voltage vector rotates into a certain region, which may be achieved by a different combination over time of two adjacent nonzero vectors and zero vectors that make up this region. The action time of the two vectors is repeatedly applied in one sampling period, so that it controls the action time of each voltage vector. This rotates the voltage space vector in accordance with the circular trajectory and approaching ideal flux circle through the actual magnetic flux, generated by different switching states of the inverter. Then, it determines the inverter switch state by the comparison, at the end form of the PWM waveform. In comparison with other control methods, SVPWM demonstrates lower total harmonic distortion (THD) and may even concurrently improve the continuous and dynamic status of the connected PV grid system. But in the meantime, SVPWM control strategy output findings of inverters provide some higher output quality than those of inverters with certain control strategies. The three-phase3-level inverter control strategy for SVPWM is efficient and feasible [17].

The effective switching instants are calculated as follows

$$T_1 = \frac{\sqrt{3}}{V_{dc}} \times \left( T_2 \times V_{ref} \times \left( \sin\left(\frac{n\pi}{3}\right) \times \cos\alpha - \cos\left(\frac{n\pi}{3}\right) \times \sin\alpha \right) \right) \quad (1)$$

$$T_2 = \frac{\sqrt{3}}{V_{dc}} \times \left( T_2 \times V_{ref} \times \left( \cos\left(\frac{(n-1)\pi}{3}\right) \times \sin\alpha - \cos\alpha \times \sin\left(\frac{(n-1)\pi}{3}\right) \right) \right) \quad (2)$$

where, $T_1$, $T_2$ and $T_0$ are calculated switching instants for the switching vectors, "*n*" is the sector number (Sectors 1 to 6),

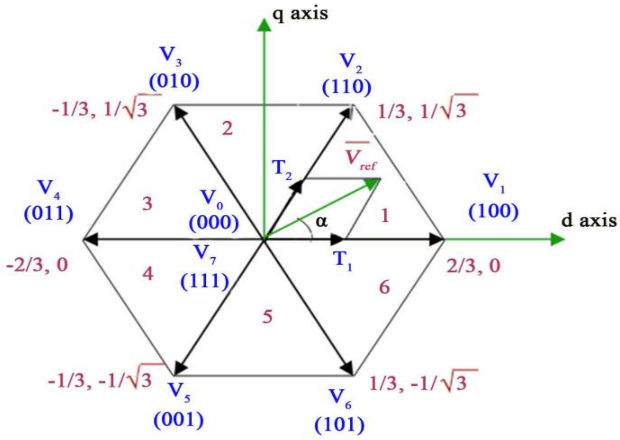


**Fig.2: Principle of SVPWM**

Perhaps the option of shifting patterns is liberty in space vector modulation (SVM) [20]. The fundamental idea behind a certain SVM pattern is really the average voltage that sometimes results in a sampling interval. However, the going to contribute vectors is switched with the acceptable null vector and sequence of events for their computed time (T1 and T2). Conversely, the different systems deliver those not only relative merits such as transition effects, condensed switching losses

### B. Selective Harmonics Elimination PWM

The Selective Harmonic Elimination Pulse Width Modulation (SHE-PWM) is widely used in UPS, reactive power compensators and power filters as this provides the highest quality output among all the PWM methods. In spite of all the advantages mentioned above, it is very difficult and complex to obtain the desired solutions from a non-linear transcendental equation which contains trigonometric terms that exhibit multiple solutions naturally. Many tools and algorithms [15, 16, 17, and 18] have been proposed which led to feasible implementation of SHE-PWM techniques for various applications; all these techniques are very complex and time consuming. There is a need to develop a simple method to solve nonlinear equations of SHE-PWM, which is less complex, less time consuming and capable of giving results with higher accuracy.

As mentioned earlier the Fourier expansion of the obtained signal is formulated as

$$V(\theta)=\frac{4}{\pi}\left\{\sum_{k=1,3,5\ldots}^{\infty}\frac{\sin(k\theta)}{k}\times\left(1+2\sum_{i=1,2,3\ldots}^{N+1}(-1)^{i}\cos(k\alpha_i\right)\right\} \quad (3)$$

The issue would then be devised on the basis of the optimal value of the essential aspect to be generated. The technique then somehow strives to identify the angles to provide certain amplitude and in addition, the selected harmonics will be eliminated. As stated above, in order to eliminate odd harmonics, 1 angles need to be found, if possible, and the following system of equations must be solved:

$$1+2\sum_{i=1}^{N+1}(-1)^{i}\cos\left(a_i\right)-M=0\ldots.$$
$$1+2\sum_{i=1}^{N+1}(-1)^{i}\cos\left(na_i\right)=0 \quad (4)$$

where

$n=3,5,\ldots,2N+1$ for single-phase systems (5)

$n=5,7,\ldots,2N+1$ when $N$= even for single-phase systems

$n=5,5,\ldots,3N+2$ when $N$= odd for single-phase systems (6)

and

$$0\le\left|M\right|\le 1 \quad (7)$$

If is the amplitude of the fundamental component to be generated then from (1) yields

$$\left|V_1\right|=\frac{4M}{\pi} \quad (8)$$

It should be noted that for the bipolar waveform when $-1\le\left|M\right|\le 0$, the independent solutions for the angles to be found will result in a PWM waveform that has a phase-shift of $180^0$ against the square-wave.

**Modified algorithm:** The previously described set of equations must be solved in order to get the desired values of the angles for any value of *M*. It is proposed that the following function is minimized first:

$$Min\left[\left(1+2\sum_{i=1}^{N+1}(-1)^{i}\cos\left(\alpha_i\right)-M\right)^2+\ldots+\left(1+2\sum_{i=1}^{N+1}(-1)^{i}\cos\left(na_i\right)\right)^2\right] \quad (9)$$

with the constrain that

$$0\le\alpha_1\le\alpha_2\le\ldots\le\alpha_i\le\frac{\pi}{2} \quad (10)$$

The minimization problem to find the first set of solutions for one value of can be dealt with using a Nelder-Mead simplex algorithm [19]. Perhaps the recently announced technique, together by a random test and biased sequence for initial values, identifies all the alternative approaches for *M*, i.e. *M*= 0.1, and then uses more such data as an initial value for finding all alternative approaches for every value. The possible solutions from the previous value of M are specifically being used as the initial point for the next value of M. Iterative algorithms like Newton-Raphson can be used in this particular aspect to achieve the desired angle solutions. This would be done to fix the speed of the method further.

## IV. SIMULATION RESULTS

In this section the proposed modulation procedure, which permits to make proper change between space vector and selective harmonic elimination PWM algorithm, was implemented in Matlab/Simulink.

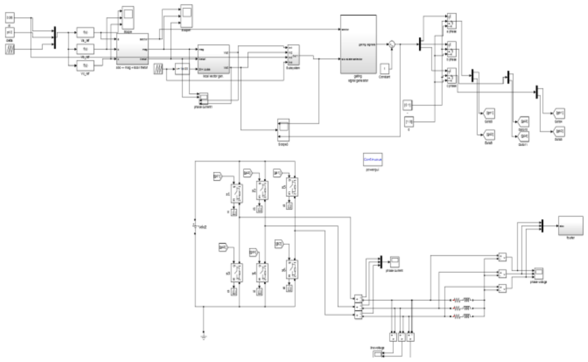

Fig.3: Simulink model

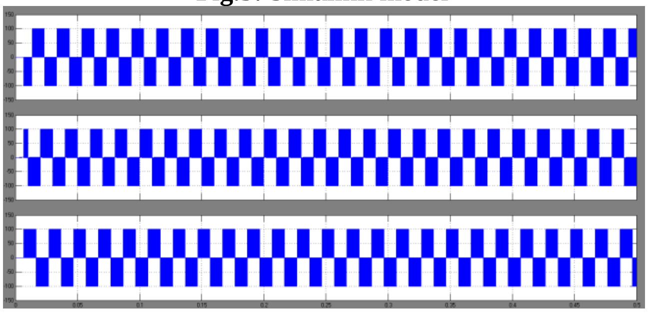

Fig.4: Line voltage

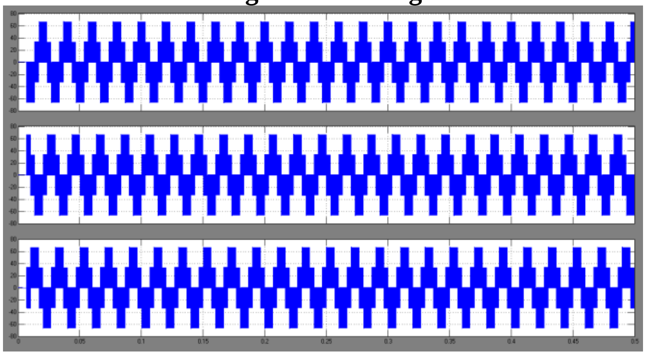

Fig.5: Phase voltage

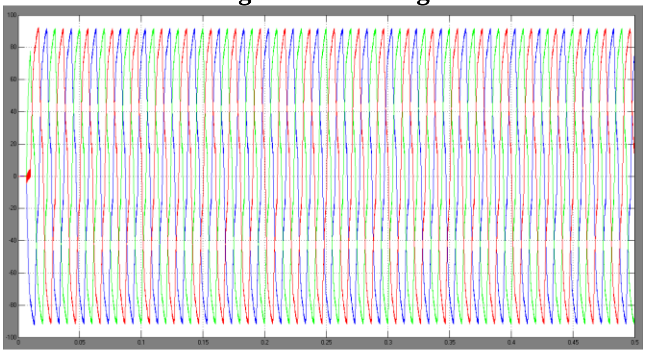

Fig.6: Phase current


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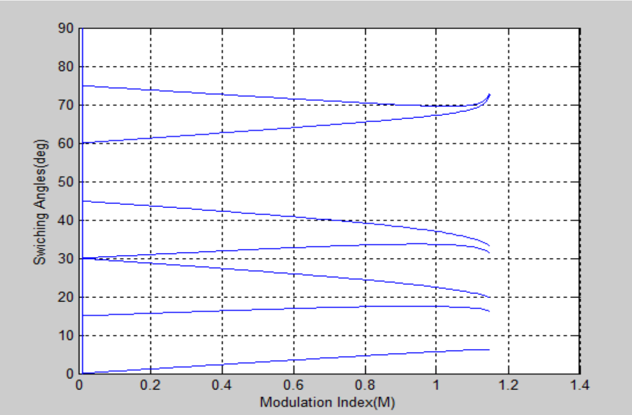


**Fig.7: Simulink model**

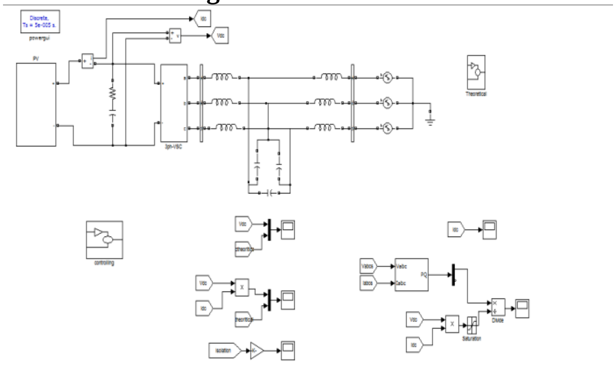

**Fig.8: Simulink model**

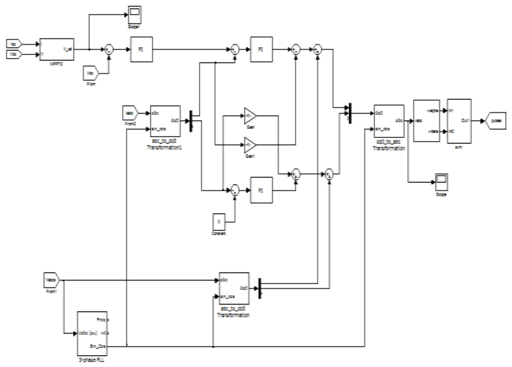

**Fig.9: Simulink model**

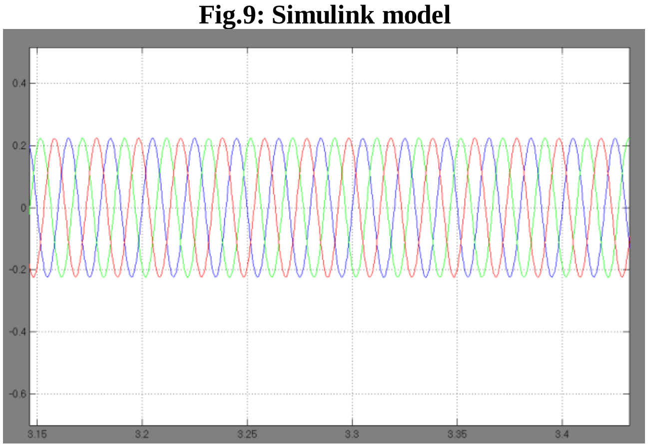

**Fig.10: Phase current**

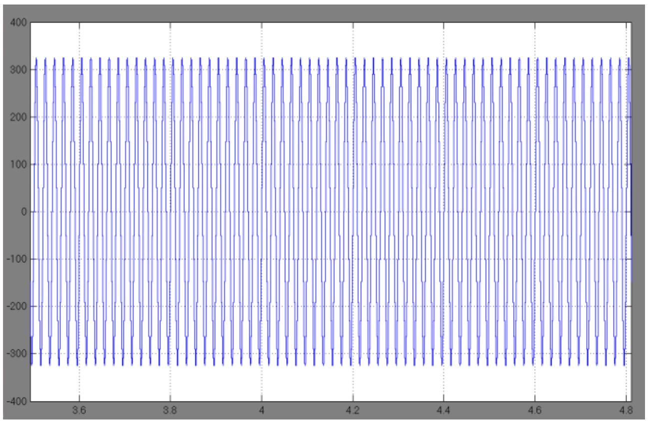

**Fig.11: Phase voltage**

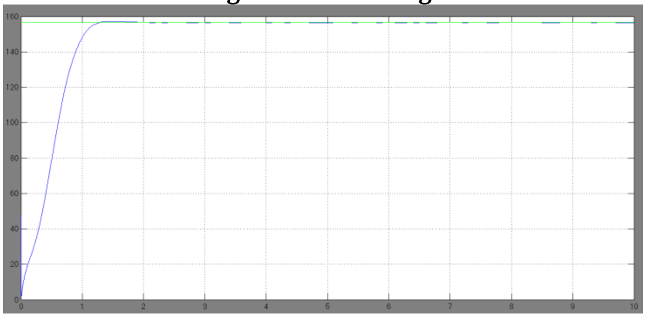

**Fig.12: PV voltage theoretical and simulated**

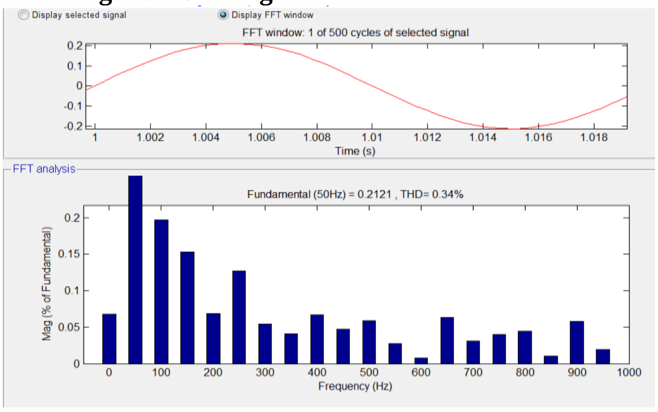


**Fig.13: THD level of source current during 1sec**

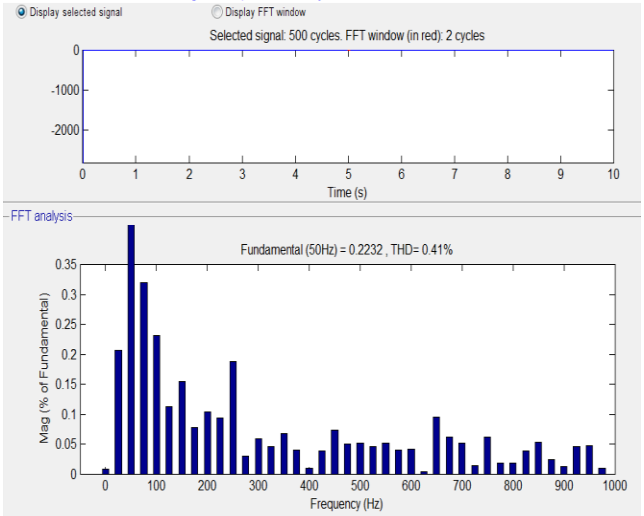


**Fig.14: THD level of source current during 2sec**


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## V. CONCLUSION

This paper introduces new multi-level solar grid-connected inverter configurations as per the basic building block suggested by previous developers. We proposed the topology of the hybrid inverter, comprised of two absolute best units. This framework benefits the two devices fully, which reduces the converter's harmonic content and power loss and improves the system's conversion efficiency. Progress the hybrid modulation algorithm which mostly empowers the switching between SVPWM algorithm with base space vector switching under the frequency of switching 300Hz and the SHEPWM process to remove harmonics. We use the space vector pulse width modulation (SVPWM) method to build the SIMULINK models of the proposed hybrid type and traditional three-level inverter in the MATLAB software and compare them with each other. The simulation results show that the proposed topology presents lower output harmonics than the traditional topology.

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