

# MODELING OF 3-LEVEL DIODE CLAMP INVERTER USING SPWM METHOD FOR GRID CONNECTED PHOTOVOLTAIC (PV) INVERTER GENERATION SYSTEM

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**Abstract:** Generally inverter is developed with centre on high reliability, low cost and mass-production for transformed electrical energy from the PV module to the grid. Basically the DC/AC inverters are used in grid connected photovoltaic energy production systems as the power processing interface between the electric grid and the photovoltaic energy source. The energy injected into the electric grid by the photovoltaic system depends on the amount of power extracted from the photovoltaic power source and the efficient processing of the DC/AC inverter power. Basically the line commutated inverter has generate square shaped waveform of line current, which has produces large amount of harmonic and also produces excess of heat which causes the transformer winding is damage. The effects of the electric grid standards and regulations as well as the photovoltaic array working characteristics on the design of grid-connected photovoltaic inverters have been considered. In this paper explain the basic idea about the control methods and topologies like cascaded multilevel inverter, Sinusoidal Pulse width Modulation (SPWM), 3-level diode clamp inverter and Space Vector Pulse Width Modulation (SVPWM) to grid connected inverter for solar photovoltaic based system. After analysis the technique Sinusoidal Pulse Width Modulation (SPWM) is apply to control the inverter because of its high efficiency and simulation is done through MATLAB/Simulink.

**Keyword:** Photovoltaic system, Harmonic, Inverter topology, multilevel inverter, SPWM

## I. INTRODUCTION

Recent year renewable energy sources, like wind, tides, solar, geothermal heat, biomass etc., are advantageous for electrical power generate due to the friendly environmental nature and infinite existence. Recent year energy policies and global warming have become a main topic on the international agenda. Today developed countries are trying to mitigate the greenhouse effect [1]. In this circumstance, generation of photovoltaic power has an important role to play due to the fact that it is a green source. Basic idea about the grid connected solar photovoltaic system is composed of solar photovoltaic array, boost converter, power inverter and utility grid as illustrate in Fig. 1. Solar photovoltaic array generates DC power at its maximum by using boost converter with help of Maximum Power Point Tracking (MPPT) algorithm while power inverter converts this DC power to AC power and feeds to utility grid.

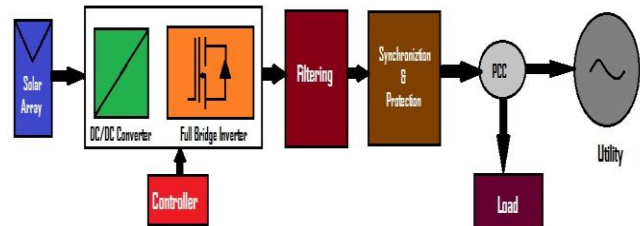


Figure 1 Grid connected solar Photovoltaic system

Requirement of renewable energy sources is rapidly increasing because of the high cost and limited conventional energy sources as gas, oil, coal and multilevel inverters are more reliable to interface with renewable energy sources than a conventional two-level inverter for a high power application in aspects of better quality of power [2-10], further more multilevel Inverters have become more popular over the years in application of electric power with the secure of less disturbances outputs and the possibility to function at higher switching frequencies other than ordinary two-level inverter [2]. There are two topologies for multilevel inverter [2]:

- Diode Clamped Multilevel inverter and
- Cascaded H-Bridge Multilevel inverter

In this topologies work diode clamped topology has been apply. To controlling of multilevel inverters has different types of pulse width modulation (PWM) techniques are used [2-4]:

- Sinusoidal PWM and
- Space Vector PWM

In Sinusoidal Pulse width modulation the gating signals created by comparing sinusoidal reference signal with a triangular carrier wave [5]. In Space Vector pulse width Modulation rotating phase is obtained by adding all the three voltages [4-8]. Space Vector PWM technique is mostly applied for multilevel inverters compared to Sinusoidal PWM technique [4]. Space Vector PWM technique was initially developed as a vector approach to pulse width modulation for three phase inverters. It is a computation and advanced method and it is relatively different from other pulse width modulation methods.

For Sinusoidal PWM:  $V_{max} = V_{dc}/2$

For Space vector PWM:  $V_{max} = V_{dc}/\sqrt{3}$

## II. PHOTOVOLTAIC (PV) SYSTEM

Recently, solar energy is rapidly used for power generation. As it has lot of advantages i.e. Energy Environmentally friendly, independence, Required “energy” is already

distribute freely everywhere, It desires least maintenance, Maximum reliability, and these systems are easily expanded [11]. Equivalent circuit of photovoltaic and I-V Characteristics illustrate in fig. 2 and fig. 3 respectively.

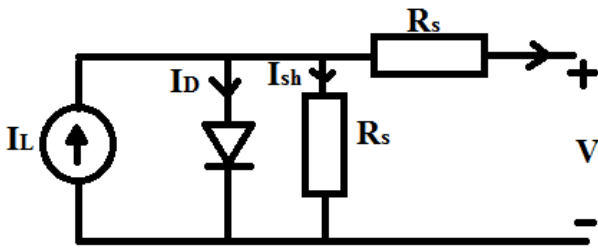


Figure 2 Equivalent circuit of Photovoltaic solar cell  
 Fundamentally solar cell is like as P-N junction and while it exposes to light then current is generated which is proportional to solar irradiance [12].

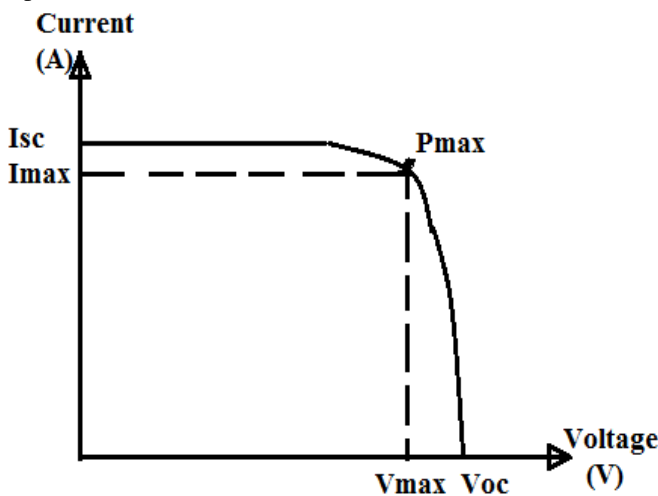


Figure 3 V-I characteristics of Solar cell

### III. MAXIMUM POWER POINT TRACKING (MPPT) SYSTEM

Basically solar energy constitutes a suitable choice for different kinds of applications as solar cells converts' directly solar energy into the electrical energy. However to utilize photovoltaic system is now a day still more expensive than electricity produced from traditional sources. Therefore to reduce the total cost of photovoltaic system and also consider the maximum power point tracking (MPPT) system. MPP is achieved at single point plotted in photovoltaic graph and MPPT point with continuously variations in radiation intensity and also temperature is essential to ensure the competent operation of the solar cell array. Maximum Power Point Tracking system is enables an increase in the power delivered from the photovoltaic module to the load or inverter, as well as also increase the operating lifetime of the photovoltaic system, [13].

**MPPT Methods:** Generally MPPT method have two basic kinds of methods: first one is Off line method which have also two method like open circuit voltage method and short circuit current method, and other one is On line methods which have also two method like perturb & observe method and Incremental conductance Method

In this paper I apply perturb & observe method which is On line method has been used.

#### A. Perturb & Observe method

In this method algorithm given in illustrate in fig.4, which is states that when the operating voltage of the photovoltaic panel is perturbed by a small increment, if the resulting change in power  $\Delta P$  is positive, subsequently we are going in the direction of maximum power point and we will keep on perturbing in the same direction. Consider, If the  $\Delta P$  is negative than we will go away from the direction of maximum power point and perturbation sign supplied has to be changed. Illustrate in Fig. 4 the flowchart of this algorithm [13].

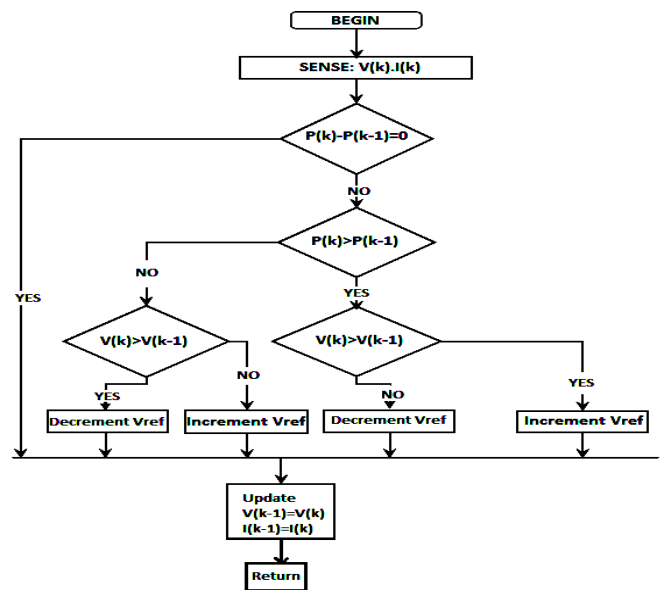


Figure 4 Flow chart algorithms for perturb & observe method

P&O technique have some limitations that reduces Maximum Power Point Tracking's efficiency as:

- It cannot establish when it has actually reached the maximum power point in P & O. Instead, it the operating point of oscillates around the photovoltaic after each cycle and somehow reduces photovoltaic efficiency during the constant irradiance situation.
- It has been illustrate that it can display irregular response in cases of quickly changed atmospheric conditions as a result of moving clouds.

### IV. INVERTER

PV generated energy can be transmit to power system networks through grid-connected inverters. Usually a single-phase grid-connected inverter is used for domestic or low-power applications of power ranges that are less than 10 kW. There are various types of single-phase grid-connected inverters have been investigated. A device which converts dc power into ac power at desired output frequency and voltage is called an inverter. When operated in the inverter mode, Phase controlled converters are called line-commutated inverters but line-commutated inverters need at the output terminal an accessible ac supply which is used for their

commutation. This means that function of line commutated inverter cannot work as isolated ac voltage sources or as variable frequency generators with dc power at the input. As a result frequency, voltage level and waveform on the ac side of line commutated inverters cannot be changed; on the other side force commutated inverters provide an free from ac output voltage of adjustable frequency and adjustable voltage and have therefore much wider application. Basically, the inverters have four classifications: 1) the type of power decoupling between the PV module(s) and the single-phase grid; 2) the number of power processing stages in cascade; 3) whether they utilizes a transformer (either line or high frequency) or not; and 4) the type of grid-connected power stage. Inverter can be widely classified in to two types-voltage source inverter and current source inverter. In this paper, I explain the cascaded multilevel inverter, 3-level diode clamp inverter, SVPWM and SPWM method respectively.

V. CASCADE MULTI LEVEL INVERTER

Illustrate in fig. 5 Cascade multilevel inverter which is avoids the used of clamping diodes and voltage balancing capacitors.

In this method, each bridge has separate DC sources thus it is called as cascade multilevel inverter with separate DC sources [SDC's]. This all bridge have generates three levels of output  $-V_{dc}$ , 0,  $V_{dc}$  and this bridge having four switching devices [12].

Advantages:

- Less number of apparatus are required
- Additional capacitors and diodes are not required.

Disadvantages:

- Separate DC sources are required for the real power conversion

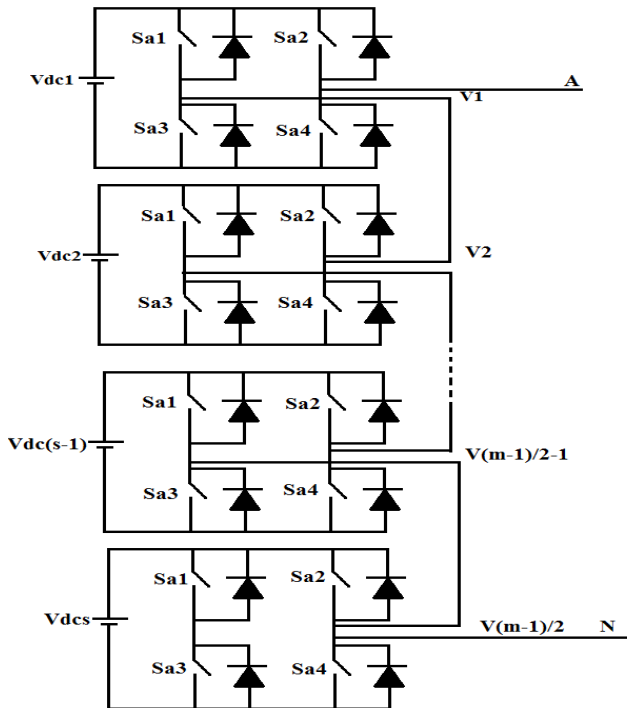


Figure 5 Cascade Multilevel Inverter

VI. 3-LEVEL DIODE CLAMP INVERTER

Usually simple two-level inverters are generally used to generate an AC voltage from a DC voltage. Working of the two-level inverter can create only two different output voltages for the load is  $+V_{dc}/2$  and  $-V_{dc}/2$  (This is consider when the inverter is fed with  $V_{dc}$ ). The basic circuit diagram of 3-level diode clamped inverters as illustrate in fig. 6 does not depend on just two levels of voltage to generate an AC signal. When we get the smoother waveform, the more voltage levels generated in the inverter. However if many levels of voltage will make raise the complexity of the circuit, with more apparatus and a more complications the controllers for the inverter are required and being used [4].

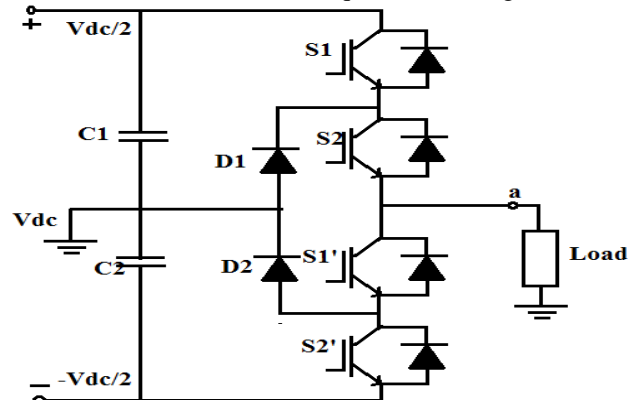


Figure 6 Three level diode clamp inverter for 1-phase In neutral point clamp topology or diode clamp topology, multilevel inverter diodes have been apply as a clamping device to generate required output voltage levels [3]. In 3-level diode clamp inverter, the duty cycle for switches ON/OFF is done shown in Table 1 [3].

Magnitude of Voltage ( $V_{dc}$ )	No. of Switching to be ON/OFF			
	S1	S2	S3	S4
$+V_{dc}/2$	ON	ON	OFF	OFF
0	OFF	OFF	ON	OFF
$-V_{dc}/2$	OFF	OFF	ON	ON

Table 1: Switching modes of 3-level inverter.

VII. PULSE WIDTH MODULATION (PWM) TECHNIQUE

The inflection strategies can mainly divided into two strategies as: high switching frequency and Fundamental switching frequency pulse width modulation. Illustrate the fig. 7 present the different PWM techniques.

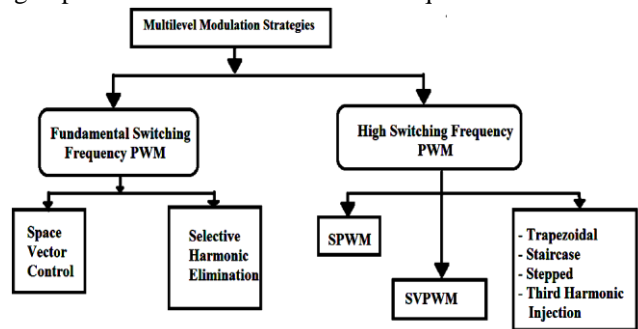


Figure 7 Different PWM techniques

Block diagram of different PWM techniques represents the overview of PWM techniques. Out of these techniques in this paper SPWM techniques are presented.

VIII. SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

For the switching techniques inverters that use PWM techniques have a DC input voltage that is always constant in magnitude. The inverter will acquire this as an input voltage and output AC where the frequency and magnitude can be controlled as per the requirement.

There are various ways by which PWM can be implemented to make the output to be AC. A widespread technique known as SPWM (Sinusoidal Pulse Width Modulation) has been used and discussed here. In order to get output as a sinusoidal waveform for 3-level inverter at a definite frequency a sinusoidal control signal ( $V_{sine}$ ) at the definite frequency is compared with a  $(m-1)$  triangular waveform ( $V_{tri}$ ) as illustrate in fig.9; here,  $m$  is number of inverter level(2,3,4,...,etc). The basic block diagram arrangement of the SPWM technique is illustrate in fig. 8. Usually the inverter will use than the frequency of the triangle wave as the switching frequency which is essentially kept constant [3][4][5].

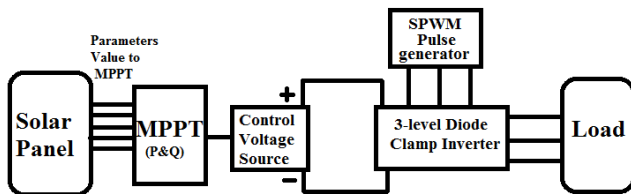


Figure 8 Block diagram arrangement of the entire system along with SPWM technique

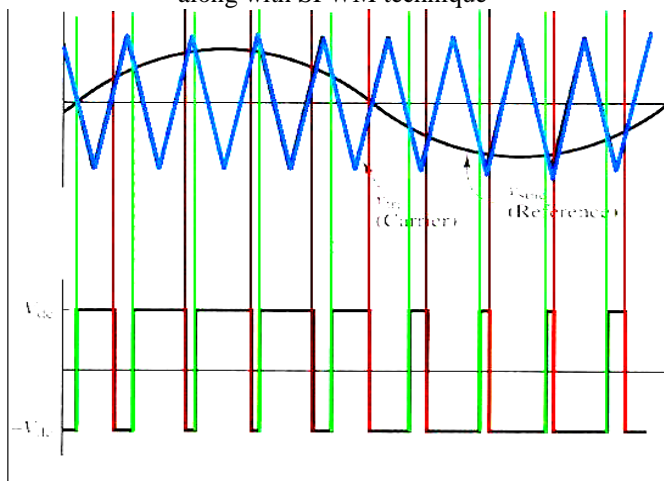


Figure 9 SPWM for 3-level inverter

In the fig.9 the triangle waveforms ( $V_{tr1}$ ,  $V_{tr2}$ ) are at the switching frequency ( $f_s$ ), this frequency is controls the speed at which the inverter switches can turn on and off. In this technique the control signal ( $V_{sine}$ ) is used to adjust the duty ratio of the switch and has a frequency ( $f$ ), which is recognized as fundamental frequency of the inverter output voltage. The inverter output voltage is affected by the switching frequency. One of the inverter switches duty cycle here is called as amplitude modulation ratio:

$$Ma = V_{sin} / V_{tri} \dots (1)$$

When,  $V_{sin} > V_{tr1} = +V_{dc}/2$  When,  
 $V_{sin} < V_{tr2} = -V_{dc}/2$   
 when,  $V_{tr2} > V_{sine} = 0$

In SPMW for the 3-level inverter the switches  $S+$  and  $S-$  are controlled based on the comparison of signals  $V_{tri}$  and  $V_{sine}$ . Here, at the same time the two switches are never gets off which results in the output voltage fluctuating between  $\pm V_d/2$  and the remaining switches will be output as 0 [3][4][5].

IX. SIMULATION AND RESULT

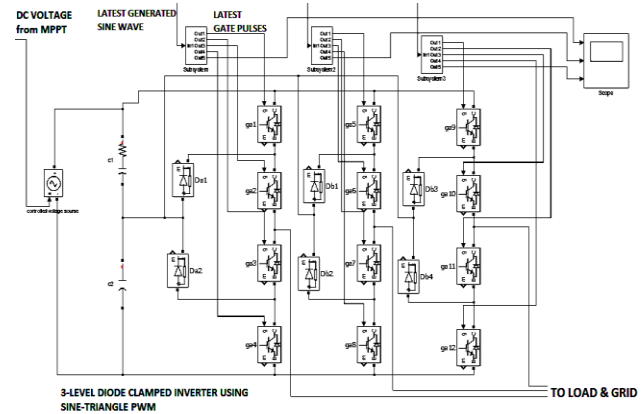


Figure 10 Simulink model of system along with SPWM technique

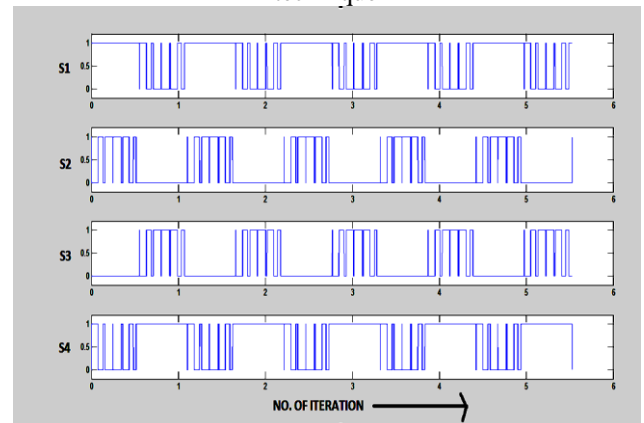


Figure 11 Gate pulse generated by SPWM

Here is fig. 11 which illustrate the gate pulse generated by SPWM technique to making the switches ON and OFF to convert the DC in AC to feed the load.

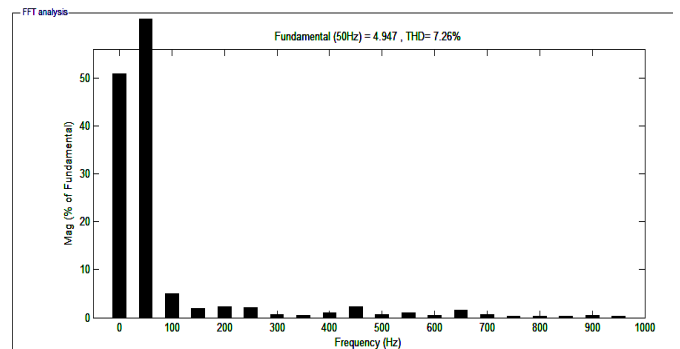


Figure 12 THD for voltage of 3-level Inverter

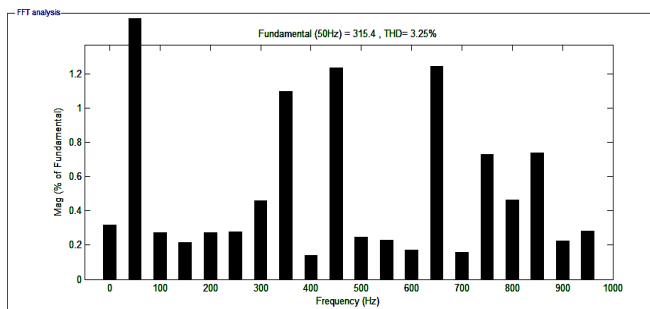


Figure 13 THD for current of 3-level Inverter

## X. CONCLUSION

The energy injected into the electric grid by a photovoltaic installation depends on the amount of power extracted from the photovoltaic power source and the competent processing of this power by using the DC/AC inverter. In this paper, SPWM techniques are presented for the photovoltaic inverter power section. SPWM technique, based on signal generate on three level diode clamp inverter for reduction harmonics in the multilevel inverter output. The paper has existing the model of the 3-level diode clamped inverter for solar application along with MPPT by using SPWM modulation techniques and simulation is done by using MATLAB. By doing different analysis on basis of MATLAB results we can conclude that SPWM technique is more efficient by giving enhanced and smoother output waveforms than traditional technique. In addition to the %THD of line voltage and current are less in the system in which SPWM technique is being used.

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