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# Paper Diode Clamped Based Standalone Photo-Voltaic System with POD Technique

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***Abstract:*** *Modern technology has widely increased the utility of power, which causes the extension of conventional energy sources. So to meet the needs extracting energy from renewable energy sources has become popular in now-a-days. Modeling and simulation of solar panel integrated to grid using multilevel inverter is proposed in this paper. This design is aimed for obtaining the voltage with less harmonic distortion. Maximum Power Point Tracking (MPPT) control for Photo-Voltaic (PV) system is concerned here to attaining maximum power irrespective of changes in environmental conditions from the PV array. Multilevel inverters development creates a new era in the renewable energy utilization. Voltage based pulse width modulation technique is applied in the designing of multilevel inverter.*

***Keywords:*** *PV cell operation; modeling equations; MPPT algorithm; diode clamped converter; POD modulation.*

Nomenclature:
ISC = Current at Short Circuit
Uoc = Voltage at Open Circuit
Uout = Output Voltage
V mp = Maximum peak Voltage
Imp = Maximum peak Current
V pv = Panel Voltage
Ipv = Panel Current
T = Temperature
Tref = Temperature Reference
S = Solar Irradiance
Iph =Solar current
Rs = Series Resistance
Rsh = Shunt Resistance
a,b =Constants
C1,C2 =Capacitances

## I. Introduction

Renewable energy sources have become increasing importance as because of their eminent features. Among all the renewable sources PV system has gained wide acceptance and integration in modern electric grids as it is available in abundant amount, easily erectable and pollution free [1-3]. The output energy from the solar system is in the form of DC which is difficult to inject directly into the grid. Converter system is required to utilize this DC effectively. Power electronic converters made the interfacing easy between the renewable sources and grid [4-6]. For a specific amount of solar irradiation PV panel can produce maximum amount of power for a peak point of power corresponds to voltage at that irradiance level [7-8]. Modeling of PV array plays a prominent role to attaining higher efficiencies [9-13]. MPPT technique is developed to track the maximum power at any instant irrespective of climatic conditions, P&O algorithm is developed because of its versatile features [14-23].

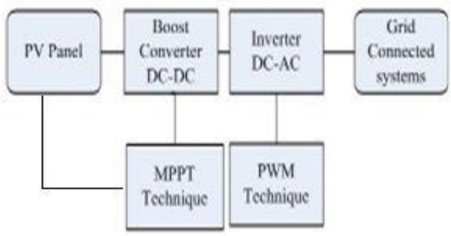


**Fig. 1.** Layout of PV Panel Integration

A boost rectifier is used to boost up the output DC and the output from the DC is input for the inverter system. Inverter system converts the DC from the rectifier to AC [6].By using conventional two level inverters stress on the switches is more and also harmonic distortion is high but increasing the inverter levels total harmonic distortion and voltage stress on the devices can be reduced. So because of this distinct feature multilevel inverters are popular in high- power medium-voltage applications [24-28]. Various modulation techniques are developed for the operation multilevel inverter for better performance. Selection of the proper modulation techniques makes the switching operation more feasible and low total harmonic distortion (THD) can be achieved. [12-15],[25-30].

## II. PV Cell

### *A. Operation of PV Cell*

In a PV system prominent role is played by solar cell module. The electrical equivalent circuit of solar cell model is commonly represented by diode which is generally used for module based analysis. The equivalent circuit consists of single or double diode model, current source, Series and parallel resistance. A photo-current Iph is generated from the source, which is a function of solar cell radiation and temperature because of photo voltaic effect on the semiconductors. DC current is produced from the PV cells [7-8].The I-V characteristics of a PV cells is highly depend on solar irradiation, so these characteristics are non-linear as it is generally temperature dependent. [8-13].

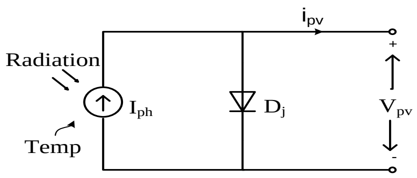


**Fig.2** PV Cell Circuit

### *B. Modelling of PV Cell*

Single diode equivalent model is shown in figure which offers more accuracy and design simplicity, because of these features this model is widely used. For a practical solar cell, voltage loss is observed at the external contacts way, to denote this voltage loss a series resistances is used and parallel resistance is used to express the leakage currents [9-12].

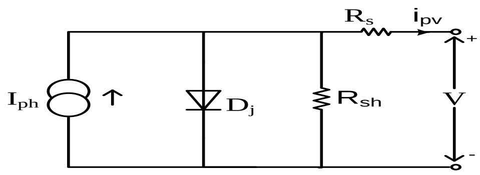


**Fig.3** PV Cell Equivalent Circuit

Modeling equations of the proposed solar model is given below:

$$\Delta I = \left(T - T_{ref}\right)a + \left(\frac{S}{S_{ref}} - 1\right)I_{sc} \tag{1}$$

$$\Delta V = \left(T - T_{ref}\right)b + \left[\left(T - T_{ref}\right)a + \left(\frac{S}{S_{ref}} - 1\right)I_{sc}\right]R_s \tag{2}$$

$$C_1 = \left(1 - \frac{I_{mp}}{I_{sc}}\right)\exp\left[\frac{-V_{mp}}{C_2 U_{oc}}\right] \tag{3}$$

$$C_2 = \frac{\left(\frac{V_{mp}}{U_{oc}} - 1\right)}{\log\left(1 - \frac{I_{mp}}{I_{sc}}\right)} \tag{4}$$

$$I = I_{sc}\left(1 - C_1 \exp\left(\frac{U_{out} - \Delta V}{C_2 \times U_{oc1}}\right) - 1\right) + \Delta I \tag{5}$$

$$P = (VOC * ISC)FF * \eta inv\ \eta MPPT \tag{6}$$

## III. MPPT

The first paragraph under each heading or subheading should be flush left, and subsequent paragraphs should have a five-space indentation. A colon is inserted before an equation is presented, but there is no punctuation following the equation. All equations are numbered and referred to in the text solely by a number enclosed in a round bracket (i.e., (3) reads as "equation 3"). Ensure that any miscellaneous numbering system you use in your paper cannot be confused with a reference [4] or an equation (3) designation. (10)

PV generation system generally suffers with a problem that the quantity of generated electric power by solar panels always changes with the conditions of weather. A MPPT method is one which is used to get maximum amount of electric power generated by solar arrays in any weather condition. Various types of MPPT methods are in existence. Among the all Perturb and Observer (P&O) technique is chosen in this paper as because of its simplicity and easy of its implementation [14-17]. one can track the solar power all the time irrespective of weather conditions, aging and type of PV array [18-21].

The output voltage from the solar is Vpv and current is Ipv which are taken as reference voltage and current from which power Ppv is calculated. The control topology is designed by checking the slope (dp/dv) of PV module P-V characteristics and this algorithm involves two parameters; perturbation time interval, MPPT and perturbation amplitude [19],[21],[23].

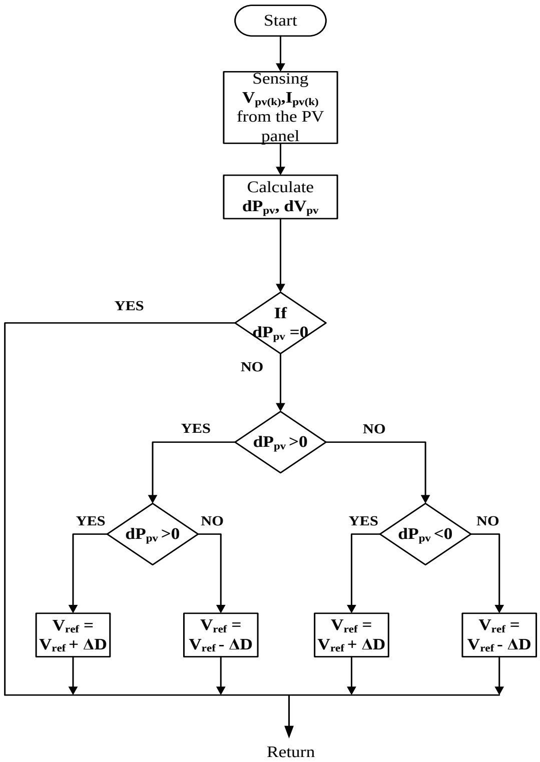


**Fig.4** Algorithm for P&O MPPT Method

## IV. Diode Clamped Multilevel Inverter

To extend the generation range and to reduce the level of harmonics in the PV system output power electronic inverters are used widely. With the usage of conventional two level inverters the harmonic content in the output has not been reduced greatly. So the development of multilevel inverters came into picture, which appreciably reduces the THD (total harmonic distortion) value so thereby increases the PV system efficiency greatly. Diode clamped MLI, flying-capacitor MLI and cascade H-bridge MLI is primary kinds of the multilevel inverter topologies [26]. Diode clamped multilevel inverter (DCMLI) is a foremost inverter topology which is most suitable for the PV system integration. Diode clamped inverter is most extensively used topology for low level applications [28].

DCMLI is a classical inverter topology which is efficiently suitable for medium voltage and high power applications [24]. Control of DC link voltage is done using the diodes is the basic concept of the DCMLI i.e., here diode behaves as a clamping device. The typical m level diode clamped inverter comprise of (m-1) capacitors to produce m levels on the phase voltages on the dc bus. An m-level inverter leg needs 2(m-1) switching devices, (m-1) capacitors and (m-1) (m-2) clamping diodes [24]. A basic 5 level diode clamped multilevel inverter topology is studied below in fig5.

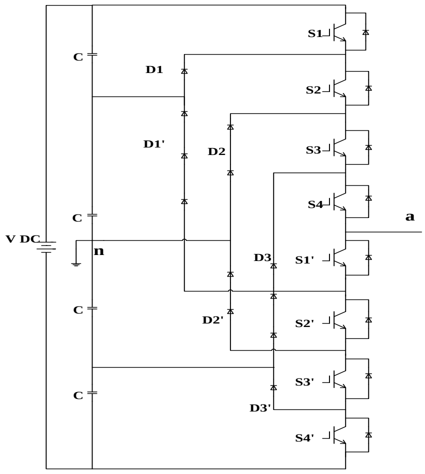


**Fig.5** Circuit Diagram of DCMLI For Single Leg

A step wise manner output is obtained from +Vdc to –Vdc and by combining these all staircases a low harmonic distortion sinusoidal wave form is obtained. The steps to synthesize a 5-level voltage is elucidate as follows. In a 5 level DCI uses four capacitors and the voltage across each capacitor is Vdc/4. DCI usually require a single dc source for supply. For each leg a 5-level DCMLI consists of 8 switches, where Sa1, Sa2, Sa3 and Sa4 are the upper group switches, Sa1', Sa2',Sa3' and Sa4' are the lower group switches[24]. Switching instants of 5level diode clamped MLI is shown below table.

**Table 1** Switching Sequence of 5-level DCMLI

| Van States | S1 | S2 | S3 | S4 | S1' | S2' | S3' | S4' |
|---|---|---|---|---|---|---|---|---|
| V=4Vdc | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| V=3Vdc | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| V=2Vdc | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| V=Vdc | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| V=0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

## V. Modulation Techniques

Even though the multilevel inverters are modeled for the application that each module delivers the same amount of power, their optimal usage in PV system needs an independent delivering of power from each one. Also most of the application are constrained to 3-level in DCMLI as it suffers with voltage unbalancing problem of dc link when levels are increased. Voltage unbalancing in capacitors and narrow pulse width problems are also experienced with a 3level DCMLI, these problems cause an inefficient performance of DCMLI which leads to low quality power. Various types of modulation techniques are in exist, which are primarily divided as PWM at fundamental frequency and at higher switching frequency. The multilevel modulation is further divided as space vector based and voltage level based. Multilevel modulation base on voltage is the resent trend of modulation technique commonly used for multilevel inverters for its easy implemented at low voltage modules and good THD performance [25-28].

Multiple carrier modulation method can be achieved by comparing a high frequency carrier triangular signal with a reference sinusoidal signal.

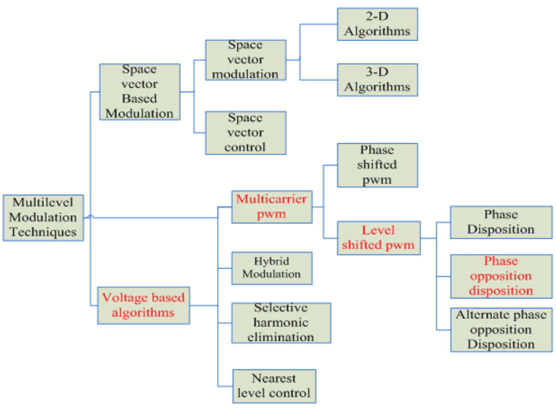


**Fig.6** Multilevel Modulation Methods

The moment were reference signal greater than carrier signal the output obtained is '1' and a positive pulse is generated and for the reference signal lower than carrier the output turns to '0' and a negative pulse is generated. Multilevel carrier PWM method yields maximum rms output voltage for 78% linear modulation range [25].

Multiple carrier method is classified into two types.

1) Phase Shifted PW

2) Level Shifted PWM

### *C. Level Shifted PWM*

in this method every pair of switches requires a carrier signal and (m-1) triangular carriers for a 'm' level multilevel inverter. same switching frequency (ts) and peak to peak amplitude is maintained for all the triangular waves. These triangular carriers are disposed vertically such that the bands occupied by them are contiguous. This level shifted PWM has three types in it[12-14]. They are given as follows

1) Phase disposition.
2) Phase opposition disposition.
3) Alternate *phase opposition and disposition.*

The modulation synthesis is obtained for each unit is by means of level shifting of the carrier waves for the different in this circuit. POD switching scheme is implemented to control the switching devices of the 3phase DCMLI which help to reduce the switching losses in great extent [13-15].

### *D. Phase Opposition Disposition (POD)*

Recent advances in multilevel inverters make development of various modulation techniques. The PODPWM is popularly used control strategy for Multilevel converters as it provides lower harmonic distortions in load voltage and current. In this all the carriers above the reference zero point are out of phase by 180° with the carriers below zero reference line. The carriers which are above the zero value reference value are in phase and below reference valve are in phase among them but both the carriers above and below the reference line are in phase opposition to each other. (180 degrees phase shifted). Each pair of carriers has the same frequency and equal amplitude in this method[29],[30]. The pattern of phase opposition disposition is shown fig7.

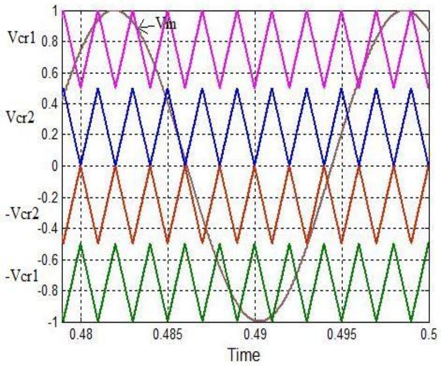


**Fig.7** Phase Opposition Disposition Pattern

## VI. Simulation Results

A 2nd order low pass filter is placed between DCMLI and the load which is used to attenuates unwanted frequencies by selecting certain bandwidth there by reduction of harmonics in the output waveform of the DCMLI. The output voltage and THD value of the line voltage without filter for RL load is shown in fig8 and fig9.

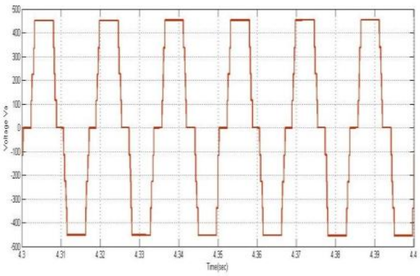

**Fig.8** Line Voltage without Filter

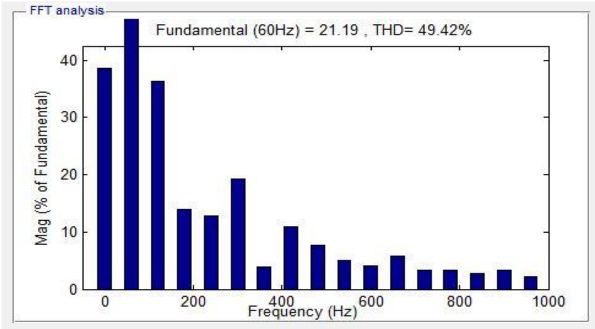


**Fig.9** THD of Line Voltage without Filter

The output voltage and line voltage THD value with filter for RL load is shown in fig10 and fig11. By using the filter distortions in the output waveform can be obtained. A pure sinusoidal output wave can be observed in fig10.

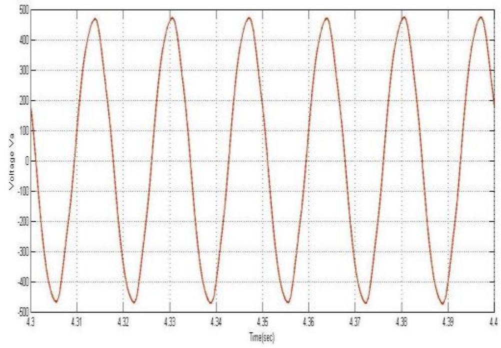

**Fig.10** Line Voltage with Filter

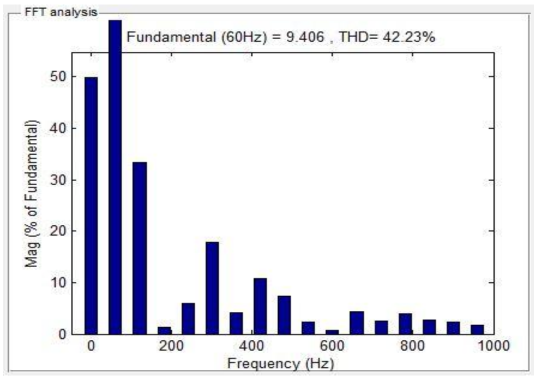


**Fig.11** THD of Line Voltage with Filter

The phase voltages Vabc without filter for RL load can be seen in fig12 and its THD is shown in fig13. In this the THD value is 63.39% which is comparatively more than with filter application.

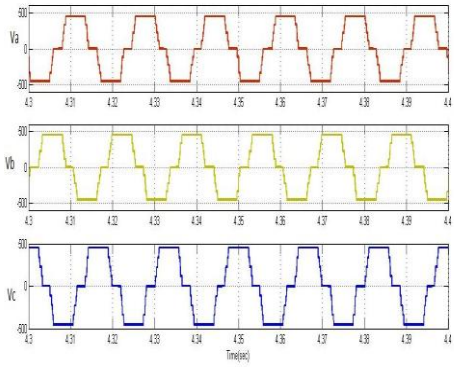

**Fig.12** Voltage Vabc without Filter

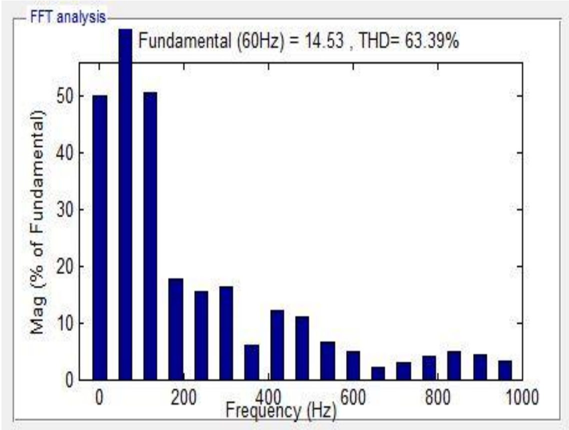


**Fig 13**.THD of Vabc without Filter

The output phase voltages Vabc with filter for RL load is shown in fig14 and fig15 gives it THD value. The THD value obtained here is 49.42%.

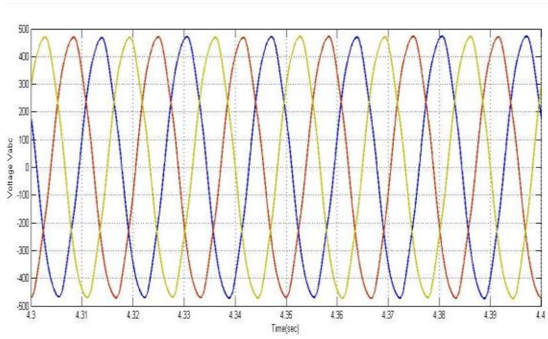

**Fig.14** Voltage Vabc with Filter

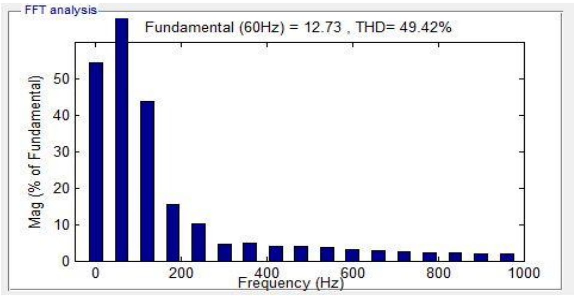


**Fig.15** THD of Vabc with Filter

On comparing fig13 and fig15 it can be observed that the THD is reduced greatly by using filter.

## VII. Conclusion

Multilevel inverters application increases the usage of renewable sources to a great extent. By using efficient methodologies of MPPT technique maximum amount of power output can be attained from the solar panel. This paper gives a brief review about most widely used P&O MPPT technique along with the modeling of solar panel. The switching operation of the diode clamped multilevel inverter with voltage based i.e; POD PWM for integration of the solar panel is also reviewed. It shows its feasible operation for renewable sources. The output results which given above shows that with filter application yields the best outputs.

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