TOTAL HARMONIC DISTORTION IN THREE PHASE- THIRTEEN LEVEL VOLTRAGE SOURCE INVERTER WITH MPPT TRACKER AND SEPIC CONVERTER FOR SOLAR PV ARRAY

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ABSTRACT

This paper deals with the analysis of Total Harmonic Distortion in three phase thirteen level voltage source inverter (VSI) for the solar photovoltaic array. The Voltage source inverter as used in high power applications here we are using for the Renewable Energy as Application. The result for the Voltage Source Inverter will be quasi square wave or square wave. The Harmonics will be high if we are using the low level inverter. The 120^0 or 180^0 are the two modes of operation for voltage source inverter and its choose based upon its application. The MPPT technique is used to get the maximum power from the Solar PV. The SEPIC converter is DC-DC converter in which it can operate either buck or boost modes and it eliminates the ripples by using the filter. In order to improve the efficiency the SEPIC and Perturb and Observe Technique is used. The focus of the paper is to analyze and reduce the Total Harmonic Distortion with the MPPT Technique and DC-DC converter and its connected to the Grid. The simulation results for the paper and the THD values are calculated for voltage source inverter (VSI) are given below.

Keywords:- *Maximum Power Point Tracking (MPPT), Perturb and Observe Algorithm (P & O), Single Ended Primary Inductance Converter (SEPIC), Voltage Source Inverter (VSI), Total Harmonic Distortion (THD).*

I.INTRODUCTION

Now-a-days the energy usage is very much integrating with our life, so the source have to be secured and the sustainable one [1], [2]. But one important thing is that, it must be inexpensive, socially acceptable and the eco friendly. The recent trends is that the energy consumption is tobe either secure or to be sustainable one. The usage of the fossil fuel is raised and its based upon cost also get raised together with increase in green house gas emission, threatens our secure energy supply [3][4]. In these century our first priority should make the clean, safe, sustainable and inexpensive energy sources to the world.

The major dis-advantage is the emission of carbon di oxide from the non renewable energy the only solution is to reduce carbon dioxide (CO_2) use Renewable energy (RE) or Non-Conventional energy sources (NCES). By using the fossil fuel or its also known as carbon foot print the CO2 is goes to the atmosphere (top layer and bottom layer of ozone). Now a days finding the fossil fuel and gas is to hard and we can’t tell that how long it will give that but the necessity is increasing day by day by using renewable energy we can reduce the necessity the renewable energy such as solar energy and the wind energy are the major one [5][6]. It is also improve our energy secure and it reduces the dependence of the fossil fuel which we are importing from other countries. The important thing in the Solar PV system is to get the maximum power for the each time from the solar photo voltaic array. So that the many maximum power point tracking method has been founded and it is implemented to in the real time. Mainly the methods are differ in the following parameters such as cost, range of effectiveness, speed, usage of sensors, complexity and the hardware implementation. The number of papers per year on solar PV cell with maximum power point tracker has grown significantly of the last decades and remains strong [7][8].

II. MAXIMUM POWER POINT TRACKING

The operating principle of the solar photo voltaic is given as that based upon the load connection only the operating point has been decided. In the day time the radiation of solar falling on the photo voltaic module is vary for every time, by varying these in throughout the day the operating point of module also gets varied. The specific method is used called maximum power point tracking (MPPT) for getting the maximum power transfer in the photovoltaic module [9],[10].The electronic circuitry is used in MPPT to transfer maximum power.

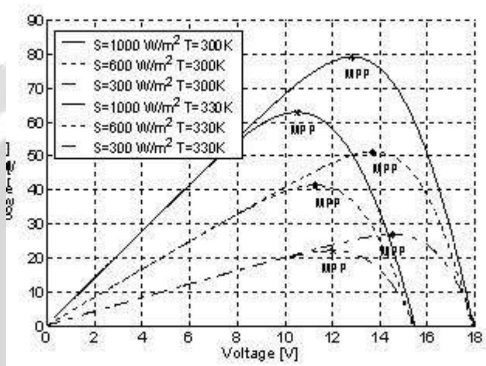

Fig. 1 PV Array Characteristics

The function of a MPPT is similar to the movement of a car. When the movement is in the wrong gear, the wheels do not receive maximum power. This is because, the engine is running either slower or faster than its approximate speed range. The purpose of movement is to couple the wheels to the engine, in a way that let the engine run in an appropriate speed, despite varying acceleration. Let's relate a PV module to a car engine. Its voltage is similar to engine speed. Its epitome voltage is that at which it can put out maximum power. This is called its maximum power point. The other name for MPP is peak power voltage (V_{PP})[11][12]. By changing the intensity of sunlight and the temperature of each photovoltaic cell the V_{PP} get varies.

III. PERTURB AND OBSERVE ALGORITHM

The most popular algorithm is hill climbing (HL) or perturb and observe algorithm [13][14]. The Perturb & Observe algorithm works on the concept of perturb is disturbance and observe the readings based upon the disturb, the regular intervals the it will get the readings of panel voltage and current based upon that it will gives the duty cycle ratio of power converter. The slope pf the PV curve is obtained by when the power is known.

In the voltage source region,

$\frac{\partial p}{\partial v} > 0$ which implies D= D+ΔD (i.e increment D) In the current source region, (1)

$\frac{\partial p}{\partial v} < 0$ which implies D= D-ΔD (i.e decrement D) At MPP, $\frac{\partial p}{\partial v} = 0$ which implies D= D or ΔD=0 (i.e retain D).

The power converter is linked with solar Photovoltaic Array by changing or by disturbing the current or voltage the duty cycle of the power converter gets varied [15][16]. From Fig. 2, it explains the operating point moves to left of Maximum Power Point when the decrementing the voltage and the operating point is moves right of the Maximum Power Point when it is incrementing on it. Consequently, based upon the power the process will be same or in reverse, if the power is raising the perturbation should be kept constant , and if the power is getting reduced means the perturbation will get reversed [17][18]. The flow chart of this algorithm explains the concept. The process will flow continuously until the maximum power to be in stable.

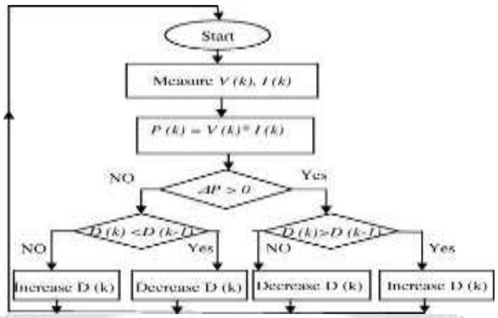

Fig. 2 Flowchart For P&O Algorithm

The system then oscillates about the MPP voltage. By disturbing the step size the oscillation can be reduced. Though, a smaller perturbation size slows down the process of MPPT, by using modified P&O algorithm will reduce the drift size compared to the normal P&O algorithm because it will sense the power , voltage, current on every duty cycle.

Perturbation	Change in Power	Next Perturbation
Positive	Positive	Positive
Positive	Negative	Negative
Negative	Positive	Negative
Negative	Negative	Positive

Table 1.Working Of P&O Algorithm

IV. SEPIC DC /DC CONVERTER

The DC-DC converters are mainly used for increasing or reducing the output voltage and the other concept is that converts the un regulated voltage to the regulated voltage or by converting the one level of DC voltage to the another level of DC voltage. Normally these topology consists of the inductor and the capacitor which are the storing elements and the power electronics switches like diodes, transistor and thyristor. The DC-DC converters are also used for the voltage and current boosting, bus regulation and the noise isolation. The power electronic converter has also been used for controlling the energy, MPPT and for blundering the PV source with different types of loads. Like the buck, boost and buck boost converter the SEPIC is also one of the DC-DC converter. The DC-DC converter or the chopper which makes the output voltage to be greater or lesser or equal to the input voltage [19][20]. By controlling the duty cycle of the SEPIC converter the output to be controlled. The SEPIC normally comes from the integration of boost into buck boost converter, it produce the non inverted output is one of the advantage, the black out will happen because of the series connection of capacitor to the input. The output moves to 0 voltage when the switches to be turned off, following a reasonably awkward transient dump of charge. The two modes of SEPIC converter are continuous conduction mode and the non continuous conduction mode.

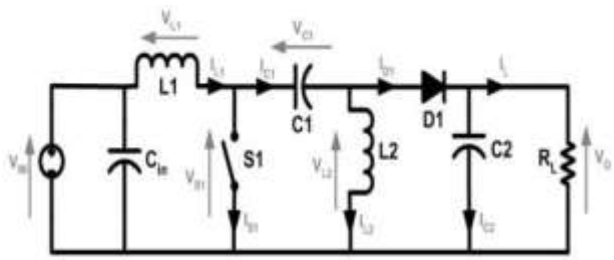

Fig.3 Circuit Diagram For SEPIC Converter

As with other switched mode power supplies (SMPS), the SEPIC exchanges the power supplies between the inductor and capacitor from one voltage to another. The energy exchanges is controlled by switch S1[21][22], which is typically a transistor such as a MOSFET. MOSFETs offer lower voltage drop and much higher input impedance than bipolar junction transistors (BJT), and do not require biasing resistors as MOSFET switching is controlled by changes in voltage rather than a current, as with BJT. A very useful application of this converters come from the fact that the variation in duty cycle can be used not only to regulate the output voltage but also to vary the input side impedance of the converter. The DC-DC converter can be controlled to present an optimum impedance across the PV array terminals which facilitates the maximum power extraction from the array. In the case of buck-boost type,the reflected impedance at input side can be less than or higher than the load impedance[23][24]. This feature can be appreciated by inspecting the input impedance (R_{in}) expression for this converter topology,

After obtaining the values of voltage across inductors in ON and OFF modes, relationship between the source and load voltages can obtained in similar as for the boost and buck-boost converters. This yields,

$$\frac{Vout}{Vin} = -\frac{d}{1-d} \qquad (2)$$

Since d is the duty cycle and it can be varied between 0 and 1 ,depending on the output of the solar PV cell. One possible drawback of this converter is that the switch cannot have terminal at ground, this complicates the driving circuitry.

V. THREE PHASE THIRTEEN LEVEL VOLAGE SOURCE INVERTER

Solar PV array generates current electricity from solar installation. However, there are several loads which will work with AC electricity. Also the grid connected applications requires that the DC is converted AC before the power the power can be fed into the grid. A DC-AC converter is also called as Inverter converts a DC quantity into an AC quantity. In the voltage source inverter by controlling the frequency of duty cycle, we can control the frequency of the output voltages and the output voltage could be fixed or variable frequency [25]. The inverter gain is defined as the ratio of the ac output voltage to the dc input voltage.

The output voltages from an ideal inverter will be sinusoidal. However, the waveforms of practical inverter are non-sinusoidal and contain harmonics. For low and medium-power applications, square or quasi-square wave voltages may be acceptable and for high power applications low distorted sinusoidal wave forms are required.

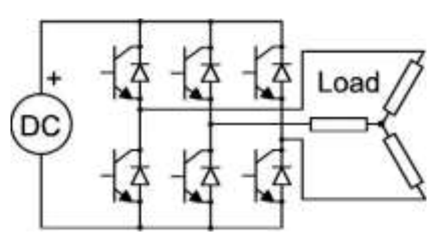

Fig.4 Three Phase-Thirteen Level Voltage Source Inverter

With the availability of high speed power semiconductor devices, the harmonic in output voltage can be minimized or reduced significantly by switching technique. However Normally, for our domestic and industrial AC appliances as well as for feeding the PV power to the grid, it is desirable to get an AC voltage of 50HZ. The gating signal of three phase inverters can be either 120^0 or 180^0 mode.

The line to neutral voltages of three phase inverter can be expressed in Fourier series as

$$\sum_{n=1,3,5..}^{\infty} \frac{2Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n\left(wt + \left(\frac{\pi}{6}\right)\right) \qquad (3)$$

$$Vbn=\sum_{n=1,3,5..}^{\infty} \frac{2Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n\left(wt - \left(\frac{\pi}{2}\right)\right) \qquad (4)$$

$$Vcn=\sum_{n=1,3,5..}^{\infty} \frac{2Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n\left(wt - \left(\frac{7\pi}{6}\right)\right) \qquad (5)$$

The line a to b voltage is $V_{ab}= \sqrt{3} V_{an}$ phase advance of 30^0. Therefore the instantaneous line to line voltae will be

$$V_{ab}=\sum_{n=1,3,5...}^{\infty} \frac{2\sqrt{3}Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n\left(wt + \left(\frac{\pi}{3}\right)\right) \qquad (6)$$

$$V_{bc}=\sum_{n=1,3,5..}^{\infty} \frac{2\sqrt{3}Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n\left(wt - \left(\frac{\pi}{3}\right)\right) \qquad (7)$$

$$V_{ca}=\sum_{n=1,3,5..}^{\infty} \frac{2\sqrt{3}Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n(wt - \pi) \qquad (8)$$

VI. TOTAL HARMONIC DISTORTION

The output of AC voltage is of square shape but not sinusoidal shape. The squared AC waveform can be considered as a distorted version of the perfect sinusoidal waveform. In principle, a square waveform can be represented by the sum of several sinusoidal waveforms of different frequency and amplitude. The distortion in the waveform is represented in the form of Total Harmonic Distortion (THD).

The THD is defined as the ratio of sum of the power of total harmonic components to the power of the fundamental component. In terms of voltages, the THD is defined as the ratio of square root of the sum of the squares (RMS voltages) of all harmonic component to the fundamental component as given in eqn.

$THD= C^2_2 +C^2_3 +C^2_4 +C^2_5 / C^2_1$

$c_1, c_2, \ldots\ldots c_n$ are the RMS values of different harmonic component of the waveform.

$$Cn= \sqrt{(a_n^2 + b_n^2)} \qquad (11)$$

The THD represents the losses in the inverter when used in the circuit. Therefore it’s value should be as low as possible.

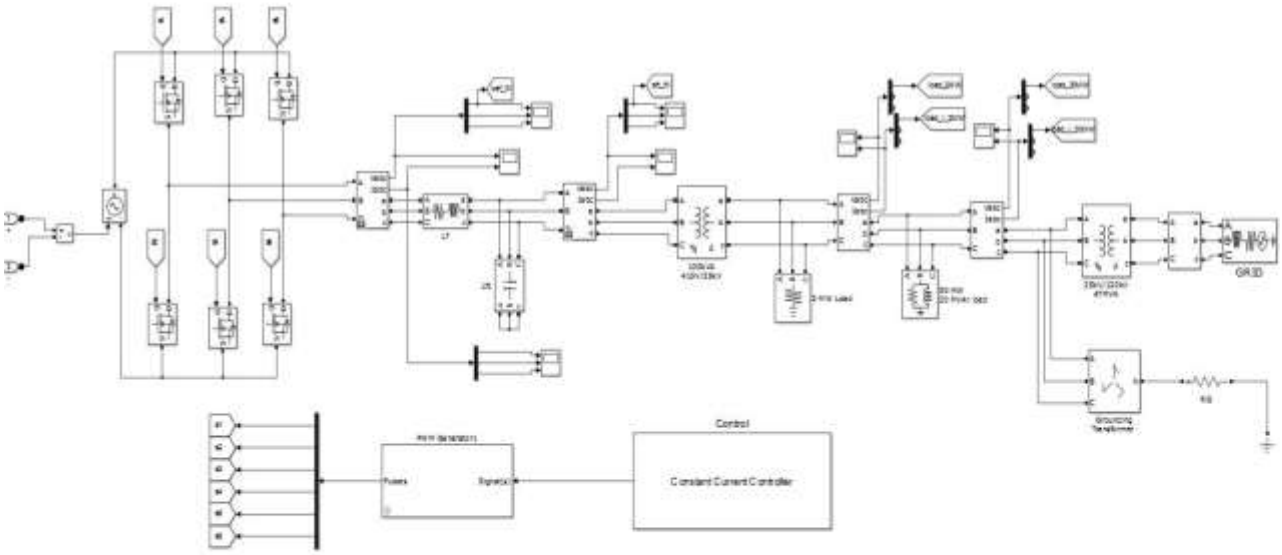

Fig. 5 Grid Connected Inverter

VII. MEASUREMENTS

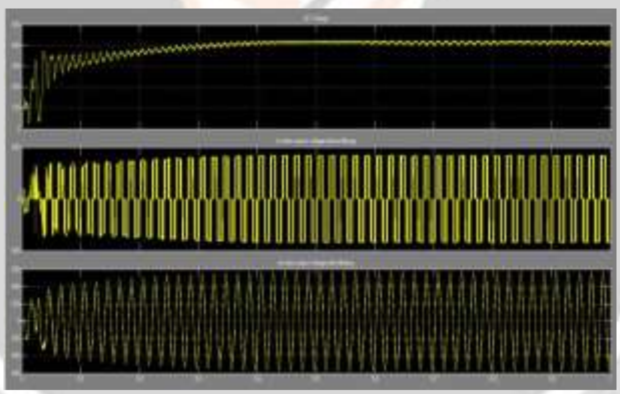

Fig.6 Output Of SEPIC Converter, VSI

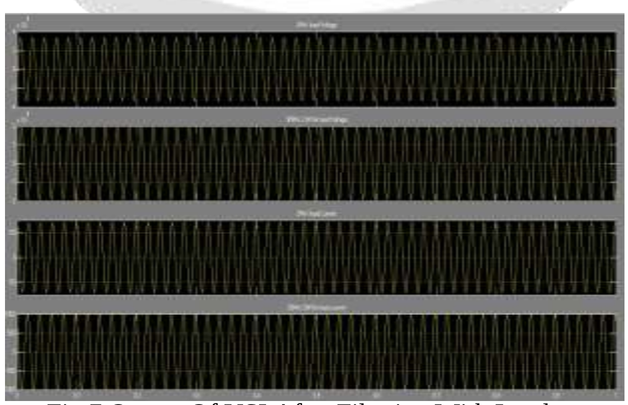

Fig 7 Output Of VSI After Filtering With Load

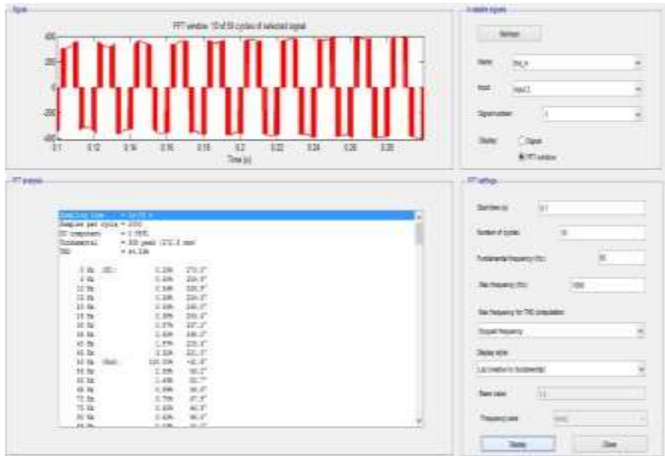

Fig.8 Output Of Inverter Before Filter

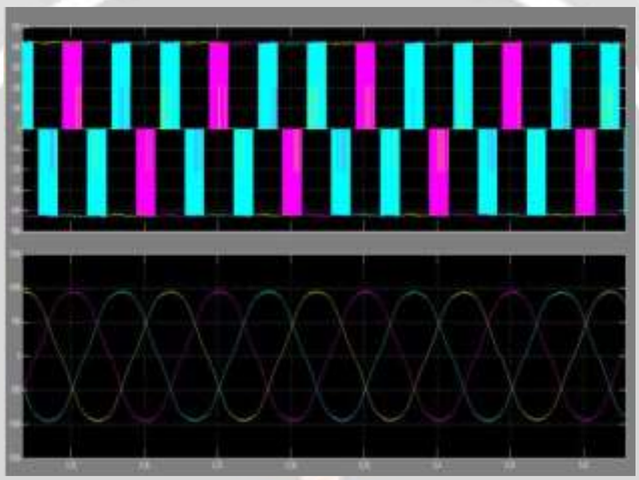

Fig.9 Total Harmonic Distortion From Inverter

VIII. CONCLUSION

By using MPPT tracker, the output of solar PV cell is 650 watts. With the help of SEPIC converter and PI controller the voltage is regulated to 415V and given as input to the VSI. As the output of VSI is thirteen level, the THD of inverter is very high. This THD can be reduced by using Multi-level inverter (MLI) or by calculating the optimal switching angles for the MOSFET switch.

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