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HARMONIC ANALYSIS FOR SOLAR PV ARRAY FED VSI USING CURRENT CONTROLLER

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ABSTRACT

A common method in the study of voltage source inverters is the hypothesis of a voltage-type input source even in the case of renewable energy (RE). The converter is supplied by an renewable energy sources, such as a Solar photovoltaic Array, the dc-link voltage is controlled by the converter with the closed loop to extract the maximum power from the solar PV. The main aim of the paper is to reduce the harmonics by the low pass filter and analyze the total harmonic distortion with current controller technique in three level voltage source inverter. The use of perturb and observe MPPT will help to produce high output efficiency from solar PV cell. The simulation result for the paper is analysed using MATLAB/SIMULINK software and the values for the total harmonic distortion is calculated

Indexing terms/Keywords

Solar Photo Voltaic Cell, 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

Due to increasing the need for electrical energy and by reducing getting the electrical energy from conventional sources, the renewable energy gets more importance [10]. The renewable energy generation such as solar energy and wind energy get more importance than other renewable energy system. By considering the solar energy [4] it has several advantages such as eco-friendly and most inexhaustible in nature. But it has low efficiency and high costs of solar photovoltaic panels. The increase in technology that improves the efficiency of solar photovoltaic system makes more confidence to use.

Generation side of the PV system has to generate maximum power which is possible. Hence an efficient DC/DC converter is to be used for tracking the maximum power point. Thus in this paper SEPIC converter is used in between the PV panel and inverter and a comparative study of this two stage system is done. In Cuk converter the source and load side are separated via a capacitor thus energy transfer from the source side to load side occurs through this capacitor which leads to less current ripples at the source and load side compared to other non-isolated converters. Thus quality of power can be maintained. The most common algorithms for maximum power point are Perturb and Observe algorithm and Incremental conductance method [2-5]. As such, many MPP trackers (MPPT) have been developed and implemented. The methods vary in complexity, sensors required, cost, convergence speed, popularity, range of effectiveness, hardware implementation and in other respects. They range from the almost evident (but not necessarily ineffective) to the most resourceful (not necessarily most effective). Many methods have been established that it has become difficult to amply determine which method, newly proposed or existing, is most suitable for a given PV system. The number of papers per year on solar PV cell with maximum power point tracker has grown considerably of the last decades and remains strong.(Figure 1)

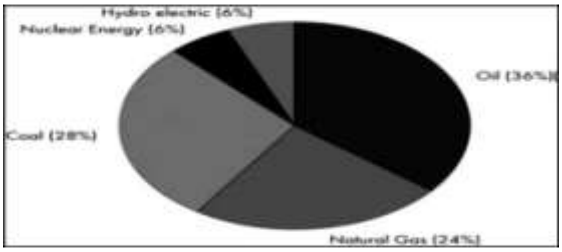

Fig. 1 World Energy Scenario.

MAXIMUM POWER POINT TRACKING

When a solar PV module is used in a system, its operating point is decided by the load to which it is connected. Since, the solar radiation falling on a PV module varies throughout the day, the operating point of module also changes throughout the day. In order to ensure the operation of PV modules for maximum power transfer, a special method called maximum power point tracking(MPPT) is employed in PV systems.[2-4] The electronic circuitry is used in MPPT to transfer maximum power.

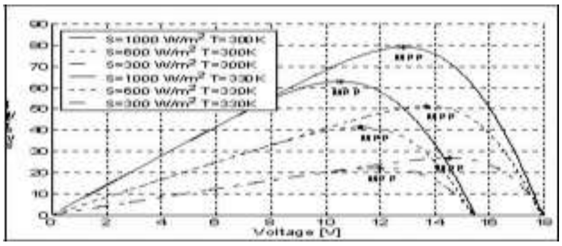

Fig. 2. PV Array Characteristics.

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. It is also called as peak power voltage (V_{PP}).[4,5] V_{PP} varies with intensity of sunlight and with temperature of the solar PV cell.

PERTURB AND OBSERVE ALGORITHM

The most popular algorithm is hill climbing (HL) or perturb and observe algorithm.[6] The P&O algorithm involves a perturbation in the duty ratio of the power converter at regular intervals and by recording the resulting array current and voltage values, thereby obtaining the power. Once the power is known, a check for the slope of the the PV curve or the operating region is carried out and the change in D is affected in the direction so that the operating point approaches MPP on power voltage characteristics.

In the voltage source region,which implies D = D+ D (i.e increment D) In the current source region,which implies D = D-D (i.e decrement D). At MPP, which implies D = D or D=0 (i.e retain D). In case of a PV array linked to a power converter, perturbing the duty ratio of power converter perturbs the PV array current and accordingly perturbs the PV array voltage.[6] From Figure 2, it can be seen that decrementing (incrementing) the voltage decreases (increases) the power. when operating on the left of the MPP and increases (decreases) the power when on the right of the MPP. Consequently, if there is an increase in power, the succeeding perturbation should be kept the same to reach the MPP and if there is a decrease in power, the succeeding perturbation should be reversed.[6,7] This algorithm is summarized in Table 1. The process is repeated periodically until the MPP is reached.(Figure 3).

The system then oscillates about the MPP voltage. The oscillation can be minimized by decreasing the perturbation step size. 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.

SEPIC DC /DC CONVERTER

The DC-DC converters are used for converting one level of DC voltage or unregulated voltage to another level of dc voltage or regulated voltage. This transformation is realized with the help of network consisting of storage elements like inductor and capacitor and power devices like transistors and diodes. These converters play a vital role in the PV systems where they are used as charge controllers, maximum power point trackers and for interfacing the PV source with different types of loads.[6,7] The DC-DC converters are also used for noise isolation, power bus regulation and current boosting. The single-ended primary inductor converter (SEPIC) is a type of DC/DC converter or chopper allowing the electric potential at its output to be less than, greater than, or equal to the input. The output of the SEPIC is controlled by the duty cycle of the control transistor. A SEPIC is fundamentally a boost converter tailed by a buck-boost converter, therefore it is analogous to a traditional buck-boost converter, but it has the advantages of having non-inverted output, with a series capacitor to couple energy from the input to the output and being capable of true blackout. When the switch is turned off, its output drops to 0 V, following a fairly awkward transient dump of charge. The SEPIC converter can be operated either in continuous conduction mode (CCM) or discontinuous conduction mode.[7] Here, the SEPIC converter is operated in continuous conduction mode.

As with other switched mode power supplies (SMPS), the SEPIC exchanges energy between the inductors and capacitors in order to convert from one voltage to another. The energy exchanges is controlled by switch S1, 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 optimum impedance across the PV array terminals which facilitate 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. This feature can be appreciated by inspecting the input impedance (R_{in}) expression for this converter topology.

Relationship Between Input And Output Voltage

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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. 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.

THREE PHASE THREE LEVEL VOLAGE SOURCE INVERTER

Solar PV array generates current electricity from solar insolation. 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. The output voltage could be fixed or variable at fixed or variable frequency. The inverter gain is defined as the ratio of the ac output voltage to the dc input voltage.[8] 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 wave or quasi-square wave voltages may be acceptable and for high power applications low distorted sinusoidal wave forms are required.[9]

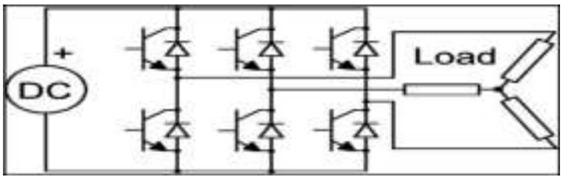

Fig. 3. Three Phase-Three Level Voltage Source Inverter.

With the availability of high speed power semiconductor devices, the harmonic contents of output voltage can be minimized or reduced significantly by switching techniques.[10-12] 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 signalof three phase inverters can be either 120^0 or 180^0 mode.[9,10](Figure 6) The line to neutral voltages of three phase inverter can be expressed in Fourier series

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.[9] 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 powers of all 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 Equations.Where $c_1,c_2 ,........c_n$ are the RMS values of different harmonic component of the waveform. The THD represents the losses in the inverter when used in the circuit. Therefore it's value should be as low as possible.

SIMULATION USING MATLAB

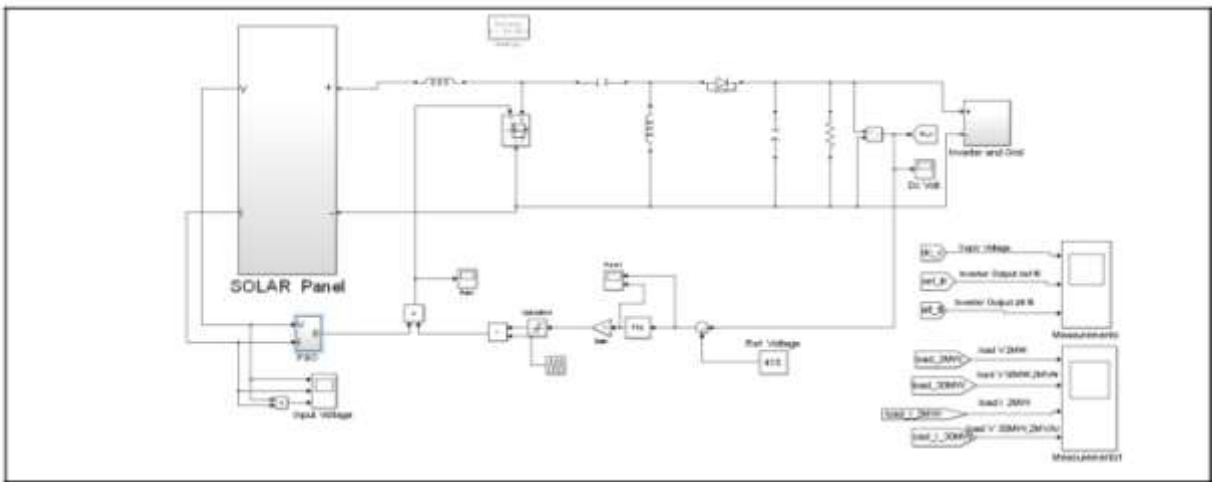

Fig. 4. SEPIC Converter with PI Controller.

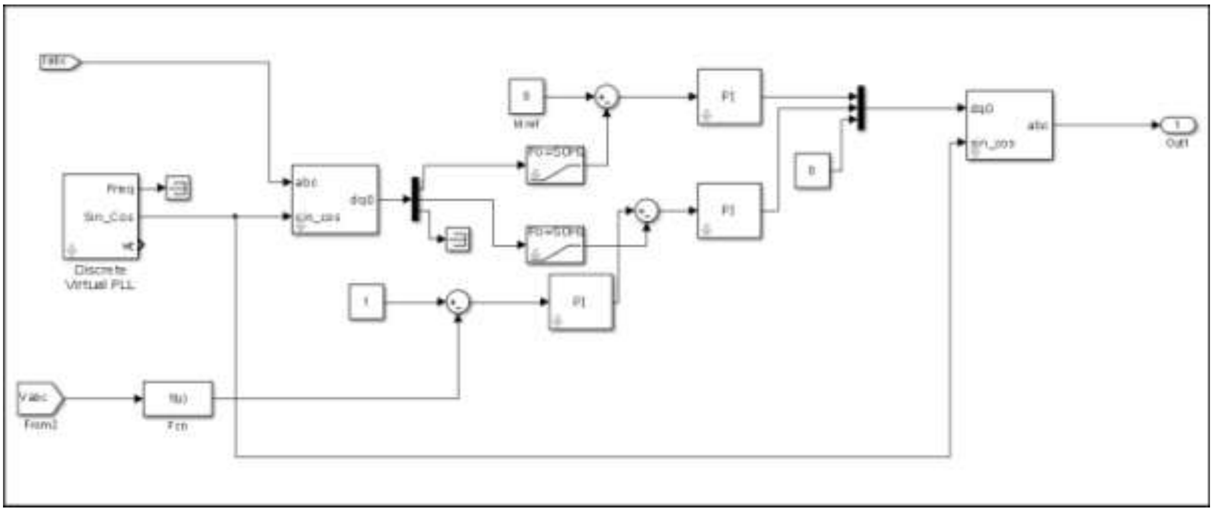

Fig. 5. Constant Current Controller from Grid to Inverter.

MEASUREMENTS

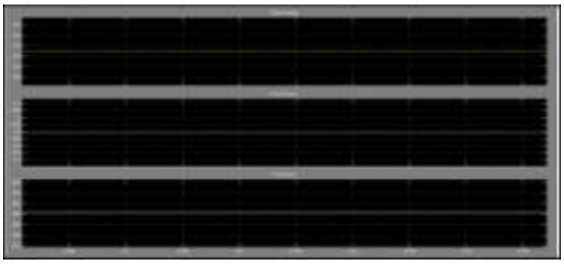

***Fig. 6. Output of PV Panel*.**

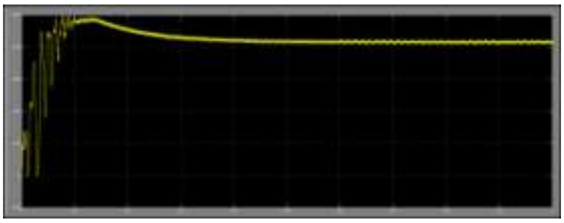

***Fig. 7**. Output of SEPIC Converter*.

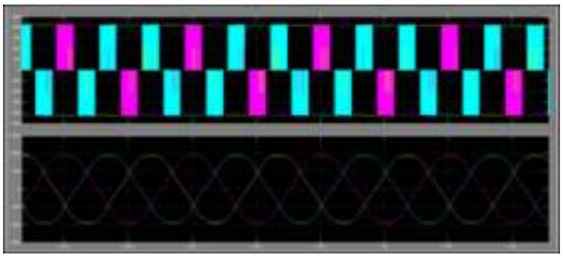

***Fig. 8**. Output of Inverter before Filter.*

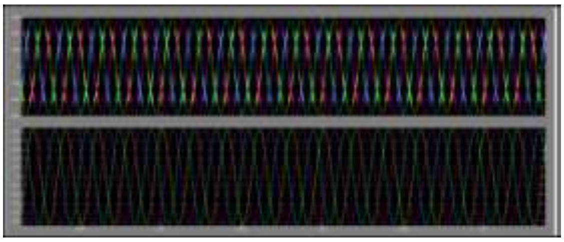

***Fig. 9.** Output of Inverter after Filter.*

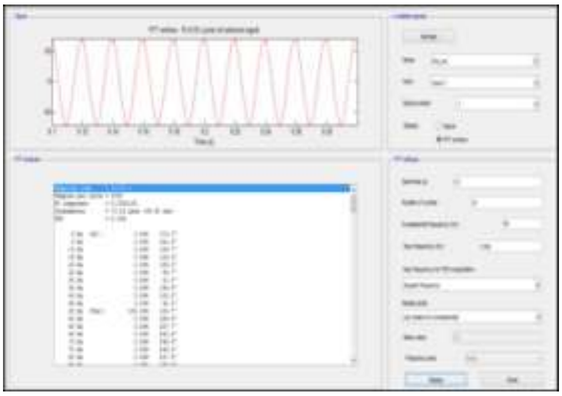

Fig. 10. Total Harmonic Distortion from Inverter after Filtering.

CONCLUSION

In the grid connected VSI with LC filters, the possible wide range of grid impedance variations can challenge the design of the controller, particularly when the grid impedance is highly inductive. From the above Fig.16 the THD of three phase three level voltage source inverter will be 42.63%. However, to reduce this harmonic distortion, it is filtered and THD is drawn below 5%. The IEEE Std.1547-2003 says, for connect the power to the grid, the THD should be less than 5% THD. The THD can also be minimized by calculating the optimal switching angle for MOSFET in the inverter or by increasing the levels in Multilevel inverter.

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