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Photovoltaic Micro Inverter System Using Maximum Power Point Tracking

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Abstract
In this paper grid connected boost photovoltaic micro inverter system using maximum power point tracking is presented. First the photovoltaic module is analyzed using SIMULINK software. The main aim of the Paper is the boost converter is to be used along with a Maximum Power Point Tracking control mechanism. The MPPT is responsible for extracting the maximum possible power from the photovoltaic and feed it to the load via the boost converter which is used to steps up the voltage to required magnitude. Both the boost converter and the solar cell are modeled using Sim Power Systems blocks. Here the voltage source inverter is cascaded and it injects sinusoidal current to the grid. The dynamic stiffness is obtained when load or solar illumination changing rapidly. This investigates in detail concept of Maximum PowerPoint Tracking [MPPT] which significantly increases the efficiency of the solar photovoltaic system.
Index Terms-Boost converter, grid connected photovoltaic [PV] system, Voltage Source Inverter, maximum power point tracking [MPPT], PWM generator.

I. INTRODUCTION

One of the major concerns in the power sector is the day-to-day increasing power demand but the unavailability of enough resources to meet the power demand using the conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. Renewable sources like wind energy and solar energy are the prime energy sources which are being utilized in this regard. Solar energy is abundantly available that has made it possible to harvest it and utilize it properly. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of a grid nearby. Thus it can be used to power rural areas where the availability of grids is very low. Another advantage of using solar energy is the portable operation whenever wherever necessary. In order to tackle the present energy crisis one has to develop an efficient manner in which power has to be extracted from the incoming solar radiation. The use of the newest power control mechanisms called the Maximum Power Point Tracking [MPPT] algorithms has led to the increase in the efficiency of operation of the solar modules and thus is effective in the field of utilization of renewable sources of energy [3], [8].In this Paper boost converter is cascaded by an inverter. Here the PWM control technique adopted for voltage source inverter] [4]- [6].

The boost converter is incorporated as the dc – dc conversion stage for grid connected photovoltaic micro inverter system. In order achieve low cost, easy control, high efficiency and high reliability the boost converter is introduced to interface with the low voltage photovoltaic module .here the full bridge inverter is incorporated it inject the sinusoidal current to the grid. In this Paper MPPT is performed by the boost converter. there are different types of algorithm is implemented. It includes perturb & observe method, incremental conductance method, ripple correlation method, reduced current sensor method, etc each method provide the different steady state MPPT efficiency , transient tracking speed, and control complexity[12].

In this paper an optimal P & Q method is proposed. The MPPT Algorithm using step changed perturbations on the PV voltage and current or converter duty cycle periodically may sometimes cause the problems such as magnetic saturation, inrush current, LC oscillation. In this paper the dynamics of boost converter carefully analyzed for guiding the MPPT design. For the main purpose of fast tracking and high efficiency, the power voltage [P-V] curve of the PV module is divided into three different operation zones, where the MPPT step size is varied accordingly.

II. MODELLING OF SOLAR CELL

Solar cell is the building block of a solar panel. A photovoltaic module is formed by connecting many solar cells in series and parallel. Considering only a single solar cell; it can be modeled by utilizing a current source, a diode and two resistors. This model is known as a single diode model of solar cell. Two diode models are also available but only single diode model is considered here [1], [2], [4], [7], [9] and [10]

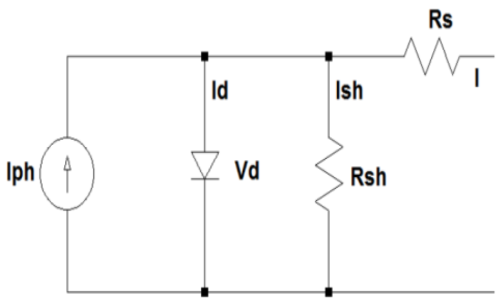

Fig 1: Single diode model of a solar cell

The output current from the photovoltaic array is

$I = Isc - I_d$ [1.1]
$Id = Io\,[e^{qVd/kT} - 1]$ [1.2]

where Io is the reverse saturation current of the diode, q is the electron charge, V_d is the voltage across the diode, k is Boltzmann constant [1.38 * 10-19 J/K] and T is the junction temperature in Kelvin [K] From eq1.1 and 1.2

$I = Isc - Io\,[e^{qVd/kT} - 1]$ [1.3]

Using suitable approximations,

$I = Isc - Io\,[eq^{[V+IRs]/nkT]} - 1]$ [1.4]

where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature [in Kelvin] and n is the diode ideality factor. In order to model the solar panel accurately we can use two diode model but in our Paper our scope of study is limited to the single diode model. Also, the shunt resistance is very high and can be neglected during the course of our study.

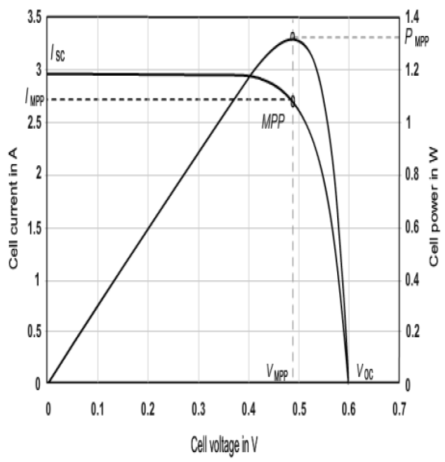

Fig 2: PV I-V curve of a solar cell at given temperature and solar irradiation

III. BOOST CONVERTER TOPOLOGY

Conventional boost converter topology for grid connected PV system is depicted in fig .1 Boost converter steps up the input voltage magnitude to a required output voltage magnitude without the use of a transformer. The main components of a boost converter are an inductor, a diode and a high frequency switch. These in a co-ordinate manner supply power to the load at a voltage greater than the input voltage magnitude. The control strategy lies in the manipulation of the duty cycle of the switch which causes the voltage change [11] and [12]. There are two modes of operation of a boost converter. Those are based on the closing and opening of the switch. The first mode is when the switch is closed; this is known as the charging mode of operation. The second mode is when the switch is open; this is known as the discharging mode of operation [12].

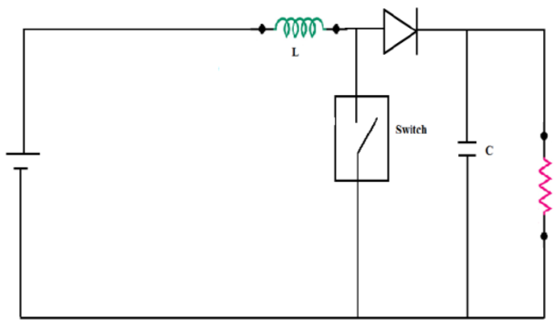

Fig 3: Boost converter

IV. OVERVIEW OF DC-DC CONVERTER

DC-DC conversion technology is a major subject area in the field of power electronic and power engineering and drives. This conversion technique is widely adopted in industrial application and computer hardware circuits. The simplest DC-DC conversion technology is a voltage divider, potentiometer and so on. But the effect of these simple conversion techniques resulted in poor efficiency due to fact that transfer output voltage is lower than the input voltage. According to [7], there have been more than 500 prototypes of DC –DC converter developed for more than 60 years. All new topology and presently existing DC-DC converters were design to meet some sort of industrial or commercial applications. They are usually called by their function, for example, Buck converter, boost converter, buck-boost converter and zero-switching [ZCS] and zero voltage switching [ZVS] converters which are used to reduce, increase voltage <.respectively. DC-DC converters [e.g. boost, buck, buck boost, etc] are also implemented with other devices as maximum power point trackers [MPPT] for photovoltaic module, for example in [8] a real time MPPT employing a DC-DC boost converter operating in conduction mode is used. It also includes a passive non dissipative turn on turn off snubber in order to achieve high efficiency and to reduce EMI level due to soft switching.

V. V BOOSTCONVERTER ANALYSIS

The designed DC-DC boost converter is connected between the photovoltaic module and the load so as to enable the module operates at maximum power at all time. Boost converter is made of up four elements as shown below in figure 1, they include the inductance, diode, capacitor and M0SFET. As the name of the converter implies, it steps up the input voltage which makes the output voltage greater than the input voltage. The converter is control through the MOSFET which act as a switch. The ON and OFF of the switch [MOSFET] controls the output voltage by changing the voltage of the inductance so as to enable the photovoltaic module power the load at maximum voltage. The operation of the converter is analyzed in different operating condition. The operation of the converter is analysis in continuous conduction mode.

$\Delta I_l / \Delta t = Vi / L$ [1]

At the end of the On-state, the increase of I_L is given by:

$$\Delta I1\ on = \frac{Vi.D.T}{L}$$ [2]

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is On. Therefore D ranges between 0 [S is never on] and 1 [S is always on]. During the Off-state, the switch S is open, so the inductor current flows through the load. By considering there was zero voltage drops in the diode, and a capacitor large enough for its voltage to remain constant, the derivation of I_L is

$Vi - Vo = L\ dI_l / dt$ [3]

Therefore, the variation of I_l during the Off-period is
$\Delta I_l\ off = [\ [Vi\text{-}Vo][1\text{-}D]\ T] / L$ [4]

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. In particular, the energy stored in the inductor is given by:
$E = ½\ L\ .\ I_l^2$ [5]

VI. DC - DC BOOST CONVERTER ANALYSIS

As stated above that DC-DC boost converter is used as photovoltaic interface and is design to boost the output voltage to 24V to meet the requirement of the load [led base light]. Based on this fact some specification Therefore, the inductor current has to be the same at the beginning and the end of the commutation cycle. This can be written as
$\Delta I_{l\ on} + \Delta I_{l\ off} = 0$ [6]

Substituting $\mathbf{\Delta I_L}$ **on** and $\mathbf{\Delta I_L}$ **off** by their expressions yields:

$\Delta I_{l\ on} + \Delta I_{l\ off} = [[V_i\ .D.T] / L] + [[V_i\ \text{-}Vo].[1\text{-}D]T]/L=0$ [7]

This can be written as:

$$\frac{Vo}{Vi} = \frac{1}{[1-D]}$$ [8]

This in turns reveals the duty cycle to be

$$D = 1 - \frac{Vi}{Vo}$$ [9]

The boost converter was assumed to meet the load demand, see table 3 and boost converter design equations as listed in equation [5], [6] [7] and [8]. Equation [1] represent the boost converter transfer function where V_o = output voltage, V_i = input voltage and D represent duty cycle. Also F_s= switching frequency, L_o =boost inductance and Co represent output capacitance.

$V_0/V_i=1/[1\text{-}D]$ [10]
$\Delta I=V_i*D/F_S*L$ [11]
$\Delta V=I_0*D/F_S*C$ [12]
$P_i = P_o = V_i*I_i = V_o*I_o$ [Assume 100% efficiency of converter]

VII. MAXIMUM POWER POINT TRACKER [MPPT]

A maximum power point tracker is a high-efficiency DC-DC converter, which functions as an optimal electrical load for photovoltaic cell, most commonly used for a solar panel or array and converts the power to a voltage or current level which is more suitable to whatever load the system is design to drive. PV cells have a single operating point where the values of current and voltage result in a maximum power output for the cell [10]. Maximum power point tracker [MPPT] is basically an electronic system that controls the duty circuit of the converter to enable the photovoltaic module operate at maximum operating power at all condition and not some sort of mechanical tracking system that physically rotate the photovoltaic modules to face sunlight directly. The advantages of MPPT regulators are greatest during cloudy or hazy days, cold weather or when the battery is deeply discharged. There are different types of maximum power point tracker methods developed over the years and they are listed below as follows [1] Perturb and observe method, [2]Incremental conductance method, [3] Artificial neutral network method, [4] Fuzzy logic method, [5] Peak power point method, [6] Open circuit voltage method, and [7] Temperature method etc. The MPPT plays a very significant role because without the MPPT the desire output electrical power will not be achieve with changing weather conditions.

VIII. PQ ALGORITHM

The MPPT control employed at the converter side. Typically the MPPT function block in a PV converter system periodically modifies the tracking reference of the PV voltage, PV current, or modulating index, or the converter duty cycles.

In many cases, the periodic perturbations yield step change dynamic responses power converters. If the converter dynamics are disregarded in MPPT control, unwanted transient responses such as LC resonance, inrush current and magnetic saturation may take place. Consequently the conversion efficiency can be deteriorated or even malfunction of the converter may occur.

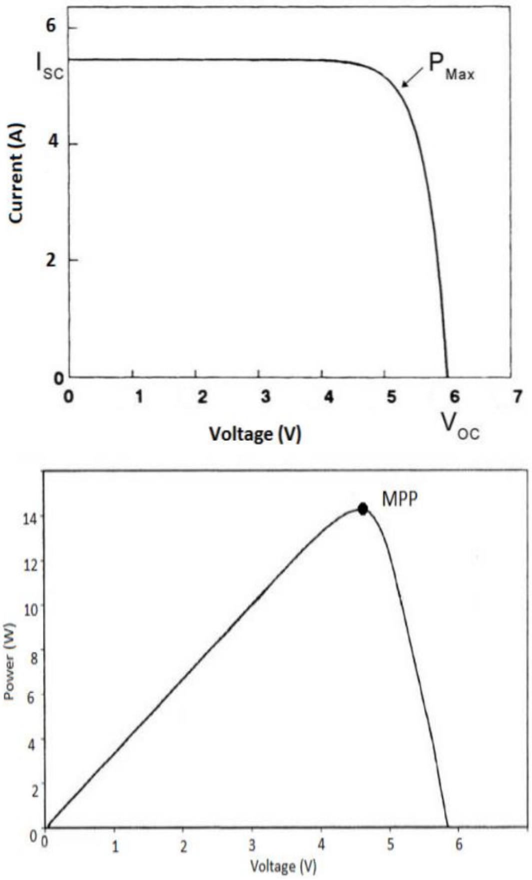

Fig 4 [a]: I-V curves, Fig 4 [b] P-V curves.

For sake of control simplicity and low cost, developing a customized MPPT method by carefully taking care of the boost converter dynamics would be more desirable.

IX. FLOW CHART FOR P&Q ALGORITHM

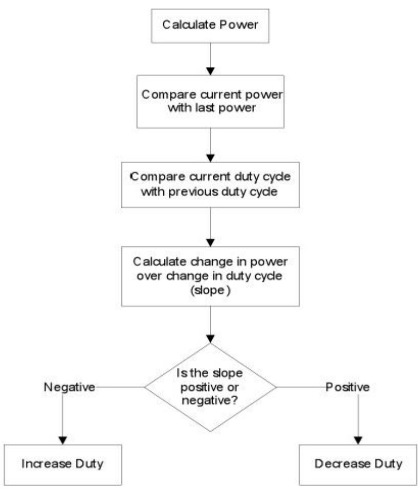

Fig 5: Flow chart of the MPPT algorithm

X. SIMULATION RESULTS

The simulation circuit for merging of boost converter and VSI by using MPPT algorithm is shown in fig 6. In above model initially the PV cell generates 74.91V voltage by using MPPT method. It is given to the boost converter. Based on the duty cycle it is used to step up the voltage level to 283.6V. Again it is given to the inverter circuit to get ac voltage of same level.

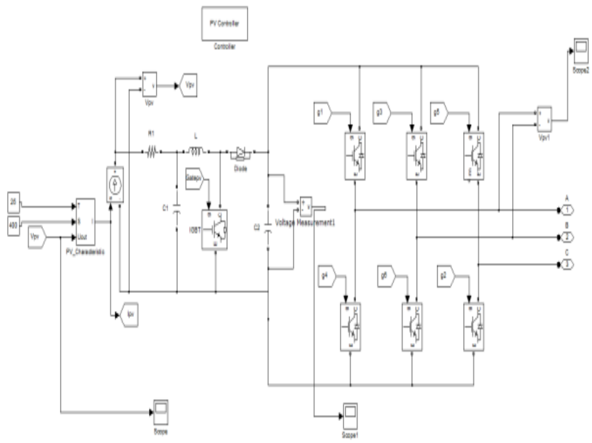

Fig 6: Simulation circuit for boost converter & VSI.

Finally it is given to the grid through the LC filter to get voltage 719.4V & current 0.276A.Depend on the source variation the MPPT technique is used to vary the duty cycle of converter.

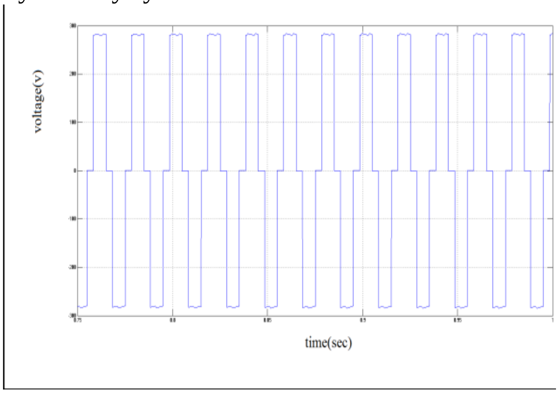

Fig 7: Output voltage of inverter without filter

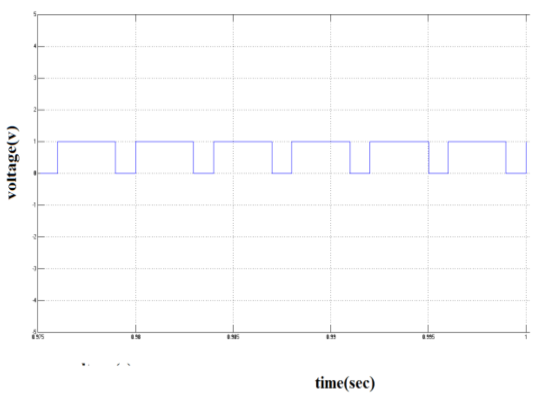

Fig 8: Gate pulse to boost converter

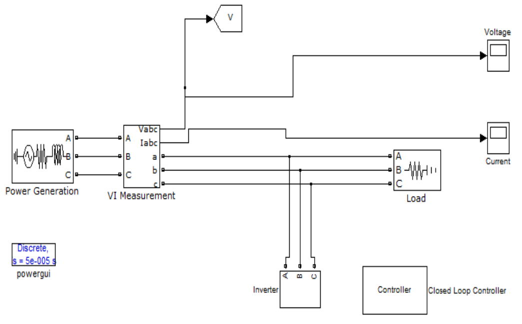

Fig 9 Closed loop photovoltaic micro inverter

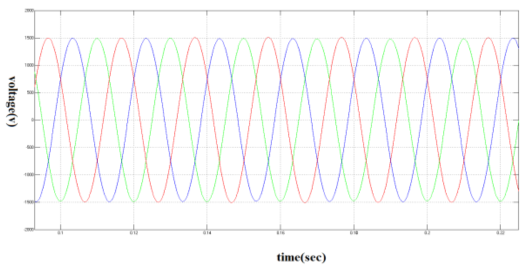

Fig 11: Voltage waveform of PV system

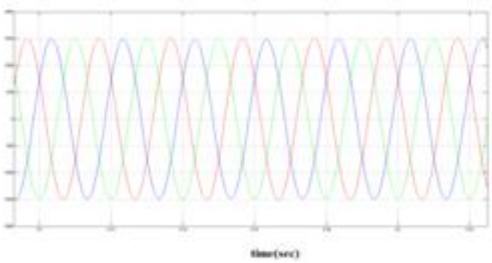

Fig 12: Output current waveform system

XI. CONCLUSION

In this paper a combined low cost, high efficiency inverter and peak power tracker has been proposed. This converter operates close to the maximum power point of the photovoltaic array and forms a DC to AC inverter. Simulation results are shown. This system shows a wide operating rage of DC to AC power conversion to utilize the available power in the photovoltaic systems.

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XII. BIBILOGRAPHY

R.Suganya was born in Tamilnadu, in 1983. Received her UG degree in Electrical and Electronics Engineering from Annai Teresa College of Engineering in 2005 and PG degree from Thiagarajar College of Engineering in 2008. Her research interest includes Power quality issues, Power System applications, Optimization control, Renewable energy sources, Electrical Drives. She is currently working at I.F.E.T College of Engineering as Associate Professor in Electrical and Electronics Engineering Department. She is a life member of ISTE

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