A MICRO CONVERTER FOR HIGH VOTAGE.GAIN AND.LOW VOLTAGE STRESS

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ABSTRACT *- An efficient converter which has high voltage gain and less voltage stress that can be connected with the Solar Panel and Maximum Power Point Tracker MPPT to get the maximum power out of the solar panel so the efficiency of the system increases. This paper proposes a simulation of system in which a micro converter can be connected with the Solar panel and maximum power point tracker (MPPT). Solar Panels have non-linear characteristics and MPPT help to get maximum power feeds to micro converter which has less voltage stress and high voltage gain. Main advantages of this micro converter are less voltage stress, high voltage gain, less space required and these are more economical in comparison with the conventional converters e.g. boost converter, buck-boost converter. The required result 24V input and the 200V output, 100W power as the requirement of the converter high gain is achieved.*

Key Words: Solar Panel, Solar Photovoltaic, Maximum Power Point Tracker (MPPT), Perturbation & Observation algorithm.

1. INTRODUCTION

The global increases in demand of energy, which has made important to the renewable energy sources. Renewable energy resources are working in parallel to traditional energy sources to meet user energy demand. Renewable energy resources include Solar Photovoltaic system, bio gas and wind farms etc. Solar Photovoltaic system contains the major portion of renewable energy resource [1][6]. Photo Voltaic (PV) System consists of the Solar Panels, Maximum Power Point Tracker and a boost converter. Photo Voltaic (PV) can generate 40% of its maximum power. So, system must be efficient and economical. MPPT used to get the maximum Power out from the system by calculating maximum Power with the help of V_{max} and I_{max} [10][11]. PV Power is plotted against the voltage for insulation from $200W/m^2$ to $1000W/m^2$. A Boost converter is used to change the DC voltage level from one level to another. Micro Converter is a new technique which is under consideration now a days. Micro Converter doesn't consist of the transformer, requires less space, more economical, less voltage stress and high Voltage gain [8]. Micro Converter have high voltage gain. Hence, converter does not need a transformer to step-up the voltage which makes its more attractive to the engineering applications.

Many topologies have been proposed such as fly-back, boost converter, buck-boost converter, Zeta converter, SPEIC converter, forward topology, push-pull topology, half bridge topology, full bridge topology converter can adjust voltage ratio. A boost converter consists on some inductor, capacitor and switches which convert DC voltage from one level to another level [9][17]. In this research paper Micro Converter used along with MPPT algorithm and Photo Voltaic as shown in Fig1. The high voltage gain and low the voltage stress of devices which makes Micro Converter efficient. In MPPT, the P&O algorithm used to achieve the maximum power output of photo voltaic so the efficiency of the system is increases [2][3][5]. However, the size and cost becomes less because micro converter only contains capacitor, inductor and switches. Whereas, the conventional converter mainly contains transformer which makes converter costly and bulky.

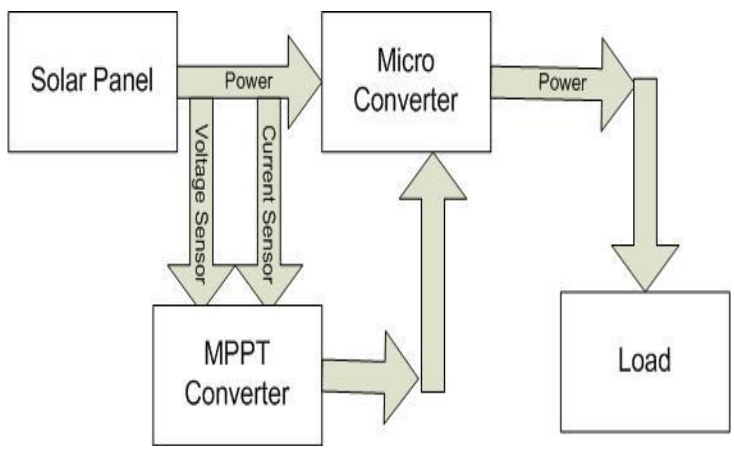

Fig 1: Proposed Functional block diagram of the system.

2. RELATED WORK

Mr. Shih-Ming Chen Proposed [16], A Photovoltaic system is designed Micro converter to help connecting the system with the grid. The Micro converter includes Zeta converter and coupled inductor used in system without the extreme duty ratio. In their research the advantage was the leaked coupled inductor energy recycled to the load. Mr. K. Hirachi proposed [18], some of the bidirectional DC/ DC converter were designed to level the small load with battery banks but the voltage level of these batteries not fulfilled, so the system required bidirectional choppers to supply the power on either direction. Mr. Henry Shu-Chung proposed [19], Bi-directional converters can be generalized for power flow on either side. Bi-directional were connected in string like a converter cells and the strings are connected in anti-phase so the output current becomes continue. A reduced-order mode and state space averaging techniques are used to study static and dynamic responses of the converter. Mr. Yi-Ping Hsieh Proposed [20] High step-up DC to DC converter with coupled- inductors and switched-capacitor techniques.

Capacitors are charged in parallel and discharged in series to achieve the step-up of the voltages. The voltage stress reduced by using a passive clamp circuit and reverse recovery of the diodes is solved by a coupled inductor. Mr. Ting Wang Proposed [8], sometimes high voltage gain is required in connecting micro converter with photo voltaic. DC to DC converter contains high frequency transformer, they have small size and insolated high voltage gain. However, disadvantages in conventional converters size is big and low voltage gain with high voltage stress across the devices. Mr. Julio C. Rosas-Caro Proposed [21], Multi-level DC-DC boost converter is designed for use in the renewable system application. Its basic working principle is to use the DC-link where unidirectional applications were installed. This converter topology achieves the self voltage balancing. Ms. R. Dhivya Proposed [22], Micro Inverter is the combination of half-bridge DC boost converter and full bridge PWM converter. IIR filter is used in boost converter to reduce the total harmonic distortion (THD) and high power factor is achieved. Ramp change algorithm is used in this converter to achieve the promising results.

3. PROPOSED DEVICES

This paper proposes an efficient DC to DC boost converter. Conventional converters face problems such as low voltage gain with high voltage stress across the devices. However, micro converter used to boost voltage level. In micro converter the main advantages include less voltage stress, high voltage gain, less size and more economical [8]. For prototype model, Nominal input voltage range is 24 volts and output voltages range is 200V with the power of 100W. To obtain the maximum efficiency of the traditional P&O MPPT algorithm is used [5]. MPPT achieves the maximum available voltage and maximum available current, which is delivered to the boost converter. Micro converter connected with MPPT algorithm, which helps the system to deliver maximum output power [3][4].

4. DESIGNING

4.1 PV MODULE

A simple equivalent solar cell is designed, which contains a small series resistance with a shunt resister as shown in Fig 2 [2][7]. R_S is a very small which is consider as the initial losses and R_P is quite a high value which is connected to ground leakage which is neglected. Current source is directly related to the sunlight intensity which is falling on the cell and diode decide the V-I characteristics [1].

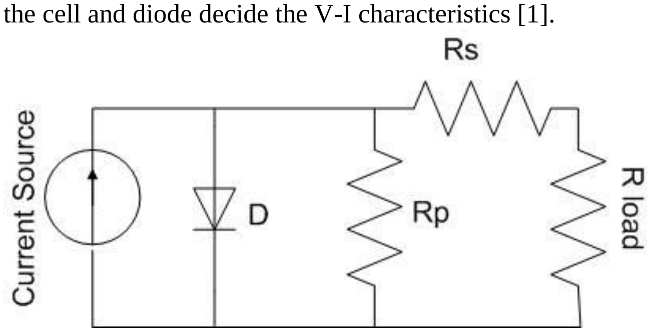

Fig2 : Equivalent Circuit of a Solar Cell

Where,

R_S = Series Resistance
R_P = Shunt Resistance
R load = Load Resistance
D = Diode

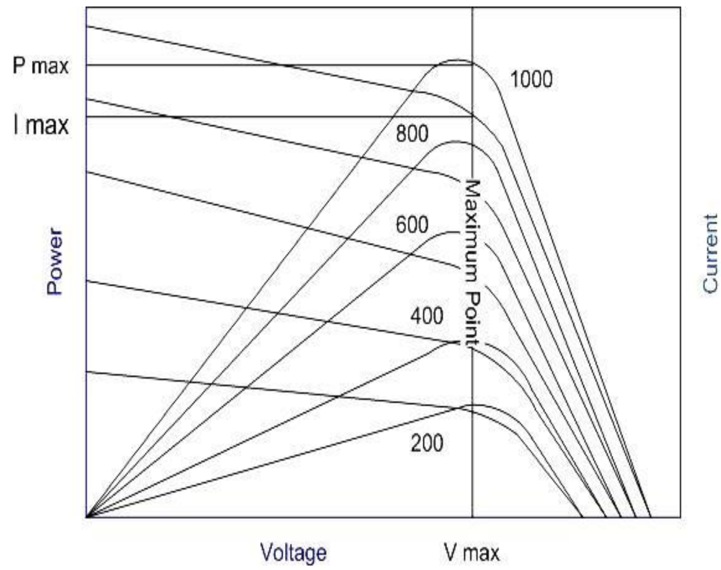

Fig 3 : Power vs. Voltage Curves & Voltage vs. Current Curve

Equation for design of PV Cell [1][15]:

$$I = Is - Io\left[e^{qv/KT} - 1\right] \quad (1)$$

$$Voc = \frac{kT}{q}\ln\left[\frac{Is}{Io} + 1\right] \quad (2)$$

$$P = V \times I = VIs - VIo\left[e^{qv/kT} - 1\right] \quad (3)$$

$$I = Is - Io\left[e^{q(v+IRs)/kT} - 1\right] - \left[\frac{V+IRs}{Rsh}\right] \quad (4)$$

Where

I = solar panel current (A)
V = voltage of the solar cell (v)
P = power of the solar cell (w)
I_S = short circuit current (A)
V_{OC} = open circuit voltage (v)
I_O = reverse current (A)
q = $1.602*10^{-19}$ (C), electronics charge (C)
k = $1.381*10^{-23}$ (J/K) (Boltzmann's constant)
T = temperature (K)

Table 1: Specifications of the Solar Cell [2] [7]

Voc (Open Circuit Voltage)	42.20V
Is (Short Circuit Current)	3.90A
Series Resitance, Rs	0.48Ω
Shunt Resistance, Rsh	1360Ω

4.2 P&O ALGORITHM FOR MPPT

Many algorithm proposed to control the switching of boost converter [5] [12]. P&O algorithm mainly used in applications because of its simplicity and easy control system. In this way it will move the working point towards the maximum power point (MPP), which is also shown in the Fig2. The panel voltage is checked by the controller [4] [6]. Perturbed means increased or decreased the voltage with comparing the previous voltage for deciding the next working power point as shown in Fig 4 [13]. Fig2 contains the flow chart of P&O which is simulated and coded in the language of Matlab using the Simulink tool.

Table 2: P&O algorithm steps

Perturbation	Power	Next Perturbation
Positive	Positive	Positive
Positive	Negative	Negative
Negative	Positive	Negative
Negative	Negative	Positive

4.3 DC BOOST CONVERTER

The function of DC boost converter is to step up the voltage from one level to the other level. The boost converter switches are controlled by the MPPT converter output. Input and output relation can be achieved by the relationship of gain [3].

$$\frac{Vo}{Vin} = \frac{1}{1-D} \quad (5)$$

Where, V_{IN} is input voltage, V_O is the output voltage and D is the duty cycle which is controlled by MPPT.

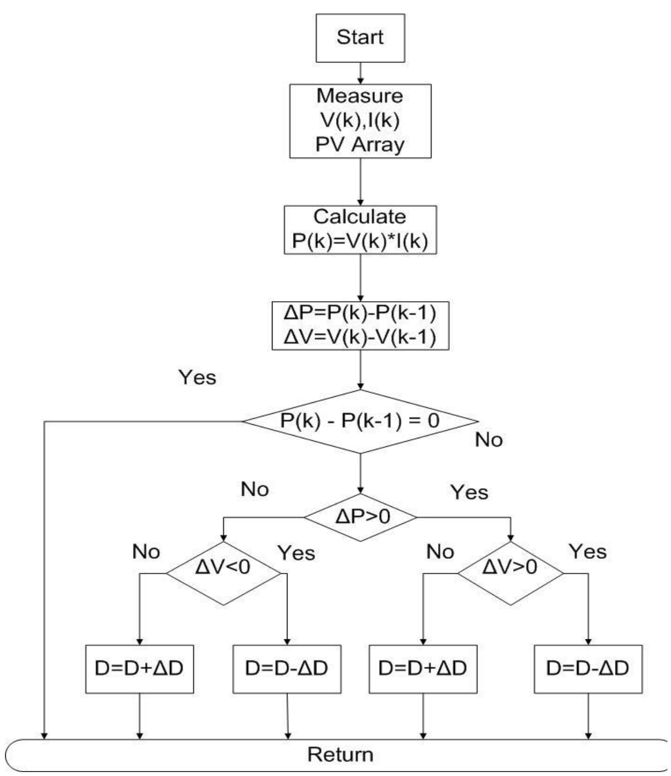

Fig 4: Conventional P&O Algorithm.

4.3.1 CONVENTIONAL DC-DC BOOST CONVERTER

This is most commonly used in the application where we need DC-DC boost circuit because it's small size and easy control. This converter can be design easily. Its design equation are as below [9] [17]:

$$\frac{\Delta I_L}{\Delta t} = \frac{V_i}{L} \quad (21)$$

$$\Delta I_{L\,on} = \frac{1}{L}\int_0^{DT} V_i dt = \frac{DT}{L} V_i \quad (22)$$

$$\Delta I_{L\,off} = \int_{DT}^{T} \frac{V_i - V_o}{L} dt = \frac{(V_i - V_o)(1-D)T}{L} \quad (23)$$

4.3.2 WORKING OF MICRO CONVERTER

Our proposed techniques consist the active network of two inductors of same inductance with switches S_1 and S_2 for the boost purpose which also refers as active network. If we connect the output of the active network (fig 5) with the number of capacitors then multi-level output will be seen [8] [9]. So, we can multiply the voltage gain. By considering practical application and simplicity in topology circuit. Therefore, proposed device has three-level converter as shown in Fig 7. Switches S_1 and S_2 works as operational signal. In order to design a three-level converter the diode D_1, D_2, D_3 and capacitors C_1, C_2, C_3 works together. Converter has two operating mode CCM (continuous conduction mode) and DCM (discontinuous conduction mode) as shown in Fig 6. g is the gain of the micro converter. For CCM mode its g_{ccm} and DCM mode is g_{dcm}.

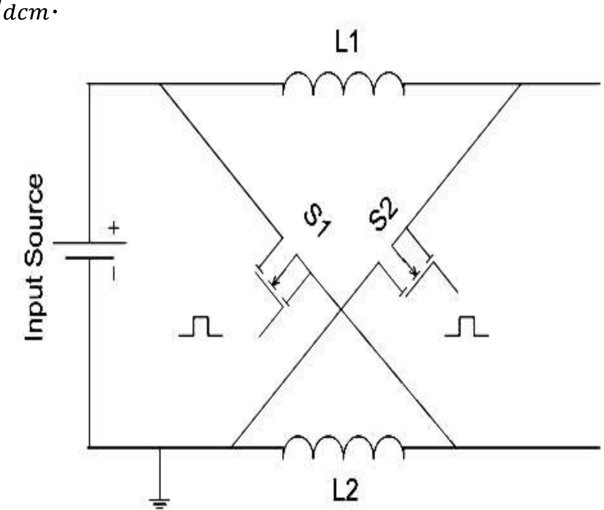

Fig 5 : Active network of Micro Converter

4.3.2.1 CCM Mode

CCM is consist of two states/modes. One states is that S_1 and S_2 both switches are in on states and other state in which S_1 and S_2 both the switches are in off states.

Mode 1, S_1 and S_2 both the switch are on for [t1, t2], during this time both the switched S_1, S_2 are in on-state. Both the inductors L_1, L_2 are charged by the DC source as in Fig 5. Capacitor C_3 charged by the C_1 as in Fig 7 and charges of C_1, C_2 capacitors are released to the load. So the Inductor voltages are:

$$V_{L1} = V_{L2} = V_{in} \quad (6)$$

By using the KVL loop through the DC source, S_1 and S_2, diode D_2, and the capacitors C_1 and C_3. Capacitor voltages can be find:

$$V_{in} + V_{C1} = V_{C3} \quad (7)$$

Mode 2, S_1 and S_2 both the switches are off for [t1, t2], during this time both the switches are in off-state. Energy stored in both the inductors L_1, L_2 and capacitor C_3 is released to charge the C_1, C_2 as in Fig 7. By using the KVL, C_1 and C_2 voltage can be find:

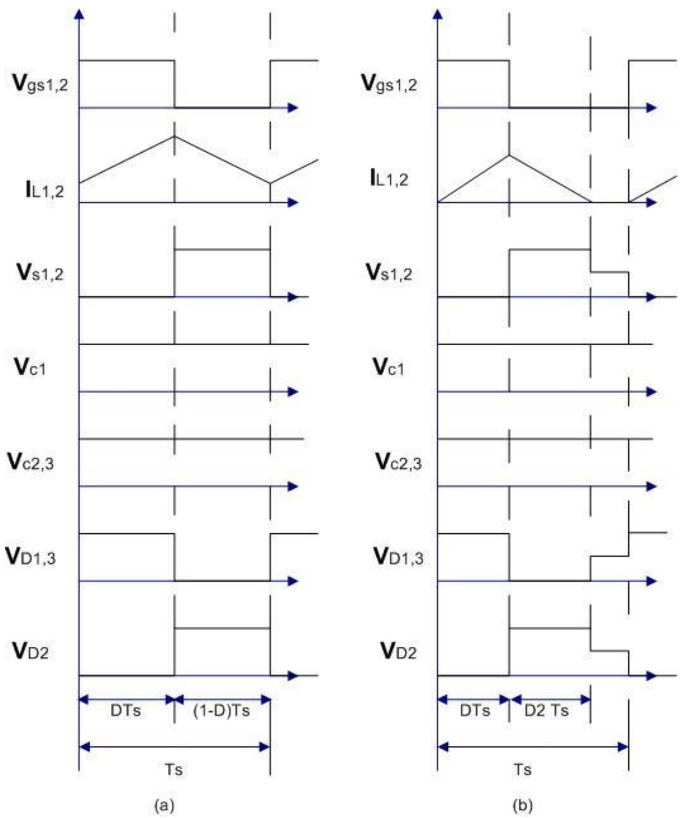

Fig 6 : (a) CCM mode (b) DCM mode [8]

$$V_{C2} = V_{C3} \quad (8)$$

$$V_{C1} + V_{C2} = V_o \quad (9)$$

From (7), (8), and (9) Capacitance we can drive:

$$V_{C1} = \frac{V_o - V_{in}}{2} \quad (10)$$

$$V_{C2} = V_{C3} = \frac{V_o + V_{in}}{2} \quad (11)$$

According to KVL, L_1 and L_2 voltage can be:

$$V_{L1} = V_{L2} = \frac{V_{in} - V_{C1}}{2} \quad (12)$$

By using the voltage balance principle L_1 and L_2, following equation can be find and simplified as:

$$g_{CCM} = \frac{V_o}{V_{in}} = \frac{3+D}{1-D} \quad (13)$$

4.3.2.2 DCM Mode

This mode can be divided into three modes. Two modes are same as CCM and last one in which inductors are also out of circuit. If system operates in this mode then the input current would be pulsed. Taking into consideration of the practical example, this will impact the life of the PV array. So simple, the voltage gain in DCM:

$$g_{DCm} = \frac{V_o}{V_{in}} = \frac{3+\sqrt{9+\frac{4D^2}{\tau}}}{2} \quad (14)$$

$$\tau = \frac{Lf_s}{R} \quad (15)$$

External Characteristics of the converter can be calculated by considering the capacitors current is zero during a switching cycle shown in Fig 7. So, Diode current can be calculated as:

$$I_{in} = I_{L1} + I_{L2} = 2I_{L1} - I_o \quad (16)$$

$$I_{D1} = I_{D2} = I_{D3} = I_0 \quad (17)$$

By simplifying the (16), (17) we have the average current of L_1, $L_{2:}$

$$I_{in} = \frac{V_o}{V_{in}} I_o \quad (18)$$

$$I_{L1} = I_{L2} = \frac{I_o + I_{in}}{2} \quad (19)$$

Average switches current $I_{a:}$

$$I_a = I_{L1} - I_o \quad (20)$$

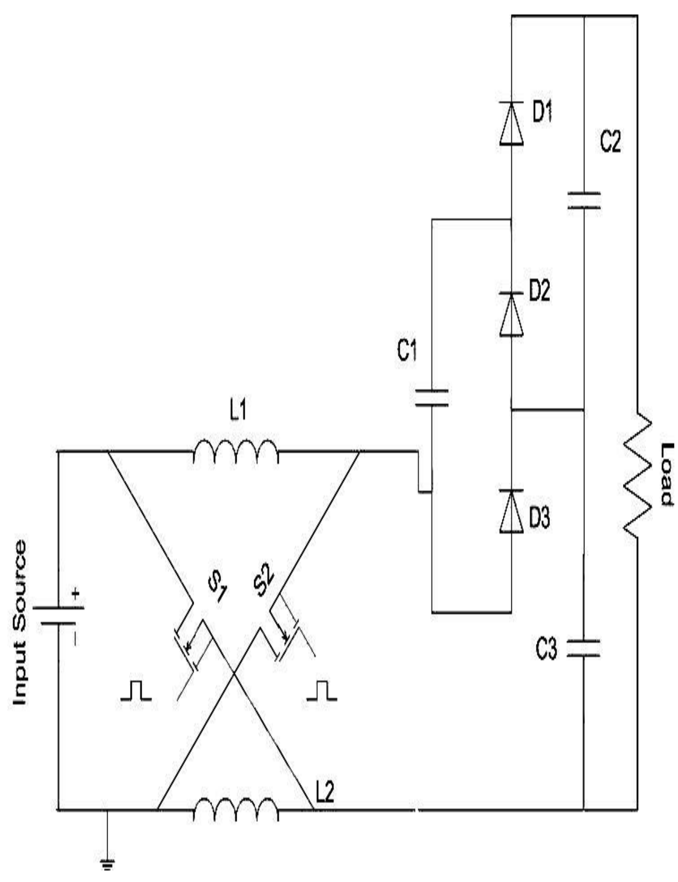

Fig 7: Multi-level Output of Micro Converter

5. SIMULATION & RESULTS

This research, first Micro converter simulation has been performed with MPPT with the Photo Voltaic as a source. Graphs of Micro Converter (Fig 8) and Boost Converter (Fig11) have been shown that result have been improved from in comparing it with the conventional boost converter. Resistive load is used to check the results of the micro converter and Boost Converter simulation. First, Micro

Converter simulation Fig 9 shows the total available power and output power of the system and Fig 10 shows the graph of output Voltage 200V and output Current 0.7A of the Micro Converter. Second, Conventional Boost Converter simulation (Fig 12) shows the available power and system output power and Fig 11 shows the graph of output Voltage 30V and output Current 8A of the Boost Converter. As we start our study to compare the voltage gain between Micro Converter and conventional DC-DC Boost Converter. Micro Converter can be used in the grid connected applications by using inverter portion because of high voltage gain.

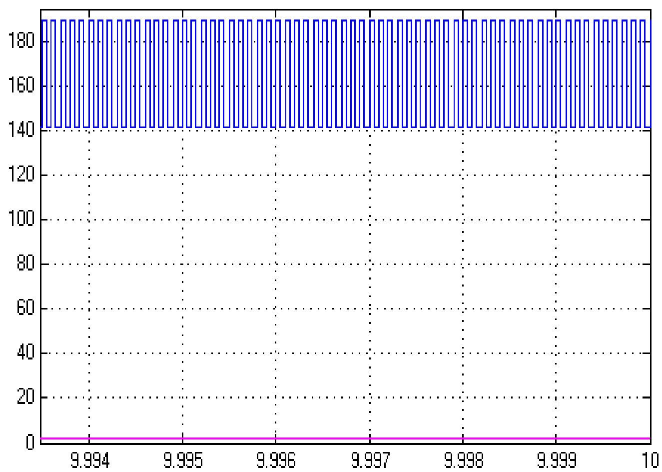

Fig 8: Graph of Micro Converter Voltage and Current

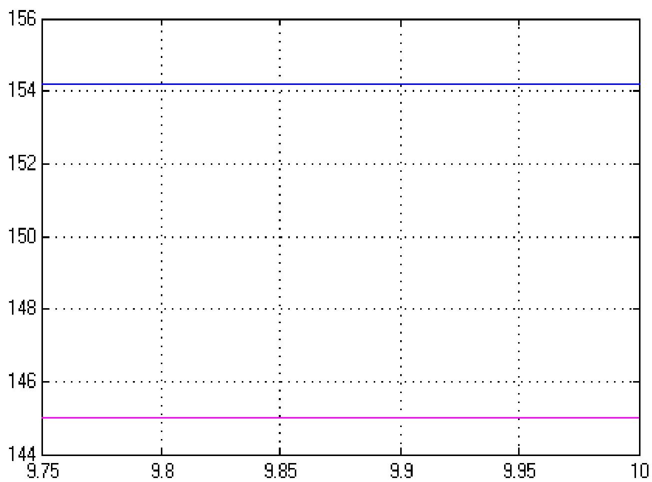

Fig 9: Graph of Total Available Power and Achieved Power through Micro Converter

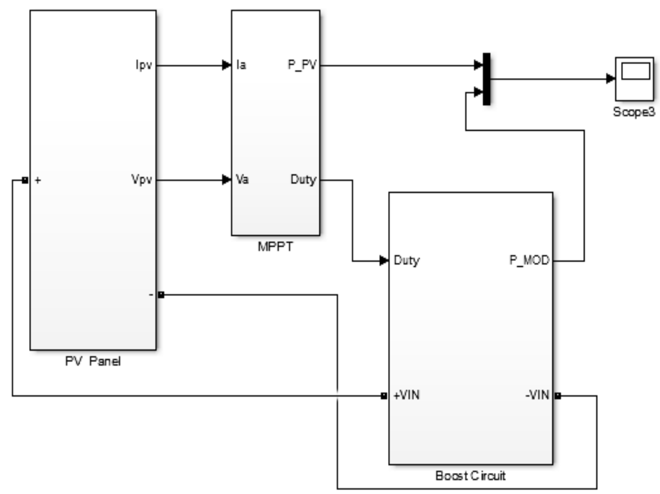

Fig 10: Simulation of Proposed System

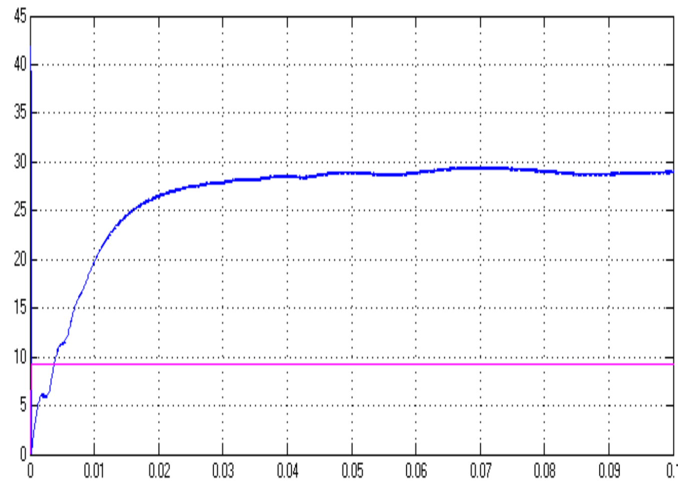

Fig 11: Graph of Boost Converter Voltage and Current

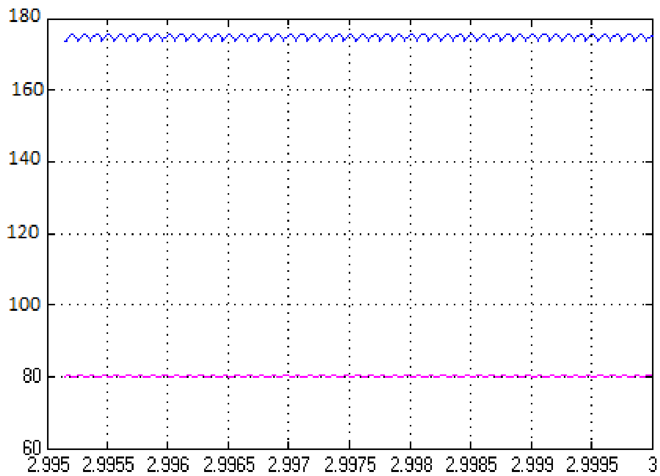

Fig 12 : Graph of Total Available Power and Achieved Power through Boost Converter

6. CONCLUSION

This paper concludes that the maximum power out of the Photo Voltaic system is achieved by connecting the boost converter. Main achievement is to improve the system efficiency with the micro converter which boost the DC-DC voltage with high gain and less voltage stress connected with the MPPT controller which takes maximum power out of the photo voltaic system. MPPT controller contains perturbation and observation (P&O) which gives the optimum output value for the duty ratio to control the switch for the maximum output. This simulation is done in matlab/ simulink software.

7. ACKNOWLEDGMENTS

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