

High Gain Multi Level Dual Load SEPIC Converter for Incremental Conductance MPPT

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Abstract- The studies on the photovoltaic system are extensively increasing because of a large, secure, essentially exhaustible and broadly available resource as a future energy supply. However, the output power induced in the photovoltaic modules is influenced by an intensity of solar cell radiation, temperature of the solar cells and so on. Therefore, to maximize the efficiency of the renewable energy system, it is necessary to track the maximum power point of the input source. This paper presents the modeling and simulation of incremental conductance (IncCond) Maximum Power Point Tracking (MPPT) using Multi level Single Ended Primary Inductance Converter (SEPIC) converter and compared its performance with self lift SEPIC converter. The solar panel model is developed using the basic circuit equations of photovoltaic cell. The MPP of a solar panel varies with irradiation and temperature. The IncCond algorithm is used to track the maximum power from the solar panel. The unregulated voltage from the panel will be regulated by using the Multi level SEPIC at the same time it can also supply the medium voltage and high voltage loads. The efficiency of the Multi level SEPIC converter over the self lift sepic converter has been tested by using Matlab/Simulink

Keywords- maximum power point tracking (MPPT), pv module, Multi level SEPIC Converter.

I. INTRODUCTION

According to the realization of high efficiency and low cost photovoltaic (PV) modules, interest in photovoltaic power generation system has increased over the past decade as a clean and infinite energy. The PV modules have maximum operating points corresponding to the surrounding condition such as intensity of the sunlight, the temperature of the PV modules, cell area, and load. When solar energy is used as a power source, the output power has to be maximized by improving the efficiency of the power conditioning equipment used and implementing an adaptive power controller that automatically tracks

the system to the point of maximum power delivered from the solar panel under all conditions. It is well known that a PV module consists of several PV cells connected in series in order to ensure a useful output voltage level. Assuming that the cells are identical, this level is calculated by summing each cell voltage. The functioning parameters [5] of the module depend mainly on the solar irradiance and on the cells temperature, as well as on the semiconductor material properties. For each meteorological condition there is a maximum power point (MPP) at which the system must work in order to deliver the optimal power to its load. The objective of the maximum power point trackers (MPPT) is to make the system [7] work in this point or near. The

functioning point of the system is the intersection between the module I-V curve and the load curve. 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. To track the maximum power a dc/dc converter is required with load voltage control. Dual converters are useful when dual output voltage levels are required from single input supply voltage with MPPT. Flyback converter is capable to produced dual output voltage levels but it required transformer. The gain of flyback converter depends upon the turns ratio of transformer. Sepic converter is used for step up and step down application [1]. High gain multilevel boost converter is used to step up the voltage level with large conversion ratio [2]. More number of switches and elements are required for generating dual output voltage level from conventional converters. Due to increases in number of switches and elements, converter circuit becomes more expensive and complex.

In this paper, sepic based dual output converter is proposed which is suitable for solar applications. The proposed converter topology is the combination of sepic and high gain multilevel DC-DC boost converter. High gain multilevel DC-DC boost converter combines the conventional boost converter and voltage multiplier functions. The gain of voltage multiplier circuit can be increases by adding diodes and capacitors. Circuit diagram of boost converter, voltage multiplier and sepic converter are depicted in Fig1. The main advantages of proposed

circuit topology are (i) dual output (ii) transformer less based design (iii) single switch.

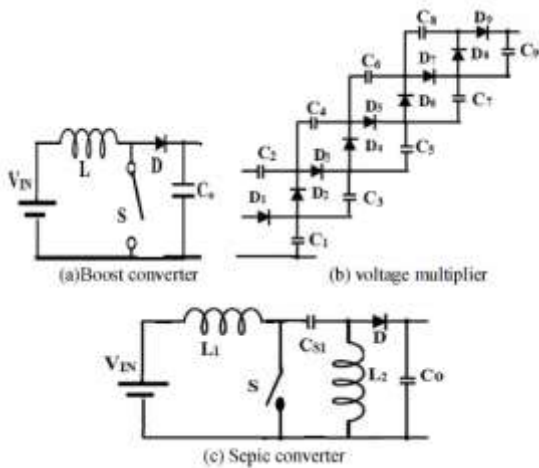


Fig.1 Circuit diagrams of boost, voltage multiplier and sepic converter

II. PV ARRAY MODELLING AND CHARACTERISTICS.

The power that one module can produce is seldom enough to meet requirements of a home or a business, so the modules are linked together to form an array. Most PV arrays use an inverter to convert the DC power produced by the modules into alternating current that can powerlights, motors, and other loads. The modules in a PV array are usually first connected in series to obtain the desired voltage; the individual strings are then connected in parallel to allow the system to produce more current The PV array is made up of number of PV modules connected in series called string and number of such strings connected in parallel to achieve desired voltage and current. The PV module used for simulation study consists of 36 series connected polycrystalline cells.

A. PV Model

The electrical equivalent circuit model of PV cell consists of a current source in parallel with a diode as shown in Fig.2.

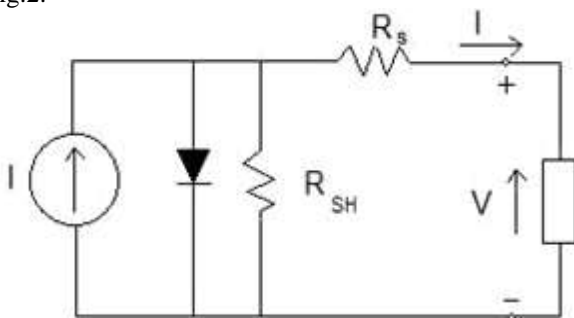


Fig.2. Electrical Equivalent Circuit Model of PV Cell

A Maximum Power Tracking (MPPT) circuit, which allows the maximum output power of the PV array. A Power Factor (PF) control unit, which tracks the phase of the utility voltage and provides to the inverter a current reference synchronized with the utility voltage. A converter, which can consist of a DC/DC converter to increase the voltage, a DC/AC inverter stage, an isolation transformer to ensure that the DC is not injected into the network, an output filter

to restrict the harmonic currents into the network. The MPPT algorithm, the synchronization of the inverter and the connection to the grid are discussed. Tracking the DC voltage and current allows MPP calculation which gives the inverter to function efficiently.

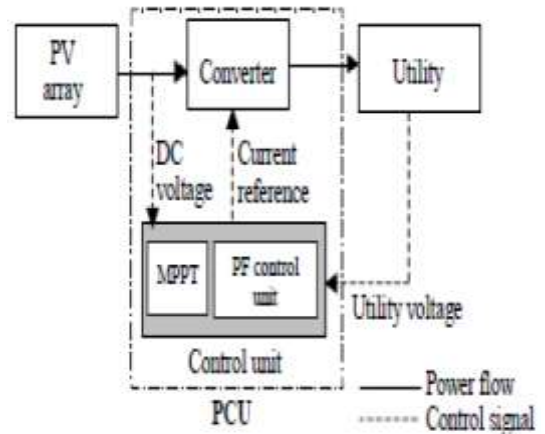


Fig.3. Schematic Diagram of Grid-Connected PV System

From the electrical equivalent circuit of the PV cell, PV output current (I_{PV}) is given by

$$I_{PV} = I_{ph} - I_D - I_{sh} \tag{1}$$

Where

$$I_D = I_0 \left(e^{\frac{q(V_{PV} + I_{PV}R_S)}{\eta kT}} - 1 \right) \tag{2}$$

And

$$I_{sh} = \frac{V_{PV} + I_{PV}R_S}{R_{sh}} \tag{3}$$

The parameters q , η , k and T denote the electronic charge, ideality factor of the diode, Boltzmann constant and temperature in Kelvin respectively. I_{ph} is photocurrent, I_0 is diode reverse saturation current, I_{PV} and V_{PV} are the PV output current and voltage respectively. As the value of R_{sh} is very large, it has a negligible effect on the I-V characteristics of PV cell or array. Thus (1) can be simplified to

$$I_{PV} = I_{ph} - I_0 \left(e^{\frac{q(V_{PV} + I_{PV}R_S)}{\eta kT}} - 1 \right) \tag{4}$$

III. Operating Modes of Self Lift SEPIC Converter

This converter performs DC-DC voltage increasing conversion in simple structure. The self lift SEPIC converter has two modes of operation.

1) Mode 1:

During the first mode of operation the switch will be turned on. The switch S, D_1 are on and diode D is off. During

switch-on period, the voltage across the capacitors C and C₁ are equal.

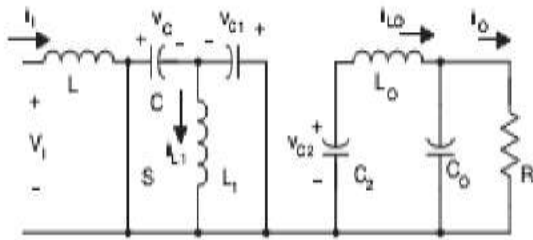


Fig.4. Electrical circuit of self lift SEPIC converter during switch ON period.

The equations for the switch conduction mode are as follows:

$$V_{c1} = V_c = V_1 \tag{5}$$

In steady state, the average voltage across inductor L₀ over a period is also zero.

Thus,

$$V_0 = V_{c2} = V_{c0} \tag{6}$$

The inductor current increases during switch on and it starts to decrease during switch off. The corresponding voltages across inductor L are input voltage V₁ and -(V_c V_{c1}+V_{c2}-V₁).

Therefore,

$$kTV_1 = (1-k)T (V_c - V_{c1} + V_{c2} - V_1) \tag{7}$$

and hence

$$V_0 = V_{c2} = V_{c0} = \frac{V_1}{(1-k)} \tag{8}$$

Since all the components are ideal, the power loss associated with all the circuit elements is neglected. Therefore the output power P_o is considered to be equal to the input power P_{IN}:

$$V_0 I_o = V_1 I_1 \tag{9}$$

$$I_L = I_1 = \frac{I_o}{(1-k)} \tag{10}$$

2) **Mode 2:** During the switch-off condition, diode D is on, switch S and diode D1 are off. The inductor current decreases and diode D is forward biased and the capacitor C is charged by using the input supply.

The capacitor C₀ acts as a low pass filter so that

$$I_{L0} = I_o \tag{11}$$

The current i_L increases during switch-on. The voltage across it during switch-on is V₁, therefore its peak to peak current variation is

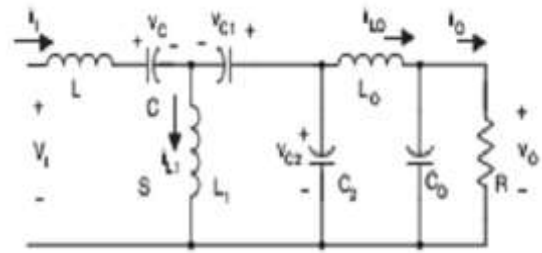


Fig.5. Electrical circuit of self lift SEPIC converter during switch OFF period.

IV. OPERATION OF MULTI LEVEL SEPIC

Power circuit diagram of proposed sepic based dual output DC-DC converter is depicted in Fig.6. In the proposed converter only one input source and switch is required to obtain two output voltages at the same time. One output voltage is obtained through 5-level multilevel boost converter and other output voltage is obtained through sepic converter. Sepic converter operates in two modes, step-up or step-down depending on duty cycle. When duty cycle is less than 0.5, sepic converter is operated in step-down mode. When duty cycle is greater than 0.5, sepic converter is operated in step-up mode. The output

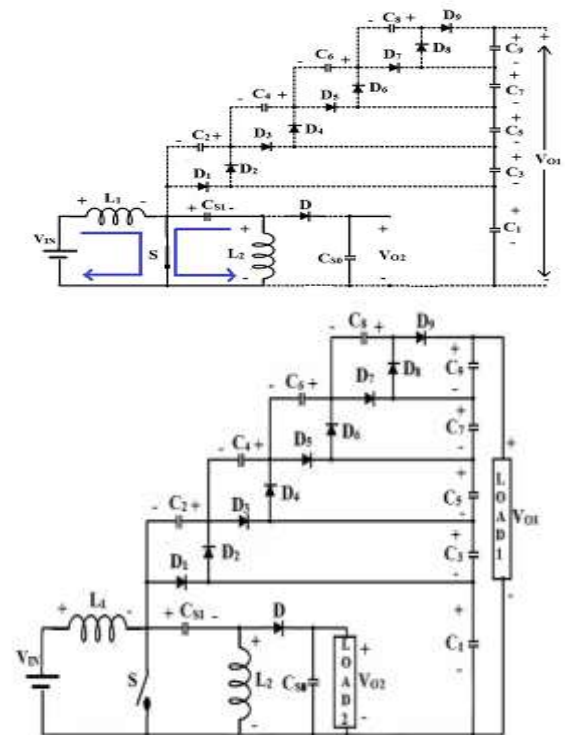
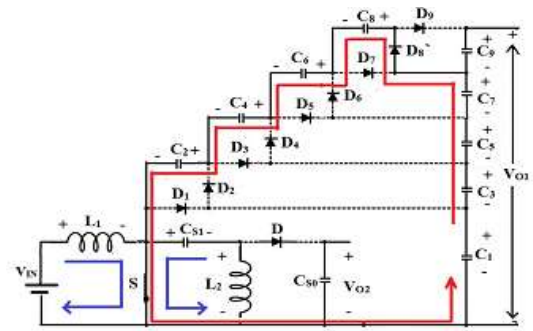


Fig.6. Power circuit diagram of proposed converter

voltage levels of high gain multilevel boost converter can be increases by adding diodes and capacitors without disturbing main sepic converter circuit.

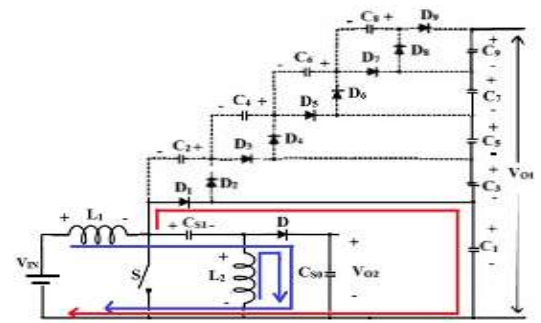
Modes of operation

The operation of the sepic based dual output DC-DC converter can be divided into two modes, when switch S is turned ON and another when switch S is turned OFF. In mode I, switch S is turned ON, the inductors L1 and L2 are charges from the input source and capacitor C_{s1} respectively. Capacitor C₁ clamps the voltage across capacitor C₂ through D₂ and switch S, when D₂ is forward biased . Voltage V_{c1}+V_{c3} clamp the voltage V_{c2}+V_{c4} through 04 and switch S, when D₄ is forward biased. Voltage across voltage V_{cZ}+V_{c4}+V_{c6} is clamp by voltage V_{c\}+V_{c3}+V_{cS} through 06 and switch S, when D₆ is forward biased. Similarly voltage V_{cZ}+V_{c4}+V_{c6}+V_{cS} is clamp by V_{c_i}+V_{c3}+V_{cS}+V_{c7} through 0s and switch S, when D₈ is forward biased. The current direction and operating modes, when switch is turned ON is shown in Fig 7 (a-c). In mode 2, switch S is turned OFF, the inductors L1 and L2 are discharges through D and D₁. The inductor current and input voltage charges the capacitors C₁ through 0\). Capacitors of the sepic converter C_{s1} and C_{s0} are charges from input voltage and inductors current through o. when 03 is forward biased, voltage V_{1N}+V_U+V_{c2} clamps the voltage V_{c1}+V_{c4}. Voltage V_{c1}+V_{c3}+V_{cS} is clamp by voltage V_{TN}+V_U+V_{c2}+V_{c4} through 0s, when 05 is forward biased. When 07 is forward biased, voltage V_{TN}+V_U+V_{c2}+V_{c4}+V_{c6} is clamp the voltage V_{c1}+V_{c3}+V_{cS}+V_{c7} through 07. Similarly, when 09 is forward biased, voltage V C_i+V C₃+V_{cS}+V_{c7}+V_{c9} is clamp by voltage V_{1N}+V_U+V_{cZ}+V_{c4}+V_{c6}+V_{c8} through 09. The current direction and operating modes, when switch is turned OFF is shown in Fig.8.(a-b).

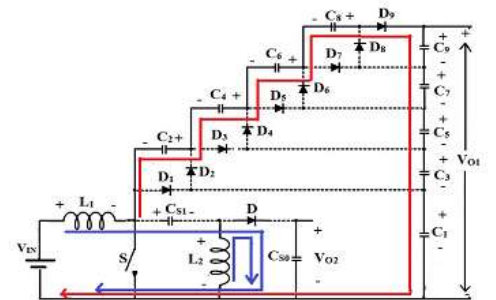


(c)

Fig.7. Operating Modes when switch S is ON



(a)



(b)

Fig.8. Operating Modes when switch S is OFF

ANALYSIS OF PROPOSED CONVERTER

When switch S is closed, both inductors L1 and L2 will charges from input voltage and capacitor C_{si} respectively.

$$V_{L1} = V_{IN} \tag{12}$$

$$V_{L2} = -V_{CS1} \tag{13}$$

Voltage V_{c2} is charges from voltage V_{c1}

$$V_{C1} = V_{C2} \tag{14}$$

Similarly,

$$V_{C1} + V_{C3} + V_{C5} + V_{C7} = V_{C2} + V_{C4} + V_{C6} + V_{C8} \quad (15)$$

When switch S is open, both inductors will discharge

$$V_{L1} = V_{IN} - V_{CS1} - V_{O2} \quad (16)$$

$$\frac{V_{O2}}{V_{IN}} = \frac{D}{1-D} \quad (17)$$

Voltages across all multiplier capacitors are equal

$$V_{O1} = V_{C1} + V_{C3} + V_{C5} + V_{C7} + V_{C9} \quad (18)$$

$$V_{O1} = 5 V_{C1} \quad (19)$$

Thus, the conversion ratio for proposed converter is

$$\frac{V_{O1}}{V_{IN}} = \frac{5}{1-D} \quad (20)$$

$$\frac{V_{O2}}{V_{IN}} = \frac{D}{1-D} \quad (21)$$

V. MATLAB/SIMULINK ANALYSIS

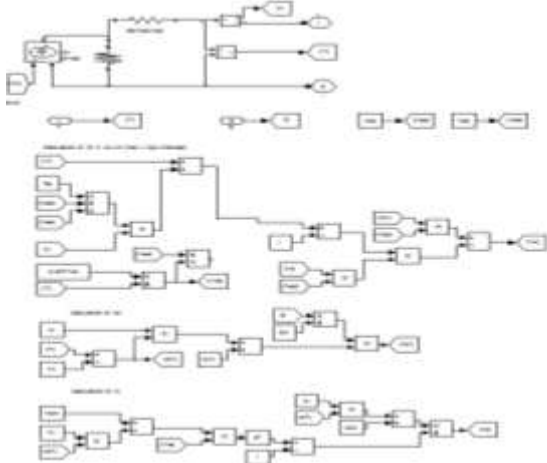


Fig.9. Mathematical model of photo voltaic cell.

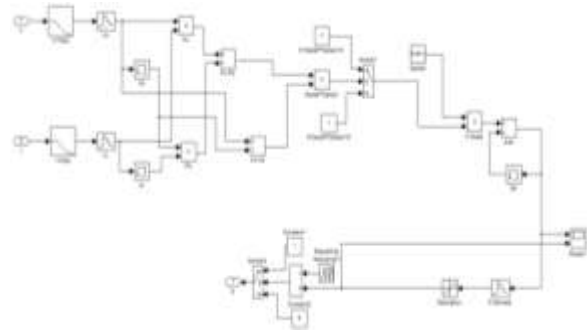


Fig.10. Simulink model of Incremental Conductance based MPPT.

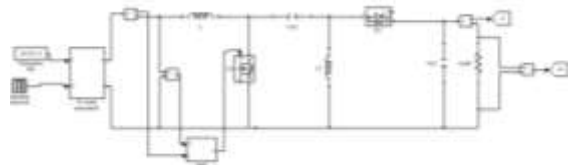


Fig.11. Simulink model of SEPIC with IC MPPT.

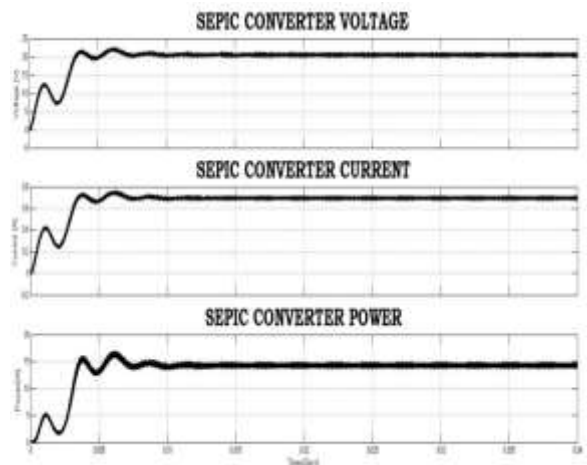


Fig.12. Simulated output wave form of SEPIC converter output voltage, current and power.

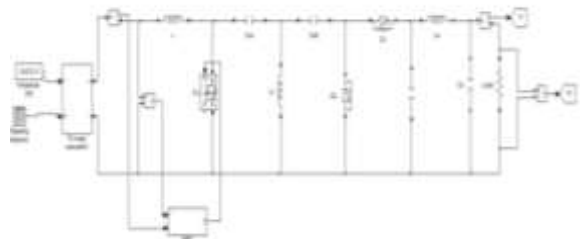


Fig.13. Simulink model of Self Lift SEPIC Converter with IC MPPT.

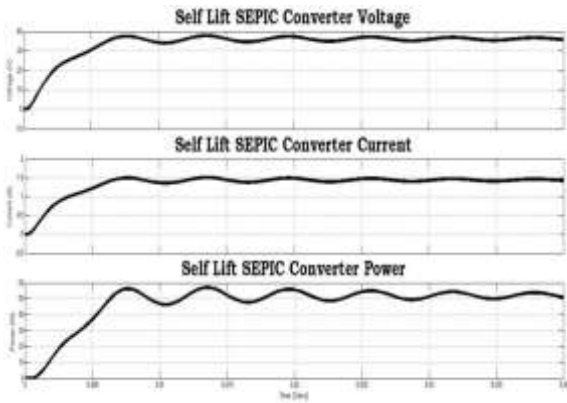


Fig.14. Simulated output wave form of Self Lift SEPIC converter output voltage, current and power.

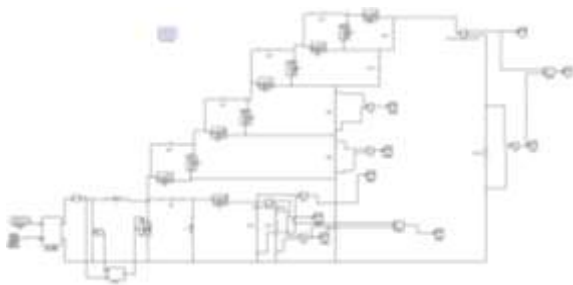


Fig.15. Simulink model of Multi level Sepic converter.



Fig.16. Simulated output wave form of High Gain SEPIC Converter Voltage.

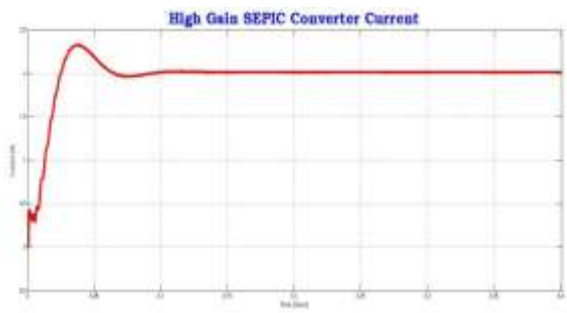


Fig.17. Simulated output wave form of High Gain SEPIC Converter.

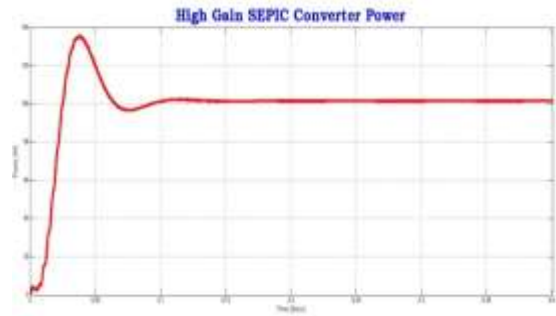


Fig.18. Simulated output wave form of High Gain SEPIC Converter.

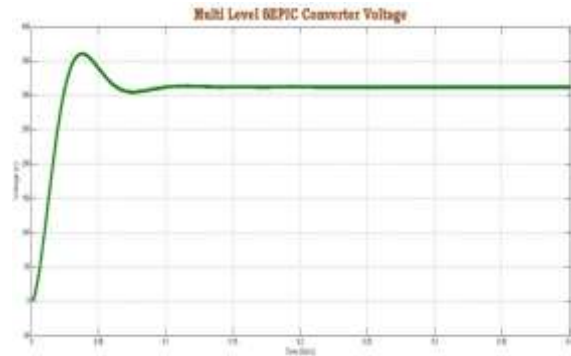


Fig.19. Simulated output wave form of Multi Level SEPIC Converter Voltage.

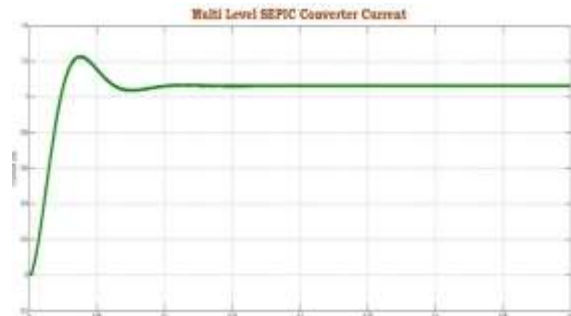


Fig.20. Simulated output wave form of Multi Level SEPIC Converter Current.

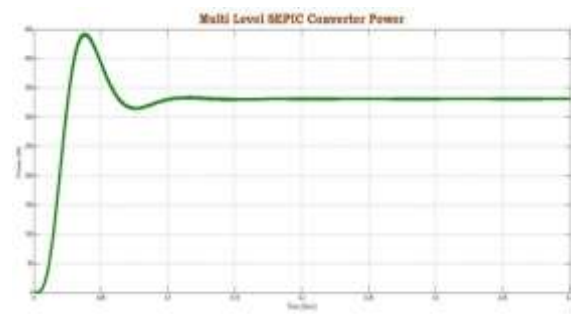


Fig.21. Simulated output wave form of Multi Level SEPIC Converter Power.

VI. CONCLUSION

This paper proposes High Gain multi level SEPIC with IC MPPT method with dual output load voltages that requires only measurements of voltage and current. The proposed Incremental conductance MPPT algorithm increases the efficiency and it tracks the maximum power from the

irradiation. This method computes the maximum power and controls directly the extracted power from the PV by changing the duty cycle in the Multi level SEPIC converter. The voltage produced by High Gain Multi level SEPIC converter is higher when compared to Self lift SEPIC converter. The proposed method offers different advantages which are: good tracking efficiency, response is high and well control for the extracted power and also for load voltage control.

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