Design and Simulation of DC-DC Converters for Photovoltaic System

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Abstract: - The importance of solar energy for future energy supply has been growing vigorously with the growing concerns about the price and availability of fossil fuels. Renewable energy sources such as solar energy has received tremendous demands since it is pollution-free from any poisonous byproducts that can pollute the environment. DC-DC converters are widely used in renewable energy generation systems that is in solar photovoltaic (PV) system. The basic PV system consists of PV panels, electric converter. The output power from the PV module or array depends upon the irradiance and temperature which are constantly varying. Therefore for these purpose we can use the converters. The converters transmits the power from PV to the load should have higher efficiency. The main advantage of the converter is that this are provide a regulated output. And this DC-DC converter are mainly designed to meet specific demand of DC loads. Therefore, a DC-DC converter are used to produce a constant voltage and deliver maximum power from PV panel to the load. We will use the converters based on MOSFETs switches.

The main objective of dissertation is 1) to design and simulate the various DC-DC converters, 2) to obtain the stable voltage of DC-DC converters and to compare their performance and 3) selection of suitable DC-DC converters for Photovoltaic System. This dissertation presents simulation and designing of PV array connected to load through DC-DC converter such as Boost converter, Cascaded Buck-Boost converter, Cuk and Single ended primary inductance converter (SEPIC) etc. are modeled in MATLAB and their results are compared.

Key Words: —*PV, MATLAB, DC-DC Converters.*

I. INTRODUCTION

The use of Renewable energy especially the solar energy is increasing rapidly due to its various advantages. Modeling, simulation and analysis of solar photovoltaic (PV) generator is a vital phase prior to mount PV system at any location, which helps to understand the behavior and characteristics of the solar cell or panel. The performance of PV system depends upon the sun radiation and temperature. The generalized block diagram of PV system with dc to dc converter is shown below:
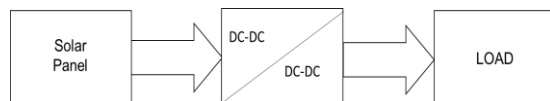

Fig.1. Block diagram of PV system with DC to DC Converter

In these generalized block diagram the solar panel is connected to the load through DC to DC Converter. A DC-DC converter connected to produce a constant voltage and deliver a maximum power from PV panel to load. The output voltages of dc-dc converters are generally controlled by using a switching concept. Converters based on MOSFETs switches are used.

The purpose of this paper is to present an introduction and functioning of a PV device and write its basic equations as well as Simulation of PV panel and Simulation of the various types of DC to DC Converters used for the PV/Solar system with its comparison.
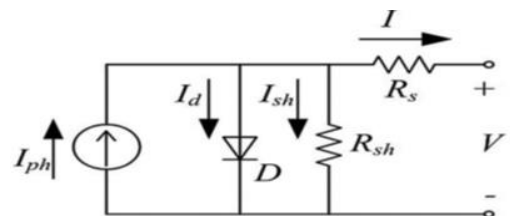
II. SIMULATION OF PV PANEL

Fig.2. Equivalent circuit of Solar cell

The equivalent circuit of an ideal PV cell consists of a current source (iph) and a diode (D) connected in anti-parallel with the current source A general model of the solar cell is consist of mainly the current source (Iph) connected in anti-parallel to a diode 'D' and the current through it is (Id), series resistance (Rs) and shunt resistance (Rsh).

Fig.2 shows the general model of solar cell. The solar cell required two input:- 1)Temperature and 2)Irradiance. So the values for these inputs needed for the mathematical modelling are considered as follows:-

Irradiance (Gn) =1000w/m^2

Temperature (To) =30 degree Celsius

The basic equation from the theoretical operation of semiconductors that mathematically describes the I-V characteristic of the ideal photovoltaic cell is:-

$$Ipv = Iph - Id - Ishunt \qquad (1)$$

$$Ipv = Iph - Io[exp(Vpv + Rs*Ipv/n(nkT/q) - 1] - [Vpv + Rs*Ipv/Rsh] \qquad (2)$$

$$Iph = Isco (G/Go) (1 + a1 (T - To)) \qquad (3)$$

$$Io = Ioref (T/To)^3 \{exp [(qEg/nKb) (1/To) - (1/T)]\} \qquad (4)$$

Where, Ipv is the current generated by the irradiation of sun light, Id is the Shockley diode equation, Io is the reverse saturation or leakage current of the diode, q is the charge of an electron =1.60217646x10−19C, k is the Boltzmann constant= 1.3806503x10−23J/K, T is the temperature in Kelvin, and *a* is the diode ideality constant=*0.4e-3.*

Here already discussed earlier that how we can represent a solar cell in terms of mathematical equation. The module, which is to be designed, is provided with the values and parameters from the data sheet.

From the simulation we expect the solar cell output to give up to do an open circuit voltage of 40 volts and short circuit current of 8.6 ampere. With reference to these parameters below is the Simulation and IV-PV characteristics of solar cell are shown:-
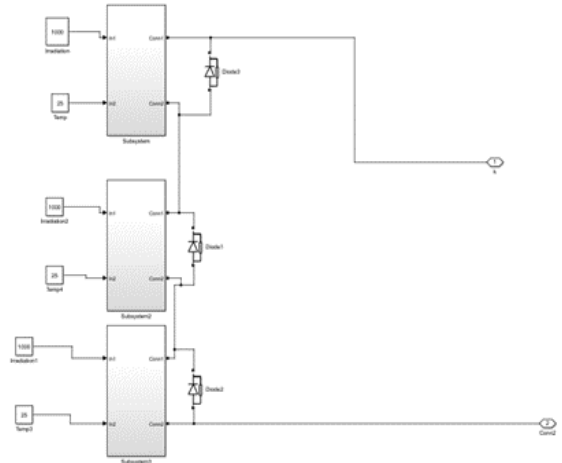

Fig.3. MATLAB Simulation of Solar cell

The solar panel is constructed using three solar modules connected to each other. The input to these panels are taken to be constant as per above given values of input.Temperature and irradiance affects the solar module. They greatly affect the characteristics of PV modules. This characteristics of solar cell shows that the change in current when voltage is zero to when voltage is higher that is open circuit voltage is constant for a while and when voltage reaches to its maximum point the current drops suddenly. This justify that at a low voltage outputs also the current value is constant and nearly up to short circuit current of the module.
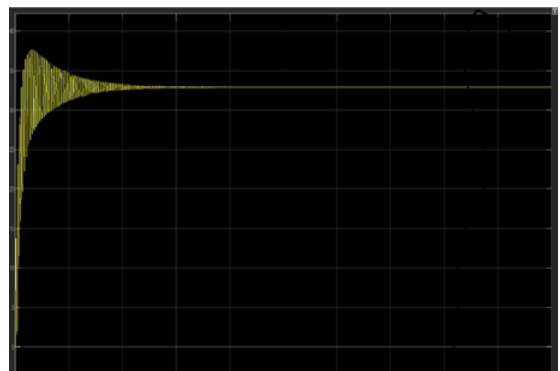
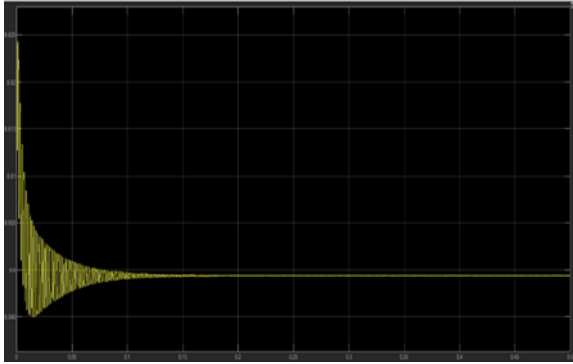

Fig.4. Output voltage of solar cell

Fig.5. Output Current of Solar module

III. DC-DC CONVERTERS AND SIMULATION

Each circuit in electronics is assumed work on some supply voltage, which generally considered constant in nature. DC to DC converter are the power electronics circuits in which the input is unregulated dc voltage and output is constant or regulated voltage. These DC to DC converters are used to convert the dc voltage to another level of dc voltage. There are variety of DC to DC converters but out of all these converters, in this paper we can study and simulate only the following listed converters:
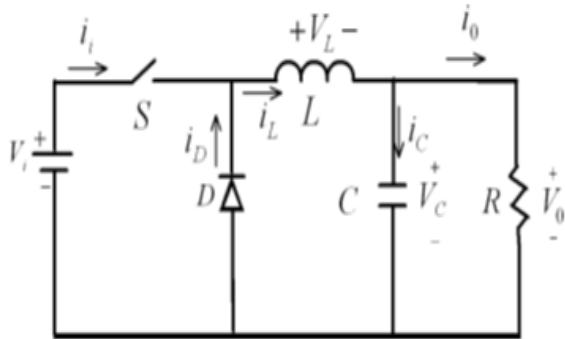
A. Buck Converter

Fig.6. Circuit diagram of buck converter

A Buck converter is a step down converter which in turns steps down a DC voltage from the input supply voltage to the output. Operation of this converter is depends on the operating state of Switch. The switch operating states are as follows:-1) If the switch is Closed or **ON** the current flowing through the inductor is increases and the diode blocks. 2) If the switch is Open or **OFF** then the current flowing through the inductor is sharply changes and the diode starts to conduct then the inductor current is decreasing due to transformation of energy from the inductor up to the capacitor. In these converter, if the duty cycle D=0

then the output voltage Vo=0 and if the duty cycle D=1 then Vo=Vin. So in between some limits the Vo in Continuous conduction mode is given by the formula:-Vo=D*Vin. The Matlab Simulink model in fig. (a) Consisting of the DC voltage source at input and scope is connected at the output to show the output voltages waveform. The output of buck converter is given by, Vo=Vin*D ; Vo<Vin
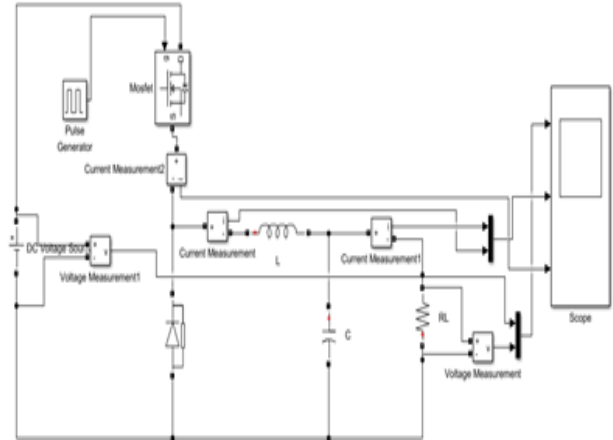

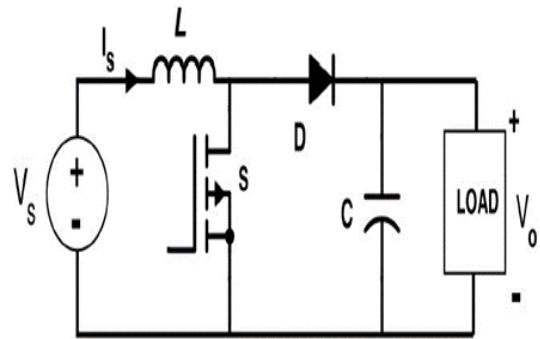Fig.7. Simulink model of buck converter

B. Boost Converter

Fig.8. Circuit diagram of boost converter

The boost converter is a converter, which increases the output voltage than that of the input; which means it boost the voltage at the output.

In these boost converter the energy goes to the load when the switch is opens. Output of boost converter is given by:- Vo=Vin*1 / (1-D) ; Vo>Vin.

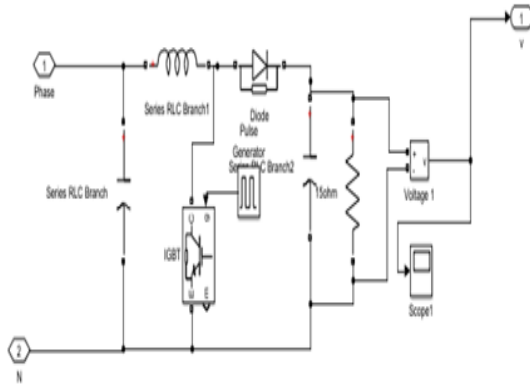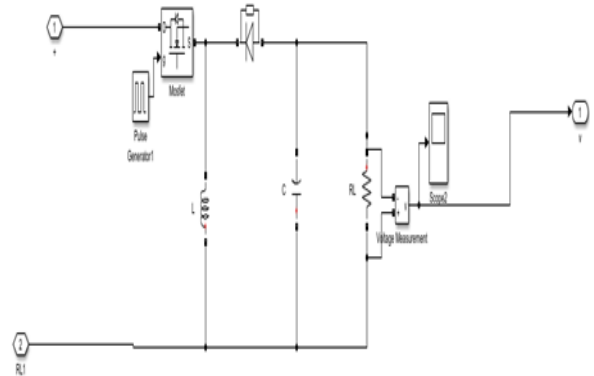The matlab Simulation diagram of boost converter is given below in Fig.9.

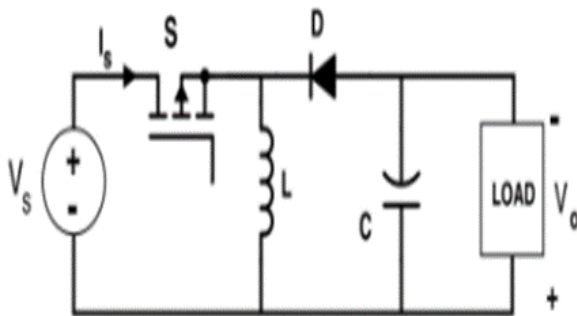Fig.9. MATLAB Simulation of boost converter

C. Buck-Boost Converter

Fig.10. Circuit diagram of buck-boost converter

In these buck boost converter its name itself suggests that it is a step up or down the voltage from input to the output. Depending upon the value of duty cycle the converter decides that the converter operates as a buck or boost. The basic working of buck-boost converter is has a MOSFET which in turns controlled the current in the circuit. It converter consist of two operating mode -1) Continuous conduction mode and 2) Discontinuous Conduction Mode. Usually a continuous conduction mode is applied for efficient power conversion. So, here we can only worry about only the continuous conduction mode i.e. CCM. The output of this converter can be change by changing the duty cycle of the converter. For the duty cycle of less than 0.5these will work as a buck and for the duty cycle greater than0.5 it work in a boost mode. Mathematically it can be express as Buck < D=0.5 < Boost. The output voltage of the

buck-boost converter is Vo=D*(Vin/ (1-D)). The Simulation diagram of Buck-Boost converter is as shown below:

Fig.11. MATLAB Simulation of buck-boost converter
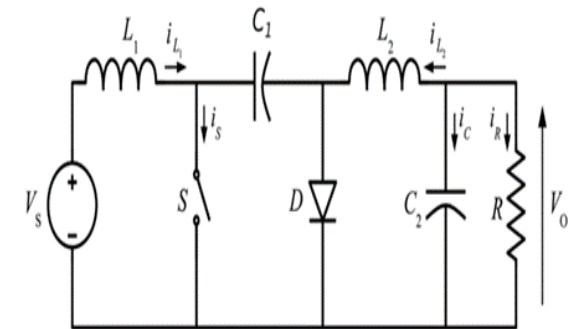
D. Cuk Converter

Fig.12. Circuit diagram of Cuk converter

The cuk converter is in fact a combination of buck as well as the boost coverter.it have the zero ripple current. Cuk converter alter a DC voltage at the input to the DC voltage at the output with reversed polarity. In comparison with the other converters the Cuk converter is use extra capacitor and inductor for the energy storage purpose. The cuk converter maintain the continuous voltage to the load regardless of the deviation at the input voltage.

This converter gives the maximum efficiency, as the switching losses are less with the continuous input current. The output of cuk converter is given by:- Vo=-Vin*(D/1-D).

All the related theory discussion is done above. So, now we can simulate these model Fig.13. Shows the matlab simulation of the Cuk converter.
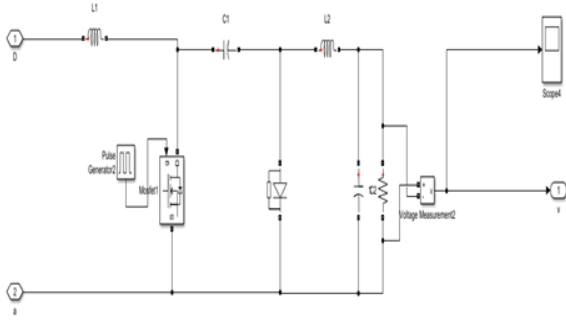
Fig.13. MATLAB Simulation of Cuk converter
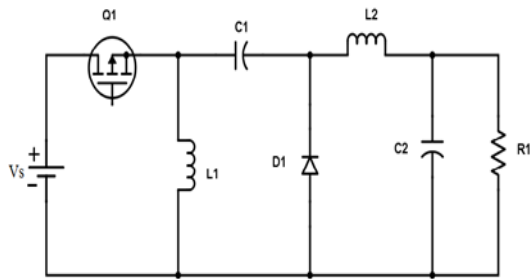
E. Zeta Converter

Fig.14. Circuit diagram of Zeta converter

The Zeta Converter delivers a positive voltage at its output. Its output is varies beyond or less the input Voltage. The zeta converter requires a two capacitor, two inductor, diode and Switch (Here we use MOSFET as a switch as it having its own advantages).The output voltage of zeta converter can be given as: - Vo=Vin*(D/ (1-D)).

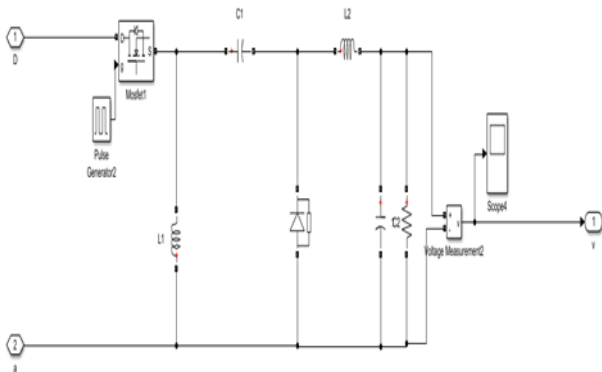Matlab simulation of zeta converter is shown in Fig.15. As follows:-

Fig.15. MATLAB Simulation of Zeta converter
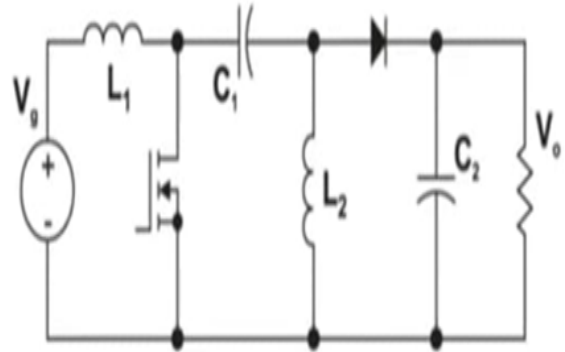
F. SEPIC Converter

Fig.16. Circuit diagram of SEPIC converter

In this type of converter in which SEPIC is stand for Single Ended Primary Inductor Capacitor.

SEPIC converter is a type of DC-DC converter which gives the output voltage is equal to or less than or greater than the input voltage. The output of these converter is controlled by the switch S1.Sepic converter is operates in two modes first is continuous conduction mode and second is discontinuous conduction mode & it can be controlled by the duty cycle of the switch.

This converter allows the voltage at the output, which is greater than, less than or equal to that of the input voltage. The half part of this converter is quite similar to that of buck-boost converter but it has the advantage of having the polarity of output voltage is same as that of input voltage.

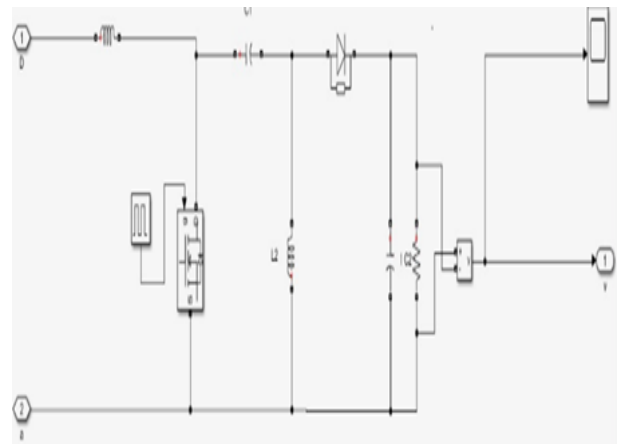The formula for the output voltage Vo of the SEPIC converter is same as that of the zeta converter.

Fig.17. MATLAB Simulation of SEPIC converter
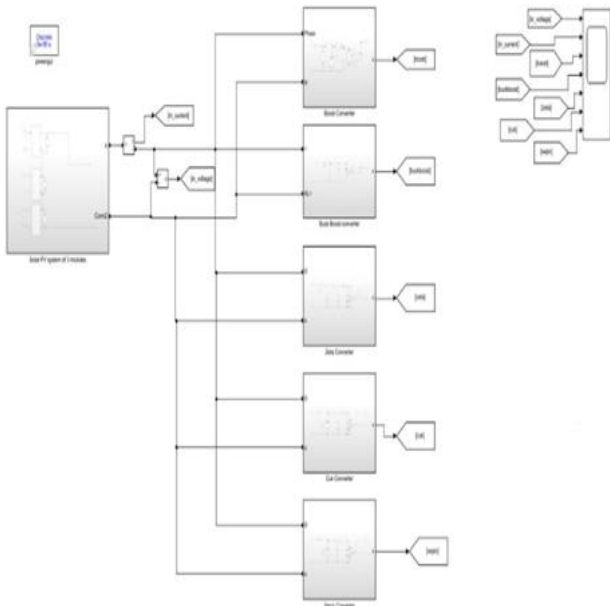
IV.   COMPARISON OF CONVERTERS IN MATLAB

Fig.18. Simulation of all converter

Above figure shows the all converter that is Boost converter, buck-boost converter, cuk converter, SEPIC converter and zeta converter, which all are taking input from the PV panel .The comparison of all the converters, which are getting input from the solar cell, is done in Matlab. The comparison of all the converter is done on some parameters which we will evaluated in the following Section.

V.   SIMULATION RESULTS AND DISCUSSION

All related theory and simulations are discussed in previous section. In our proposed simulations, the exact theoretical implementation can be done in MATLAB simulation to design the converters. The important parameter are thus provided from the library and these parameters are connected in the same way as described in the theoretical approach. The values of all component are provided from the theoretical calculations and hence the output obtained is shown below. In this section will discussed about the results of the previously discussed simulations:-

The output results which will show the output of buck converter is shown in figure below:
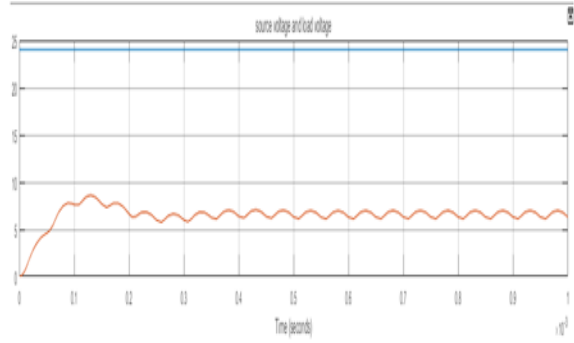

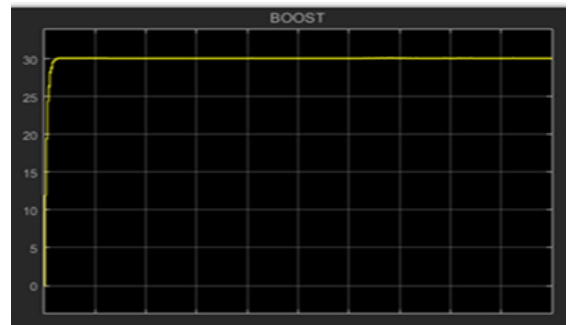Fig.19. Buck Converter source and load voltage

Fig.20. Boost Converter

The boost converter is simulated using MATLAB/Simulink. The Fig.20. Shows the output voltage obtained from the simulation.
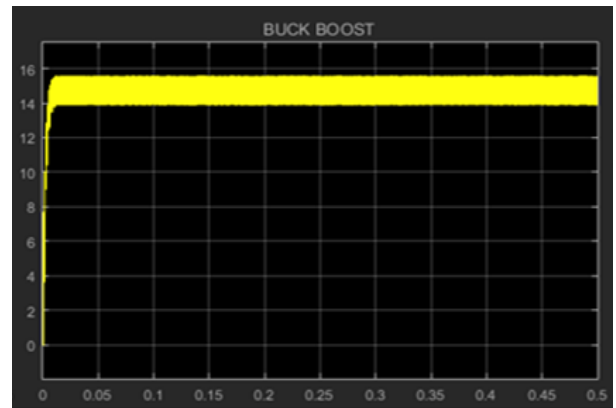

Fig.21. Buck Boost Converter

The results obtained from the Buck Boost converter are shown in above Fig.21.The simulation performed with the input voltage and for these the output voltage is as given in figure.
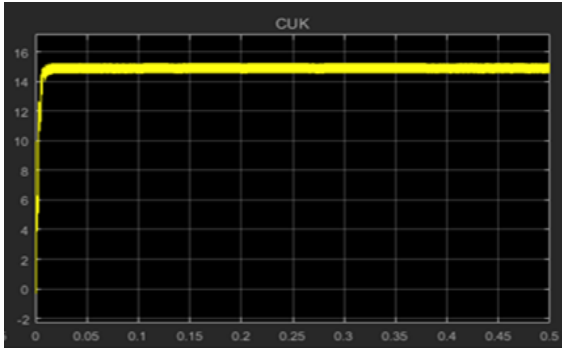
Fig.22. Cuk Converter

Fig.22. shows the simulation results of the Cuk converter. Which in turns give the output voltage of 15V.

Fig.23. Zeta Converter

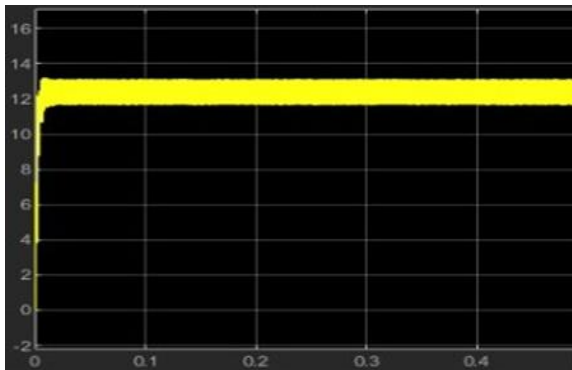The output of zeta converter is shown in Fig.23. Zeta converter

Fig.24. SEPIC Converter

Above graph shows the output of SEPIC converter

VI. CONCLUSION

This paper analyses and studies the performance of a PV system and Various Converters implemented using MATLAB/Simulink. The model including solar panel to converter is tested successfully and hence the analysis is done

for load changes converter to converter. From the proposed converters, we have simulated in these paper and compared those converters on the basis of various parameters. It is found that the converter has their unique advantages over one another. And hence the selection of converter for a particular application is depends on the type of application and the requirements of system.

REFERENCES

[1]. Ms. Mona Marodkar, Mrs. Sarala Adhau, Mrs. Manisha Sabley, and Mr. Praful Adhau "Design and Simulation of DC-DC Converters For Photovoltaic System based on MATLAB ",2015 International conference on industrial instrumentation and Control IEEE conference 2015.

[2]. Kun Ding, XinGaoBian, HaiHao Liu and Tao Peng, "A MATLAB Simulink-Based PV Module Model and its Application under condition of No uniform Irradiance", IEEE Transactions On energy conversion, vol. 27, No. 4, December 2012.

[3]. M.S.Sivagamasundari, Dr.P.Melba Mary, V.K.Velvizhi,"Maximum Power Point Tracking for photovoltaic system by peturb and Observe Method Using Buck Boost conveter", International journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol.2, Issue 6, June 2013.

[4]. Nor Hanish Baharudin, Tunku Muhammad Nizar Tunku Mansur, Fairuz Abdul Hamid, Rosnazri Ali & Muhammad Irwanto Misrun, "Topologies of DC-DC Converters in solar PV Applications" (IJEECS), Vol.8, No.2, pp-368 - 374, November 2017.

[5]. Mr. S. Sheik Mohammed College of Engineering, Dhofar University, PB. No. 2509alalah, Sultanate of Oman E-mail: ssheikmd@yahoo.co.in Simulation and Analysis of Stand-alone Photovoltaic System with Boost Converter using MATLAB/Simulink.