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ZETA CONVERTER FOR ELECTRIC VEHICLE BATTERY CHARGER

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Abstract – A Zeta converter is a DC-DC converter which works as a buck-boost converter with a non-inverted output. This paper focuses on a battery charger for an electric vehicle based on zeta converter fed from a pv array. The control technique used here is perturb & observe technique to get the appropriate duty ratio of the gate pulse for the switch of zeta converter and to achieve the maximum power point from pv array. This technique is used for this mission due to its simplicity and its quick response to achieve the mpp and can be easily implemented in low cost system. In this a complete analysis of the zeta converter applied as a photo voltaic battery charger is carried out. The proposed system is simulated using MATLAB Simulink.

Keywords: Battery charger,DC-DC converter, Photovoltaic, MPPT, Zeta converter.

I. INTRODUCTION

The EVs that are widely used worldwide can be either hybrid EVs or battery EVs. The hybrid EVs is composed of an internal combustion engine in addition to an electrical rechargeable battery. The battery will be charged while the vehicle is moving through the regenerative braking. The battery EVs can also be charged from an electrical external charging outlet. The battery charger must be built by using a DC-DC converter. EVs have to contain a DC-DC converter which is used to convert from one voltage level to another. Some battery chargers can be built with conventional buck-boost, Cuck or SEPIC converters .

The proposed system will be built using a zeta converter. Zeta converter is a fourth order DC-DC converter. It acts as a conventional buck-boost but with a non-inverted output voltage polarity. In another word, the input and the output terminals have the same ground.

Zeta converter is similar to that of a buck-boost converter,it has an advantage of non-inverted output.It has a wider range of duty ratio than any other converter.The converter exhibits improved power factor, low input current distortion,low output current ripple and wide output power range[7].

A boost converter is a DC-DC converter in which output voltage is greater than input voltage,while stepping down a current.As the control input appears in both voltage and current equation,the controlling of boost converter is difficult[3].Problem that exist in the buck-boost converter is needed greater filter inductor and capacitor on input ana output sides,because the converter topologies such as this produces a very high ripple current[3].

The output voltage of the buck-boost and Cuk have reverse polarity with the input voltage,where as Zeta converters have the same polarity between the input signal with the output. Cuk converter, current and voltage signals on the input side had a low ripple and require a lot of components compared with the buck-boost[5].

Smallest ripple current and voltage at the output side occurred in the Zeta converter when compared to the other converters and small ripple level is considered to be very good in the process of tracking the maximum power point of photovoltaic. Maximum power point tracking signal occurred best in zeta converter circuit where signal levels ripple current and voltage on the output side were very small[8].

The zeta converter is proposed to charge the EV battery from photovoltaic array.The PVarray is composed of 12 mono crystalline panels each of 280 watts.Acontrol technique is required to get the appropriate duty ratio of the gate pulse for the switch of zeta converter and also to achieve the Maximum Power Point(MPP).The Peturb and Observe technique is used for this mission due to its simplicity and its quick response to achieve the MPP .

II. PROPOSED CONVERTER CONFIGURATION

The proposed battery charger shown in Fig. is composed of a Zeta DC-DC converter, a PV array, and a control algorithm to operate the system. In this work, operating the Zeta converter is managed by the P&O control technique. The P&O is generating the appropriate gate signal for S1 to achieve either buck or boost outputs. In addition, it achieves the MPP of the PV array

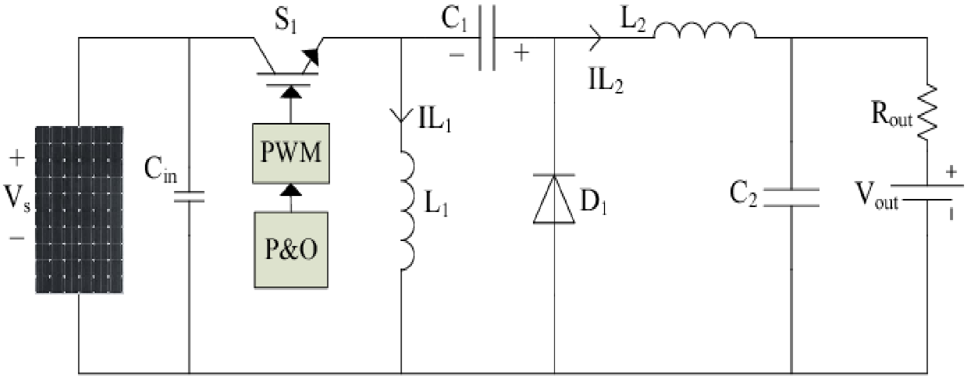

Fig -1: Circuit Diagram of Proposed Converter

The input voltage and current from the PV array are the input signals for the P&O The proposed battery charger The incremental step of the P&O is the change in the duty cycle to reach the MPP properly. In order to achieve the MPP of the panel to control the Zeta converter, operating in the buck and the boost modes, the incremental step is adjusted to 0.001. Initially, the duty cycle is set at 0.5 and the converter works in a floating mode where Vs is the same value of Vout. The P&O updates the duty cycle by the incremental step and the mode of zeta converter is set automatically. The zeta converter will be supplied through twelve 280 W mono crystalline PV panels. Six panels are connected in series to form a string and then two strings are connected in parallel to form the PV array.

III. ZETA CONVERTER

A zeta converter is a fourth-order DC-DC converter made up of two inductors and two capacitors and capable of operating in either step-up or step-down mode. The Zeta converter has received the least attention and more importantly, its dynamic modeling and control have never been reported before in the literature. Similar to the SEPIC DC/DC converter topology, the zeta converter topology provides a positive output voltage from an input voltage that varies above and below the output voltage. The zeta converter also needs two inductors and a series capacitor, sometimes called a flying capacitor. Unlike the SEPIC converter, which is configured with a standard boost converter, the zeta converter is configured from a buck controller that drives a high-side PMOSFET. The zeta converter is another option for regulating an unregulated input-power supply, like a low-cost wall wart. To minimize board space, a coupled inductor can be used.

PRINCIPLE OF OPERATION

Fig below shows a simple circuit diagram of a zeta converter, consisting of an input capacitor C_{in}, an output capacitor C_{out}, coupled inductors L_{1a} and L_{1b}, an AC coupling capacitor C_c, a power PMOSFET Q1 and a diode D1. Figure shows the ZETA converter operating in CCM when Q1 is on and when Q1 is off.

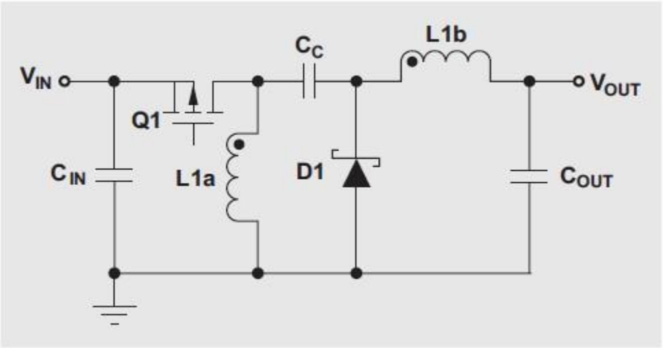

Fig-2 Zeta Converter

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This first stage is defined by the on time t_{on} of switch S1 and is shown in Fig.10. In this stage, the AC mains supply energy to the input inductor (L_{1a}). This energy is subsequently transferred to the output inductor L_{1b} through the intermediate capacitor C1. The current in the input inductor (i_{L1a}) and output inductor (i_{L1b}) increase linearly. The output DC-link capacitor voltage V_{dc} and the intermediate capacitor voltage vc1 are considered constant in this stage. They are equal to the DC voltage V_{dc}. In the first stage of converter operation, the inductor current for 0 < t < t_{on} can be defined as:

$$i_{L1a} = i + \left(\frac{V_{IN}}{L_{1a}}\right) t \qquad \ldots\ldots(1)$$

$$i_{L1b} = -i + \left(\frac{V_{IN}}{L_{1b}}\right) \qquad \ldots\ldots(2)$$

Where i_{L1a} and i_{L1b} represent the current flowing in input inductor L_{1a} and output inductor L_{1b} .Voltage V_{IN} is an absolute value of the sinusoidal input voltage (V_{IN} =V(s)|=V_S sin(ωt)).

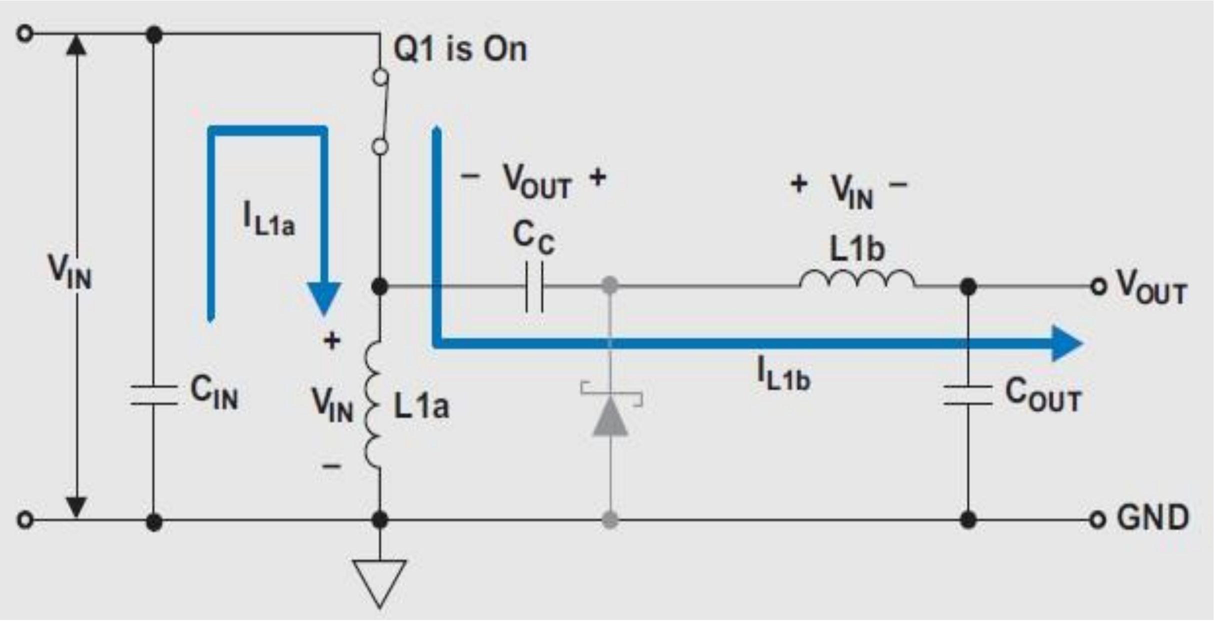

Fig-3 : First stage of opeartion

In the second stage operation of the Zeta converter, switch Q1 is turned off and diode D1 starts conducting. The stored energy from the input inductance (L_{1a}) and output inductance (L_{1b}) are transferred to the intermediate capacitor C_c and the DC link capacitor filter (C_{OUT}), respectively.

This stage continues until i_{L1a} becomes equal to the negative of i_{L1b} as shown in Fig.11. In this stage of Zeta converter operation, switch Q1 is off and diode D1 is on for t_{don} time. The inductor currents i_{L1a} and i_{L1b} for the duration, t_{on} <t <t_{don} are given as:

$$i_{L1a} = i + \left(\frac{V_{IN}}{L_{1a}}\right) DT_s - \left(\frac{V_{dc}}{L_{1a}}\right) t \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

$$i_{L1a} = -i + \left(\frac{V_{IN}}{L_{1b}}\right) DT_s - \left(\frac{V_{dc}}{L_{1b}}\right) t \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

Where D is the duty ratio of the switch and is equal to t_{on}/T_S while T_s is the switching period.

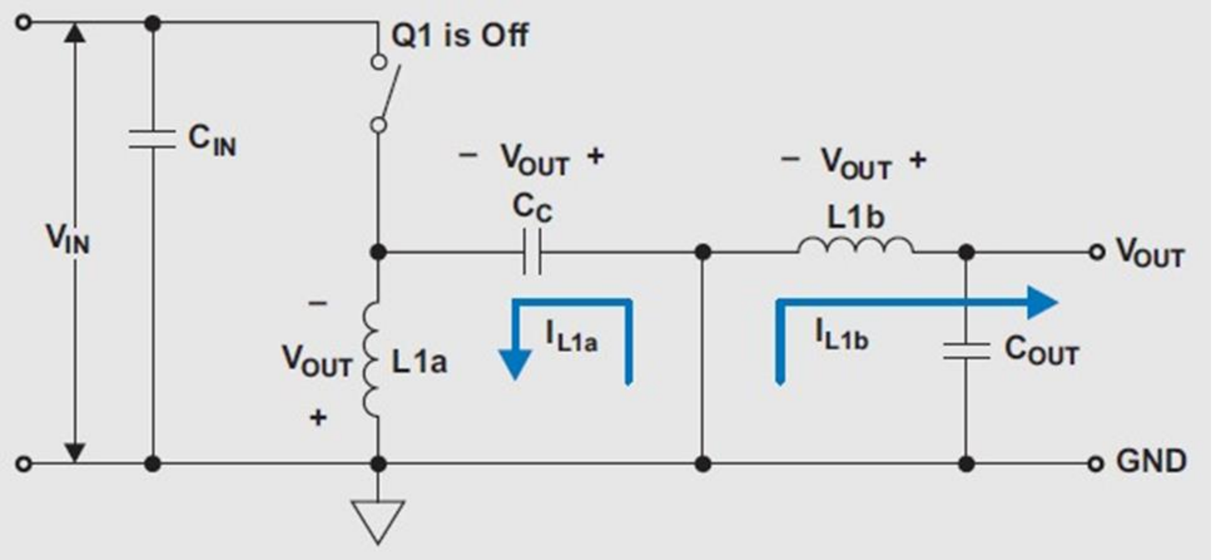

Fig -4: Second stage of operation

The mathematical State Space Representation (SSR) of the Zeta converter can be obtained by applying Node and Mesh analysis at the two modes of operation of the converter.

Equation below gives the relation between the input and the output voltages of Zeta converter in terms of the duty-ratio (K) of the switch (S1) gate pulse.

$$\frac{Vout}{Vs} = K/(1-K)$$

The maximum current (I mpp)

from the PV array can be calculated as

$$Impp = Impp\ per\ module \times No.of\ module\ per\ arrays$$

The input current for the EV battery (IDCB) can be calculated as.

$$I_{DCB} = P_{mpp}/V_{OUT}$$

The currents flowing through various circuit components are shown in the figure.When Q1 is on,energy from the input supply is being stored in input inductor,output inductor and intermediate capacitor.

When Q1 turns off,input inductor current continues to flow from current provided by intermediate capacitor,and output inductor again provides Iout.

When analyzing Zeta waveforms it is helpful to keep in mind that at equilibrium,input inductor average current equals Iin and output inductor average current equals Iout,since there

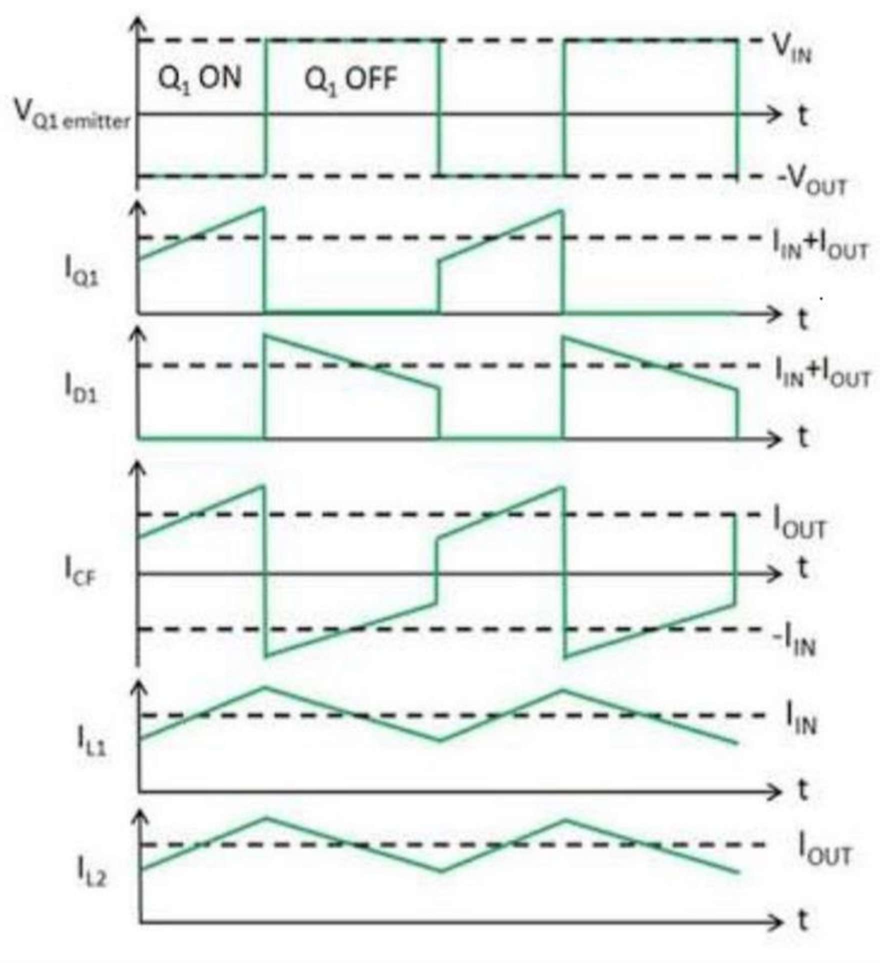

Fig-5 Waveforms of Zeta converter is no DC current through the intermediate capacitor. Also there is no DC voltage across either inductor.Therefore,intermediate capacitor sees ground potential at its left side and Vout at Its right side,resulting in DC voltage across intermediate capacitor being equal to Vout.

The Zeta converter parameters (L 1, L2, and C1) can be designed to work in the Continuous Conduction Mode (CCM). The CCM mode always results in stress reduction on the converter's components. In addition, the CCM offers low ripples on the output side because of the presence of inductor L2. Consequently, better MPP results will be achieved

In this Zeta converter is controlled by P&O method. The controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called the perturb and observe method and is most common, although this method can result in oscillations of power output.

It is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted.

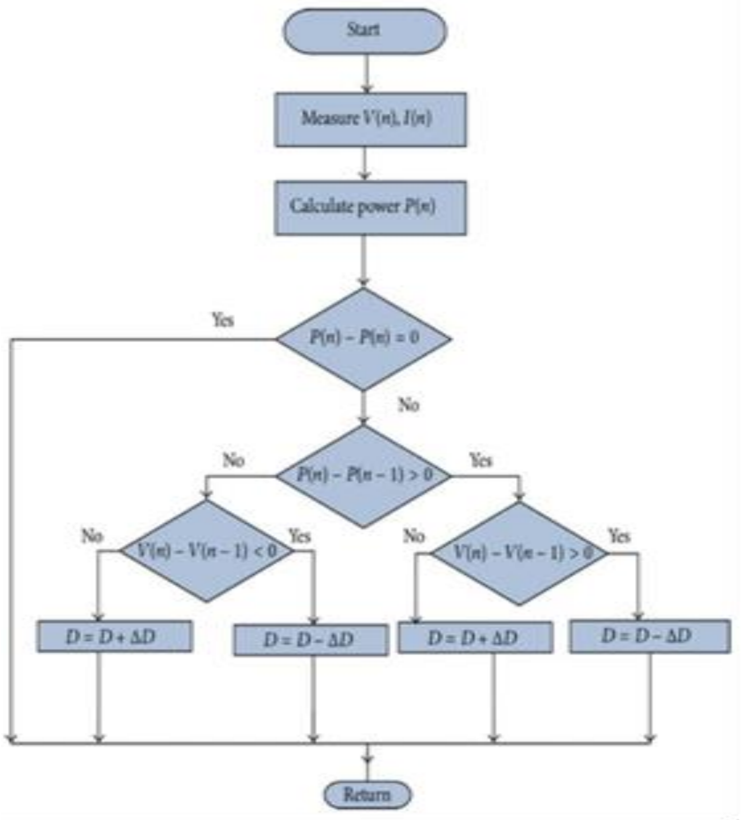

FIG -6 P&O Method Algorithm

In P and O MPP algorithm,a small perturbation is introduced in every iteration to alter the duty cycle in order to force the operating point to move near the MPP.This algorithm compares the power of the previous step cycle with the power of the new step cycle to determine the next perturbation direction.If the power increases due to perturbation then the perturbation will remain in the same direction.If the peak power is reached, the power at the next instant decreases and hence,the perturbation reverses.When the steady state is reached ,the algorithm oscillates around the peak point.In order to keep the power variation small the perturbation size is kept very small.The operation of PO MPP algorithm is illustrated in the above figure

PV solar systems exist in many different configurations with regard to their relationship to inverter systems, external grids, battery banks, or other electrical loads. Regardless of the ultimate destination of the solar power, though, the central problem addressed by MPPT is that the efficiency of power transfer from the solar cell depends on both the amount of sunlight falling on the solar panels and the electrical characteristics of the load. As the amount of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes, so that the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the *maximum power point* (MPP) and MPPT is the process of finding this point and keeping the load characteristic there. Electrical circuits can be designed to present arbitrary loads to the photovoltaic cells and then convert the voltage, current, or frequency to suit other devices or systems, and MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out.

IV. SIMULATION

For the simulation of the proposed scheme, the simulink models of PV array and the algorithm are to be developed and integrated to obtain the overall model. As shown in figure, the simulation has been run at different values of solar irradiance to evaluate the dynamic performance of the proposed system. Often the temperature doesn’t change hugely during the day; therefore, all the simulation results on this work consider the change of the solar irradiance only at constant temperature (25C) .A change in the duty cycle range has to specify whether buck or boost mode is activated . Figure shows that the two modes of Zeta converter (buck and boost) have been achieved through chang- ing the duty cycle from approximately 0.48 to 0.52 when the irradiance is reduced from1000W/m2 to 500W/m2. It is worth to be mentioned that the PO generates the duty cycle based on the measured PV voltage and current.

The behavior of Zeta converter is illustrated in Fig. Both inductors are operating at charging and discharging modes, simultaneously during buck and boost modes. The in- ductors currents have been changed due to varying the solar irradiance from 1000 W/m2 to 750 W/m2. It can be noticed that the maximum current for L1 is obtained within the buck mode at 1000 W/m2 irradiance.

The PV current is displayed in figure also demonstrates the extracted power from the PV array. Figure indicates that at 1000 W/m2 the maximum power from the PV array is obtained and by decreasing the irradiance to 750 W/m2 the power is reduced. At 500 w/m2, the extracted power from the PV array is further reduced.

It is worth mentioning that the output power oscillates around the MPP due to the continuous perturbation of the PO technique. The proposed system charges the battery with the extracted PV power around the 200V level as illustrated . A slight change in the output voltage that can be neglected occurs at the battery terminals due to variation of the duty cycle.

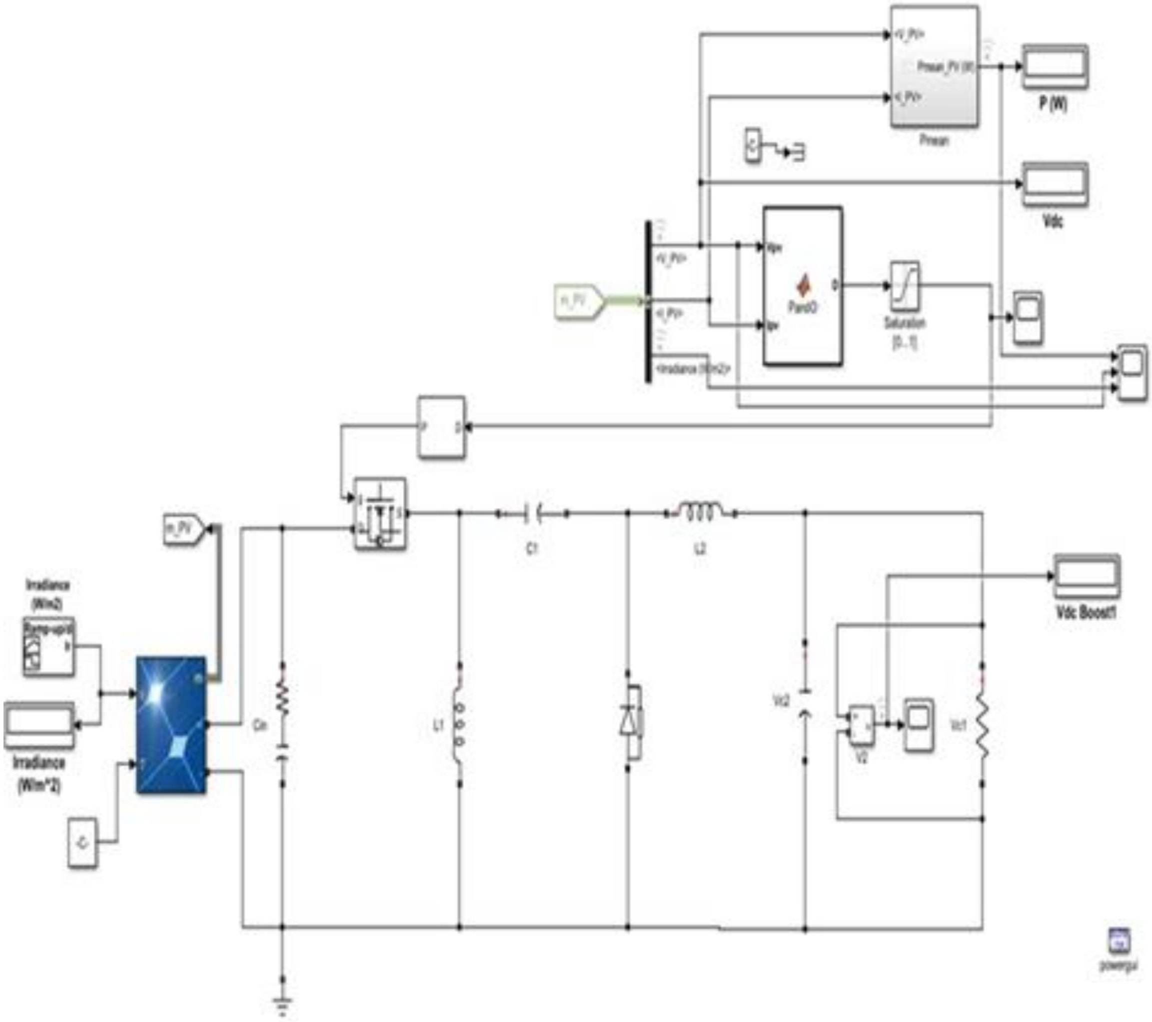

Fig -7: Simulation of proposed converter with solar PV

Figure demonstrates the PV trajectory during the MPPT under different irradiances. The MPPs are clearly indicated in the figure. The MPP has been achieved at approximately 225 V and 3560 W at 1000 W/m2. By reducing the solar irradiance, the PO achieves the new MPP. By changing the solar irradiance, PV voltage and current are changed. Finally, the PO manages to get a new duty cycle that will swap from buck to boost mode

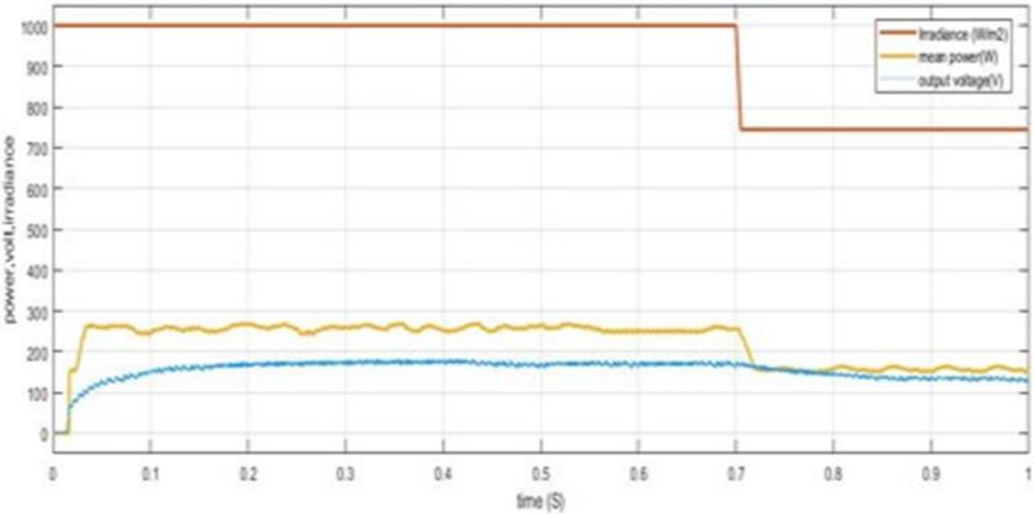

Fig -8: Power, Voltage, Irradiance

V. CONCLUSION

Here we discussed about a battery charger for an electrical vehicle based on Zeta con- verter. The proposed battery charger is fed from a PV array. The PO technique is used for generating the duty cycle for the Zeta converter to track the MPP of the PV array. This converter overcomes the drawbacks of other converters, providing lower output voltage ripple and better compensation. Simulation studies of the proposed scheme have been carried out and the results are furnished. The simulation results show that Zeta converter has been operated at buck and boost modes. The different irradiance levels are used to verify the dynamic performance of the proposed system.

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