Implementation of Zeta Converter in SPV Application

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Abstract—In this paper zeta converter is used as dc-dc converter which is designed, simulated and analyzed in solarenergy system. The complete model of solar energy system is simulated in MATLAB 20013b using simulink. This model has 250W solar panel, zeta converter and resistive load. Solar Energy is most reliable and efficient renewable source for Electrical Power Generation. The electrical power output from the solar panel can effectively be obtained from Solar Photo Voltaic (SPV) Panels. Maximum Power Point Tracking is an algorithm to obtain maximum power from the solar panel effectively. Incremental Conductance Algorithm has been developed and in this approach considering the variations of atmospheric conditions under different varying load conditions. In this paper, the detailed analysis of incremental conductance algorithm has been included. The modelling of Incremental Conductance algorithm is implemented by using MATLAB/SIMULINK environment included in this literature. The PV is modeled in MATLAB considering the design equations of single diode model of solar cell. The design of power electronic converter is very important. To ensure reliability, safety, and to provide maximum efficiency to the PV system, selection and design of power electronic converters should be correct as well as optimal. The power converter is interfaced between PV panel and load.The Reference voltage is fixed based on the open circuit voltage available at the output of the converter. The objective of this paper is to design Zeta converter operating in boost mode and to implement it in solar photovoltaic application for maximum power point tracking using Incremental conductance algorithm.

Index Terms—DC-DC Converter,Zetaconverter,Dutycycle, Solar panel, MATLAB/SIMULINK,Maximum power point tracking, Incremental Conductance algorithm.

1 INTRODUCTION

Energy demand is increasing day by day. Additional energy sources are necessary for meeting the increased load demands. Non renewable energy sources are depleting now a days. There are many different problems associated with the consumption of non renewable energy sources. Solar energy is an important renewable energy source. The main drawback of solar energy system is poor in efficiency. In order to improve the efficiency and tracking accuracy many MPPT techniques are used [1-4]. Among all other MPPT techniques Incremental Conductance algorithm is only suitable for fast changing atmospheric conductions [1].

The power delivered by a PV system of one or more photovoltaic cells is dependent on the irradiance, temperature, and the current drawn from the cells. Maximum Power Point Tracking (MPPT) is used to obtain the maximum power from the solar PV systems. The voltage-current and voltage-power characteristic of the solar panel varies with change in solar radiation and temperature conditions. In un-control mode, the power output of the panel [5]will depend on the load characteristics which are not desirable. The panel should supply the maximum power available on any particular radiation and temperature to the load side irrespective of the load. This type of panel control is called electrical tracking and gives the maximum efficiency [1].

Perturb and Observe (PO) MPPT algorithm is simple but terminal voltage is perturbed in every MPPT cycle. Therefore when the MPP is reached, the output power oscillates maximum, reducing the generable power by PV system. Thus P&O method is not suitable for during rapidly changing atmospheric condition [6]. In open circuit voltage method, open circuit voltage of a solar array at the MPP is linearly proportional to its open circuit voltage. Although the method is cost efficient, its application results in considerable errors in MPP tracking and consequent energy losses [1].

Additionally, these techniques fail to track the MPP effectively if solar array cells are partially shaded or if some cells in the array are damaged. , since the current–voltage (I–V) curve of the array is changed. However, partially shaded / damaged cells are not uncommon in practice. For that reason, applicability of these techniques is limited, since considerable energy losses may be incurred during PV module exploitation. In short circuit current method the operating current at the MPP of the solar array is linearly proportional to its short circuit current. In this method, the control circuit is complicated and both the conduction loss and the cost of the MPPT converter are still relatively high. In reality, the application of this technique always results in PV module operation below the maximum power point. Hence, in order to overcome the drawbacks of the above mentioned approaches, an Incremental Conductance MPPT Algorithm (ICMPPTA) is been used [1].

All Renewable Energy Systems require specific power electronic converters. Since the power electronic converter is the heart of the entire system, proper design is necessary. Any premature failure or wrong design will make the entire system no longer exist. Since there are different power electronic converters like Buck boost, SEPIC, Cuketc, the reason of using zeta converter was because of its advantages like less switching stress, adaptability, non pulsating output current and can be interfaced with high frequency transformers, and low settling time[2].

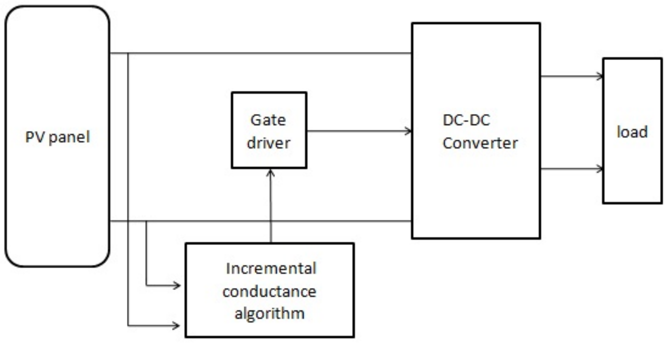


Fig 1 Overall diagram of the system

2 MODELING OF SYSTEM COMPONENTS

2.1 Design of Power Converter:

Power converters play a main role in the process, which is the heart of the entire system. It is installed between the source and load. In this paper, zeta converter has been chosen as a proposed converter, because of the advantages like low settling time, adaptability, can be interfaced with high frequency-transformersetc[2].

Zeta Converter:

The circuit diagram of zeta converter is shown in Fig 2. The zeta converter is capable of converting input voltage into a non inverted output voltage, having either a lower orhigher value than input voltage. It is capable of operating inboth continuous and discontinuous modes of operation. Thezeta converter consists of components like power electronicswitch (S), inductors (L1 and L2), a diode, capacitors (C1 andC2), and a load (R)[2].

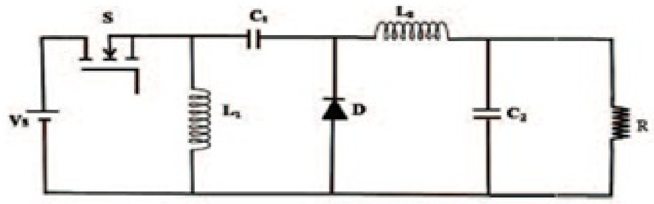


Fig 2 Zeta Converter

Mode 1: This mode is achieved, when the diode (D) is off and Switch(S) is on. The current through the inductor L1 and L2 are drawn from the source Voltage Vs. The Inductor current iL1 and iL2 increase linearly. This mode of operation is also called charging mode[2].

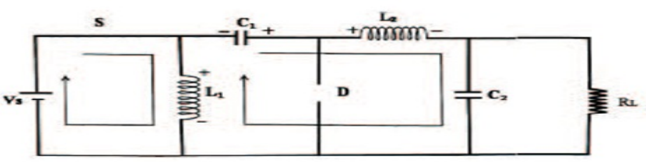


Fig 3Zeta Converter in ON state

Mode 2: This mode is achieved, when the diode (D) is in ONstate and switch (S) is off. The energy stored in the inductors discharges and transferred to the load. The current in the inductors decreases linearly. This mode of operation is also called discharging mode[2].

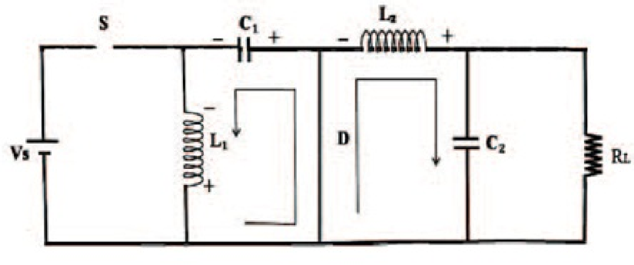


Fig 4 Zeta Converter in OFF state

The figure 5 below shows model of Zeta Converter designed in MATLAB/SIMULINK.Switching of MOSFET is controlled by using PWM generator for a duty cycle of 62% and passive components values are calculated using Zeta Converter design equations given below.

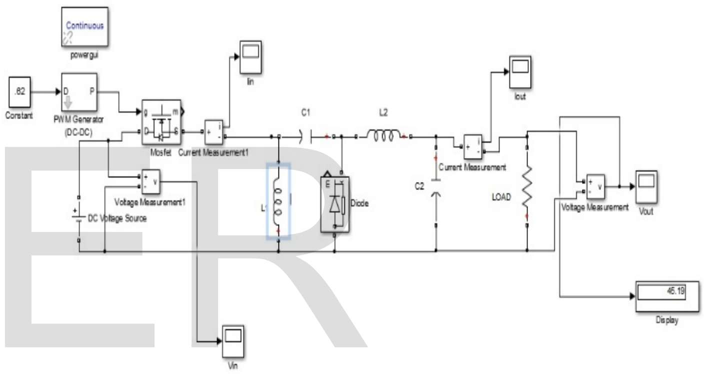


Fig 5 MATLAB/SIMULINK model of Zeta Converter

Zeta Converter design equations

To achieve the high performance and efficiency of the dc-dc Converter the values of passive elements (Inductor andCapacitor) have significant impact. Here designing equations are used to design zeta converter.

Zeta converter designing equations are as follows:
For zeta converter operating in CCM, the duty cycle is defined as,

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

And the passive components of ZETA Converter can be found using the equations,

$$L1 = L2 = \frac{Vin*D}{\Delta Il*Fs} \quad (2)$$

$$C1 = \frac{D*Vout}{\Delta Vc1*R*Fs} \quad (3)$$

$$C2 > \frac{(1-D)*Vout}{8*\Delta Vout*L2*Fs} \quad (4)$$

Where D is the duty cycle, VOUT is an output voltage of zeta converter, Vin is an input voltage of zeta converter, L1 is a first inductor, L2 is a second inductor, ΔIlis a ripple current of inductor, Fsis a switching frequency, C1 is a first capacitor, C2 is a second capacitor and ΔVc1 is a voltage ripple of first capacitor [2].

2.2 Modeling of 250W solar panel

Solar cell is a P-N junction semiconductor device when exposed to sunlight a dc current is generated. Linear variations in dc current occurs due to variation in sun irradiance. PV array is a combination of solar cells connected in series and parallel[3].The figure 6 shows MATLAB/SIMULINK model of 250W solar panel using single diode model of solar cell design equations.

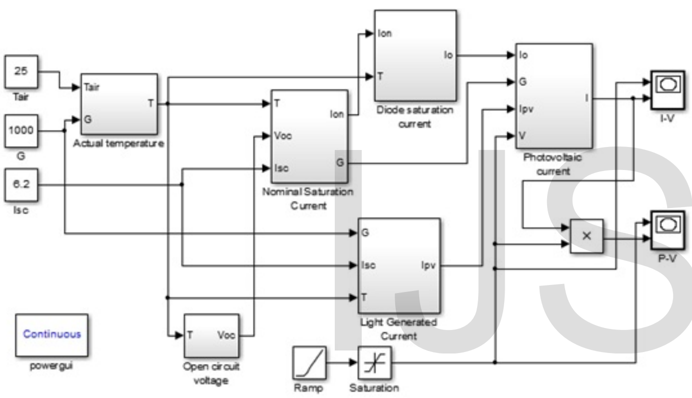


Fig 6 Simulink model of 250W PV module

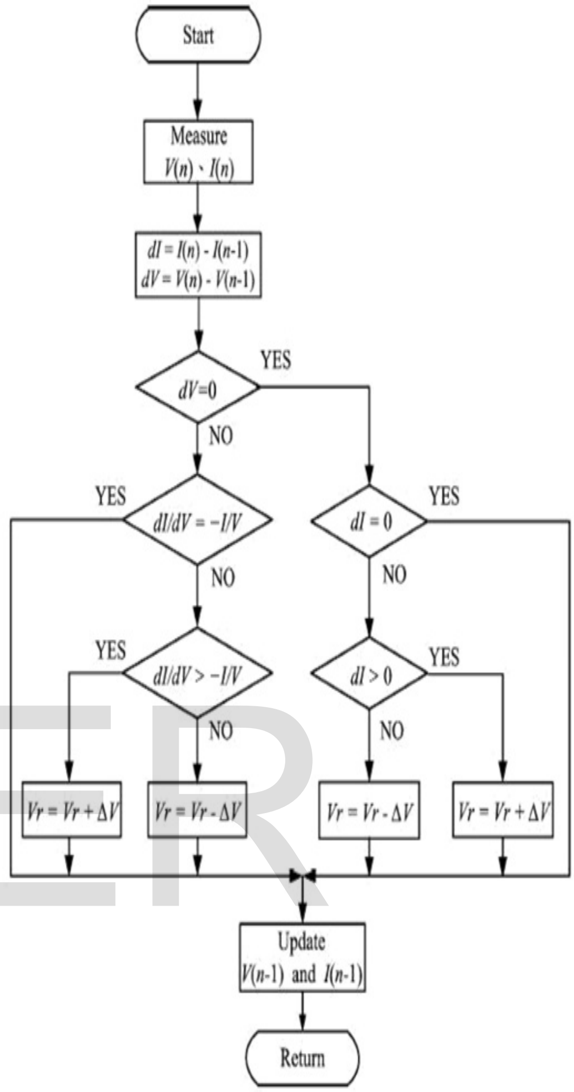


Fig. 7 Flow chart of Incremental Conductance Algorithm

2.3 Modeling of Incremental Conductance Algorithm(ICA)

The Incremental Conductance Algorithm (ICA) helps to locate the maximum power point when the instantaneousconductance is equal to the negative value of incrementalconductance. The ICA uses a search technique thatchanges a reference or a duty cycle so that Vpv changes andsearches for the condition of equation and at that condition themaximum power point has been found and searching will stop.Particularly this method is the control method that is good forthe rapidly changing solar radiations and it operates by theflowchart as shown in figure 7

The ICA will continue to calculate dIuntil the result is no longer zero. At that time, the search is started again.

At MPP $\frac{dP}{dV} = 0$, rearranging above equation we get

$$\frac{dI}{dV} = -\frac{I}{V} \quad (5)$$

When the left side of equation (5) is greater than zero, the search will increment Vpvandwhen the left side of equation (5) is less than zero, the searchwill decrement Vpv.
Maximum power can be reached when the IncrementalConductanceis equal to Instantaneous Conductance. Where $\frac{dI}{dV}$stands for incremental conductance and$\frac{I}{V}$represents instantaneous conductance.
ICA helps to locate Maximum Power Point by adjusting two

parameters such as panel voltage and converter duty ratio. ICA is modeled by using Matlab/Simulink [1].

2.4 Implementation of Zeta Converter using Incremental Conductance algorithm for Solar Photo Voltaic(SPV) Application

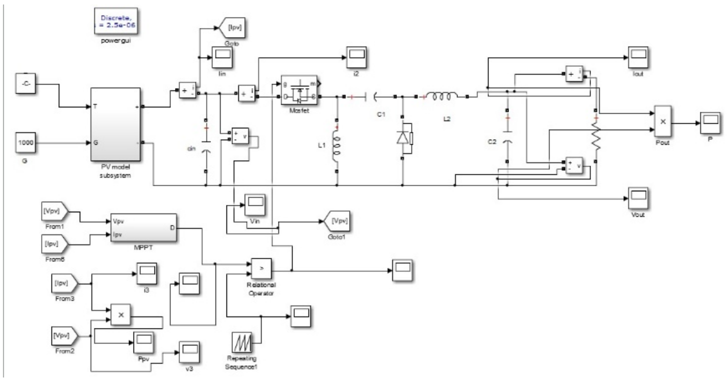


Fig 8 MATLAB/SIMULINK model of implementation of Zeta converter in SPV application using Incremental Conductance Algorithm

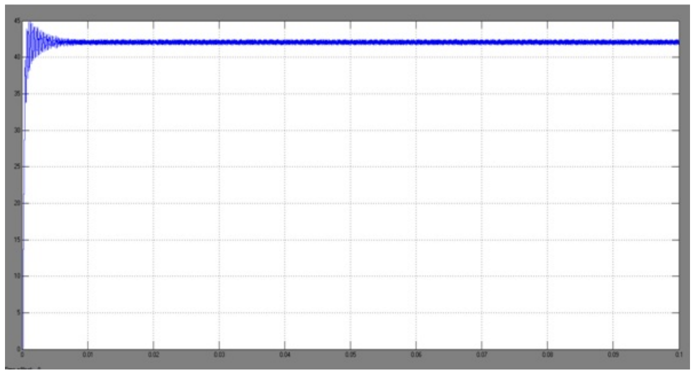
3 Simulation results

A 250W solar panel is connected to the resistive load through a zeta converter placed between the solar panel and the load.The zeta converter is used in boost mode of operation thereby boosting 26vvoltage available at the output of the solar panel to 45v.

Maximum power point tracking for the solar panel is done using Incremental conductance algorithm.The figures below shows the simulation results for the entire system consisting of 250W solar panel, zeta converter and resistive load.

Table 1.Calculation values of design of Zeta Converter

Parameter	Zeta Converter
Input Voltage,Vi	26v
Output Voltage,Vo	45v
Inductor,L1	72.06µH
Inductor,L2	72.06µH
Capacitor,C1	26.12µF
Capacitor,C2	30µF
Duty Cycle	62%
Output Power	200W



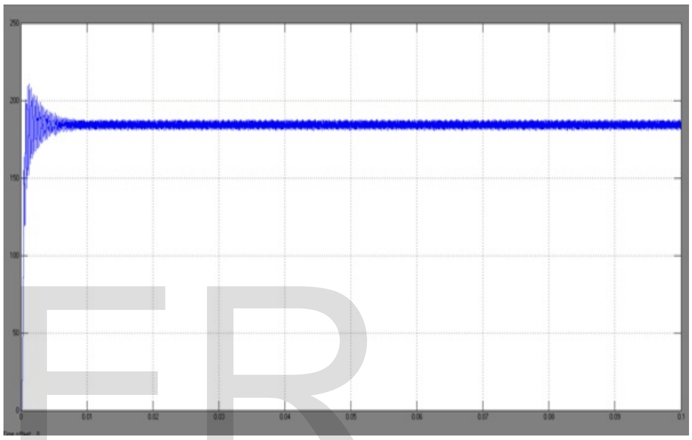


Fig 10 Output power of 250W Solar panel after implantation of zeta converter

4.Conclusion

In this approach a Zeta Converter in boost mode of operation is designed. The purpose of the zeta converter is to maintain the constant output voltage across the load under different irradiance conditions.Making use of zeta converter, the oscillation is reduced, as it can be inferred from the above graphs. The Zeta converter operates based on the duty cycle. Lower the value of dutycycle, buck operation will be performed and higher the valueof duty cycle, boost operation will be performed by the Zeta converter.The Incremental Conductance MPPTAlgorithm (ICMPPTA) has been employed for Zeta Converter using MATLAB/SIMULINK for improving the tracking accuracy of solar paneldduring rapidly changing environment. The output voltage obtained is 45 V from a SPV panel of 250 W, 26V input.

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