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Photovoltaic Fed a New Design of Zeta Converter

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***Abstract*–This paper presents a new design of Zeta Converter fed by photovoltaic module as input power source. The Perturb and Observe (P&O)algorithm is used for photovoltaic systems to achive Maximum Power Point(MPP) .This proposed design of Zeta Converter with two control switches, two diodes, four inductors and four capacitors can be used to benefit much from photovoltaic energy. By using this design the single source can be able to give a voltage to two outputs, one of them controls the first stage(0-kT) of duty cycle and the other operates during the remainig period.**

***Index Terms*–Photovoltaic, P&O algorithm, Zeta Converter**

I. Introduction

Nowadays power electronic converters are becoming more popular for various industrial applications. A Zeta Converter is a DC-DC converter, which is capable of amplifying and reducing the input voltage levels without inverting polarities[1], [2]. A photovoltaic (PV)system is able to supply electric energy to a given load by directly converting sunlight into electricity[3]. PV systems can be generally classified into two major groups[4]:

1. Stand-Alone Systems: These types of systems are isolated from the electric distribution grid.
2. Grid-Connected Systems: These systems are directly coupled to the electric distribution network and do not require storage units. This operation mode requires an inverter to convert DC currents to AC currents and a DC-DC converter to be used like an interface between PV module and the grid. These converters must be chosen to be able to match the maximum power point (MPP) of PV module when climate conditions change with differed load values[5], [6]. So DC-DC converter must be used with MPPT controller in order to reduce losses of the global PV system. Many MPPT techniques such as the Perturb and Observe (P&O), Incremental Conductance (IC) and Constant Voltage methods have been proposed in the literature[7], [8]. Perturb and Observe (P&O) method is widely used because of its low-cost and ease of implementation[9].This paper presents employing a two-output Zeta Converter and using P&O tracking method.

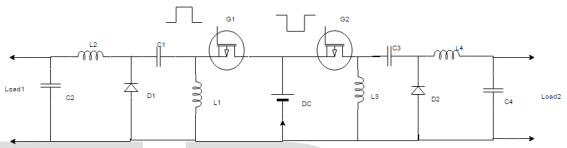


Figure 1: Zeta Converter

II. A New Design of Zeta Converter

A non-isolated Zeta Converter circuit is shown in fig.1. The analysis of this circuit uses the following assumptions:

1. Semi conductors switching devices are considered to be ideal.
2. Converter operating in continuous inductor current mode.

A. *Modes of Operation*

Mode 1: In the first mode the switch G1 is on, the diode D1 is off. An equivalent circuit shown in fig.2a. This mode is the charging mode for the first output. During this mode, the current through L1 and L2 is charged from the source DC.

Mode 2: In the second mode the switch G1 is off, the switch G2 is on, the diode D1 is on and the diode D2 is off . An equivalent circuit is shown in fig.2b. This mode is the charging mode for the second output and the discharging mode for the first output. During this mode, the current through L3 and L4 is charged from the source DC and the energy stored in L2 is transferred to the load 1 at the same time.

In this circuit when the switch G1 is closed so the first part of the circuit is in charging mode, the second part of the circuit works as discharging mode. The same when the switch G2 is closed so the second part of the circuit in the charging mode, the first part of the circuit works as discharging mode at the same time.

B. *Circuit Analysis*

The circuit behavior of the proposed converter during one switching cycle of operation is taken place of two different actions. In the following, the circuit analysis and operational principle of the proposed converter for each stage are described.

Stage 1 [t:0 $\longrightarrow$KT ; fig.3]: In this stage, the main first switch G1 turns on, and the diode D1 turns off so in the first part of the circuit the current through L1 and L2 is charged from source DC. On the other hand the main second switch G2 is off and the diode D2 is on to allow the stored energy in L4 transferred into the load2.

Stage 2 [t:KT $\longrightarrow$(1-K)T ; fig.3]: In this stage, the main second switch G2 turns on, and the diode D2 turns off so in the second part of the circuit the current through L3 and L4 is charged from source DC. On the other hand the main first switch G1 is off and the diode D1 is on to allow the stored energy in L2 transferred into the load1.

As a result these output equations can be obtained

$$V_{out1} = \frac{K \times V_{in}}{1-K} \tag{1}$$

$$I_{out1} = \frac{(1-K) \times I_{in}}{K} \tag{2}$$

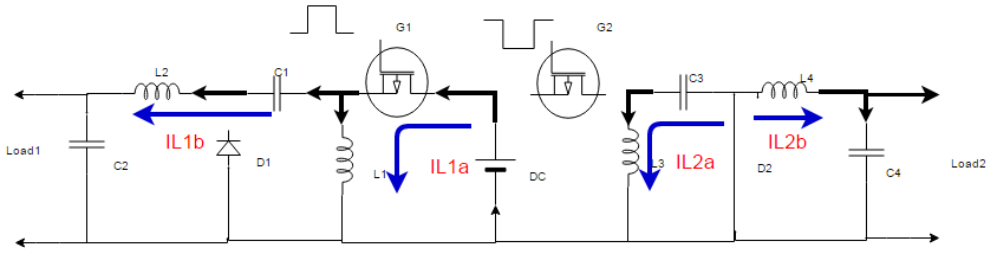
$$V_{out2} = \frac{(1-K) \times V_{in}}{K} \tag{3}$$

$$I_{out2} = \frac{K \times I_{in}}{(1-K)} \tag{4}$$

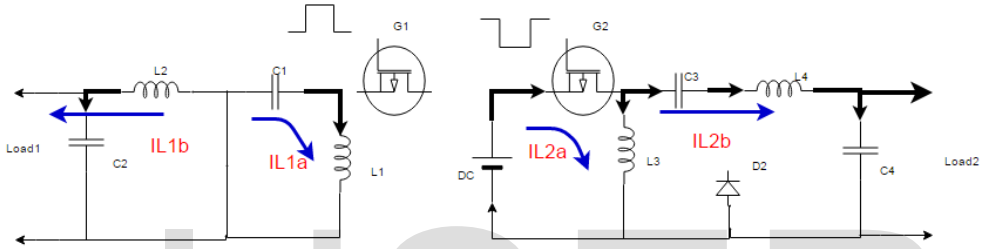
Equations (1) and (2) are the same of the normal outputs of Zeta Converter which is used as an interface between PV module and the grid, but according to (3) and (4) we have an additional output which can be used for charging a battery or supply electricity to anther load. This additional output works only in the remaining period so this is a disadvantage for the additional part.

III. PV System (P&O Method)

The solar cells are arranged in series and parallel combinations to form a solar PV module[10]. Recently, photovoltaic array system is widely recognized to the forefront in electric power systems[10]. An equivalent circuit of a solar cell is a current source in parallel with a diode[11] as shown in fig.5. The output of the current source is directly proportional to the light falling on the cell (photocurrent Ipv, cell). A MPPT technique shown in the following block diagram Fig.4, is used for tracking the maximum energy from the PV module and then transferring that power to the connected load[12]. Here,the new design of Zeta Converter acts as an interface between the inverter and the PV module. The peak power is reached by adjusting the duty cycle of the Zeta Converter. An automatic tracking can be performed by utilizing Perturb & Observe (P&O) algorithm.



(a)



(b)

Figure 2: Modes Of Operation

A. *Perturb & Observe Algorithm*

In this algorithm, a perturbation is given periodically to the module output voltage and then the matching current is measured to calculate the power of PV system.[13]. This PV power is compared with the previous power at the previous perturbing. As shown in fig.6. So if the change in output power of the PV module is positive i.e., at the point number (1), then it keeps perturbing in the same direction to achieve MPP. And if the change in output power is negative i.e., at the point number(2), then it keeps perturbing in the direction which is reversed to the previous direction to achieve MPP. The flow chart of the algorithm is shown in the Fig.7.

IV. Simulation Models and Results

Through these simulation models, the PV system is represented as a constant voltage source. The Simulink model of Zeta Converter is shown in fig.8. The values of components of the simulation models :

Inductors(L1,L2,L2,L4)	50 mH
Capacitors(C1,C2,C3,C4)	4e-5 F
Load 1, Load 2	20 ohm
Input DC source	150 V
K(Duty Cycle)	0.6

The voltage and current outputs for the first part of the circuit are shown in fig.9. The voltage and current outputs for the second part of the circuit are shown in fig.10. In Normal zeta converter, The current source changes from

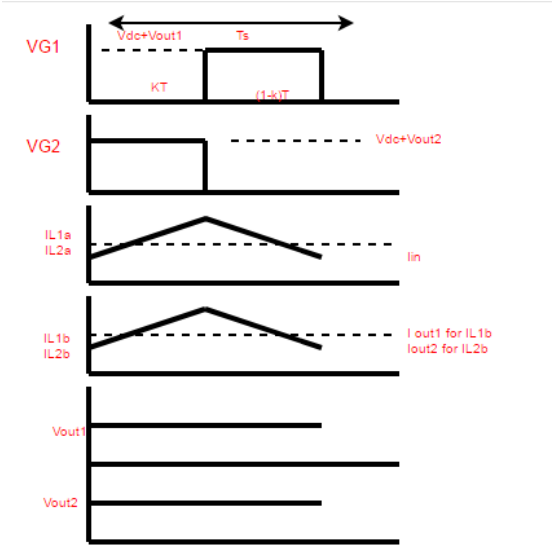


Figure 3: Signals of Zeta Converter

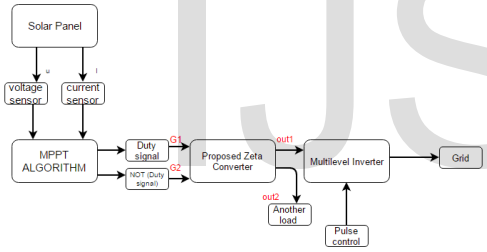


Figure 4: Block diagram of MPPT technique

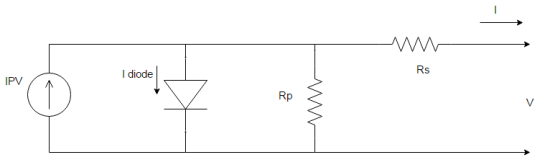


Figure 5: Equivalent Model of a Photovoltaic Cell.

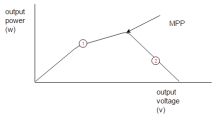


Figure 6: PV characteristics of a panel

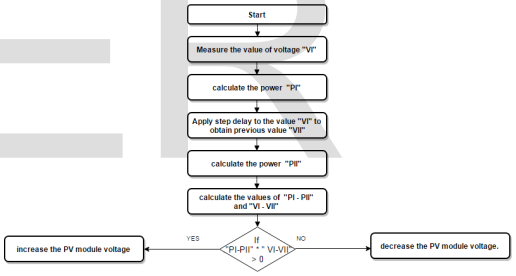


Figure 7: Control Flowchart of P&O Algorithm

the peak value to zero. In this design of zeta converter, The current source changes from peak value to minimum value. The current source is shown in fig.11.

V. Conclusion

Analysis of new structure of Zeta Converter is carried out and as a result a new source of power from PV systems is obtained. The disadvantage of the additional source is that limited control of output because it operates only in the re-mainig period. So if the triggering controller for the first switch works on i.e K=0.6, then the second switch can

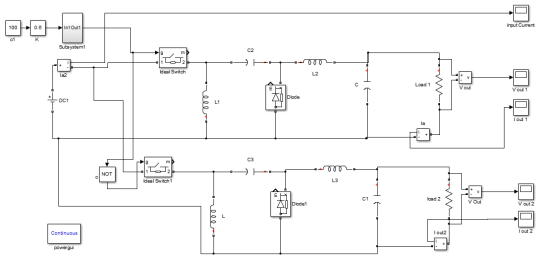


Figure 8: Simulink Model of Zeta Converter

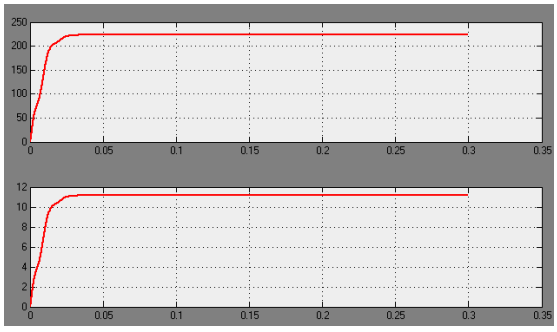


Figure 9: Voltage and Current signal for the first output

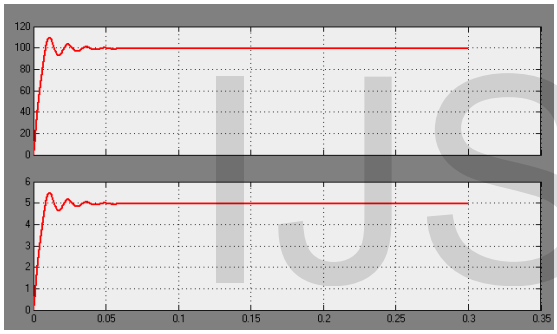


Figure 10: Voltage and Current signal for the second output

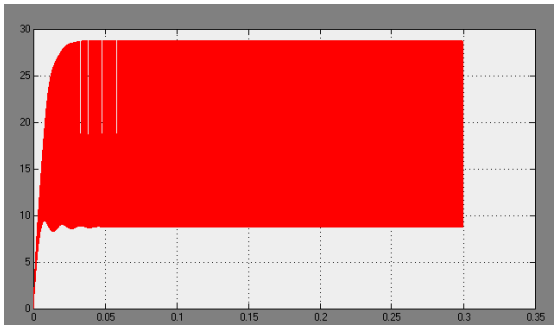


Figure 11: The current source

be controlled only in [0→(1-K)=0.4] period. When the power from the PV is maximum then the Perturb and Observe gives low triggering angle to the main switch so the output from the second source is big enough to be stored in a storage unit, and when the power from the PV is minimum the Perturb and Observe gives high triggering angle to the main switch so the output from the second source is limited, in this situation the energy stored in the storage unit can be used to support the system.

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