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PV fed Zeta converter

N. Sowmya Smitha Raj*, B. Urmila**
*(M.Tech Scholar, Department of EEE, G. Pulla reddy engineering college, Kurnool
** (Asst professor, Department of EEE, G. Pulla reddy engineering college, Kurnool

ABSTRACT

This project envisages a zeta converter fed by photovoltaic module as input power source. 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 proposed scheme consists of a solar panel, a zeta dc-dc converter, and MPPT controller. In this Maximum power point tracking is achieved by using Perturbation and Observation (P&O) method, also known as hill climbing method, is popular and most commonly used in practice because of its simplicity in algorithm and the ease of implementation.

***Keywords* -** Photo voltaic module, P&O algorithm, Zeta Converter

I. INTRODUCTION

Nowadays a dc-dc converter is widely used as power supply in electronic systems. A zeta converter is a fourth order dc-dc converter capable of amplifying and reducing the input voltage levels without inverting the polarities [1]. The reason being is that it includes two capacitors and two inductors as dynamic storage elements. Compared with a Cuk or Sepic converters, the Zeta converter has received the least attention.

Among the renewable options, solar PV energy has been drawing increasing interest in recent years as an alternative and important source of energy for the future. Solar cells transform energy from an essentially unlimited source 'the Sun' into useable electricity. PV systems constitute an environmentally friendly alternative way for energy production using the energy from the sun. PV system, virtually zero running cost energy is the input source of power. They operate quietly without emissions, even if the load increases. With recent developments, solar energy systems are easily available for industrial and domestic use with the added advantage of minimum maintenance. However, the output power induced in the photovoltaic modules depends on solar radiation and temperature of the solar cells. Photovoltaic modules have a very low conversion efficiency of around 15% for the manufactured ones. Besides, due to the temperature, radiation and load variations, this efficiency can be highly reduced. In fact, the efficiency of any semiconductor device drops steeply with the temperature. In order to ensure that the photovoltaic modules always act supplying the maximum power as possible and dictated by ambient operating conditions, a specific circuit known as Maximum Power Point Tracker (MPPT) is employed therefore, to maximize the efficiency of the renewable energy system, it is necessary to track the maximum power point of the PV array. In most common applications, the MPPT is a DC-DC converter controlled through a strategy that allows imposing the photovoltaic module operation point on the Maximum Power Point (MPP) or close to it. The proposed scheme consists of a solar panel, a zeta dc-dc converter, and MPPT controller. In this Maximum power point tracking is achieved by using Perturbation and Observation (P&O) method, also known as hill climbing method, is popular and most commonly used in practice because of its simplicity in algorithm and the ease of implementation

II. ZETA CONVERTER

A zeta converter is a fourth order non linear system being that, with regard to energy input, it can seen as buck-boost-buck converter and with regard to the output, it can be seen as boost-buck-boost converter.

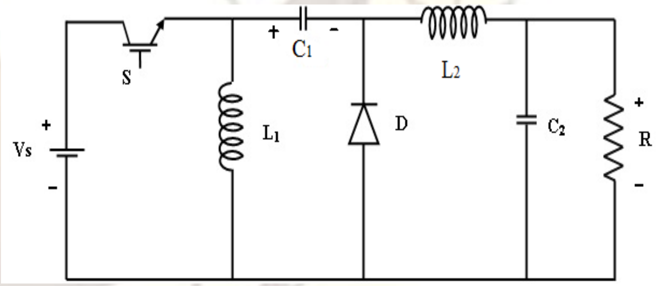


Fig.1 Basic Zeta converter circuit

The ideal switch based realization of zeta converter is depicted. A non-isolated zeta converter[2] circuit is shown in the fig.1 above. Although several operating modes are possible for this converter depending on inductance value, load resistance and operating frequency, here only continuous inductor current 'i_{L1}' analyzed using the well known state-space averaging method[3] .

The analysis uses the following assumptions.

1. Semiconductors switching devices are considered to be ideal.
2. Converter operating in continuous inductor current mode.
3. Line frequency ripple in the dc voltage is neglected.

II.1 MODES OF OPERATION

Zeta converter exhibits two different modes as follows:

Mode1: The first mode is obtained when the switch is ON (closed) and instantaneously, the diode *D* is OFF. An equivalent circuit shown in Fig.2. During this period, the current through the inductor *L*1 and *L*2 are drawn from the voltage source V_s. This mode is the **charging** mode.

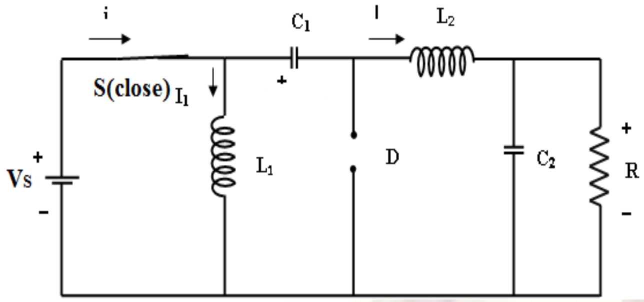


Fig.2 Equivalent circuit of converter (switch ON)

Mode2: The second mode of operation starts when the switch is OFF and the diode *D* is ON position, the equivalent circuit shown in Fig.3. This stage or mode of operation is known as the **discharging** mode since all the energy stored in $\mathbf{L_2}$ is now transferred to the load **R.**

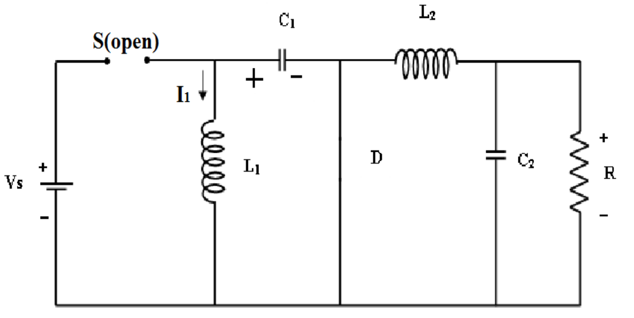


Fig.3 Equivalent circuit of converter (switch OFF)

III. PHOTOVOLTAIC SYSTEM

With increasing concerns about fossil fuel deficit, skyrocketing oil prices, global warming, and damage to environment and ecosystem, the promising incentives to develop alternative energy resources with high efficiency and low emission are of great importance. Among the renewable energy resources, the energy through the photovoltaic (PV) effect can be considered the most essential and prerequisite sustainable resource because of the ubiquity, abundance, and sustainability of solar radiant energy. Regardless of the intermittency of sunlight, solar energy is widely available and completely free of cost. Solar cell is the basic building block of solar panel. A number of solar cells are arranged in series and parallel combinations to form a solar PV module. Recently, photovoltaic array system is likely recognized and widely utilized to the forefront in electric power applications. It can generate direct current electricity without environmental impact and contamination when is exposed to solar radiation. Being a semiconductor device, the PV system is static, quite, and free of moving parts, and these make it have little operation and maintenance costs. Even though the PV system is posed to its high capital fabrication cost and low conversion efficiency, the skyrocketing oil prices make solar energy naturally viable energy supply with potentially long-term benefits. The output characteristics of PV module depends on the solar insolation, the cell temperature and output voltage of PV module. Since PV module has nonlinear characteristics, it is necessary to model it for the design and simulation of maximum power point tracking (MPPT) for PV system applications. The mathematical PV models used in computer simulation have been built for over the past four decades. Almost all well-developed PV models describe the output characteristics mainly affected by the solar insolation, cell temperature, and load voltage. However, the equivalent circuit models are implemented on simulation platforms of power electronics. Recently, a number of powerful component-based electronics simulation software Package has become popular in the design and development of power electronics applications. The simplest equivalent circuit of a PV cell is a current in parallel with a diode. The output of the current source is directly proportional to the light falling on the cell. During darkness, the PV cell is not an active device; it works as a diode, i.e., a p-n junction .It produce neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generates current , called diode current or dark current. The diode determines the V-I characteristics of the PV cell[4][5]. Fig.4 shows the equivalent circuit of a solar cell

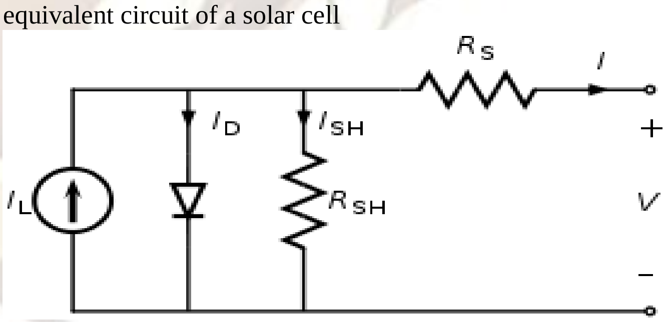


Fig.4 equivalent circuit of a solar cell

Here I and V represent the output current and voltage of solar cell. Rs and Rsh are series and shunt resistances respectively. IL and ID are photo current and diode current. The current-voltage characteristics of solar cell are governed by the equation following:

$$I = I_L - I_0\left(\exp\left(\frac{q(V+IR_S)}{AkT}\right)-1\right) - \frac{V+IR_S}{R_{SH}}$$

The solar energy conversion using photovoltaic system and zeta converter circuit are presented. The block diagram of proposed scheme with PV array is given in fig.5 below. The system consists of following components: 1.) PV array 2.)Zeta converter 3.) MPPT system 4.) resistive load.

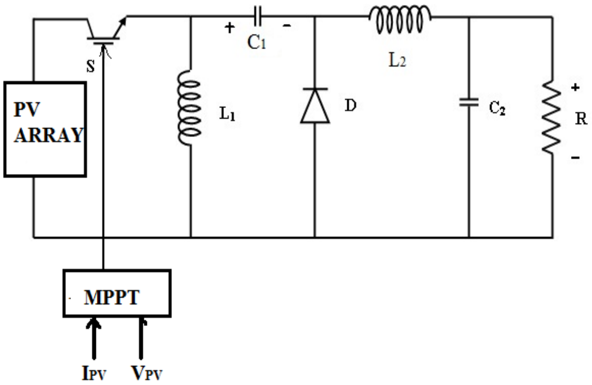


Fig.5 block diagram of proposed PV system

The PV panel converts solar radiation into electrical power that is fed to the ZETA DC-DC converter. A maximum power point tracker (MPPT) is used for extracting the maximum power from the solar PV module and transferring that power to the load. The peak power is reached with the help of a DC-DC converter by adjusting its duty cycle such that the resistance corresponding to the peak power is obtained. An automatic tracking can be performed by utilizing Perturb & Observe (P&O) algorithm. The algorithm changes the duty cycle of the DC-DC converter to maximize the power output of the module and make it operate at the peak power point of the module.

IV. PERTURB & OBSERVE ALGORITHM

In this algorithm a slight perturbation is introduced by the MPPT system. Due to this perturbation, changes the power of the module. If the power increases due to the perturbation then the perturbation is continued in that direction. After the peak power is reached the power at the next instant decreases and hence after that 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 algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller then acts moving the operating point of the module to that particular voltage level. It is observed that there some power loss due to this perturbation also it fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular and simple. This algorithm is selected and certain changes are made in the present work. The flow chart of the algorithm is shown in the Fig.6

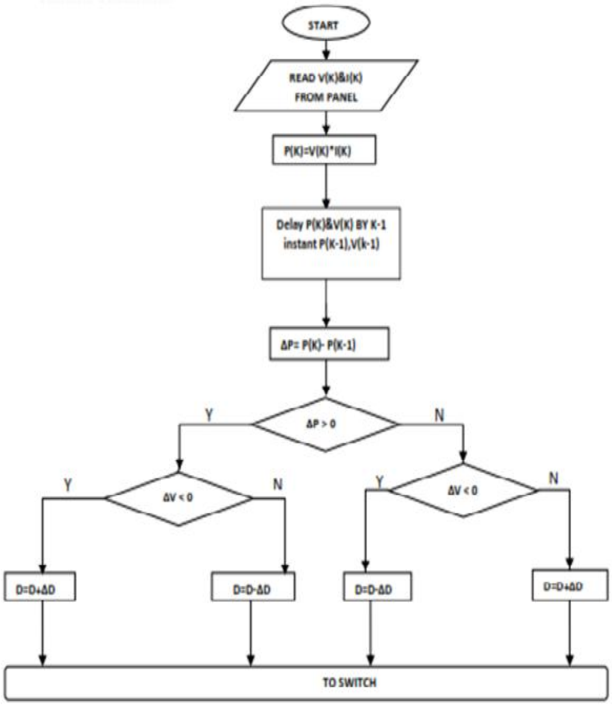


Fig.6 Control flowchart of P&O algorithm

The algorithm has a single loop and can be easily implemented using SIMULINK environment.

V. SIMULATION MODELS AND RESULTS

For the simulation of the proposed scheme, the Simulink models of PV array and the MPPT algorithm are to be developed individually and integrated to obtain the overall model.

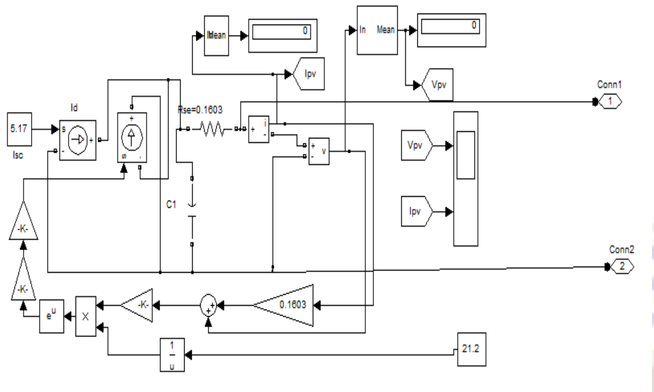
1. PV Array: This section presents a power system block set-based simulation model of PV array. The PV array in the proposed scheme consists of one solar panel of 21V, 5.17A. To develop a complete solar photovoltaic power conversion system in simulation and to allow the interaction between a proposed converter and the PV array, it is necessary to develop a simulation model for a PV cell[6].

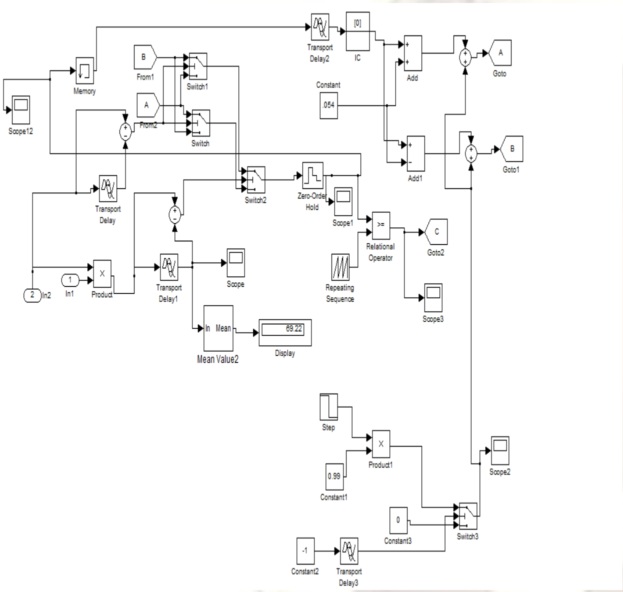
1. Zeta converter

Component	Value
Inductor(L1,L2)	24.2mH
Capacitor(C1.C2)	3.48e-4F
Resistance	40ohms
Switching frequency	10 kHz
Input voltage	100V

Table.1 Values of various components of zeta converter

SIMULINK MODELS:
Fig.7 Simulink model of PV cell
Fig. 8 Simulink model of P&O algorithm





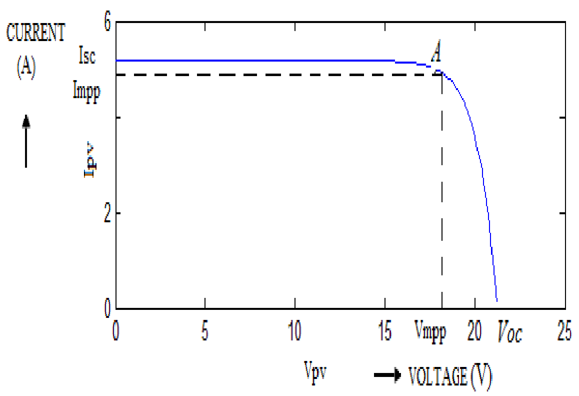


Fig.9 I-V Characteristics

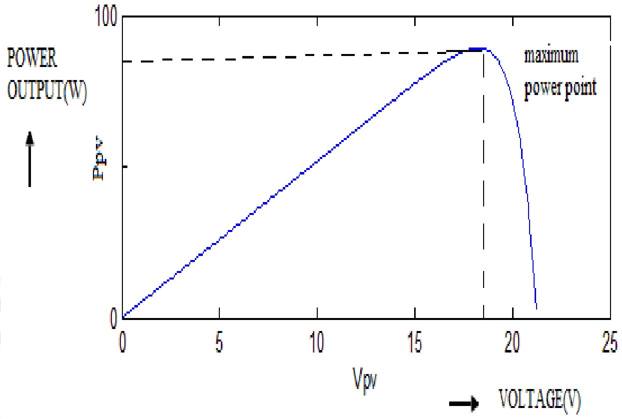


Fig. 10 P-V Characteristics

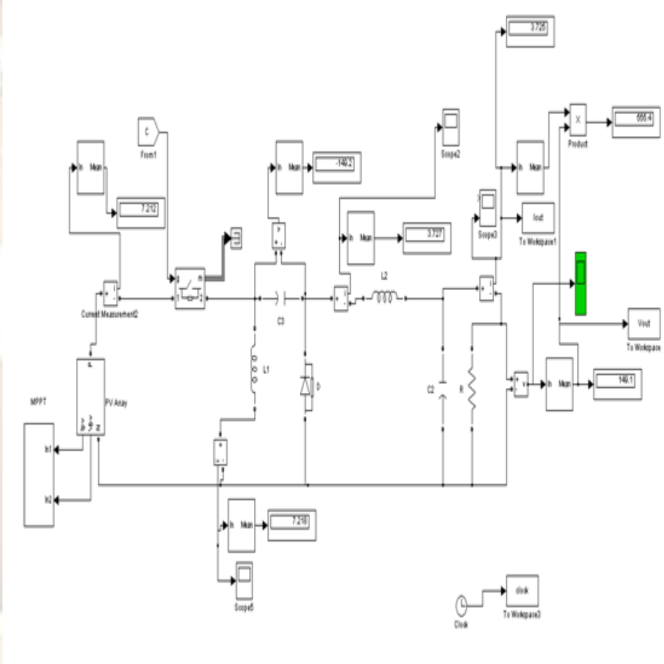


Fig.11 Simulink model of zeta converter fed by PV source and P&O algorithm implementation

Output waveforms of zeta converter with PV source with MPPT algorithm implementation

Input voltage: 100V
Output voltage: 230V (boost mode, duty cycle=70%)
: 42V(buck mode, duty cycle= 30%)

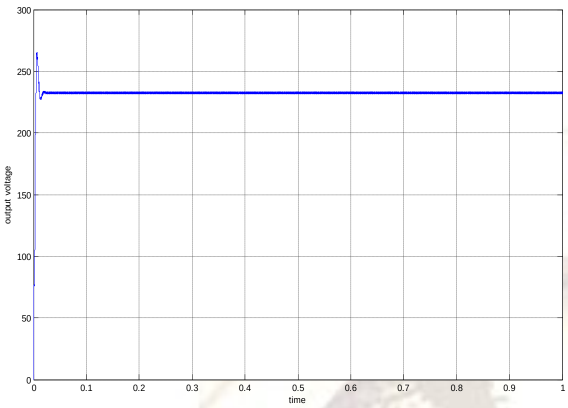


Fig.12 Zeta converter in boost mode

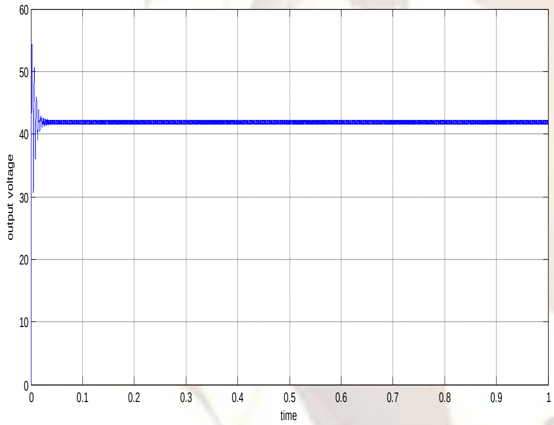


Fig.13 Zeta converter in buck mode

VI. CONCLUSION

Mathematical analysis of ZETA converter is carried out for design values of the capacitor and inductor. A simple power electronic controller for interfacing PV array with the load has been simulated using ZETA converter. The subsystems of overall scheme such as PV array model, ZETA converter model have been built and tested individually before integrating to the overall system. A maximum power point tracking algorithm has also been incorporated. The simulation studies of the proposed scheme MPPT have been carried out and the results are furnished. The values of parameters used for simulation are listed

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