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Performance Analysis of Solar Photovoltaic Module using Buck Boost Converter and Zeta Converter

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Abstract: ***This paper compares the performance of buck-boost and zeta converter fed solar photovoltaic module. The study is carried out by considering a solar pv module, dc-dc converter, MPPT controller and a resistive load. The voltage gain, output voltage ripple and output current ripple of the two converters were compared. Maximum Power Point tracking is implemented and and ensures the extraction of maximum power from the solar panel. Here MPPT is achieved by using perturbation and observation method. Zeta converter topology provides a non inverted output voltage with increased voltage gain. Output has lesser voltage and current ripple compared to buck-boost converter. Photovoltaic module with Buck-Boost and Zeta converter are simulated using MATAB Simulink software and the result are shown.***

Keywords: ***Solar photovoltaic module, Buck-Boost converter, Zeta Converter, Maximum Power Point Tracking.***

I. INTRODUCTION

Now a day's energy consumption is increasing continuously and availability of non-renewable resources are decreasing due to the continuous consumptions of energy. Also excessive use of the fossil fuels like coal, petroleum, diesel etc. affects the environmental conditions. In order to overcome these drawbacks from fossil fuels, renewable energy is the best alternative. Hence a lot of research is going on power generation using the renewable energy resources. Renewable source includes wind, solar, biomass and ocean energy. Solar energy is the highly available, clean source of energy and mainly it is environment friendly source[1]. The photovoltaic modules are used to convert solar energy into electrical energy effectively. These are developed and used in many applications to generate electricity. Solar energy is converted to electrical energy using photo voltaic principle. In renewable energy sources, dc-dc converters are the most important component. Output voltage from the solar panels is varying depending on the irradiance and hence they require voltage increase or decrease to get the required voltage. In order to overcome these problems, solar based system uses dc-dc converters [2]. The generated voltage is given as the input for the dc-dc converters. The most commonly used topologies for DC-DC converter are buck, boost and buck-boost depending on the duty ratio and the output requirement. The buck-boost converter can buck or boost the output voltage but with a negative polarity [3]. Zeta converter configuration is similar to buck boost converter[8] configuration but the output voltage polarity obtained is not inverted. The converters output magnitude and accuracy mainly depends on the selection of duty cycle, capacitor, Inductor and switches. The duty cycle for dc-dc converters are generated by considering the maximum power point operation of the converters. The extract maximum solar power from PV panels MPPT technique is used [4]. Depending on the maximum power point tracking algorithms used the variable duty cycle pulses can be generated for the converter.

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II. SYSTEM DISCRIPTION

The system consists of PV array, Maximum Power Point Tracking, DC-DC converters, and resistive load. The PV panel converts solar radiation into electrical power that is fed to the DC-DC converter. The output obtained from PV panel is variable depending on the solar radiation. So for output voltage regulation a DC-DC converter is employed. Here the converter used is Buck-Boost converter and Zeta converter [5]. Maximum power point tracking methods are used to extract maximum power from the solar PV module and transferring that power to the load [6]. The dc-dc converter duty ratio is adjusted to match the impedances of the source side and load side. The tracking of maximum power is done by utilizing Perturb & Observe (P&O) algorithm [7]. The algorithm monitor the present power and the previous power and change the duty cycle of the DC-DC converter to obtain maximum output power from the module and operate it at the peak power point of the module.

A. Photovoltaic System

The basic building block of solar panel is solar cells. Series or parallel connection of solar cells are used to form a solar PV module based on the voltage and current requirement. Recently, photovoltaic systems are widely recognized and utilized to the forefront in electric power applications.

The cell temperature, solar irradiation and output voltage are factors affecting the characteristics of a PV module. To design and simulate the solar PV system modeling of the system is done.[8]. Fig.1.shows the equivalent circuit of a solar cell.

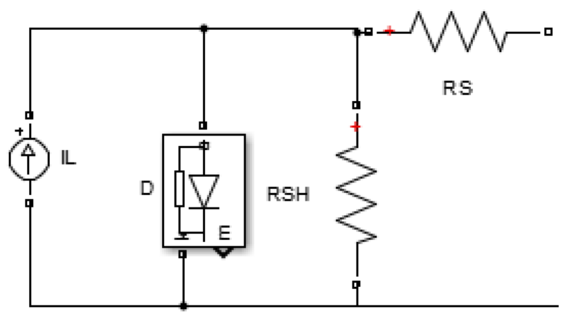

Fig. 1. Equivalent circuit of solar cell

Here I, V, Rs, Rsh, I_L, I_D represent the output current, output voltage, series resistance, shunt resistance, photon current and diode current respectively.

The electrical characteristics of a PV cell or module is given by the relationship between the current and voltage produced by a solar cell I-V characteristics curve. The amount and intensity of solar radiation falling on the solar cell controls the current produced by the solar cell, For variable voltages of the PV panel the current produced remains constant. With increase in the temperature of the module the output voltage reduces

B. DC-DC Converters

The dc-dc converters convert the dc voltage from one voltage level to a different voltage level. Various types of dc dc converters are used[9]. The buck dc-dc converter can reduce the voltage, boost dc-dc converter can increase the voltage. Both decrease and increase in voltage can be obtained by using buck-boost converter, cuk converter, zeta converter[10] etc. Reduction in voltage is obtained when the duty ratio of the converter is less than 0.5 and increase in duty ratio is obtained if the duty ratio is greater than 0.5. The dc-dc converters operate in two modes namely continuous conduction mode and discontinuous conduction mode. In continuous conduction mode the current through the inductor is continuous whereas in discontinuous conduction mode this current is discontinuous. For high efficiency and better utilization of the converter switches and other passive elements Continuous conduction mode is preferred.

C. Buck Boost Converter

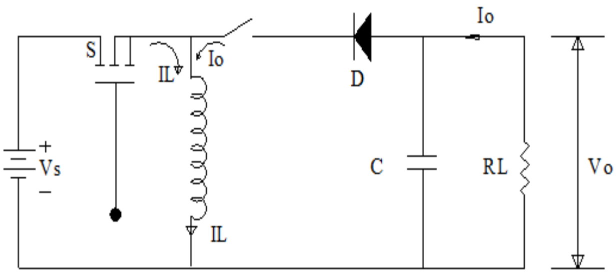

Fig.2. Buck Boost DC-DC converter

In buck-boost dc-dc converter the output voltage can be changed to greater or less than the input voltage. The duty cycle of the switch decides the amplitude of output voltage. There are two modes of operation .In the first mode the switch is in the on-state, the inductor is connected across the supply voltage. Energy is accumulated in the inductor. The capacitor discharges through the output load. When the switch is in the off-state, supply got disconnected from the circuit the inductor discharges through the output load and capacitor, thus energy transfer occurs from inductor to capacitor and resistance. The output voltage obtained is having a reverse polarity with respect to the input voltage. The output is expressed in terms of input voltage and duty cycle and is given by (2),

$$\frac{V_o}{V_i} = \frac{-D}{1-D}$$

(2)

D. Zeta Converter

Zeta converter [11] is a type of dc-dc converter used to buck or boost the input voltage. The main elements are a switch, inductors L_1 and L_2, a diode, capacitors C_1 and C_2, and Resistor R1.

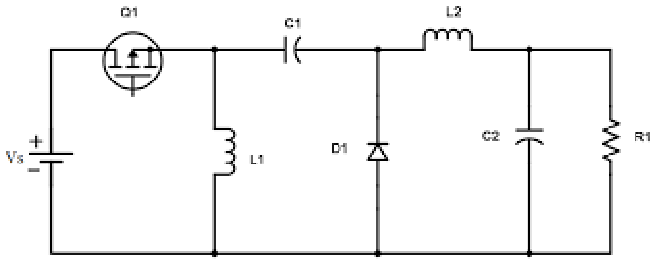

Fig.3. Zeta Converter

Mode 1: When switch is ON, the diode D1 is reverse biased and inductor draws current from the source (Vs). The current increases through the inductor and energy gets stored in the inductor. The voltage across the inductor will equal the source voltage. At the same time capacitor C1 starts charged to output voltage.

Mode 2: In mode 2 the switch is OFF condition, now diode is in forward biased, capacitor will be parallel to L2 inductor and across the inductor output voltage will be available. The inductor discharges and is called the discharging mode. Here the stored energy in inductor L2 is given to the load resistance. The relation between output voltage, duty ratio and output current is given by (3)

$$V_o = \frac{D}{D-1} * V_s \qquad (3)$$

E. MPPT

The output from a PV module varies from time to time with environmental factors. A solar panel usually converts only 25 to 45 percent of the solar insolation into electrical energy. For extracting the maximum power available from a module at a particular instant, we make use of Maximum Power Point Tracking techniques.

It adopts mainly the maximum power transfer theorem – when the source and load impedance matches, the maximum power transfer occurs. For this, DC – DC converters are used, by changing the duty cycle of the converter the load impedance is made to match the varying impedance of PV modules. The MPPT technique automatically finds out the panel operating voltage that allows the maximum power output. By using maximum power point tracking of a particular solar photovoltaic module the size of the panel can be reduced for the same wattage. There are different types of MPPT methods like Perturb & Observe method[12], Incremental Conductance method, fully logic controller etc. Here Perturb & Observe method is used.

Perturb and Observe algorithm is extensively used due to its simplicity and it requires minimum number of parameters and is explained in the flowchart in Fig.5. In this algorithm continuous observation and perturbation is carried out till the maximum power point is reached. In this algorithm the power and voltage at two nearby samples are compared and predicts the time to approach to MPP. The change in power and voltage are calculated and see whether to increment the duty cycle or decrement the duty cycle.

III. SIMULATION RESULTS

MATLAB/ Simulink based simulation is carried out to demonstrate the performance of the proposed system. The PV cell is used as the input source with an insolation level, of 1000 W/m^2 and the PV cell output voltage is 24V. The PV output is given to Buck Boost Converter and Zeta Converter with MPPT. The Output voltage, output voltage ripple, output current ripple is observed for both the converters. The designed values of inductors and capacitors used are given in the Table I & Table II.

Table- I: Design Values of Buck Boost Converter

Buck Boost Converter	
Input voltage	24v
Inductor	7mH
Capacitor	100uF
Resistance	100
Switching frequency	5kHz

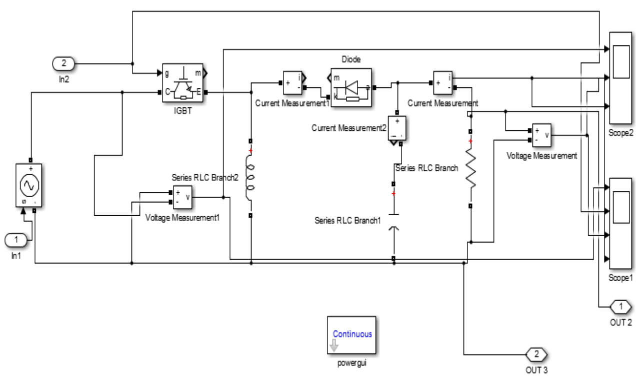

Fig. 4. Simulation Model of Buck Boost Converter

The integrated circuit simulation of PV, MPPT, Buck Boost converter is shown in Fig.5. Figures 6 to 12 shows the simulation results.

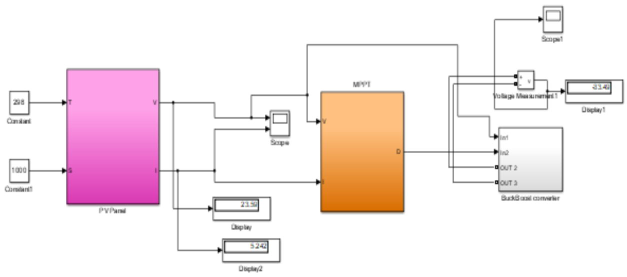

Fig. 5. Integrated Simulation Model using Buck Boost converter

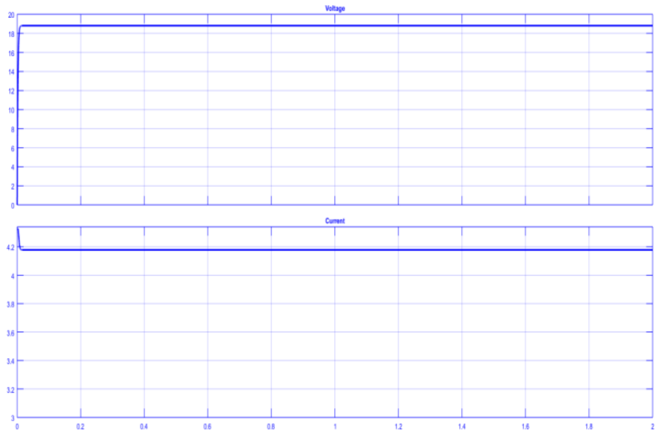

Fig.6. PV output at irradiation of 500W/m^2

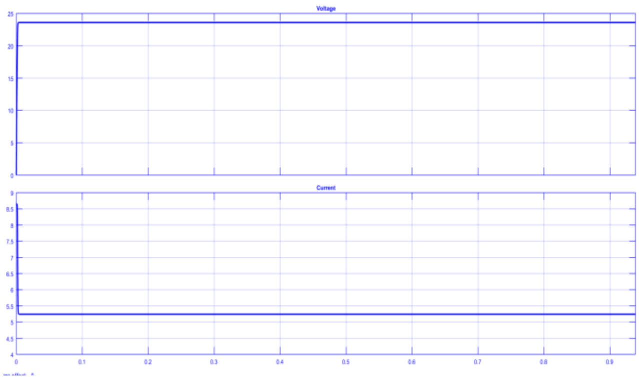

Fig.7. PV output at irradiation of 1000W/m^2

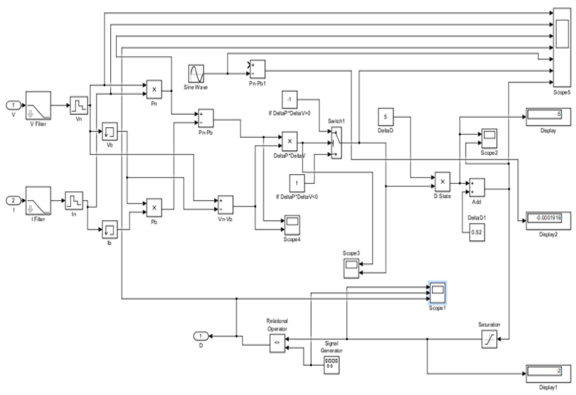

Fig.8. Perturb and Observe Algorithm simulation

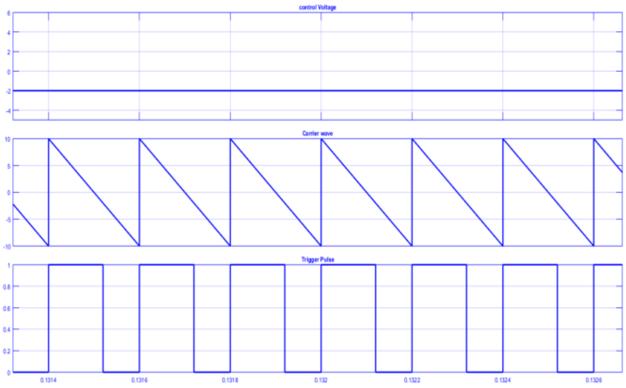

Fig.9. Trigger pulse obtained

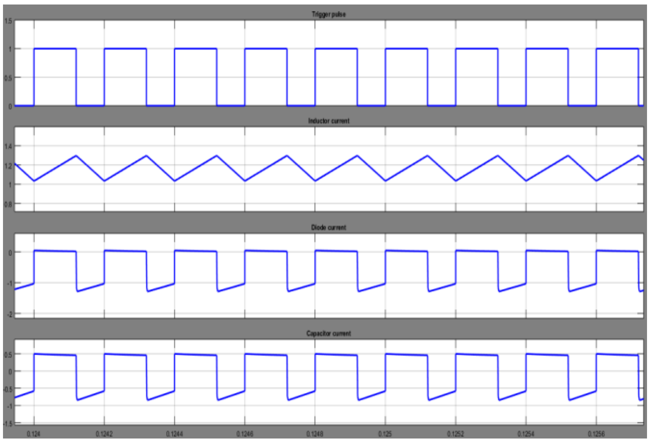

Fig.10.Waveform of inductor current & capacitor current

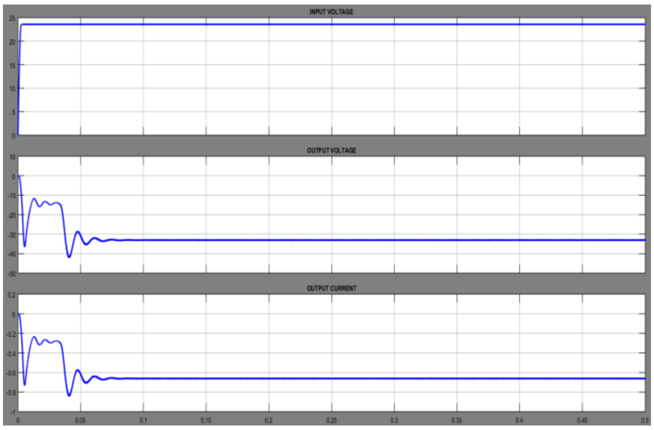

Fig.11.Result of Buck-Boost Converter simulation

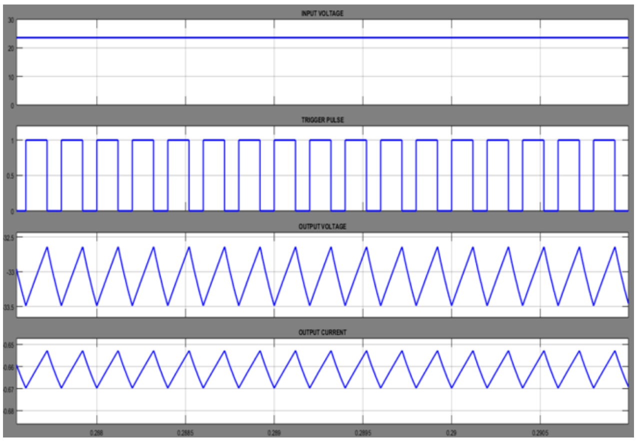

Fig.12.Voltage & Current Ripple of Buck Boost Converter

Table- II: Design Values of Zeta Converter

Zeta Converter	
Input voltage	24V
Inductor L_1	7mH
Inductor L_2	100mH
Capacitor C_1	10uF
Capacitor C_2	100uF
Resistance R	100
Switching frequency	5kHz

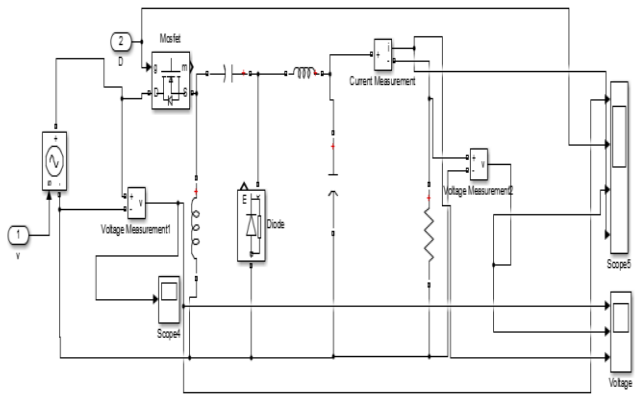

Fig.13. Model of Zeta Converter

The integrated circuit simulation of PV, MPPT, Zeta converter is shown in Fig.14 and the simulation results are shown in Fig.15 to Fig.17.

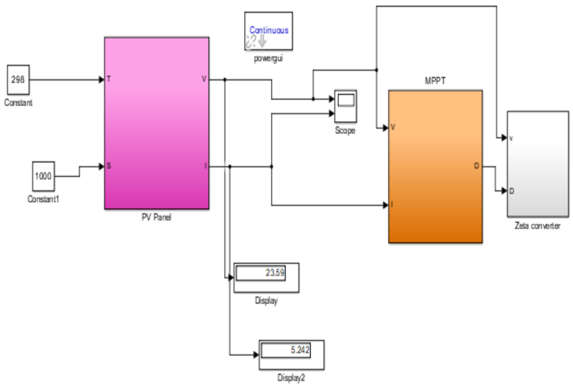

Fig.14. Integrated Simulation Model using Zeta Converter

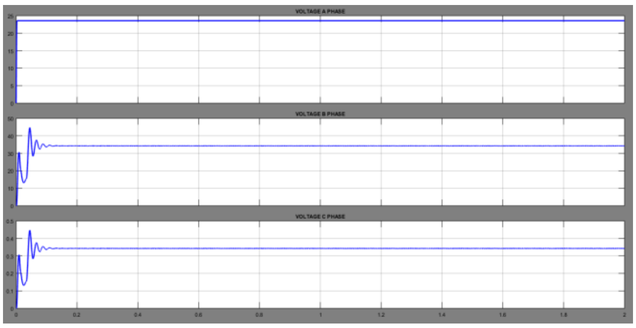

Fig.15. Simulation Result of Zeta Converter

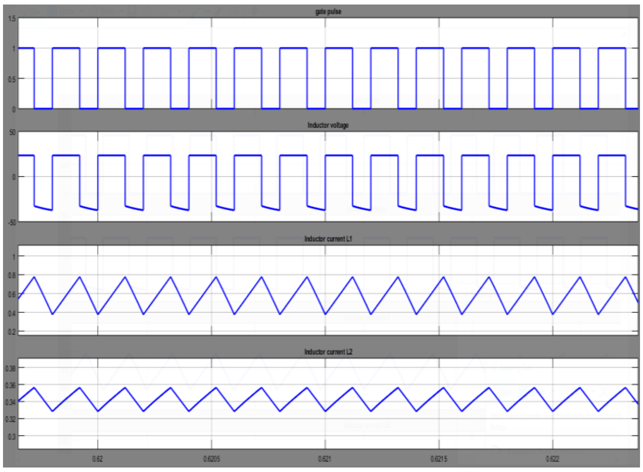

Fig.16.Simulation result of Inductor voltage and current

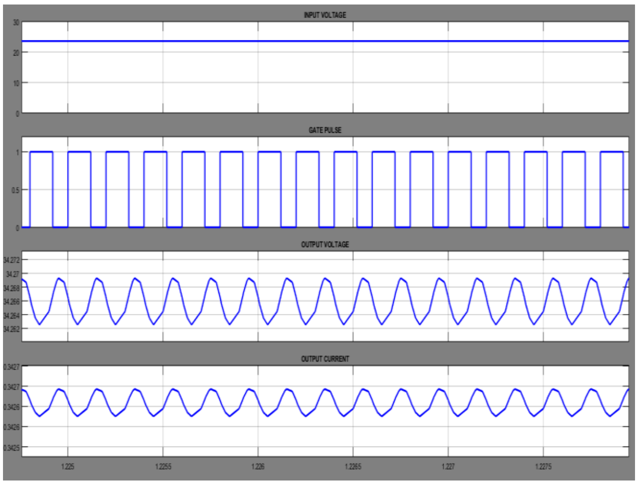

Fig.17. simulation result of Ripple in Zeta Converter

From the simulation results the output voltage, output current, output voltage ripple and output current ripple is obtained. The compared values are shown in the Table III. Simulation result shows that Zeta converter has more voltage gain, low output voltage and current ripple.

Table- III: Comparison Results

Parameters	Buck Boost Converter	Zeta Converter
Input voltage	24	24
Duty Ratio	67%	67%
Output Voltage	-33V	34.26V
Output Current	-0.43A	0.47A
Output Voltage Ripple	2.42%	0.0204%
Output Current Ripple	2.32%	0.029%

IV.CONCLUSION

In this paper, study of buck-boost and zeta converter for interfacing PV module with the load is done. Analysis is carried out for designing values of the capacitor and inductor. Subsystems such as PV array model, buck boost converter model and zeta converter model have been built and simulated individually before integrating as a whole system. A maximum power point tracking algorithm perturb and observe is also included. The simulation study of the whole scheme has been carried out and results are compared. Simulation result shows that the output ripple is less in zeta converter. The performance of the zeta converter is identified to more efficient with high voltage gain, lower output voltage ripple and output current ripple.

REFERENCES

1. V. C Sontake and R V Kalamkar, "Solar Photovoltaic water pumping system - A comprehensive review", Renew Sustain Energy Rev, vol 59, pp, 10381067, June 2016
2. Jian Fu, Bo Zhang, Dongyuan Qiu and Wenxun Xiao, "A Novel single switch cascaded DC-DC converter of Boost and Buck-Boost converters. 2014 16th European Conference on Power Electronics and Applications. Doi:10.1109/epe.2014.6910723.
3. R, Kumar and B. Singh, "Buck-Boost converter fed BLDC motor drive for solar PV array based water pumping", in Proceedings of IEEE International Conference on Power Electronics Drives Energy Systems (PEDES), December 16-19, 2014 pp. 1-6.
4. R. F Coelho, W. M Dos Santos and D. C. Martins, "Influence of power converters on PV maximum power point tracking efficiency" in Proceedings of 10th IEEE/IAS International conference Appl. (INDUSCON), November 5-7, 2012, pp. 1-8.
5. Kumar R, Singh B, "BLDC motor driven solar PV array fed water pumping system employing Zeta converter", IEEE transactions Ind. April 2016. 52, (3), pp. 2315-2322.
6. Bidyadhar Subudhu and Raseswari Pradhan "A comprehensive study on maximum power point tracking techniques for Photovoltaic power systems" IEEE transactions on sustainable Energy, Vol. 4, No. 1, January 2013.
7. Chen H. C, Huang H. H "Design of Buck type current source inverter fed brushless DC motor drive and its applications to position sensorless control with square wave current" IET Electric and Power Appl., 2013,7, (5), pp. 416-426.
8. Gow J. A and Manning C. D "Development of a photovoltaic array model for use in power electronics simulation studies" IEEE "proceedings on Electric Power Applications, Volume:146, Issue: 2, pp. 193-200 March 1999
9. J.M.Andujar,"Comparative analysis of buckboost converters used to obtain I-V characteristic curves of photovoltaic modules",2008 IEEE Power Electronics Specialists conference 06/2008
10. Sariki Murali,Vulisi Narendra Kumar,Gayadhar Panda,"Solar Powered BLDC Drive with Hybrid Energy Storage System Using Zeta Converter",2018 3rd International Conference for Convergence in Technology,2018
11. Venma Prabhash,P.Vandana,"PV fed BLDC motor using zeta converter with minimized torque ripple for water pumping",2016 International Conference on Emerging Technological Trends(ICETT),2016
12. Surbhi Shringi, Santosh Kr Sharma,Kuldeep singh Rathode,"Comparative study of Buck Boost,cul and Zeta Converter for maximum output power using P&O technique with solar",2019 2nd International Conference on Power Energy, Environment and Intelligent Control,2019

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