A Zeta Converter Fed Induction Motor Drive For Solar PV Array Based Water Pumping

S.KARTHIKA[1]
M.E scholar, Department of EEE
Sona College of Technology

S.VIJAY SHANKAR[2]
Associate Professor, Department of EEE
Sona College of Technology
Salem, Tamilnadu,India

***Abstract*— The main objective of the proposed system is meant for designing zeta converter fed induction motor drive for solar PV array based water pumping. The best alternative method for the conventional energy sources is solar energy. Now a days PV fed water pumping have a wide attention due to available solar energy. Zeta converter is a DC-DC converter. The input voltage of the zeta converter is variable and the output voltage is constant. The DC ripple is variable and the output voltage is constant. The DC ripple currents are reduced while using Zeta converter. The DC voltage is converted to AC using PWM inverter and then induction motor was drived. IncCond MPPT algorithm is used for detecting the peak voltage from the solar cells. Simulation and experimental results are presented to verify zeta converter fed induction motor drive for solar PV array based water pumping using MATLAB-SIMULINK.**

***Keywords*—Zeta-converter, MPPT, PV-array, Induction motor.**

I. INTRODUCTION

For extracting as much energy as possible from photovoltaic (PV) modules, the energy utilization needs to be improved, as well as power conversion efficiency of converters. Renewable energy sources are becoming an alternative source for cleaned and for generating the sustainable electricity in which photovoltaic (PV) systems have gaining advantages mainly due to increasing the modules efficiency, reduction of cost and political incitement. PV modules have strong dependence on solar radiation and surface temperature hence it cannot have a specified voltage or current across its terminals. The Maximum Power Point (MPP) is used as operation point in order to avoid extreme PV output power oscillations and ensure its operation with the highest efficiency (given a solar radiation and temperature condition). For ensuring PV systems operation on the MPP, specific circuits named by Maximum Power Point Trackers (MPPT) are employed. In most of application, a MPPT is achieved thought a dc-dc converter (hardware block), a tracking algorithm (software block) and external sensors (usually voltage, current or both), as From the software point of view, the most commonly employed tracking algorithms are Perturb and Observe (P&O) and Incremental conductance (IncCond). P&O method is simple, however it failure to track the MPP under abrupt changes on solar radiation and present oscillations around the MPP on steady-state. IncCond technique is accurate, nevertheless, its implementation is more complex, and similarly to the P&O method, it needs a voltage and a current sensor for properly work be capable of meeting the demanding reliability and performance criteria required. On the other hand, a zeta converter exhibits following advantages over the conventional buck, boost, buck-boost converters and Cuk converter when employed in SPV based applications.

- Belonging to a family of buck-boost converters, the zeta converter may be operated either to increase or to decrease the output voltage. This property offers a boundless region for maximum power point tracking (MPPT) of a SPV array. The MPPT can be performed with simple buck and boost converter if MPP occurs within prescribed limits.
- This property also facilitates the soft starting of BLDC motor unlike a boost converter which habitually steps up the voltage level at its output, not ensuring soft starting.
- Unlike a classical buck-boost converter, the zeta converter has a continuous output current. The output inductor makes the current continuous and ripple free.
- Although consisting of same number of components as a Cuk converter, the zeta converter operates as non-inverting buck-boost converter unlike an inverting buck-boost and Cuk converter. This property obviates a requirement of associated circuits for negative voltage sensing hence reduces the complexity and probability of slow down the system response. These merits of the zeta converter are favorable for proposed SPV array fed water pumping system.

II. CONFIGURATION OF PROPOSED SYSTEM

A zeta converter is utilized in order to extract the maximum power available from a SPV array, soft starting and speed control of Induction motor coupled to a water pump. Due to a single switch, this converter has very good efficiency and offers boundless region for MPPT. This converter is operated in continuous conduction mode reduces the stress on its power devices and components. Furthermore, the switching loss of VSI is reduced by adopting fundamental frequency switching resulting in an additional power saving and hence an enhanced efficiency. The phase currents as well as the DC link voltage sensors are completely eliminated, offering simple and economical system without scarifying its performance. The speed of Induction motor is controlled, without any additional control, through a variable DC link voltage of VSI. Moreover, a soft starting of Induction motor is achieved by proper initialization of MPPT algorithm of SPV array. These features offer an increased simplicity of proposed system.

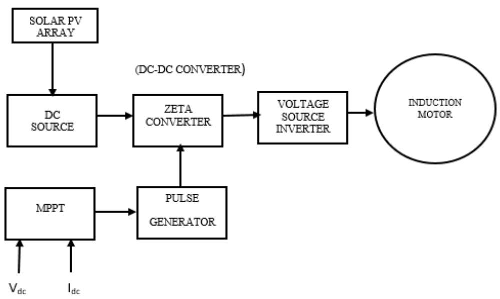

Fig.1 Block diagram of proposed system

III. OPERATION OF THE PROPOSED SYSTEM

The advantages and desirable features of converter and Induction motor drive contribute to develop a simple, efficient, cost-effective and reliable water pumping system based on solar PV energy. Simulation results using MATLAB/Simulink and experimental performances are examined to demonstrate he starting, dynamics and steady state behavior of proposed water pumping system subjected to practical operating conditions. The SPV array and Induction motor are designed such that proposed system always exhibits good performance regardless of solar irradiance level.

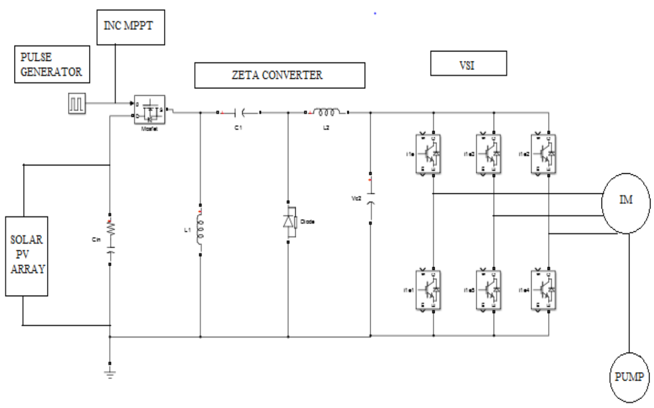

Fig.2. Operation of zeta converter

The VSI, converting DC output from a zeta converter into AC, feeds the Induction motor to drive a water pump coupled to the shaft. The VSI is operated in fundamental frequency switching through an electronic commutation of Induction motor assisted by its built-in encoder. The high frequency switching losses are thereby eliminated, contributing in an increased efficiency of proposed water pumping system.

IV. DESIGN OF THE PROPOSED SYSTEM

The various operating stages of the configuration are shown in fig. 1 such as the solar PV array, the zeta converter and the centrifugal pump are designed such that a satisfactory operation is always accomplished under any kind of change in solar insulation level. An Induction motor of 4 kW rated power is selected for a centrifugal water pump of 1 kW power rating. According to the selected power ratings, each stages of the proposed system are designed as follows.

A. Design of Solar PV array

The practical converters are associated with various power losses. The motor pump set also introduces the electrical and mechanical losses. To compensate these losses, the size of SV array is selected with slightly more peak power capacity to ensure the satisfactory operation regardless of power losses. A solar PV array of 4 kW peak power capacity, somewhat more than required by the motor, is selected so that the performance of the system is not affected by the losses associated with the converters and the motor.Table- I summarizes the estimation of the various parameters to design a solar PV array of appropriate size.

TABLE – I

DESIGN OF SOLAR PV ARRAY	
DC Input voltage from PV array	96.87 V
Voltage at MPPT (V) V_m	96.87 V
Current at MPPT (I) I_m	2.1 A

B. Design of Zeta Converter

The Zeta converter is the next design process consists of an estimation of input inductor, *L1*, output inductor, *L2* and intermediate capacitor, *C1*. These components are designed such that the zeta converter always operates in CCM resulting in reduced stress on its components and devices. An estimation of the duty cycle, *D* initiates the design of zeta converter which is estimated as

$$D = \frac{V_{dc}}{V_{dc}+V_m} = \frac{200}{200+96.87} = 0.673$$

TABLE-II

Zeta converter	
Input voltage	96.87 V
Output voltage	415 V

The components used in the zeta converter are two inductors, two capacitors, two resistors and their values are tabulated below in the table.

Table-III

Zeta converter components value	
C_{in}	R=100 Ω C=0.75 μF
L_1	0.06 mH
L_2	0.06 mH
C_1	2 mH
VC_2	0.1 mH
VC_1	100 Ω

C. Design of voltage source inverter

The voltage source inverter is designed next to zeta converter. A new design approach for estimation of DC link capacitor of VSI is presented here. This approach is based on the fact that 6th harmonic component of the supply (AC) voltage is reflected on the DC side as a dominant harmonic in the three phase supply system [3].

Here, the fundamental frequencies of output voltage of the VSI are estimated corresponding to the rated speed and the minimum speed of Induction motor essentially required to pump the water. These two frequencies are further used to estimate the values of their corresponding capacitors. Out of these two estimated capacitors, larger one is selected to assure a satisfactory operation of proposed system even under the minimum solar irradiance level.

The fundamental output frequency of VSI corresponding to the rated speed of Induction motor is estimated as is given as:

$$\omega_{rated} = 2\Pi f_{rated} = 2\Pi \frac{N_{rated} * P}{120} = 2\Pi \frac{1430}{120} 6 = 449 \text{rad/s}$$

D. Design of induction motor

The induction motor designed for coupling with the pump. The power rating, voltage, speed, frequency of the induction motor as shown in Table –IV. The 15 HP induction motor is used for coupling with the centrifugal pump. The torque value of the induction motor is constant. The frequency of the induction motor is 449 rad/sec.Induction motor RPM is given as 1430 rpm and the number of poles is 6. The rated frequency is 50 Hz.

TABLE-IV

Induction motor rating	
Power	4 KW
Voltage	400V
Frequency	50 Hz
Speed	1430 RPM

V. SIMULATION AND RESULTS

The FIG. (3) below, shows the simulated schematic diagram of the complete designing of zeta converter fed induction motor drive for solar PV array based water pumping. The modeling and simulation of the whole system has been done in MATLAB-SIMULINK.

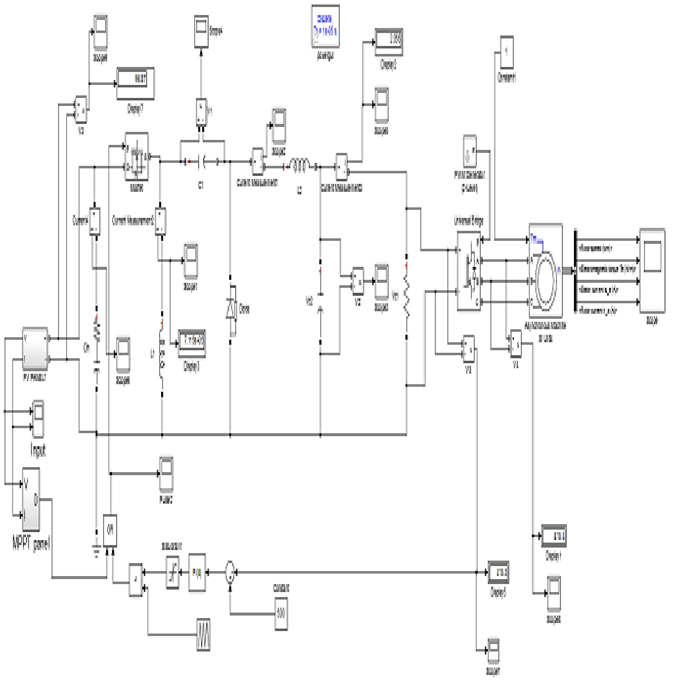

Fig.3. Simulink model of zeta converter fed IM drive for solar PV array based water pumping.

A. *Input voltage to* zeta coverter

The input voltage to zeta converter is DC voltage from solar PV array . The input voltage of zeta converter is 96.87 V. The input voltage of zeta converter is variable and the output voltage is constant.

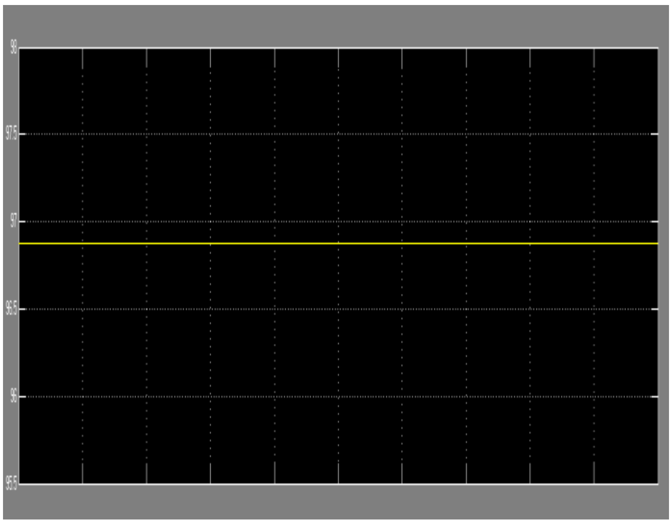

Fig.4. Input voltage to zeta converter

B. Output voltage of zeta coverter

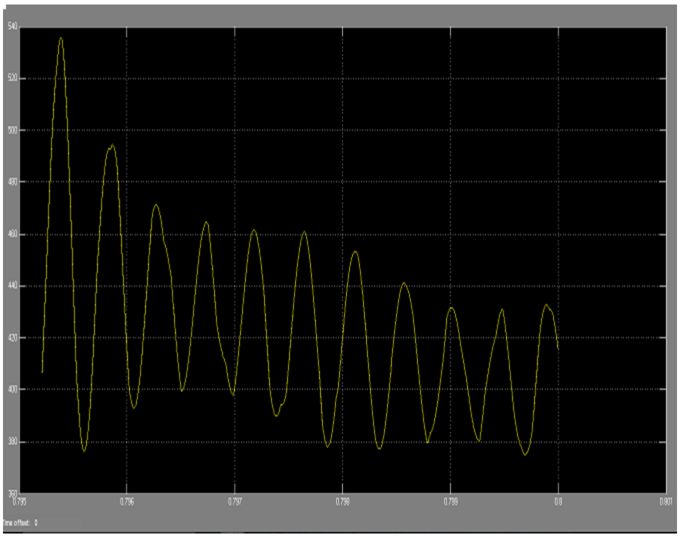

Fig.5. output voltage of zeta converter

The output voltage of the zeta converter is 415 V. The input voltage from the SPV array is boosted and the output is increased.

C. voltage source inverter output

The VSI converts 415 DC voltage to 415.4 AC supply for driving the Induction Motor. PWM signals are given to gate terminal for PWM output voltage.

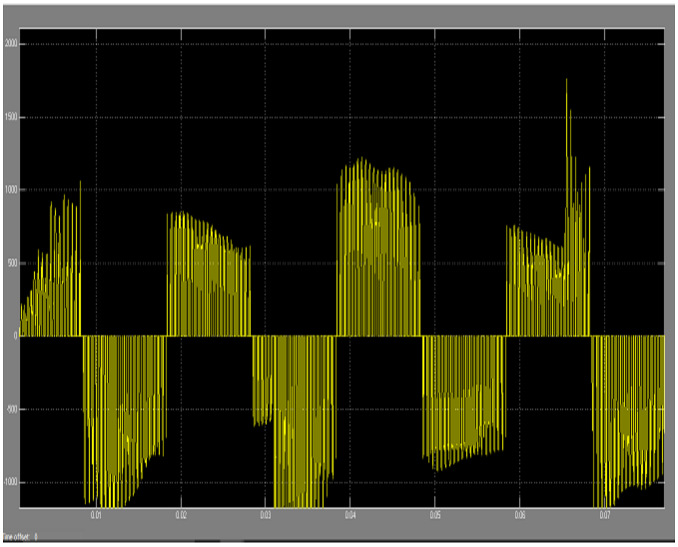

Fig.6. output waveform for VSI

D. Output waveforms for induction motor

The output waveforms of induction motor are given below (a) Rotor Speed, (b) Electromagnetic Torque, (c) Stator Current and (d) Rotor current.

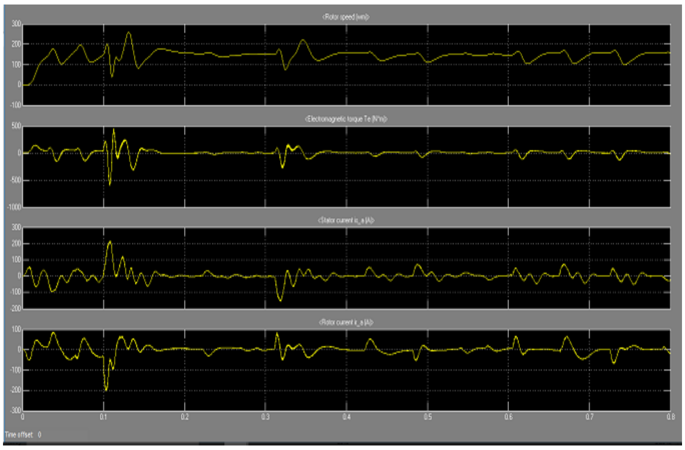

Fig.7. output waveforms of IM

VI. CONCLUSION

The transient, dynamic and steady state behaviors of the proposed zeta converter fed induction motor drive for solar fed PV array have been validated for water pumping. The proposed system has been modeled, designed and simulated in MATLAB/Simulink environment. A DC-DC zeta converter provides the flexibility of increasing and decreasing the voltage level and hence does not possess a limited region of MPPT. Taking the advantages of very good conversion efficiency of zeta converter, the induction motor and centrifugal pump, a suitable water pumping system based on solar PV array has been developed. The proposed system is designed brilliantly, such that the performance is not affected by the weather condition and efficiency limitations of the converters and motors. Using the simulated results, a zeta converter with the Induction motor is proved as a suitable combination for solar PV based water pumping.

References

[1] Rajan Kumar and Bhim Singh, Buck-Boost Converter Fed BLDC Motor Drive for Solar PV Array Based Water Pumping, 2014 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES).

[2] Rajan Kumar and Bhim Singh, BLDC Motor Driven Solar PV Array Fed Water Pumping System Employing Zeta Converter ,

[3] K.H. Ahmed, M. S. Hamad, S.J. Finney and B.W.Williams,"DC-Shunt Active Power Filter for Line Commutated Rectifiers to Mitigate the Output Voltage Harmonics," IEEE Energy Conversion Congress and Exposition (ECCE), 12-16 Sept. 2010, pp.151-157.

[4] Rahul P. Argelwar, V. S. Nandanwar, Sapna Verma,PFC Zeta Converter Fed BLDC Motor Drive for Fan Applications, International Journal of Research in Advent Technology, Vol.2, No.2, February 2014,E-ISSN: 2321-9637.

[5] Sreedevi K J , C Sojy Rajan ,A New Pulse Width Modulated PFC Zeta Converter Fed Sensorless BLDC Motor Drive with Position Feedback, International Journal of Science and Research (IJSR).