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Simulation Analysis of BLDC Motor Fed Solar Water Pumping System Using Zeta Convertor

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Abstract: *This paper present the simulation analysis of BLDC motor fed solar water pumping system using zeta convertor. In order to extract maximum power from SPV array for intermediate DC-DC convertor using an incremental conductance maximum power point technique. The main advantages of Zeta convertor like soft starting of BLDC motor and low ripple at the output voltage etc. The output of zeta convertor is given to three phase voltage source invertor via DC link capacitor for driving BLDC motor and centrifugal water pump is coupled to the shaft of BLDC motor which act as a load. The size of proposed system is selected such that, the performance not affected under dynamic condition. The performance under various operating condition is analyze and suitability of proposed system is demonstrated using MATLAB/Simulink software.*

Keywords: *SPV array, Zeta convertor, BLDC motor, Electronic commutation.*

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I. Introduction

A continuous reduction in the cost of the solar photovoltaic (SPV) panels and the power electronics devices has encouraged the researchers and the industries to utilize the solar PV array generated power for different applications.[1]-[2] The water pumping, a standalone application of the SPV array generated electricity is receiving wide attention now a days for irrigation in the fields, household applications and industrial use. Although several researches have been carried out in an area of SPV array fed water pumping, combining various DC-DC converters and motor drives, the zeta converter in association with a permanent magnet brushless DC (BLDC) motor is not explored precisely so far to develop such kind of system. However, the zeta converter has been used in some other SPV based applications. Due to a single switch, the zeta converter possesses very good conversion efficiency.[3]-[5] Its utilization is initiated in this paper for soft starting of the BLDC motor coupled to a centrifugal pump for water pumping. A centrifugal pump is selected because of its availability in a wide range of heads and flow rates, simplicity, low maintenance requirements and cost effectiveness. The BLDC motor having the merits of high efficiency, high reliability, high ruggedness, low EMI problems and excellent performance over a wide range of speed is used to drive this centrifugal pump. The ratings of the solar PV array and the BLDC motor are selected such that the proposed system operates successfully under all the variations in the atmospheric conditions. The various performances are analyzed through the simulated results using MATLAB/Simulink environment. Simulated results verify the suitability of the proposed system for solar PV based water pumping. A zeta converter exhibits the following advantages over the conventional buck, boost, buck–boost converters, and Cuk converter when employed in SPV-based applications. [6]-[8]

These merits of the zeta converter are favorable for proposed SPV array-fed water pumping system. In existing system the PV inverters dedicated to the small PV plants must be characterized by a large range for the input voltage in order to accept different configurations of the PV field. This capability is assured by adopting inverters based on a double stage architecture where the first stage, which usually is a dc/dc converter, can be used to adapt the PV array voltage in order to meet the requirements of the dc/ac second stage, which is used to supply an AC load or to inject the produced power into the grid. This configuration is effective also in terms of controllability because the first stage can be devoted to track the maximum power from the PV array, while the second stage is used to produce ac current with low Total Harmonic Distortion (THD). The additional control scheme causes increased cost and complexity, which is required to control the speed of BLDC motor. Moreover, usually a voltage-source inverter (VSI) is operated with high-frequency PWM pulses, resulting in an increased switching loss and hence the reduced efficiency. Although a Z-source inverter (ZSI) replaces dc– dc converter in, other schematic of Fig. 1 remains unchanged, promising high efficiency and low cost. Contrary to it, ZSI also necessitates phase current and dc link voltage sensing resulting in the complex control and increased cost. To overcome these problems and drawbacks, a simple, cost effective, and efficient water pumping system based on

SPV array-fed BLDC motor is proposed, by modifying the existing topology (Fig. 1) as shown in Fig. 2. A zeta converter is utilized to extract the maximum power available from an SPV array, soft starting, and speed control of BLDC motor coupled to a water pump. Due to a single switch, this converter has very good efficiency.[9]-[12]

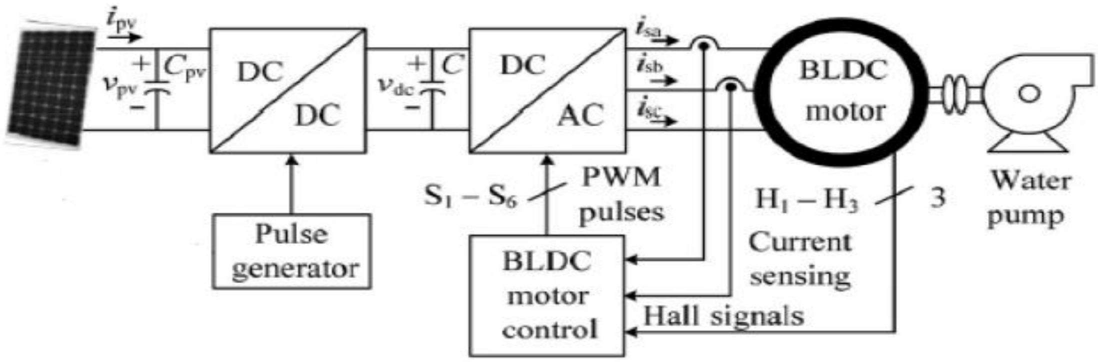

Fig.1. Existing Topology

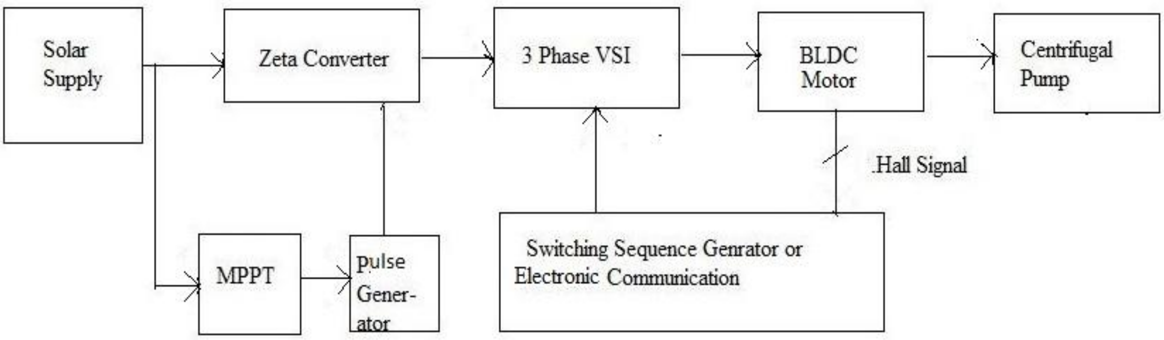

Fig.2. Proposed Topology

II. Operation Of The Proposed System

The proposed system consists of the SPV array, the zeta converter, the VSI, the BLDC motor and the centrifugal water pump which is coupled to its shaft. The BLDC motor having inbuilt encoder. The pulse generator is used to provide switching pulses to the zeta converter.The SPV array generates the electrical power. This electrical power is fed to the motor-pump system through the zeta converter and the VSI. SPV array act as the power source for the zeta converter. In ideal condition,, the same amount of power is transferred at the output of zeta converter which act as a input source for the VSI. But practically, due to the various losses related with a DC-DC converter, slightly less amount of the power is transferred at the VSI. The switching pulse for the IGBT switch of the zeta converter is generated through INC-MPPT algorithm. The INC-MPPT algorithm takes the voltage and current variables as feedback from SPV array and returns an optimum value of duty cycle. Further, the pulse generator generates actual switching pulse by comparing the duty cycle with the high frequency carrier wave. In this way, the maximum power extraction is possible and hence the efficiency optimization of the SPV array is possible.On the other hand, VSI converting the DC power output which is obtained from the zeta converter into the AC power which feeds the BLDC motor to drive the centrifugal pump coupled to its shaft. The VSI is operated by the fundamental frequency switching availed by the so called electronic commutation of BLDC motor assisted by its built-in encoder. The high frequency switching losses are thereby eliminated, contributing in the effective and increased efficiency operation of the proposed water pumping system.

III. Control Of Proposed System

The proposed system is controlled by electronic commutation are discussed as follows.For controlling the BLDC motor, the VSI operated through the electronic commutation of BLDC motor. There are 6 switching pulses are generated from the various possible combinations of 3 Hall-effect signals. These 3 Hall-effect signal is produced for specific range of rotor position. The electronic commutation provides fundamental frequency switching pulses to the VSI, thus the losses associated with the high frequency switching is completely eliminated.

IV. Simulated Results And Performance Analysis

The performance of the proposed solar PV powered zeta converter fed VSI-BLDC motor-pump system is simulated in the MATLAB/Simulink environment.To elaborate the dynamic performance of the proposed system, the solar isolation level is varied. The performances are evaluated using the simulated results as shown in Fig.3-Fig.7. These results verify the satisfactory performance of the proposed system even under the rapid and slow change in weather condition. A solar PV array of 1.5 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. The parameters of the solar PV array are estimated at the standard solar isolation level of 800 W/m^2 and 1000 W/m^2 . Voltage of the solar PV array at MPP is selected in view of the DC voltage rating of the BLDC motor same as the DC link voltage of the VSI. The steady-state performance of zeta converter at 800 W/m^2 and 1000 W/m2 . The input inductor current iL1, intermediate capacitor voltage Vc1, output inductor current iL2, voltage stress on IGBT switch VSW, current stress on IGBT switch ISW, blocking voltage of the diode VD, current through diode iD and dc-link voltage Vdc are presented. The zeta converter is operated in CCM. The operation of converter in this mode reduces the stress on power devices and components. These converter indices follow the variation in the weather condition and vary in proportion to the solar irradiance level, such as iL1, Vc1, iL2, and Vdc. The zeta converter automatically changes its mode of operation from buck mode to boost mode and vice versa according to the irradiance level to optimize the output power of SPV array. A small amount of ripples in the zeta converter variables are observed caused by permitting the ripples up to an extent to optimize the size of the components.

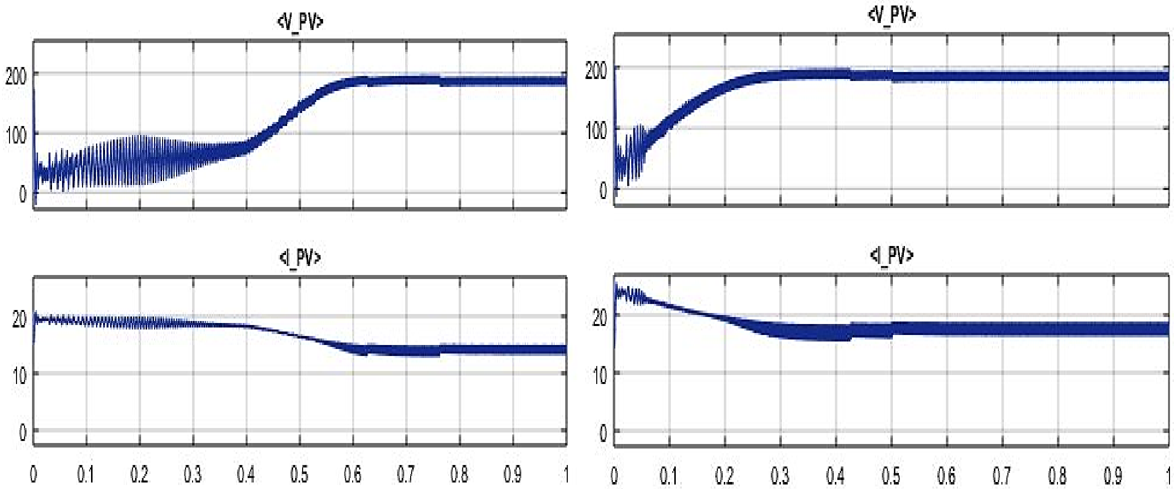

Fig.3. Performances of SPV array For Solar Irradiance (a) 800w/m^2 and (b) 1000w/m^2

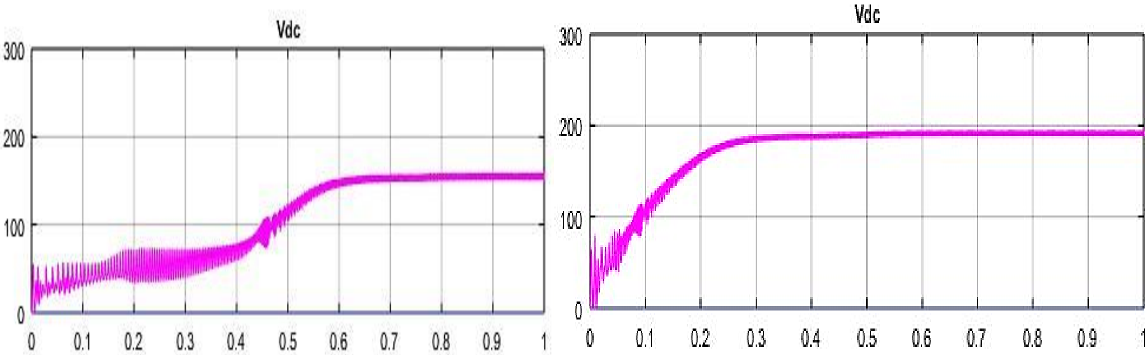

Fig.4. Performances of Zeta convertor for Solar Irradiance (a) 800w/m^2 and (b) 1000w/m^2

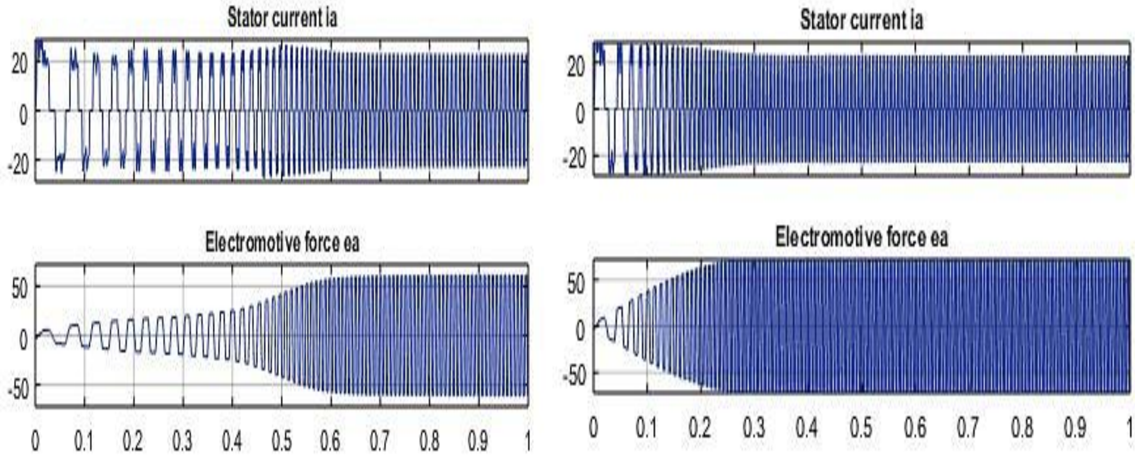

Fig.5. Performances of Stator Current and Electromotive force for Solar Irradiance (a) 800w/m^2 and (b) 1000w/m^2

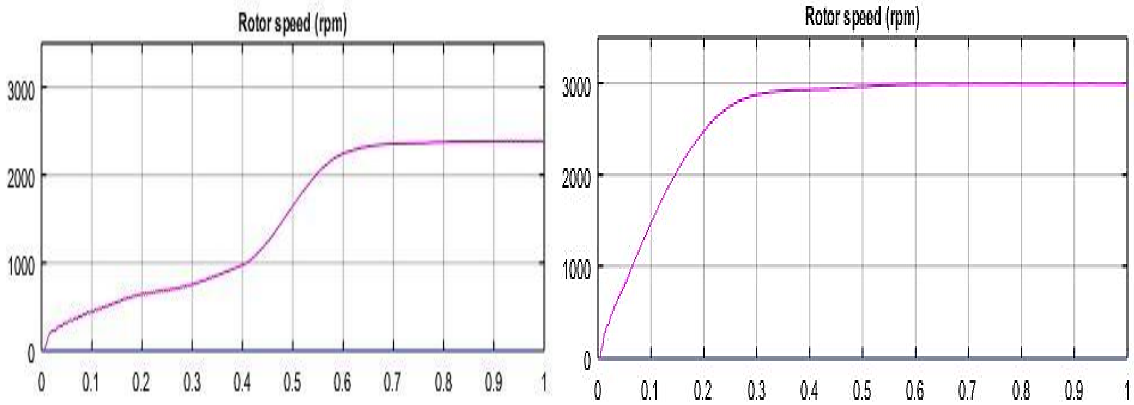

Fig.6. Performances of rotor speed for Solar Irradiance (a) 800w/m^2 and (b) 1000w/m^2

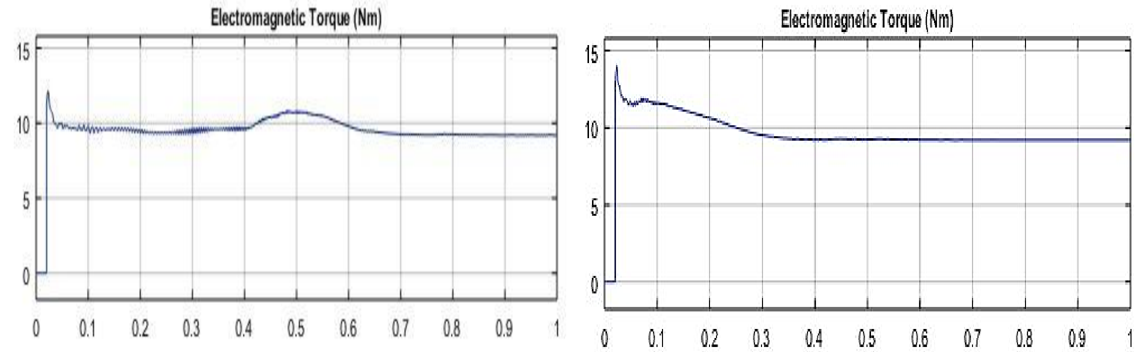

Fig.7. Performances of Electromagnetic torque for Solar Irradiance (a) 800w/m^2 and (b) 1000w/m^2

As the solar isolation level alters, the various BLDC motor–pump indices such as the back EMF, the stator current, isa, the speed, N, the electro-magnetic torque developed, Te and the load torque, TL vary in proportion to the solar isolation level. Two important facts are observed from the simulated results. First, the stator current, isa at the starting is controlled such that it takes time to reach its steady state value and hence the BLDC motor has a soft starting. Second, the BLDC motor develops the electromagnetic torque, Te equal to the torque required to drive the pump, TL under all variations in solar insolation level which manifest the stable operation of the proposed system regardless of the weather condition. However, a small pulsation in Te results from the electronic commutation of the BLDC motor. Besides these, the BLDC motor attains a speed higher than 2000 rpm, a minimum required speed to pump the water, regardless of the solar isolation level.The starting and steady state behaviors of the BLDC motor–pump at the standard solar isolation level of 800 W/m^2 and 1000 W/m^2 are shown in Fig. 6. All the motor indices increase and reach their rated values under steady state condition. Soft starting along with the stable operation of the motor–pump is observed and hence the successful operation of the proposed system is verified. The satisfactory performance of the BLDC motor–pump is verified at the minimum solar isolation level of 800 W/m2 also as shown in Fig. 6. The BLDC motor attains a higher speed than 2000 rpm, a minimum speed required to pump thewater, under this minimum solar isolation level also. Moreover, the soft starting and stable operation of the BLDC motor–pump contribute to the successful operation of the proposed system.

V. Conclusion

The performance analysis of BLDC motor fed solar water pumping system using zeta convertor has been proposed and its suitability has been demonstrated by analyzing its various performance indices using MATLAB based simulation study. A simple, efficient and economical method for speed control of BLDC motor has been suggested, which has offered absolute elimination of current sensing elements. The SPV array and MPPT is properly sized such that, system performance is not influence by the variation of atmospheric condition. Thus switching losses are reduced and maximum utilization of zeta convertor is achieved. The proposed system performance for various desired function such as soft starting of BLDC motor ,maximum power point extraction of SPV array, fundamental switching frequency of the voltage source invertor ,which result in reduce switching losses, reduce stress on zeta convertor switch and its component operating in it continuous conduction mode and stable operation. Hence the proposed system can be operated even under low radiation. The desired performance of proposed system even at 20% of standard solar irradiance has justified its suitability for solar PV based water pumping.

References

[1]. M. Uno and A. Kukita, ―Single-switch voltage equalizer using multistacked buck–boost converters for partiallyshaded photovoltaic modules,‖ IEE Trans. Power Electron., vol. 30, no. 6, pp. 3091–3105, Jun. 2015

[2]. R. Arulmurugan and N. Suthanthiravanitha, ―Model and design of a fuzzy-based Hopfield NN tracking controller for standalone PV applications,‖ Elect. Power Syst. Res., vol. 120, pp. 184–193, Mar. 2015.

[3]. S. Satapathy, K. M. Dash, and B. C. Babu, ―Variable step size MPPT algorithm for photo voltaic array using zeta converter—A comparative analysis,‖ in Proc. Students Conf. Eng. Syst. (SCES), Apr. 12–14, 2013, pp. 1–6.

[4]. R. Kumar and B. Singh, ―BLDC motor driven solar PV array fed water pumping system employing zeta converter,‖ in Proc. 6th IEEE India Int. Conf. Power Electron. (IICPE), Dec. 8–10, 2014, pp. 1–6.

[5]. Singh, V. Bist, A. Chandra, and K. Al-Haddad, ―Power factor correction in bridgeless-Luo converter-fed BLDC motor drive,‖ IEEE Trans. Ind. Appl., vol. 51, no. 2, pp. 1179–1188, Mar./Apr. 2015.

[6]. Singh and V. Bist, ―Power quality improvements in a zeta converter for brushless dc motor drives,‖ IET Sci. Meas. Technol., vol. 9, no. 3, pp. 351–361, May 2015.

[7]. R. F. Coelho, W. M. dos Santos, and D. C. Martins, ―Influence of power converters on PV maximum power point tracking efficiency,‖ in Proc. 10th IEEE/IAS Int. Conf. Ind. Appl. (INDUSCON), Nov. 5–7, 2012,pp. 1–8.

[8]. M. A. Elgendy, B. Zahawi, and D. J. Atkinson, ―Assessment of the incremental conductance maximum power point tracking algorithm,‖ IEEE Trans. Sustain. Energy, vol. 4, no. 1, pp. 108–117, Jan. 2013.

[9]. M. Sitbon, S. Schacham, and A. Kuperman, ―Disturbance observer based voltage regulation of current-mode-boost converter-interfaced photovoltaic generator,‖ IEEE Trans. Ind. Electron., vol. 62, no. 9, pp. 5776– 5785, Sep. 2015.

[10]. R. Kumar and B. Singh, ―Solar PV array fed Cuk converter-VSI controlled BLDC motor drive for water pumping,‖ 6th IEEE Power India Int. Conf. (PIICON), 5-7 Dec. 2014, pp. 1-7.

[11]. M. A. Elgendy, B. Zahawi and D. J. Atkinson, ―Assessment of the Incremental Conductance Maximum Power Point Tracking Algorithm,‖ IEEE Trans. Sustain. Energy, vol.4, no.1, pp.108-117, Jan. 2013.

[12]. J.V. Mapurunga Caracas, G. De Carvalho Farias, L.F. Moreira Teixeira and L.A. De Souza Ribeiro, ―Implementation of a High-Efficiency, High-Lifetime, and Low-Cost Converter for an Autonomous Photovoltaic Water Pumping System,‖ IEEE Trans. Ind. Appl., vol. 50, no. 1, pp. 631-641, Jan.-Feb. 2014.

[13]. Rajan kumar,Bhim sing,"BLDC motor driven solar pv arry fed water pumping system employing zeta convertor"IEEE,2014

[14]. S. Satapathy, K.M. Dash and B.C. Babu, "Variable Step Size MPPT Algorithm for Photo Voltaic Array Using Zeta Converter – A Comparative Analysis," Students Conference on Engineering and Systems (SCES), pp.1-6, 12-14 April 2013.

[15]. R.F. Coelho, W.M. dos Santos and D.C. Martins, "Influence of Power Converters on PV Maximum Power Point Tracking Efficiency," 10th IEEE/IAS International Conference eon Industry Applications (INDUSCON), pp.1-8, 5-7 Nov. 2012.

[16]. W.V. Jones, "Motor Selection Made Easy: Choosing the Right Motor for Centrifugal Pump Applications," IEEE Industry Applications Magazine, vol.19, no.6, pp.36-45, Nov.-Dec. 2013.

[17]. B.Devi Aarthi, Mr. P. Selvkumar, "BLDC motor fed by solar pv arry for water pimping system based on luo convertor",IJETCSE, april2016

[18]. Bhim Sing, Vashist Bist, "a single sensor based pfc zeta converter fed BLDC motor drive for fan application "IEEE, 2012

[19]. Huiying Zheng, Shuhui Li, Dong Zhang,"Comparative Study of Maximum Power Point Tracking Control Strategy for Solar PV System ",IEEE, 2012

[20]. Denizar Cruz Martins, "Zeta Converter Operating in Continuous Conduction Mode Using The Power Factor Technique"power electronics and varriabl speed drive, 23-25september 1996,conference publication no. 429,IEE,1996

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