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Design and Implementation of Modified Zeta Converter for BLDC Driven Solar PV Fed Water Pumping System

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Abstract: This work projects the design of modified Zeta converter for maximum power point tracking in solar Photo Voltaic based water pump driven by permanent magnet brushless DC motor. The ultimate objective is to provide an economic way for water pumping system in sub-urban region. In this work, the design and evaluation of a BLDC motor-driven water pumping system that is powered by solar PV array is configured. To examine the behaviour of individual components of system, the interaction of various components and fine tuning of the set points of control device have been studied through simulation based study and hardware model.

The starting, steady state and dynamic state characteristics of the solar PV module fed PMBLDC motor powered water pump is presented here to demonstrate the reliability of the proposed system. It is expected that using a BLDC motor will significantly improve the system performance for the same investment over other conventional drives. The modelling & simulation of the proposed system has been carried out in MATLAB-Simulink platform.

Keywords: Solar Photovoltaic array, Incremental Conductance method, Maximum Power Point Tracking, modified Zeta converter, Brushless DC motor, Water pump.

I. INTRODUCTION

Water pumping system is inevitable in the domestic and industrial environments. Different types of water pumping system have been developed to uplift water with high efficiency.

The electrical energy sources such as, human energy, animal power, wind, solar, hydro power and fossil fuels are used for water pumping system. Latest cognizance of global warming and increasing prices of fossil fuels had been drawn more attention towards the usage of non-conventional energy resources today.

Among the various non-conventional energy systems, solar energy systems have their merits such as clean energy without any pollution, infinite in quantity, and are becoming one of the promising future energies. Solar PV cells converts the luminous energy from the sun into electricity.

Among the assorted alternatives, solar energy is predominant, because of its abundance, and even more distribution in the nature than other renewable energy sources such as hydro, geothermal, wave, tidal and wind energies. Moving to the solar water pumping module, there is a tremendous scope in this area particularly in India. Because, about 250 clear sunshine days per year, the theoretical solar power acceptance on its land area in India is about 4 Petta watt-hour per year (PWh/yr). The average of daily solar energy occurrence towards India varies from 3 to 6 kWh/m^2 of about 1500-2000 day hours per year (depends upon its location), which is too far than present total energy consumption.

For an example, assume that efficiency of solar PV modules was low as 15%; this would be many times greater than local electricity demand. This would be sufficient as well to meet the electricity demands in urban areas and electricity requirements for irrigation would be easily settled.

In this paper, section 2 explains the problem formulation, section 3 narrates the operation of the proposed system, section 4 explains the design of proposed system, section 5 gives the control strategies for the proposed system, section 6 explains the simulation results of proposed system and section 7 list out the conclusions of the proposed system.

II. PROBLEM FORMULATION

BLDC motor driven water pumping based on a single stage solar PV generation provides a solution for converter less operation for PV system. Moreover the motor phase current sensing elements have been eliminated, resulting in a simple and cost-effective drive. Solar PV array - Cuk fed water pumping system using BLDC motor topology properly controls the Cuk through MPPT algorithm providing the smooth starting of the PMBLDC motor [3]. A single-stage sensor less control of bore-well PV based submersible PM BLDC motor topology has provided a position control sensor less scheme, used to eliminate the hall-sensors, improves the reliability of the system [4]. Design of photovoltaic BLDC motor-water pump system with single converter topology has provided a single converter that is implemented by a three phase three leg inverter was used as an interface between the PV modules and the motor [5]. Solar PV array - SEPIC fed water pumping system using BLDC motor topology properly regulates the SEPIC through MPPT algorithm offers the smooth starting of the PMBLDC motor [10].

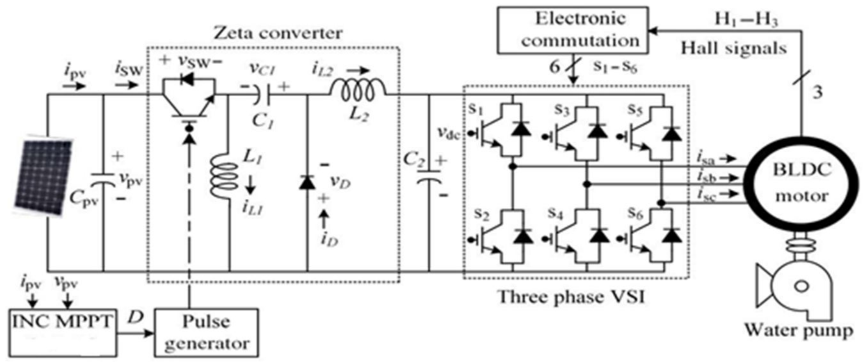

Fig. 1. Proposed SPV-modified zeta converter-fed BLDC motor drive for water pump.

III. OPERATION OF PROPOSED SYSTEM

The Solar (PV) module produces the necessary electrical power required by the motor to drive the water pump. This obtained electrical power given to the PMBLDC motor-pump drive via zeta converter & voltage source inverter. Ideally, the power given to input of VSI is same as the power delivered to the output of (DC-DC) Zeta converter. Practically, due to different kind of losses in a dc- dc converter, slightly less amount of input power is transferred to the VSI. The pulse generator triggers the switching pulses for an IGBT switch present in the zeta converter through Incremental Conductance-MPPT algorithm. The INC-MPPT algorithm utilizes current & voltage as feedback input from Solar (PV) array and generates an ideal value of duty cycle. Further, it generates an actual switching pulse by compare with the duty cycle of a higher frequency carrier wave. The VSI, converts the DC power from zeta converter into an AC power which gets feed to the BLDC motor for water pump which is coupled through its shaft. The Voltage Source Inverter (VSI) is operated by fundamental frequency switching technique through an electronically commutated circuit of BLDC motor accelerated through its encoder. The higher frequency switching losses gets eliminated, which contributes an enhanced reliability of preferred water pumping system. The structure of the proposed Solar (PV) array powered PMBLDC motor gets driven water pumping system engaging a zeta converter as shown in Fig. 1. The pulse generator produces pulses to operate a zeta converter.

IV. DESIGN PROCEEDING OF PROPOSED SYSTEM

Different operating stages of the system shown in the Fig. 1 are properly decided to develop an optimized water pumping system, which is capable of working under an uncertain conditions. A PMBLDC motor drive of 100W rated power & Solar (PV) array of 250W capacity is processed under standard test conditions (STC) to design the preferred system. The design procedure for each phases such as Solar (PV) array, zeta converter, VSI, BLDC motor drive & water pump are reported as follows.

A. Design Procedure for SPV Array

The power ratings of Solar (PV) array is selected thrice the peak load power demand in order to fortify the adequate operation irrespective of power losses. Therefore, the Solar (PV) array of peak power capacity of P_{mmp}= 250W under STC (STC: 1000 W/m^2, 25 $^\circ$C, AM 1.5), more than the demanded capacity of motor-pump is used and its sufficient parameters are get designed accordingly.

Electrical specifications of solar module are listed in appendix. The number of solar modules connected in parallel/series are estimated upon the voltage of Solar PV array at MPP under STC as V_{mpp} = 35.55 V.

The current of Solar PV array at MPP I_{mpp} is evaluated as $I_{mpp} = P_{mpp}/V_{mpp}$ = 250/35.55 = 7.04 A.

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B. Design Procedure for Zeta Converter

The components associated in Zeta converter such as input inductor L_1, intermediate capacitor C_1 and output inductor L_2. These required components are designed to operate a zeta converter, so that is always operates in continuous current mode resulting to relieve stress on their components and devices.

An evaluation of duty ratio *D* follows the design process of zeta converter which is estimated through below equation,

$$D = \frac{V_{dc}}{V_{dc}+V_{mpp}} = \frac{24}{24+35.355} = 0.4030 \quad (1)$$

An average amount of current passing through dc link capacitance of the VSI I_{dc} is calculated as

$$I_{dc} = \frac{P_{mpp}}{V_{dc}} = \frac{250.272}{24} = 10.428\ (A) \quad (2)$$

Then, $L1$, $L2$, and $C1$ are estimated as

$$L_1 = \frac{D*Vmpp}{fsw*\Delta Il1} = \frac{0.4030*35.55}{20000*7.04*0.06} = 1.69*10^{-3} \approx 2 (mH) \quad (3)$$

$$L_2 = \frac{(1-D)*Vdc}{fsw*\Delta Il2} = \frac{0.597*24}{20000*10{,}428*0.06}$$

$$= 1.14*10^{-3} \approx 1\ (mH) \quad (4)$$

$$C_1 = \frac{(1-D)*Vdc}{fsw*\Delta Il2} = \frac{0.4030*10.428}{20000*24*0.1} = 8.75*10^{-5} (F) = C_2 \quad (5)$$

Where, f_{sw} denoted as switching cycle frequency of the IGBT switch in zeta converter; ΔIL_1 is the amount of allowed current ripple flowing through L_1, same as $IL_1 = I_{mpp}$; ΔIL_2 is the amount of allowed ripple in the current flowing through L_2, same as $IL_2 = I_{dc}$; ΔVC_1 is allowed ripple in the voltage across C_1, where's same as $VC_1 = V_{dc}$.

Based upon the specification of estimated SPV array in appendix, buck the maximum voltage of 36 V to 24 V by using Zeta Converter.

C. Calculation of DC-Link Capacitor for 3Φ VSI

An approach for calculation of dc-link capacitor for VSI is presented here. This is based on a fact that the 6th harmonic component present in the AC supply, voltage which get feedback on DC side which makes a predominant harmonic occurs in three-phase AC supply.

These frequencies are required to estimate their corresponding capacitor values. From these two capacitors, larger value is selected to satisfy a sufficient performance of the preferred system irrespective to the variation in irradiance level of PV panel.

The fundamental switching frequency of VSI corresponding towards the rated speed of the Permanent magnet Brushless DC motor ω_{rated} is calculated through this equation,

$$\omega_{rated} = \frac{2\pi*Nrated*P}{120} = \frac{2*\pi*4000*8}{120} = 1675.51 (rad/sec) \quad (6)$$

The fundamental switching frequency of VSI corresponding towards the minimum speed of the Permanent magnet Brushless DC motor essentially required to pump the water (N = 1100 r/min), ω_{min} is calculated through this equation

$$\omega_{min} = \frac{2\pi*N*P}{120} = \frac{2*\pi*1100*8}{120} = 460.766 (rad/sec) \quad (7)$$

where f_{rated} and f_{min} are fundamental switching frequencies of voltage for VSI corresponding to minimum speed & rated speed of BLDC motor essentially required to pump the water, respectively, in Hz; N_{rated} is rated speed of the BLDC motor; *P* is a number of poles present in PMBLDC motor.

The value of dc link capacitor of VSI at ω_{rated} through this equation.

$$C_{2rated} = \frac{Idc}{p*\omega h*\Delta Vdc} = \frac{10.428}{8*1675.51*24*0.1} = 3.241\ (mF) \quad (8)$$

Similarly, a value of dc link capacitor of VSI at ω_{min} through this equation

$$C_{2min} = \frac{Idc}{P*\omega l*\Delta Vdc} = \frac{10.428}{6*460.766*24*0.1} = 1.178\ (mF) \quad (9)$$

Where, ΔV_{dc} is an amount of allowed ripple across dc-link capacitor C_2. Finally, C_2 = 1.3 mF is selected as the dc-link capacitor. i.e., (C_{2min}).

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D. Design Procedure for Water Pump

In order to give load torque to the BLDC motor, we have to calculate the proportionality constant K_p to give feedback to motor.

$$Kp = \frac{P}{\omega r^{\wedge}3} \qquad (10)$$

Where, P = 100 W is required power developed by PMBLDC motor and ω_r is mechanical speed of rotor. (k_p = 1.36e-8).For a hydraulic applications such as water pump rotor speed ω_r, is squared up with the proportionality constant k_p, to produce desired load torque T_L to particular application

$$T_L = K_p * \omega_r^2 \qquad (11)$$

Rate of discharge of water can be expressed in litre per minute can get obtained by the expression,

$$Q = \frac{T\omega}{g*H*60} \qquad (12)$$

Where, g is acceleration due to gravity constant (9.8 m/s^2), H denotes height of the outlet of pump is expressed in mm i.e., 1000.

V. CONTROL STRATEGIES FOR PREFERRED SYSTEM

The preferred solar water pumping system is get managed by two separate control techniques through Maximum Power Point Tracking and Electronic commutation. Are explained as follows.

A. INC- Maximum Power Point Tracking (MPPT) Algorithm

The Incremental Conductance technique is utilized, in order to avoid the drawbacks of P&O MPPT method. It is based on, derivative of output power P_{pv} of solar panel with respect to its corresponding panel voltage V_{pv} is equivalent to zero at the maximum power point.

$dI = \Delta I = I(k) - I(k-1).$ (13)

$dV = \Delta V = V(k) - V(k-1).$ (14)

The maximum power point can get tracked by comparing the incremental conductance (dI/dV) to the instantaneous conductance (I/V),

$(dI_{pv}/dV_{pv}) = -(Ipv/Vpv)$, at MPP (15)

$(dI_{pv}/dV_{pv}) > -(I_{pv}/V_{pv})$, to the left of MPP (16)

$(dI_{pv}/dV_{pv}) < -(I_{pv}/V_{pv})$, to the right of MPP (17)

The equation above used, provides a control algorithm to control operating point of the converter by measuring the instantaneous and incremental inverter conductance (dI_{pv}/dV_{pv} and Ip_v/Vp_v, respectively). Thus, based upon the relation between incremental and instantaneous conductance, the MPPT decides the perturbation direction. In addition, an optimal perturbation step size ($\Delta D = 0.001$) is chosen, which grants to the soft of BLDC motor.

B. Electronic Commutation for the PMBLDC Motor

The PMBLDC motor get regulate by using a VSI which get manage through the electronic circuitry of PMBLDC motor. An electronic commutation for BLDC motor provides current commutation which flowing through the primary windings with a sequence employing a decoder. Switching pulses were produced as per various possible Hall-effect signal. The necessary combination of three Hall-effect signals get generated for each specific rotor position at regular interval around 60◦. The six switching pulses regarding to rotor position was tabularized in the Table I. It is detectable that only two switches can conduct at a time i.e., in 120◦ conduction mode VSI operation, due to that conduction losses may get reduced. A BLDC motor with an inbuilt encoder is used in the preferred system and its detailed decoder combination are given in the Table. I.

Table I. Truth Table for switching states of BLDC Motor

Rotor Position	Hall Signals			Switching Signals					
(Degree)	H1	H2	H3	S1	S2	S3	S4	S5	S6
NA	0	0	0	0	0	0	0	0	0
0-60	0	0	1	0	0	0	1	1	0
60-120	0	1	0	0	1	0	0	0	0
120-180	0	1	1	0	1	1	0	1	0
180-240	1	0	0	1	0	0	0	0	1
240-300	1	0	1	1	0	0	1	0	0
300-360	1	1	0	0	0	1	0	0	1
NA	1	1	1	0	0	0	0	0	0

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VI. SIMULATION RESULTS OF THE PROPOSED SYSTEM

The presented system is modelled, designed & simulated considering the static and random variations with respect to irradiance level of PV array and its satisfactory performance is demonstrated by examine the starting, steady state & dynamic behaviour are shown in Figs. 2, 3. To illustrate the reliability in dynamic condition, under at different irradiance levels of about [200, 1000, 650, 800, 1000] w/m^2, operating temperature is 25 degree Celsius.

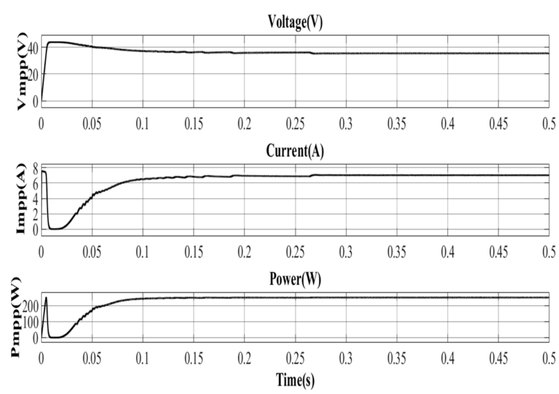
A. Performance of Solar PV array

Fig. 2(a) reveals the steady-state performances of Solar PV array at 1000 W/m^2. The MPP is properly tracked for low value of duty cycle (D). However, a negligible tracking time is required to show the dynamic condition with respect to solar irradiance variations as shown in Fig. 3(a).

Two studies were conducted on the solar PV module using the MATLAB SIMULINK. In first study, the effect of solar irradiance level regarding the performance of the PV module is investigated. This is done by simulating the module under irradiance values between 500-1000 W/m^2 In 200 W/m^2 steps while maintaining the cell temperature at a constant level which is taken to be 25 °C. It can be observed from the curves that the short circuit current I_{sc} and the open circuit voltage V_{oc} of the PV module increase with increasing irradiance levels. Accordingly, the maximum output power of the solar module increases.
In the second study, the effect of the PV cell temperature regarding the performance of solar PV module is investigated. This is done by simulating the module with the temperature values 0 °C, 25 °C, and 50 °C, while maintaining the irradiance at its reference level of 1000 W/m^2. It is observed that the maximum power and V_{oc} increase with decreasing temperature. However, decreasing the temperature leads to a marginal decrease in I_{sc}.

B. Performance Validation of Zeta Converter

Fig. 2(b) presents the steady-state performance of zeta converter at 1000 W/m^2. The input inductor current I_{L1}, intermediate capacitor voltage V_{c1}, output inductor current I_{L2}, voltage stress on IGBT switch V_{SW}, current stress on IGBT switch I_{SW}, blocking voltage of the diode V_D, current through diode I_D, and dc-link voltage V_{dc} are presented. The zeta converter is always operated in Continuous current mode. In this converter simulation result shows the variation in solar irradiance level, such as I_{L1}, V_{c1}, I_{L2}, and V_{dc} shown in Fig. 3(b).



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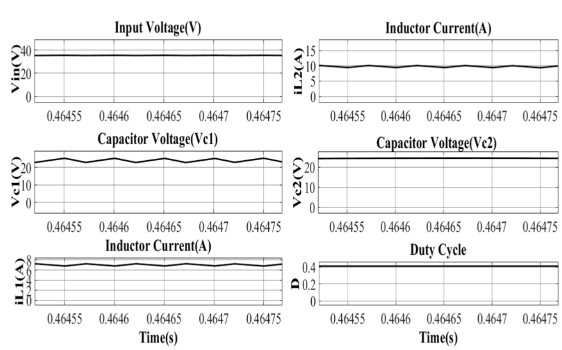

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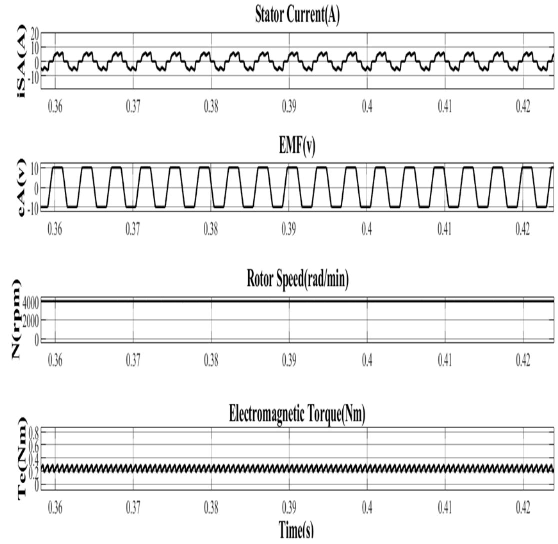

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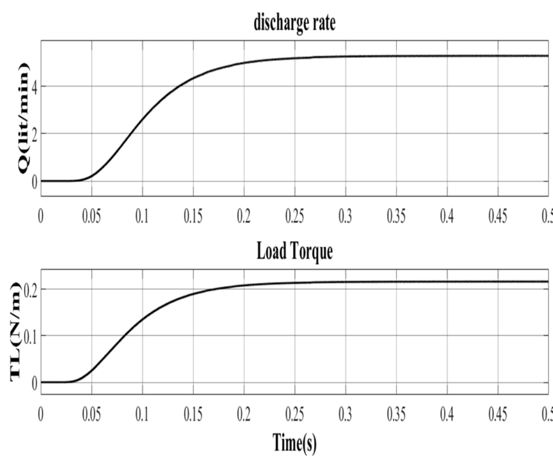
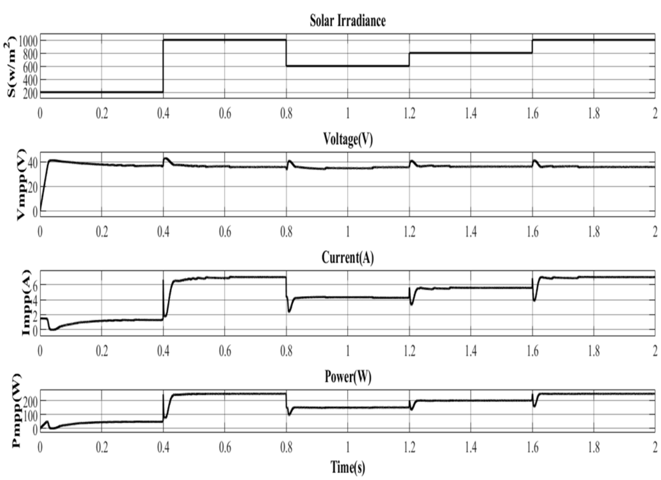
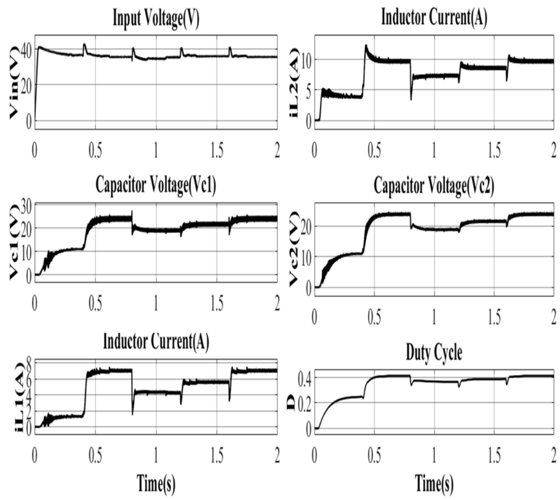


(d)

Fig.2 Steady-state performances of preferred Solar PV array based zeta converter-fed BLDC motor drive for water pump. (a) Solar PV array variables. (b) Zeta converter variables. (c) PMBLDC motor variables (d) Water pump variables.



(a)



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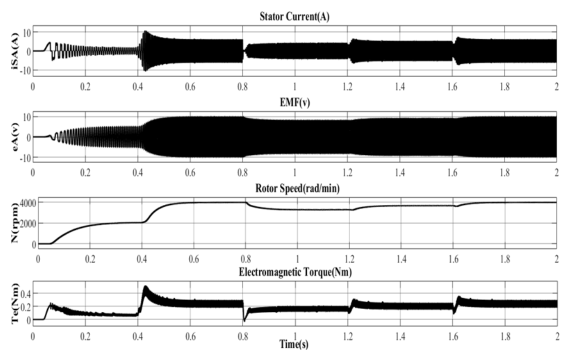

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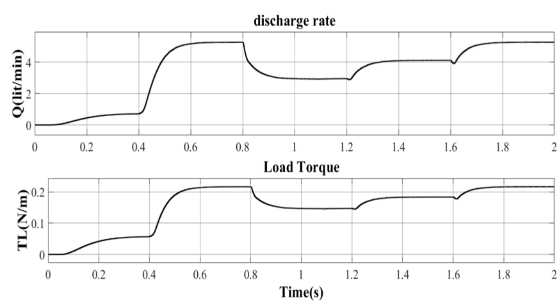


(d)

Fig.3 Dynamic performances of preferred Solar PV array-based zeta converter-fed BLDC motor drive for water pump. (a) Solar PV array variables. (b) Zeta converter variables. (c) PMBLDC motor variables. (d) Water pump variables.

C. Performance of BLDC motor

Motor parameters such that the speed N, back EMF E_a, stator current I_{sa}, the developed electromagnetic torque T_e, and load torque T_L reach their rated values are taken. Fig. 2(c) presents the steady state performance of preferred system is analysed. In that, preferred system is operated under steady state operating condition i.e., solar irradiance is 1000 w/m^2, operating temperature is 25 degree Celsius. Through that condition we analyse that at constant supply of 24 V dc link voltage to inverter maintains motor at rated speed of 4000 rpm and rated torque of 0.25 N-m.

Fig. 3(c) presents the dynamic performance of preferred system. In that preferred system is operated under solar irradiance levels of about [200, 1000, 650, 800, 1000] w/m^2, operating temperature is 25^{o}C. Through that condition we analyse that the proposed system is operated even under low solar irradiance level of 200 w/m^2 at minimum speed of 2000 rpm and minimum torque of 0.187 N-m.

D. Performance of Water pump

The simulated performances are considered to evaluate the performance of water pumping system. Table. III and Figs. 5(a), 5(b) show the evaluated performance of the Solar PV array-fed BLDC motor-pump, undergoing variation in solar insolation level, where S, N, and Q are the solar irradiance from the SPV array, Speed of the BLDC motor, and rate of discharge of water pump. Hence, this efficiency includes the efficiency of zeta converter, INC-MPPT algorithm, VSI, and BLDC motor. The consistent discharge rate of water about 5.3 litre/min is obtained at STC of 1000 W/m^2, whereas motor pumps water at rate of 0.75 lit/min even at 200 W/m^2.

Table II. Estimated Efficiency of Proposed System

Solar Irradiance (w/m^2)	Duty Cycle(D)	$P_{pv\,(W)}$	$P_{m(W)}$	η(%)
400	0.32	100	76	76
650	0.35	164	134	81.7
800	0.38	200	173	86.5
1000	0.41	250	232	92.8

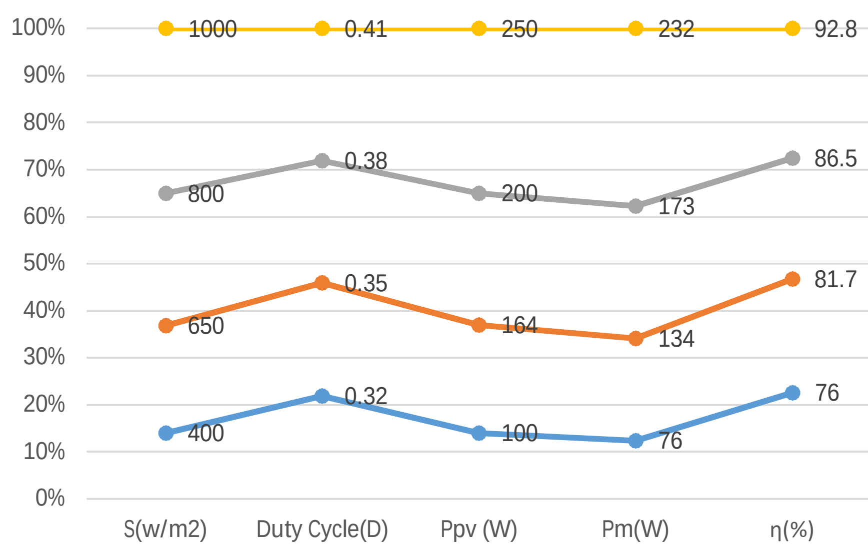
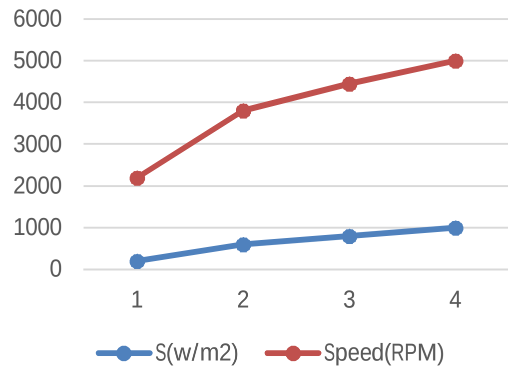


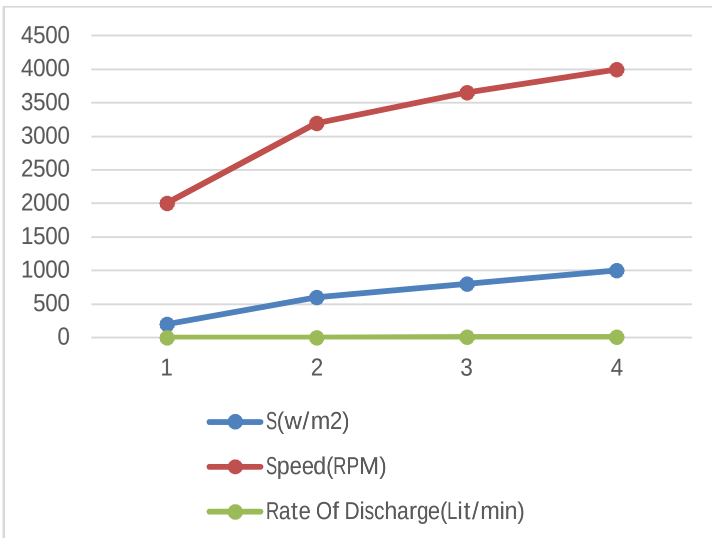
Fig. 4 Efficiency and power with solar irradiance levels.

Table .III Water pump Estimation

Solar irradiance level (w/m^2)	Speed (RPM)	Load Torque(N/m)	Rate Of Discharge(Lit/min)
200	2000	0.0526	0.750
600	3200	0.147	2.96
800	3650	0.186	4.12
1000	4000	0.216	5.3



(a)



(b)

Fig. 5 Water pump performance (a) Solar irradiance vs Shaft speed, (b) Solar irradiance vs motor speed, Rate of Discharge of pump.

E. Efficiency Evaluation of Preferred System

The simulated performances are considered to evaluate the efficiency of the preferred water pumping system. Table II and Fig. 4 show the calculated efficiency for the Solar PV module fed PMBLDC motor pumping system subjected to a variation in the insolation level, where P_{pv}, P_m, and η are, the maximum power extracted from the Solar PV array, mechanical power output of the BLDC motor, and efficiency. A very good efficiency of 92.8% is obtained at the optimum solar irradiance level of 1000 W/m^2, whereas it is 76% even at 400 W/m^2.

VII. CONCLUSION

In this paper, modified Zeta Converter based BLDC drive for solar powered water pumping system has been proposed and its appropriateness has been demonstrated through simulated results. In the proposed system, the maximum power of solar array has been obtained through INC-Maximum Power Point Tracking technique in which maximum power point get tracked and maintained according to its operating conditions. Zeta converter is designed for rated voltage of BLDC motor and efficiency of converter is improved in standard operating condition and the results were tabulated. DC link capacitance is designed to regulate the speed of PMBLDC motor which eliminates the speed controller and current controlled circuitry that reduces cost and complexity. PMBLDC motor drive is implemented and the performance of this drive for solar power water pumping system is validated under steady and dynamic behaviour of PV system. The proposed system has operated successfully even under minimum solar irradiance.

VII. APPENDIXES

A. Parameters of Solar PV array (Simulated Data)

V_{oc} = 44 V; I_{sc} = 7.58 A; P_{mpp} = 250W; V_{mpp} = 35.55 V; I_{mpp} = 7.04 A; N_{ss} = 54.

B. Parameters for BLDC motor (Simulated Data)

Stator phase/phase resistance, R_s = 0.18 Ω; stator/phase inductance, L_s = 0.7 mH; torque constant, K_t =0.036 Nm/A; voltage constant, K_e = 17 V_{LL}/kr/min; rated speed, N_{rated} = 4000 r/min; no. of poles, P = 8.

REFERENCE

[1] Rajan Kumar, Bhim Singh," BLDC Motor Driven Solar PV Array Fed Water Pumping System Employing Zeta Converter," IEEE Transactions On Industry Applications, Vol. 52, No. 3, pp:2315 - 2322,may-june.2016.
[2] Rajan Kumar, Bhim Singh," Single Stage Solar PV Fed Brushless Dc Motor Driven Water Pump," IEEE Journal Of Emerging And Selected Topics In Power Electronics ,Volume: 5, No. 3,pp: 1377 - 1385, Sept.2017.
[3] S. Sashidhar , V. Guru Prasad Reddy , B. G. Fernandes," A Single-stage Sensorless Control Of A PV Based Bore-well Submersible BLDC Motor," IEEE Journal Of Emerging And Selected Topics In Power Electronics (Early Access), February. 2018.
[4] Rajan Kumar, Bhim Singh," Solar PV Powered BLDC Motor Drive For Water Pumping Using Cuk Converter," IET Electric Power Applications ,Volume: 11, No. 2, pp:222 - 232, February.2017.
[5] S. Sashidhar, B.G.Fernandes," A Novel Ferrite SMDS Spoke-Type BLDC Motor for PV Bore-Well Submersible Water Pumps," IEEE Transactions on Industrial Electronics, Volume: 64, No. 1, pp:104 – 114, Jan. 2017.
[6] Parackal R., Koshy R.A, "PV powered zeta converter fed BLDC drive," Annual Int. Conf. on Emerging Research Areas: Magnetics, Machines and Drives (AICERA/iCMMD), vol.24–26, pp.1–5, July 2014.
[7] Dursun M, Ozden S, "Application of solar powered automatic water pumping in Turkey," International Journal for Computer Science and Electrical Engineering (IJCEE), vol.(2), pp.161–164, May 2012.
[8] Slamet Riyadi ," Design of photovoltaic BLDC motor-water pump system with single converter," 3rd International Conference of Information Technology, Computer and Electrical Engineering (ICITACEE), Oct. 2016.
[9] Taghvaee M.H, Radzi M.A.M, Moosavain S.M, "A current and future study on non-isolated DC–DC converters for photovoltaic applications," Renew. Sustain. Energy Rev., vol.17, pp. 216–227, Jan 2013
[10] Rajan Kumar, Bhim Singh," Solar PV array fed water pumping system using SEPIC converter based BLDC motor drive" 2014 IEEE National Power System Conference(NPSC), pp:104 – 114Dec. 2014.
[11] Terki, A. Moussi, A. Betka, and N. Terki, "An improved efficiency of fuzzy logic control of PMBLDC for PV pumping system," Appl. Math Modell., vol. 36, no. 3, pp. 934–944, Mar. 2012.
[12] 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.
[13] 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.
[14] H. El Khateb, N. Abd. Rahim, J. Selvaraj, and B. W. Williams, "DC- DC converter with low input current ripple for maximum photovoltaic power extraction," IEEE Trans. Ind. Electron., vol. 62, no. 4, pp. 2246 – 2256, Apr. 2015.
[15] M. Ouada, M. S. Meridjet, and N. Talbi,"Optimization photovoltaic pumping system based BLDC using fuzzy logic MPPT control," in Proc. Int. Renew. Sustain. Energy Conf. (IRSEC), pp. 27–31, Mar. 7–9, 2013.
[16] W. V. Jones, "Motor selection made easy: Choosing the right motor for centrifugal pump applications," IEEE Ind. Appl. Mag., vol. 19, no. 6, pp. 36–45, Nov/Dec. 2013.

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