

Intelligent Hybrid Fuzzy Controller Based Zeta DC-DC Conversion Device for Brush-Less-DC Motor Drive Water Pumping System fed from PV

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Abstract: In this interpreted paper, one un-conventional form of energy originating source feeding the water-pump machine implementing a conversion device as an intermediary chopper called Zeta converter (ζ -DC-to-DC converter) which collect the utmost possible power available at the un-conventional originating source of energy. Incremental MPPT regulates smooth and safe start of BRUSH-LESS-DC motor to fed centrifugal water pump, which is connected to shaft to run the ζ dc-dc converter. By using ζ dc-dc converter, smooth and safe of BL-DC motor is reduced for the harmful nature of high amount of starting current. A VSI is fed to BL-DC motor over commutation electronically so that eliminating losses in switching with high frequency switching. The mentioned system in this interpreted paper is designed and simulated; hence, the performance is effected under the normally running scenario. The demonstration of both dynamically changing and steady state conditions is done by using MAT-LAB/Simulink software and the outputs are analyzed.

Index Terms: Renewable energy, Zeta-converter, Incremental conductance mode-Maximum power point tracking method [INC-MPPT], Brush-less-DC motor, Electronically commutated.

I. INTRODUCTION

Substantial decrement in the expense of electronic devices and decay of non-renewable fuel sources in near future invite to use the un-conventional mode of energy generated electrical power for applied in various operations to great extent. Electric power generated by pumping water, an independently operated and applied in un-conventional energy, is receiving wide attention recently for in the agriculture fields, applied in household and industrial usage. Although the various developments achieved in the un-conventional mode of energy field implementing water pumping, together different motor drives, DC-DC converting devices and the ζ dc-dc conversion device in collaboration with the PMBRUSH-LESS-DC motors (Permanent Magnet Brush-less-DC) motor is still not evaluated to develop this type of system. However, the ζ -dc-dc conversion device is applied in some other un-conventional mode of energy sources. [1-4]. The advantages both the Brush-Less-DC motor & ζ dc-dc conversion device can allot to develop an appropriate

energy from un-conventional source feeding the water pump motor having the strength of operating fulfilment under changing atmospheric conditions dynamically. Some of the benefits of Brush-Less-DC motor are improved cooling, radio interference, low frequency value and noise. It is greatly efficient, reliable, and has large torque/inertia ratio & it doesn't need any maintenance [5-6]. Moreover, a ζ dc-dc conversion device has dominance over the usual DC-DC converters like Step-up, Step-Down and Step up-down Choppers when applied in un-conventional mode of energy sources. It is from Chopper family and can be used to higher or low value of the output voltage. Hence mostly the available power can be tracked from un-conventional mode of energy source using a ζ dc-dc converter. Using a simple Step-up chopper we can get the maximum power, but only within the suggested limits. As previously mentioned, the ζ dc-dc conversion device property also provides the smooth and safe start of the Brush-less-DC motor, but at output end side Step-up chopper habitually step up the level of voltage. Where as the ζ converter has continuous current at output end and the induction at output end gives out the ripple free continuous current. The ζ dc-dc conversion device operates as non-inverting converter as an inverting converter. This property forecloses the requirement of belonging circuits for negative voltage sensing hence decreases the complication of slowing the response [8].

INC-CON MPPT algorithm [9-10] is followed to run the ζ dc-dc conversion device so that where the non-conventional source of energy always with its MPP and the BRUSH-LESS-DC motor experience a decrease of current at the starting. For the accomplishment of commutation of brush-less DC motor, a 3-Phase VSI is run by main frequency range of switching [6]. The demonstration of both dynamically changing and normal operating conditions is done by using MAT-LAB/Simulink software and the outputs are analyzed at random values of solar irradiance that are exposed to following proposed system. In following proposed system, the solar panel is manufactured in a way that it performs well at various solar irradiance values.

In this interpreted paper the system used is structured as follows. In section II and section III respectively, the activity of the system is explained. In Section IV, the design in different levels of the given system is represented.

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The controlling techniques used and briefly described in section V. Lastly, the system is executed and analysed with the help of outputs obtained after simulation in section VI thereby final observations in section VII.

II. CONFIGURATION OF THE PLANNED SYSTEM

The planned system for water that is pumped by a Brush-less-DC motor consisting a ζ dc-dc conversion device with the help of solar energy is mentioned in Fig. 1. By showing the Fig. 1, the planned system comprises array of solar panel, the ζ dc-dc converter, the VSI, the Brush-less-DC motor and the centrifugal pump. The Brush-less-DC motor has an interally attached encoder and a commutation circuit with hall sensors for the usage of hybrid fuzzy controller. The pulse generator will to give a pulses to the ζ dc-dc conversion device switching operation. The successive operation of the circuit is elaborated in the coming section in detail.

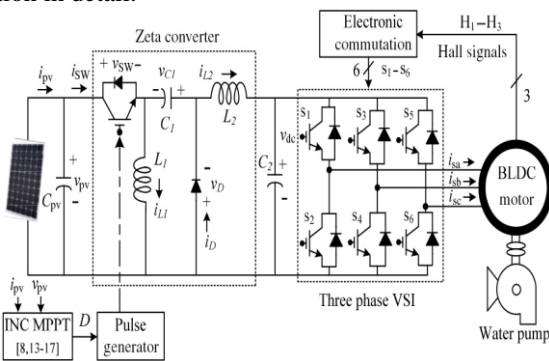


Fig.1 Configuration of proposed Solar Panel Zdc-dc conversion device for Water Pump

III. OPERATION OF THE PLANNED SYSTEM

The dc power is produced by the solar system for the demand of the water pump. This dc power is supplied to water pump through the ζ dc-dc converter, hybrid new fuzzy controller and VSI. Solar panel acts as a source of DC power for the ζ dc-dc conversion device presented in Fig. 1. Now, the power obtained is supplied to the ζ dc-dc conversion device output. In practically, because of losses in the ζ dc-dc conversion device [11], very low value of power is transferred to VSI. The pulses are provided to IGBT switches of the ζ dc-dc conversion device by Pulse-Generator using Maximum Power Point Tracking algorithm. The algorithm accepts the V&I variables (voltage and current) as a feedback from solar input and returns through the duty cycle (D) value. Next, the comparison of high frequency pulses with duty cycle the maximum power extraction of high efficiency can be obtained. Further, ζ converter gives a voltage output in DC. It is an VSI input voltage. Hence, it transforming the DC to Pulsating alternating power supplied through Brush-less-DC motor to run the water pump coupled to its shaft. The VSI is run under the main switching frequency and fed for the commutation of BRUSH-LESS-DC motor in-built encoder. Additionally, there is a controller of hybrid fuzzy to control drive operation. It gives a better response for the drive speed and torque. Here, the losses at switches due to high frequency range are thereby cleared, in effectiveness and improvement in the efficiency of the system.

IV. DESIGN OF FOLLOWING PROPOSED SYSTEM

There are different operating stages as mentioned in Fig. 1 are intellectually and technically designed in order to develop an effective water pumping system. The capability of operating under uncertain conditions. The designing ratings of sustainable system is follows, A BRUSH-LESS-DC motor 2.89 kW power rating and the array of PV of 3.4 kW

The best available power capacity under Std-Test-Conditions (STC) is selected to design following proposed system. The detailed design of the various stages such as the solar panel array, ζ dc-dc converter, BRUSH-LESS-DC motor and the centrifugal pump are described as follows.

A. Design of Solar panel Array

Practically, there are few losses in converters which are in operation condition. In addition, there is a mechanical and an electrical loss influenced by the BRUSH-LESS-DC motor is included. The size of PV array is chosen with large MPP capacity to balance the losses, hence to confirm the satisfactory operation without considering power losses. So, the solar panel array maximum power capacity is $P_{mpp} = 3.4$ kW under Std-Test-Conditions (STC: 1000Watt/meter², 25°C Centigrade, AM 1.5), marginally greater than desired by the water pump is chosen and its parameters are designed. Sun module *Plus_SW_280_mono* [12] SPV module made by Solar World is chosen to make the Solar PV array of an appropriate size.

The current at MPP of the SPV array, I_{mpp} is hence estimated as,

$$I_{mpp} = P_{mpp} / V_{mpp} = 3.4 / 0.18 = 18.1 \text{ A} \quad (1)$$

Total quantity of modules need to connect in series are,

$$N_s = V_{mpp} / V_m = 187.2 / 31.2 = 6 \quad (2)$$

Total quantity of modules need to connect in parallel are as,

$$N_p = I_{mpp} / I_m = 18.16 / 9.07 = 2 \quad (3)$$

B. Design of Zeta - converter:

After SPV panel, the following stage is ζ dc-dc converter. The collection of following components such as input inductor, L_1 , output inductor, L_2 and intermediate capacitor C_1 is represented in its design. These components will experience low value of stress on them as they operate in CCM (continuous conduction mode) resulting in ζ dc-dc converter.

The evaluation of duty cycle D, initializes the designs of ζ dc-dc conversion device which is estimated as [6],

$$D = V_{DC} / (V_{DC} + V_{MPP}) = 200 / (200 + 187.2) = 0.52 \quad (4)$$

Where V_{dc} is the ζ dc-dc conversion device output voltage and it is equal to input voltage of BRUSH-LESS-DC motor



An average amount of current passing through the DC link of the VSI I_{DC} is estimated as,

$$I_{dc} = P_{mpp} / V_{dc} = 3400/200 = 17 \text{ A} \quad (5)$$

Then, L_1 , L_2 and C_1 are estimated as

$$L_1 = DV_{MPP} / F_{SW} * I_{L1} = 0.52 * 187.2 / 20000 * 18.16 * 0.06 = 5 \text{ mH} \quad (6)$$

$$L_2 = (1-D) * V_{DC} / F_{SW} * I_{L2} = (1-0.52) * 200 / 20000 * 17 * 0.06 = 5 \text{ mH} \quad (7)$$

$$C_1 = D I_{DC} / F_{SW} * V_{C1} = 0.52 * 17 / 20000 * 200 * 0.1 = 22 \mu\text{F} \quad (8)$$

Where F_{sw} is the switching frequency of IGBT switch of Z converter. The level of ripple allowed in the current that passing through L_1 is ΔI_{L1} is same as the I_{mpp} ; the level of ripple allowed ripple current that passing through L_2 is ΔI_{L2} , same as I_{dc} ; ΔV_{C1} is the level of ripple allowed in voltage across, same as V_{DC} .

C. Estimation of DC link Capacitor of VSI

VSI is presented in sub section in this new design approach for the estimation of DC-link Capacitor. This method is related on a matter that sixth harmonic element of the AC supply voltage is reflected as dominant harmonic on DC side in 3-Phase AC supply system [13]. The main frequencies of the VSI voltage at output end are calculated corresponding to nominal speed and minimum speed of the BRUSH-LESS-DC motor which is needed to pump water. Estimated values of their corresponding capacitors are further used for these two frequencies. Out of the two estimated capacitors, Larger one is selected to assure the satisfactory operation of following proposed system even under the duration of minimum solar irradiance level.

The main frequency of output V-S-I (Voltage Source Inverter) corresponding to nominal speed of BRUSH-LESS-DC motor

$$\begin{aligned} W_{nominal} & \text{ is estimated as,} \\ W_{nominal} & = 2\pi f_{nominal} = 2\pi (N_{nominal} P) / 120 \\ & = 2\pi * (3000 * 6) / 120 \\ & = 942 \text{ rad / sec} \quad (9) \end{aligned}$$

The main frequency at output side of V-S-I (Voltage-Source-Inverter) corresponding to the minimum speed of BRUSH-LESS-DC motor essentially needed to pump the water ($N = 1100 \text{ R/ min}$) W_{min} is estimated as,

$$\begin{aligned} W_{min} & = 2\pi f_{min} = 2\pi (N * P) / 120 = 2\pi * (1100 * 6) / 120 \\ & = 345.57 \text{ rad/sec} \quad (10) \end{aligned}$$

where $f_{nominal}$ and f_{min} are main frequencies of output voltage of VSI corresponding to nominal speed and a minimum speed of BRUSH-LESS-DC motor essentially needed to pump the water. respectively, in Hz; $N_{nominal}$ is nominal speed of the

BRUSH-LESS-DC motor; P is a number of poles in the BRUSH-LESS-DC motor.

The size of capacitor link of VSI at W_{rated} is as follows

$$\begin{aligned} C_{2nominal} & = I_{dc} / (6 * W_{min} * V_{dc}) = 17 / (6 * 942 * 200 * 0.1) \\ & = 150.4 \mu\text{F} \quad (11) \end{aligned}$$

Similarly, size of dc capacitor link of VSI at w_{min} is as follows

$$\begin{aligned} C_{2min} & = I_{dc} / (6 * W_{mi} * V_{dc}) = 17 / (6 * 345.57 * 200 * 0.1) \\ & = 410 \mu\text{F} \quad (12) \end{aligned}$$

Where V_{dc} is the permissible ripple value in the voltage across the DC link capacitor, C_2 .

Finally, $C_2 = 410 \mu\text{F}$ is selected to design the Dc link capacitor.

D. Design of Centrifugal Pump

To calculate proportionality constant, K for the selected centrifugal water pump, its torque-speed characteristics [14] is used as,

$$T = K \omega^2 \quad (13)$$

Where T_L is torque of the load offered by the water pumping motor which is same as electro-magnetic torque developed by the BRUSH-LESS-DC motor under final operating condition for the stable operation and Wr is the rotor speed (mechanical) in rad/sec. Since the standard torque, T_L and the nominal speed, $N_{nominal}$ of the selected BRUSH-LESS-DC motor is 9.2 Nm and 3000 rpm respectively, the constant of proportionality, K is estimated using (13) as,

$$K = \frac{T_L}{\omega_r^2} = \frac{9.2}{2\pi * 3000 / 60^2} = 9.32 * 10^{-5} \quad (14)$$

The appropriate or right model for pumping is arranged for the needed data proposed system and its details are mentioned in Appendix C.

V. CONTROL OF THE PRESENTED PLANNED SYSTEM

The needed system is controlling by 3 stages. They are namely, MPPT and electronically commutated and hybrid new fuzzy controller are discussed in brief as follows.

A. INC_MPPT Algorithm

Highly efficient and favourably used technique is INC-MPPT [9] in different renewable energy applications is used to obtain the best available power from PV array for the BRUSH-LESS-DC motor. By selecting a suggested value of perturbation size ($\Delta D = 0.001$), it avoids the oscillations in MPP and gives smooth and safe start of BRUSH-LESS-DC motor. To achieve the objectives of tracking time and perturbation size is an intelligent agreement.

B. Electronically commutated

The operated VSI system is fed for BRUSH-LESS-DC



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motor through electronically commutated. Here the presence of 6

pulses in VSI, and controlling of BRUSH-LESS-DC motor with 3 hall signals is present. These signals are provided by in-built encoder as per the rotor position. There is an elimination of losses of switches in VSI, the electronically commutated circuit is used. The detailed information for following proposed system in Appendix C.

C. Hybrid fuzzy controller

This is one of the controlling technique in proposed system. Here this controller is placed in between VSI and the BRUSH-LESS-DC motor. It is the collaboration of PI and Fuzzy controller to advance the system output. It is a condition based system for controlling of the drive.

VI. RESULTS

Representation assessment of the planned system of the solar input employing BRUSH-LESS-DC motor which runs the water pump with ζ dc-dc conversion device to operate using simulated outputs in MATLAB/Simulink. The suggested system is Following proposed system is sketched, created and simulated considering the rare and instant variation in solar irradiance level and its appropriateness is verified by checking the analysis of the needed conditions.

Fig. 2 represents the steady state and dynamically changing state responses of the suggested system. To verifying the suitability of following proposed system under dynamically changing conditions, the irradiance of PV level is changed as displayed in Table II. The execution of array of PV, ζ dc-dc conversion device and BRUSH-LESS-DC motor-pump at various stages are illustrated on individual basis in the following sub-sections.

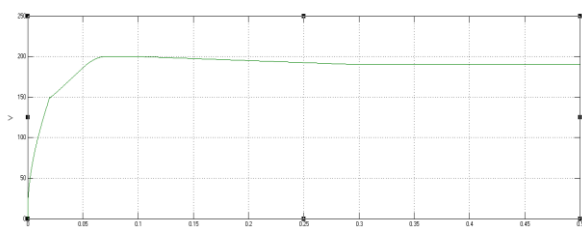


Fig 2: Photo voltaic input voltages with magnitudes

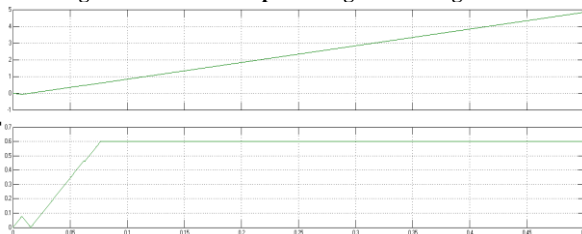


Fig3: MPPT response with voltage & current

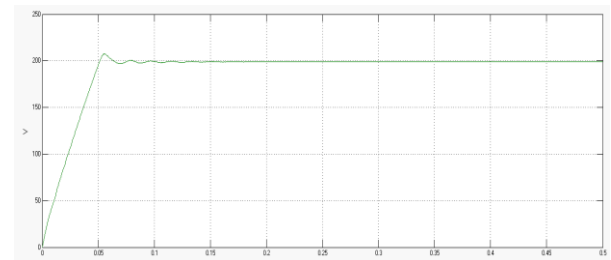


Fig4: Z dc-dc conversion device output voltage response with their magnitude

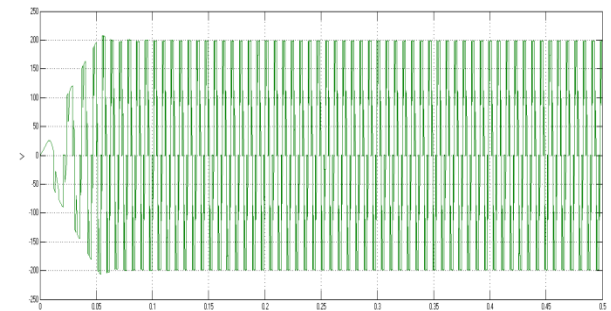


Fig5: BRUSH-LESS-DC motor input voltage response with their magnitude.

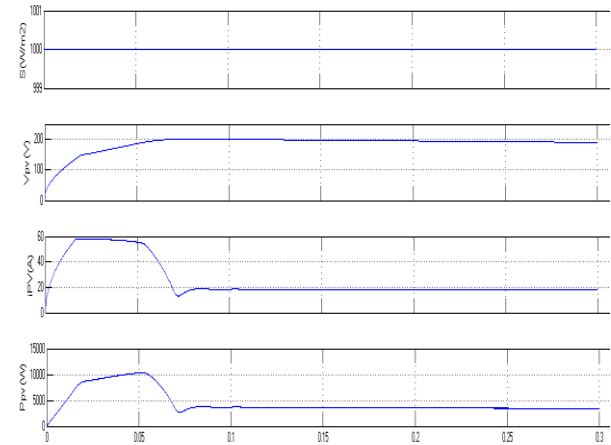


Fig6: Photo voltaic final working output with their magnitudes

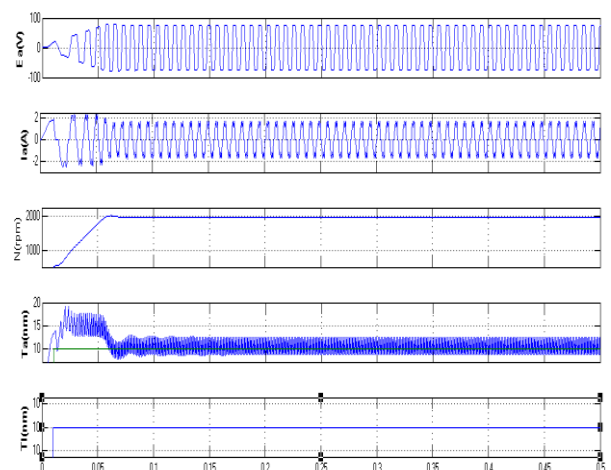


Fig7: Brush-less-DC motor final working output with their magnitudes

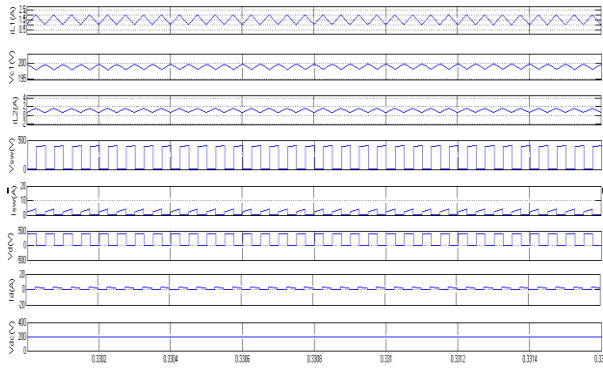


Fig8: ζ dc-dc conversion device final working output with their response

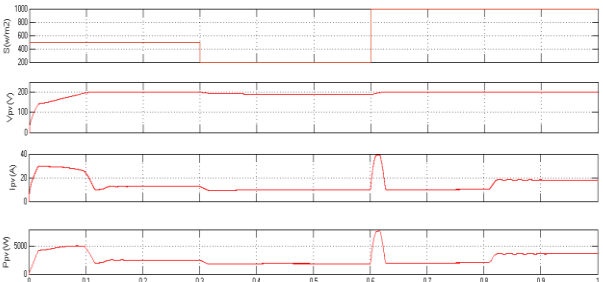


Fig9: PV dynamically changing state response with their magnitudes.

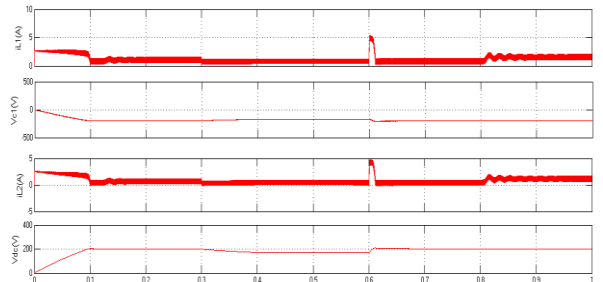


Fig10: Z dc-dc conversion device dynamically changing state response with their magnitudes

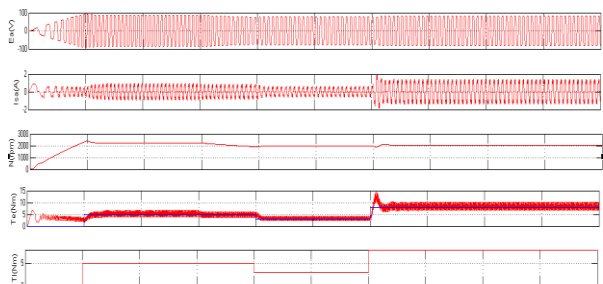


Fig11: Brush-less-DC motor dynamically changing state response with their magnitudes

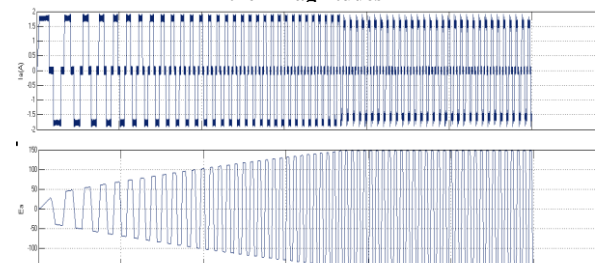


Fig12: PI controller with stator current & voltage

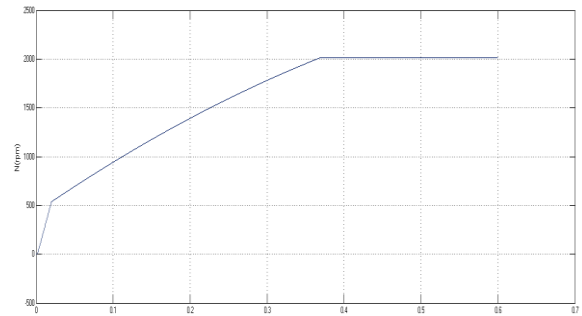


Fig13: PI controller with their speed

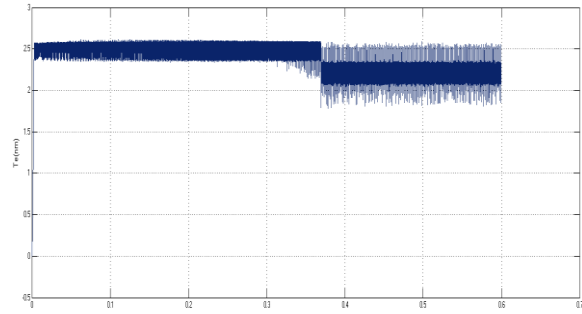


Fig14: PI controller with their torque

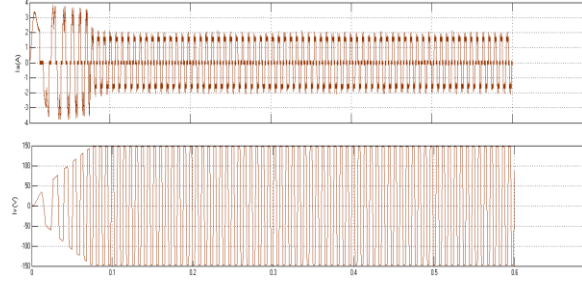


Fig15: Hybrid new fuzzy controller with their stator current & voltage

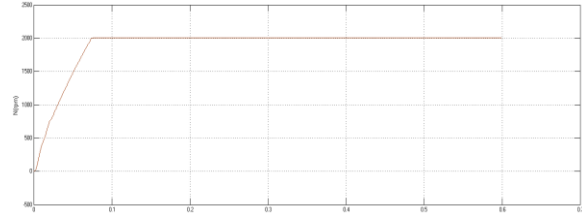


Fig16: Hybrid new fuzzy controller with their speed

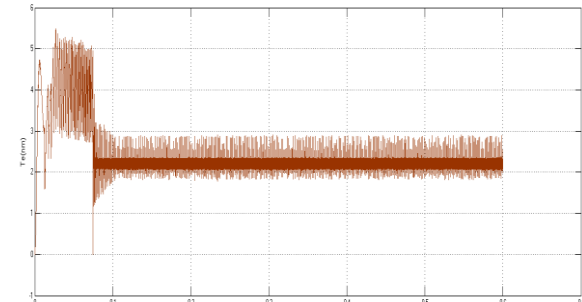


Fig17: Hybrid fuzzy controller with their torque

Table 1: Comparison table

S.no	Parameters	Pi controller	Hybrid fuzzy
1.	Current	4A(p-p)	8A(p-p)
2.	Voltage	280V	300V
3.	Speed	2000RPM(ref)	2000RPM
4.	Torque	2.5N-M	5.5N-M

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5.	Time	0.35Sec	0.05Sec
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Micro-Controller,” Solar Energy, Vol. 86, Issue 5, pp. 1477-1484, May 2012.

9. Ali Reza Reisi ,Mohammad Hasan Moradi and ShahriarJamash, “Classification and Comparison Of maximum power point tracking techniques for PV system.

Table 2: VARIATION IN SOLAR IRRADIANCE LEVEL

Solar irradiance level, S (W/m ²)	Duration (sec.)
600	0.0-0.3
200	0.3-0.6
1000	0.6-0.9

VII. CONCLUSION

The Solar input– ζ (Zeta) converter fed VSI (Voltage_Source_Inverter) –Brush-less-DC motor-pump for pumping water was proposed and it’s compatibility isanalyzed by verifying outputssimulated in MATLABinSim-power system toolbox. Firstly, the design of plannedsystemachieve some objectives. To examine the various performances under dynamically changing, starting and normal runningscenario.The evaluationof performance has been approve the sequence of zeta-converter and Brush-less-DC motor drive for Solar PVconnected to water pump. Under study, the system satisfy the following requirements like MPP extraction from Solar PV array, smooth and safestart of the Brush-less-DC motor, mainfrequency range of switching of the Inverter resulting with low value of switching losses, low value of stresses on IGBT and the device s of ζ dc-dc conversion device by running it in continuous-conduction-mode and balanced operation. Finally, even at smaller solar irradiance value, the presented model is executed successfully.

REFERENCES

1. M. Uno And A. Kukita, “Single-Switch Voltage Equalizer Using Multi-Stacked Buck-Boost Converters For Partially-Shaded Photovoltaic Modules,” IEEE Transactions On Power Electronics, No. 99, 2014.
2. R. ArulmuruganAnd N. Suthanthiravanitha, “Model And Design Of A Fuzzy-Based Hopfield NN Tracking Controller For Standalone PV Applications,” Electr. Power Syst. Res. (2014). Available: <http://dx.doi.org/10.1016/j.epsr.2014.05.007>
3. S.Stapathy , 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.
4. A. Trejos ,C.A. Ramos- Paja and S. Sema , “Compensation Of DC-link Voltage Oscillations in Grid - Connected PV Systems Based On high Order Dc/Dc Converters,” IEEE International Symposium On Alternative Energies And Energy And Energy quality (SIFAE) , pp.1-6, 25-26 Oct 2012.
5. G.K. Dubey , Fundamentals Of Electrical Drives, 2nded. New Delhi, India: Narosa Publishing house Pvt.Ltd, 2009
6. B. Singh and V. Bist , “A single Sensor Based zeta Converter Fed BLDC Motor Drive for Fan applications,” Fifth IEEE Power India Conference ,pp.1-6,19-22 Dec 2012.
7. R.F. Coelho , W.M. Dos Santos and D.C. Martins, “Influence Of Power Converters On PV Maximum Power Point Tracking efficiency ,” 10 thIEEE/IAS International Conference On Industry Applications (INDUSCON) pp.1-8, 5-7 Nov 2012.
8. Dylan D.C. Lu and Quang Ngoc Nguyen, “A Photovoltaic Panel Emulator Using A Buck-Boost DC/DC Converter And A Low Cost

