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Zeta Controlled Based DC-DC Converter for BLDC Motor Drive Water Pumping System fed from PV System

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ABSTRACT

In this interpreted paper,one un-conventional form ofenergy originatingsourcefeeding the water-pump machine implementing a conversion device as an intermediary chopper called Zeta converter (ζ –DC-to-DC converter) whichcollect the utmost possible power available at the un-conventional originating source of energy. Incremental MPPT regulates smooth and safe start ofBRUSH-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 toBL-DC motor overcommutation electronically so thateliminating losses in switching with high frequency switching. The mentioned system in this interpreted paper isdesigned and simulated; hence, the performance is effected under the normally runningscenario. The demonstration of both dynamically changingand steady state conditions is done by using MAT-LAB/ Simulink software and the outputs are analyzed

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

I. INTRODUCTION

Substantial decrement in the expense of electronic device s and decay of non-renewable fuel sourcesin near future invite to use the un-conventional mode of energy generated electrical power for applied in various operationsto great extent. Electric power generated by pumping water, a independently operated and applied inun-conventional energy, is receiving wide attention recently for in the agriculture fields, applied inhousehold 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 device s 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 conversiondevice is applied in some other un-conventional mode of energy sources.[1-4]. The advantagesboth the Brush-Less-DC motor &ζ dc-dc conversion device can allot to develop a appropriate energy from un-conventional sourcefeeding the water pump motorhaving the strength of operating fulfilment under changing atmospheric conditions dynamically. Some of the benefits of Brush-Less-DC motor are improved cooling,radiointerference oflow frequency valueand 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 orlow value ofer 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 continous current at output end and the induction at output end gives out the ripple free continous 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 torun 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 mainfrequency 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 randomvalues 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 atvarious 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. 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 comprisesarray of solar panel, the ζ dc-dc converter, the VSI, the Brush-less-DCmotor 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.

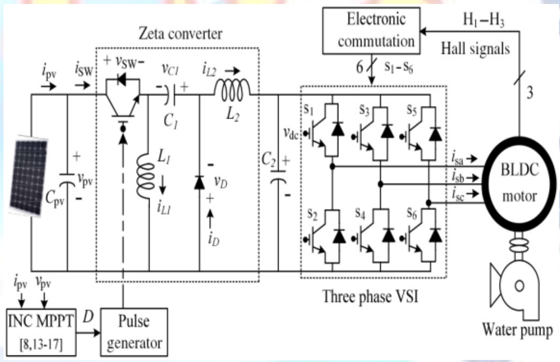

Fig.1 Configuration of proposed Solar Panel Zdc-dc conversion device for Water Pump

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 pumpthrough theζ dc-dc converter, hybrid new fuzzy controller and VSI. Solar panel acts as a source ofDC power for the ζ dc-dc conversion device presented in Fig. 1. Now, the powerobtained issupplied to the ζ dc-dc conversion device output. In practically, because of losses in the ζ dc-dc conversion device [11], verylow 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 algorithmaccepts the V&I variables (voltage and currennt) 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 runnedunder 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 confirmn 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°Centigrade, AM 1.5), marginallygreater 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 MPPof 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 isζ dc-dc converter. The collection of following components such as input inductor,L1,output inductor,L2 and intermediate capacitor C1 is represented in its design. These components will experiencelow value of value ofstress on them as they operate in CCM (continuous conduction mode) resulting in 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 Vdc 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 , L1 , L2 and C1 are estimated as

$$L_1 = DV_{MPP} /F_{SW}*I_{L1}= 0.52*187.2/ 20000*18.16*0.06$$

$$= 5mH \quad (6)$$

$L_2=(1-D)*V_{DC}/ F_{SW}*I_{L2} = (1-0.52)* 200/ 20000*17*0.06$

$=5mH$ (7)

$C_1 = D\ I_{DC}/ F_{SW}*V_{C1} = 0.52*17/20000*200*0.1$

$=22\mu F$ (8)

Where Fsw is the switching frequency of IGBT switch of Z converter. The level of ripple allowed in thecurrent that passing throughL_1 is ΔI_{L1} is same as the I_{mpp} ; the level of ripple allowedripple current that passing through L_2 is ΔI_{L2}, same as I_{dc}; ΔV_{C1} is the level of ripple allowedin 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 isrelated 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 endare calculated corresponding tonominal 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 tothenominal speed of BRUSH-LESS-DC motor Wnominalisestimated as,
$W_{nominal}= 2\pi\ f_{nominal} = 2\pi\ (N_{nominal}P)\ /\ 120$
$= 2\pi * (3000*6)\ /120$
$= 942$ rad / sec (9)

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 R/ min) Wmin is estimated as ,

$W_{min} = 2\pi\ f_{min} = 2\pi(N*P)/\ 120 = 2\pi * (1100*6)/\ 120$

$=345.57$ rad/sec (10)

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

$C_{2nominal} = I_{dc}/6*W_{min}*\ V_{dc}= 17/6*942*200*0$

$= 150.4\mu F$ (11)

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

$C_{2min} =I_{dc}/(6*W_{mi}\ *V_{dc})=17/(6*345.57*200*0.1)$

$=410\mu F$ (12)

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

Finally, $C_2 = 410\mu F$ 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,

$$T_L = K\omega_r^2 \quad (13)$$

Where $T_L$is torque of the load offered by the water pumping motor which is sameas 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 ,Nnominal of the selected BRUSH-LESS-DC motor is 9.2Nm and 3000 rpm respectively, the constant of proportionality, K is estimated using (13) as,

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

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

V. CONTROL OF THE PRESENTEDPLANNED SYSTEM

The needed system is controlling by 3 stages. They are namely, MPPT and electronically commutated and hybridnew 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 (ΔD = 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 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 thecollaboration of PI nd 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 withζ dc-dc conversion device to operate using simulatedoutputs 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 irradianceof 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.

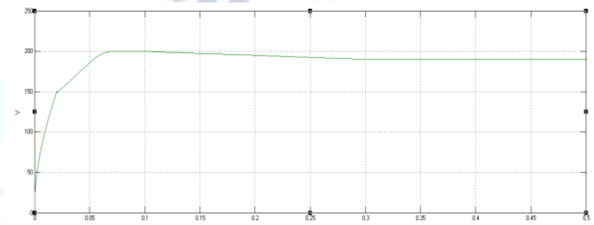

Fig 2: Photo voltaic input voltages with magnitudes

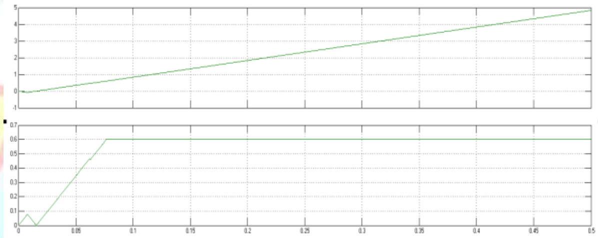

Fig3: MPPT response with voltage & current

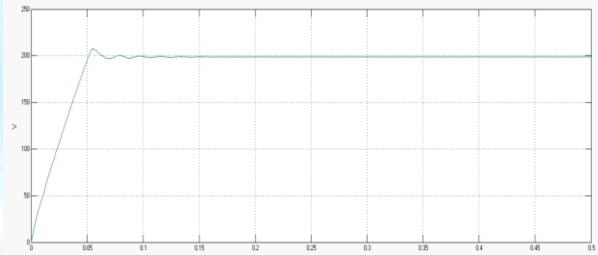

Fig4: Z dc-dc conversion device output voltage response with their magnitude

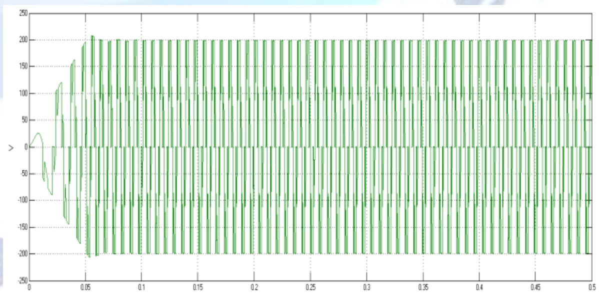

Fig5: BRUSH-LESS-DC motor input voltage response with their magnitude.

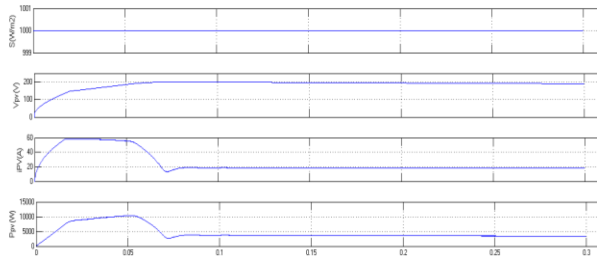

Fig6: Photo voltaic final working outputwith their magnitudes

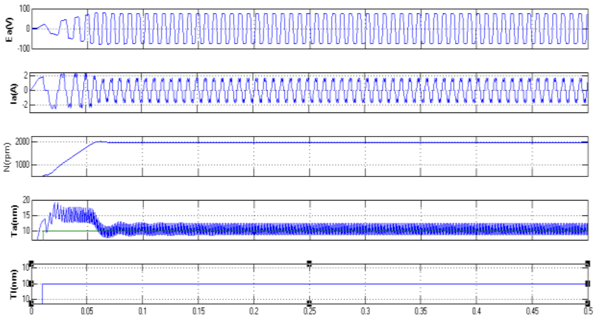

Fig7: Brush-less-DC motor final working outputwith their magnitudes

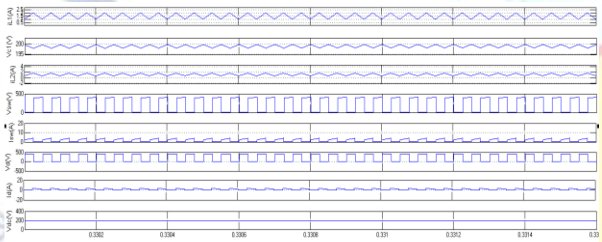

Fig8: ζ dc-dc conversion device final working outputwith their response

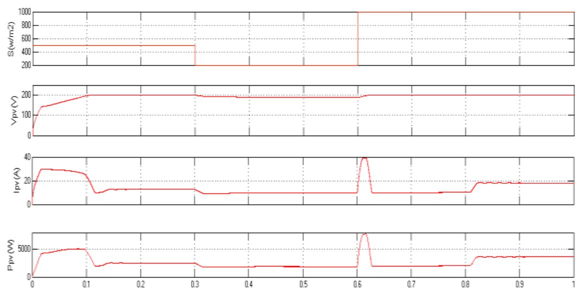

Fig9: PV dynamically changing state response with their magnitudes.

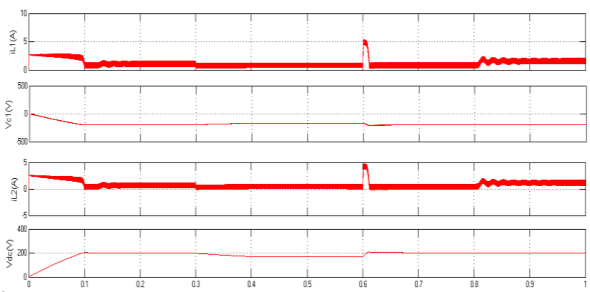

Fig10: Z dc-dc conversion device dynamically changing state response with their magnitudes

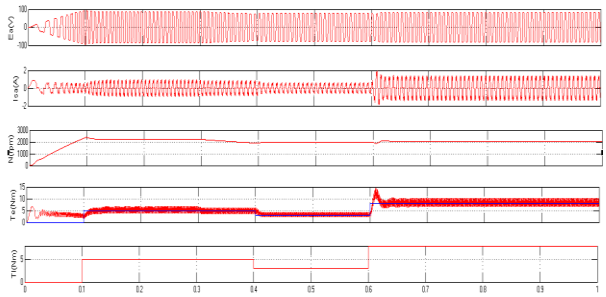

Fig11: Brush-less-DC motor dynamically changing state response with their magnitudes

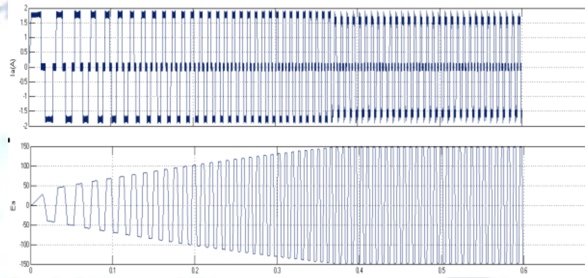

Fig12: PI controller with stator current & voltage

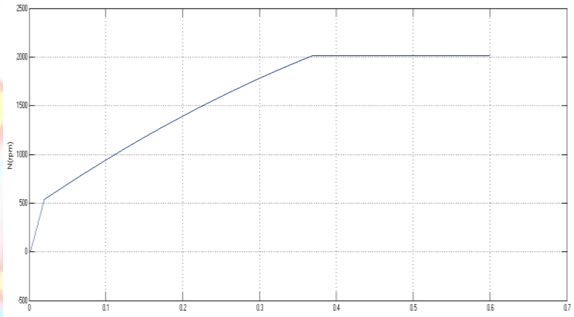

Fig13: PI controller with their speed

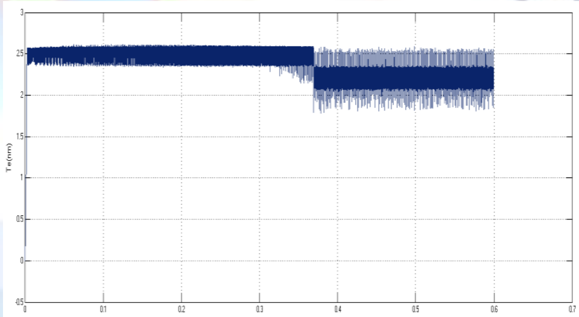

Fig14: PI controller with their torque

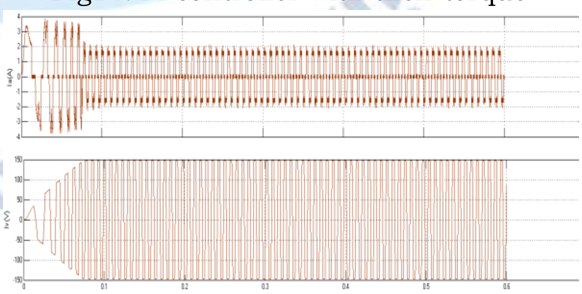

Fig15: Hybrid new fuzzy controller with their stator current & voltage

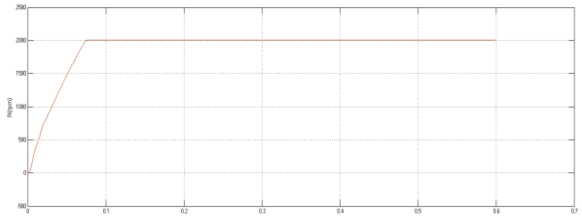

Fig16: Hybrid new fuzzy controller with their speed

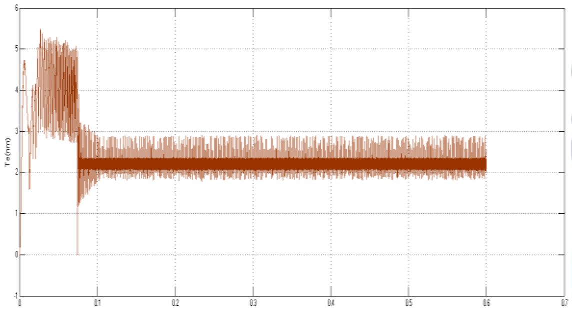

Fig17:Hybrid fuzzy controller with their torque

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
5.	Time	0.35Sec	0.05Sec

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 withlow 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 presentedmodel isexecuted successfully.

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