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POWER QUALITY ENHANCEMENT IN A ZETA CONVERTER FOR BRUSHLESS DC MOTOR DRIVES

[1]**S MAHESHWARI**, M.Tech(PEED), Mahatma Gandhi institute of technology, College address: Gandipet, Hyderabad, Telangana 500075, smaheshwari_pgeee215407@mgit.ac.in

[2]**Dr.P.Ram Kishore Kumar Reddy(professor &Head),** Electrical and electronics engineering (Power systems), Mahatma Gandhi institute of technology, kokapet(Village), Gandipet (Mandal), Hyderabad,500075, Telangana Mail id:prkumarreddy_eee@mgit.ac.in

Abstract

This project proposes a simple, cost effective and efficient brushless DC (BLDC) motor drive for solar photovoltaic (SPV) array fed water pumping system. A zeta converter is utilized in order to extract the maximum available power from the SPV array. The proposed control algorithm eliminates phase current sensors and adapts a fundamental frequency switching of the voltage source inverter (VSI), thus avoiding the power losses due to high frequency switching. No additional control or circuitry is used for speed control of the BLDC motor. The speed is controlled through a variable DC link voltage of VSI. An appropriate control of zeta converter through the incremental conductance maximum power point tracking (INC-MPPT) algorithm offers soft starting of the BLDC motor. The proposed zeta converter is used for sensor-less motor speed control. A zeta converter has employed a fourth-order DC-DC converter that is constructed with two inductors and two capacitors and proficient of function, system is designed and modelled such that the performance is not affected under dynamic conditions. The suitability of proposed system at practical operating conditions is demonstrated through simulation results using MATLAB/ Simulink followed by an experimental validation.

Keywords: BLDC, Zeta converter, power quality, brushless BLDC.

1. Introduction

The advantages of having the BLDC motor also the zeta conversion can help to design an SPV array supplied water pumping system capable of working adequately under rapidly shifting environmental circumstances. The BLDC motor is very reliable, efficient, has an elevated torque/inertia ratio, enhanced cooling, minimal radio frequency interference and noise, & needs almost little maintenance. When used in SPV-based programmes, a zeta converter has a number of benefits over traditional buck, boost, buck-boost, and Cuk converters.

The zeta converter, which belongs to the buck-boost converting family, could be used to either boost or reduce the output voltage. This attribute provides an infinite zone for an SPV array's maximum power point tracking (MPPT) . If MPP happens inside the specified limitations, MPPT can be done using simple buck and boost converters. This trait also allows for gentle beginning of BLDC motors, as opposed to boost converters, which often step up the voltage threshold at their output without providing soft beginning. The zeta translator, unlike a traditional buck-boost converter, has a continuous output current. The output capacitors ensure that the current is sustained & devoid of ripple. Despite having the same amount of elements as a Cuk converter, the zeta converter functions as a non-inverting buck-boost adapter, as opposed to a reversing buck-boost & Cuk converter. This characteristic eliminates the need for accompanying circuits for voltage reduction sensing, reducing complications and the possibility of slowing down the system's reaction. These advantages of the zeta converter are advantageous for the planned SPV array- fed water pumping system. The zeta converter is operated using an incremental conductivity (INC) MPPT method such that the SPV array is constantly at its MPP.

The current work investigating SPV array-based BLDC motor-driven water pump depends on the design depicted in Fig. 1. As is customary, a DC-DC converter is employed for MPPT of an SPV array. Two phase currents are measured coupled with Hall signal input for BLDC motor control, which increases the cost. The extra control method increases the expense and complexity necessary to manage the velocity of the BLDC motor. Furthermore, a voltage source inverter (VSI) is often controlled with extremely frequent PWM pulses, leading in greater switching loss as well as as a consequence, less effectiveness. However, in a Z- source inverter (ZSI) substitutes the DC-DC converter, but the rest of the Fig. 1 scheme remains intact, promising excellent efficiency and cheap cost. In contrast, ZSI requires phase current as well as DC link voltage monitoring, leading to complicated control and greater expense.

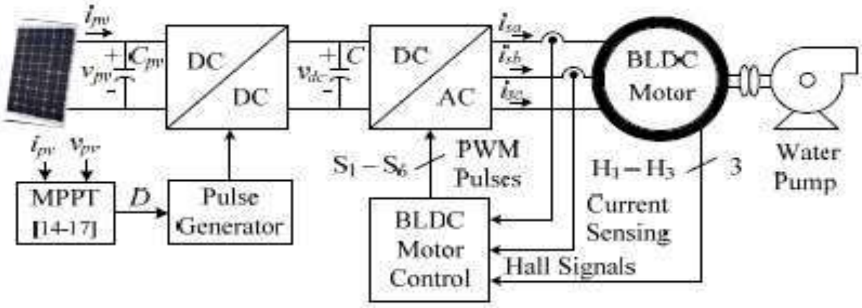

Fig. 1 Conventional SPV fed BLDC motor driven.

To address these issues and shortcomings, an easy, affordable, reliable water pumping structure built on an SPV array supplied BLDC motor is presented by altering the current topology (Fig. 1) to the one illustrated in Fig. 2. A zeta converter is used for getting the most power out of an SPV array, as well as soft beginning and frequency regulation for a BLDC motor attached to a water pump. This converter has excellent performance and a limitless region for MPPT due to the use of one switch. Additionally, by using basic frequency-changing, the switching loss of VSI is minimised, leading in extra power savings and hence improved efficiency. The phase currents & DC link voltage sensors are totally deleted, providing a simple and cost-effective solution without sacrificing efficiency. lacking any further control, the BLDC motor's speed is regulated by a variable DC link voltage of VSI. Furthermore, appropriate initialization of the MPPT algorithm of the SPV array results in gentle beginning of the BLDC motor. These elements contribute to the recommended system's greater simplicity.

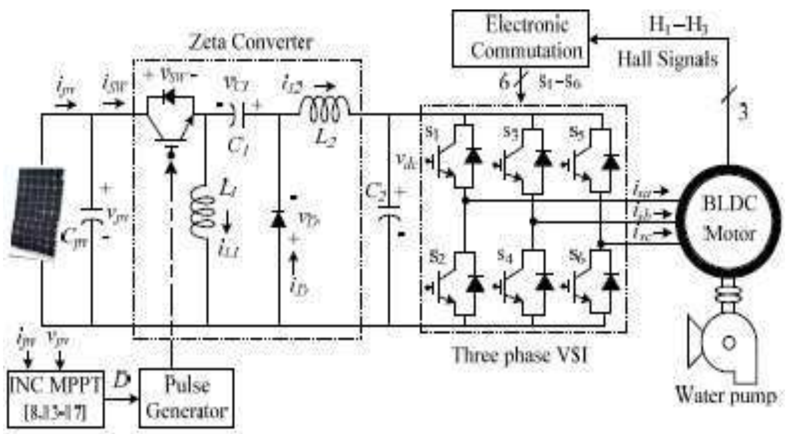

Fig.2.Proposed solar PV-zeta converter fed BLDC motor drive.

The benefits and desired qualities of the two-phase zeta converter as well as the BLDC motor drive led to the development of a straightforward, productive, cost-effective, & dependable solar PV-powered water pumping system. The simulation results using MATLAB/Simulink and the experimental data are compared to illustrate the beginning, dynamics, including the steady-state performance of the suggested water pumping arrangement under realistic operating circumstances. The SPV array and BLDC motor are constructed in such a manner that the proposed system continually performs well despite the level of solar irradiation.

2. Literature

A literature review on power quality enhancement in a Zeta converter for BLDC (Brushless DC) motor drives involves examining various research papers, articles, and publications that focus on improving power quality in the context of Zeta converters used in BLDC motor drive applications. Here is a structured review highlighting key aspects and findings from relevant literature:

The integration of BLDC motors in various applications has gained popularity due to their efficiency and reliability. However, issues related to power quality, such as harmonic distortion and power factor, can arise. Zeta converters, with their unique topology, offer a potential solution to address these challenges.

2.1 Zeta Converter Basics

Start the review by providing an overview of the Zeta converter and its operation principles. Explain how it differs from other converter topologies and discuss its advantages and disadvantages in the context of power quality enhancement for BLDC motor drives.

2.2 Power Quality Issues in BLDC Motor Drives

Highlight the power quality issues associated with BLDC motor drives, including harmonic distortion, power factor correction, and voltage/current ripple. Emphasize the impact of these issues on the overall performance and efficiency of the motor drive system.

2.3 Zeta Converter Control Strategies

Examine various control strategies employed in Zeta converters for BLDC motor drives. This may include voltage control, current control, and the integration of advanced control algorithms. Discuss how these strategies contribute to power quality improvement.

2.4 Harmonic Mitigation Techniques

Explore the literature on harmonic mitigation techniques specific to Zeta converters. This may involve the use of passive filters, active filters, or hybrid solutions to reduce harmonic content in the system.

2.5 Power Factor Correction

Review studies that focus on power factor correction in Zeta converters. Evaluate different methods and control techniques employed to enhance power factor and, consequently, improve power quality.

2.6 Efficiency and Performance Optimization

Discuss research efforts aimed at optimizing the overall efficiency and performance of Zeta converters in BLDC motor drives. This may include studies on component selection, modulation techniques, and overall system design considerations.

2.7 Simulation and Experimental Studies

Examine both simulation-based and experimental studies conducted to validate the proposed power quality enhancement techniques. Highlight key findings, challenges encountered, and areas for further improvement.

2.8 Comparative Analysis

Conduct a comparative analysis of different approaches discussed in the literature. Compare the effectiveness of various power quality enhancement techniques in Zeta converters for BLDC motor drives, considering factors such as cost, complexity, and practical implementation.

2.9 Future Research Directions

Conclude the literature review by identifying gaps in current research and suggesting potential avenues for future exploration. This may include emerging technologies, novel control strategies, or integration with other power electronics devices to further enhance power quality in BLDC motor drive applications.

Remember to cite the relevant studies, papers, and publications throughout the review to provide a comprehensive and well-supported overview of the current state of research in the field of power quality enhancement in Zeta converters for BLDC motor drives.

3. Methodology

Zeta converter stable-state effectiveness at 1000 w/m2 is exposed in Fig. 4(b). We offer the following data: voltage pressure on IGBT change v_sw, present strain on IGBT modification i_sw, delaying power of the diode v_D, existing over diode i_D, & DC link energy v_DC. Input inductor current i_L1. In CCM, the zeta conversion is used. This mode's converter function lessens the strain on electrical parts and applications. These converter indicators, such as i_L1, v_C1, i_L2, & v_DC as illustrated in fig.(b), track variations in the weather and change giving to the solar irradiance stage. In command to maximize the output control of the SPV array, the zeta converter regulates its mode function between boost and back mode according on the degree of irradiance. To maximise the magnitude of the elements, a tiny number of waves in the zeta converter amounts remain detected, which are generated by allowing the waves to some amount.

B. Presentation of BLDC Motor-Pump

Fig. 4(c) displays the BLDC motor-pump's beginning & steady state performances at 1000 W/m2. Beneath steady-statecircumstances, all of the motor indices—together with the load torque (TL), the speed (N), the electro-compelling twisting created (Te), the back EMF (ea), the stator current (isa), and the load torque (TL)—achieve their respective rated values. The suggested system's effective functioning is confirmed by observing the motor-pump's steady operation and gentle start. Nonetheless, the BLDC motor's electrical modulation causes a slight pulsation in Te. As seen in Fig. 5(c), all of the BLDC motor-pump indices change in percentage to the solar irradiation equal as it changes. The BLDC motor consistently reaches a rapidity more than 1100 rpm, which is the smallest needed to pump water at a solar irradiation equal of 200 W/m2. The weather has no effect on the BLDC motor-pump's effectiveness, then it effectively pumps aquatic.

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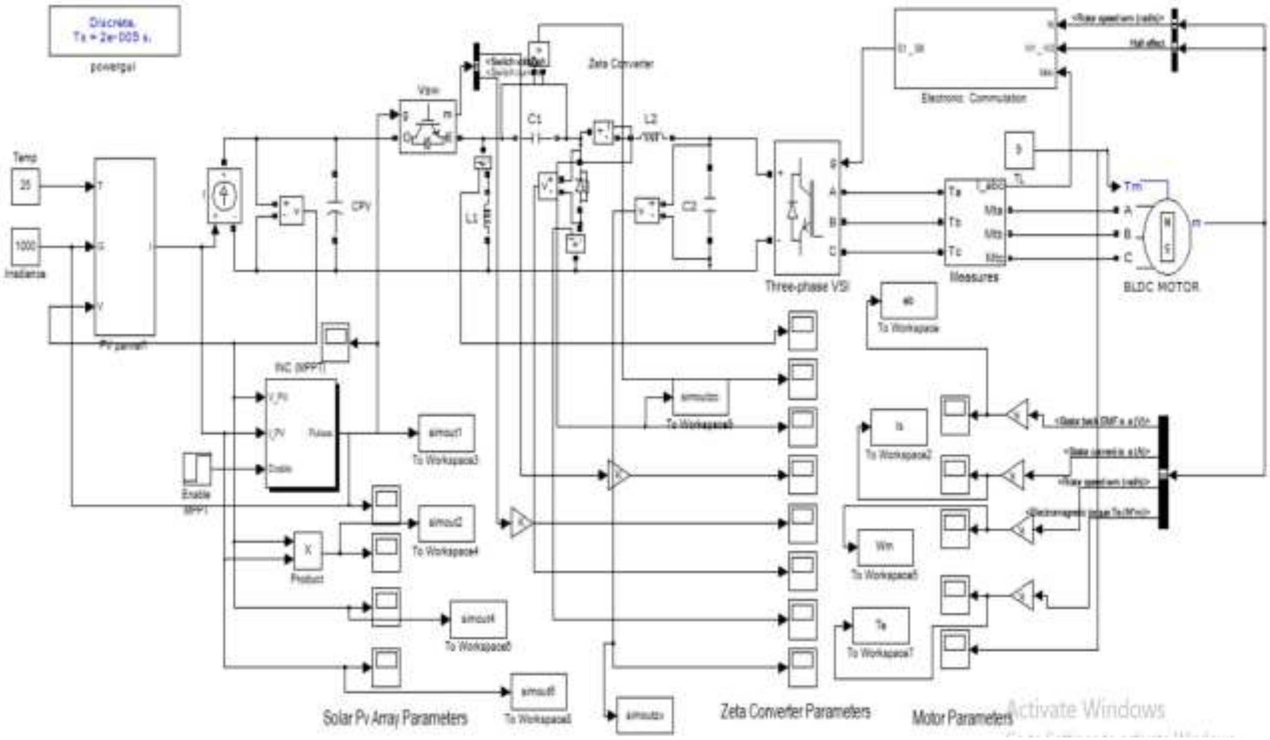

Fig: 3. Simulation of SPV - Zeta converter for BLDC Motor Drive

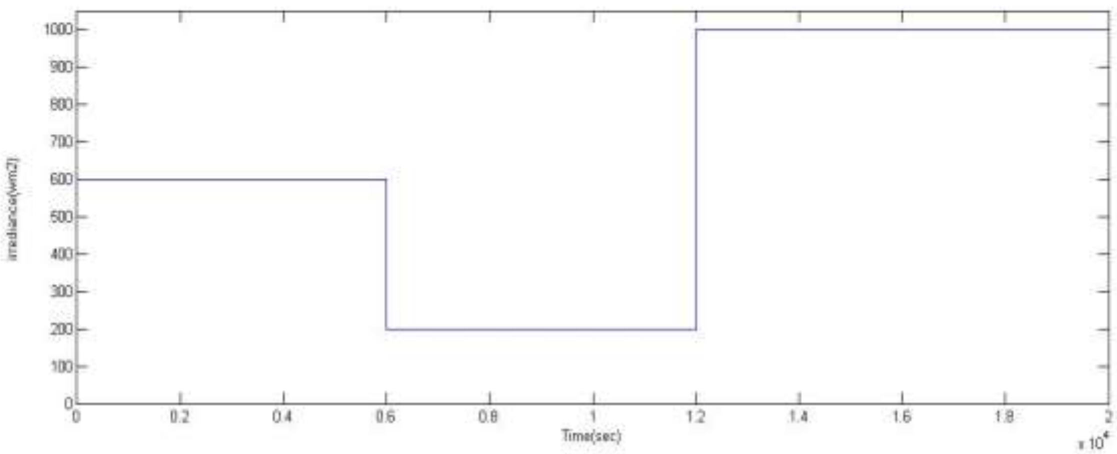

Fig: 4 Irrediance(S) Vs Time(sec)

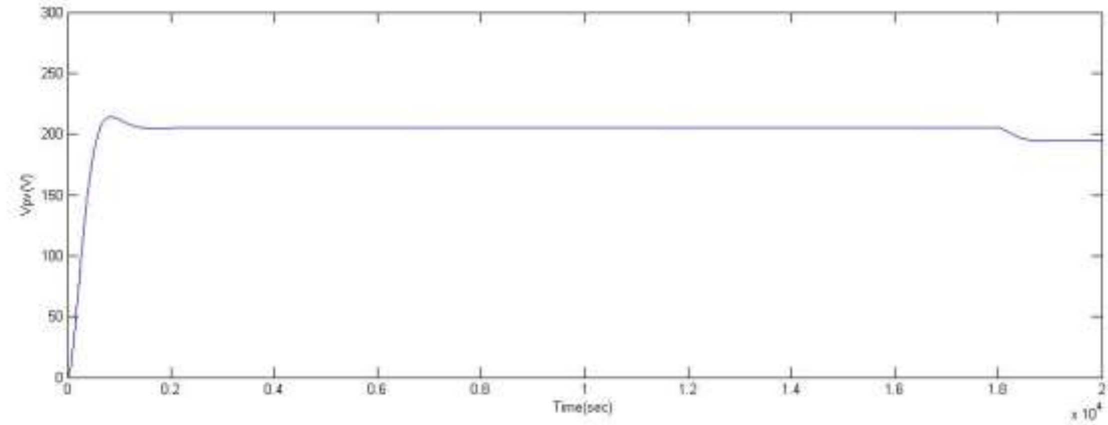

Fig: 5 PV Voltage(Vpv) Vs Time(sec)

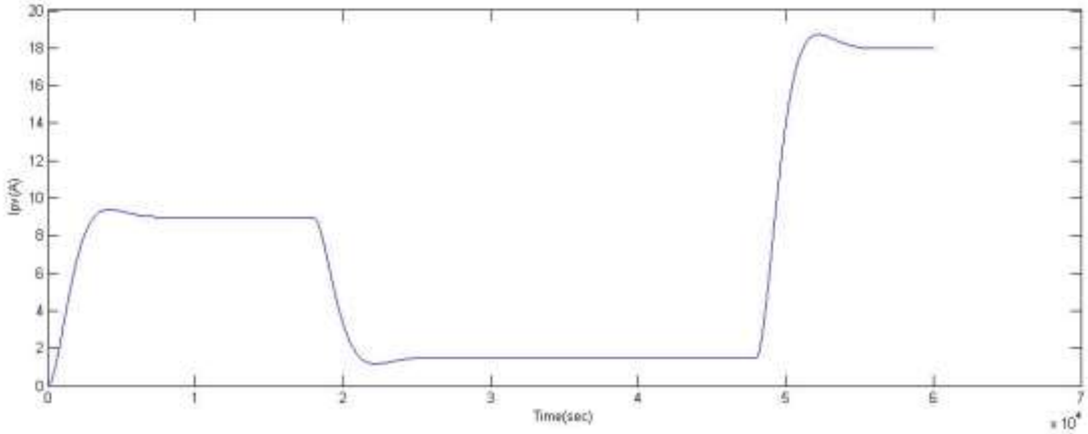

Fig: 6 PV Current (Ipv) Vs Time(sec)

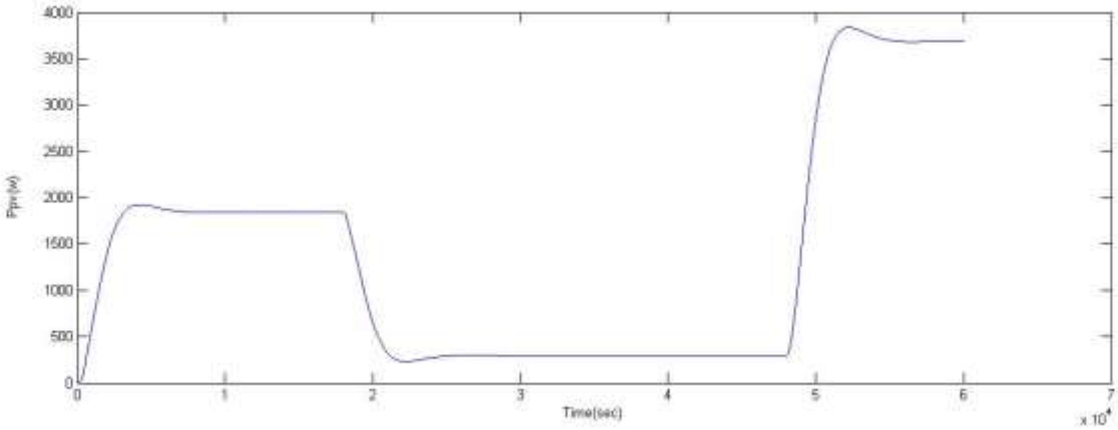

Fig: 7 PV Power (w) Vs Time(sec)

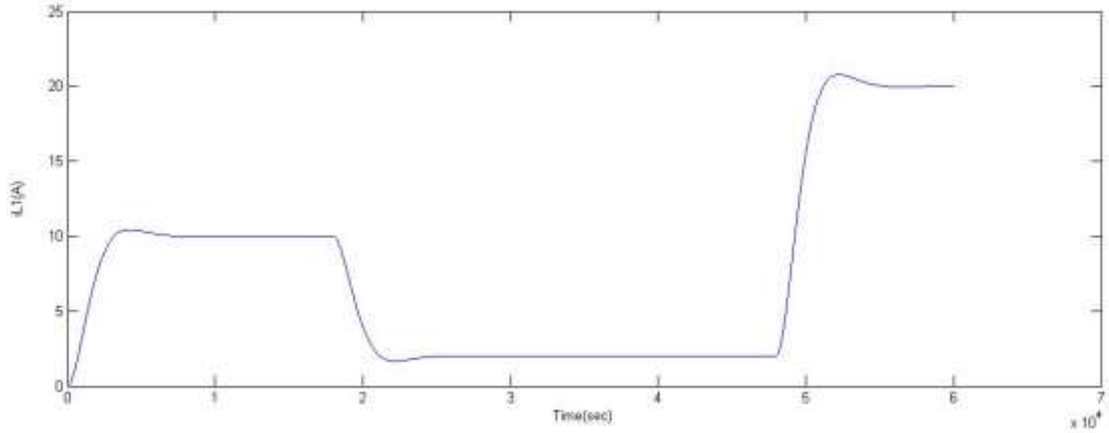

Fig : 8 Zeta conveter input current

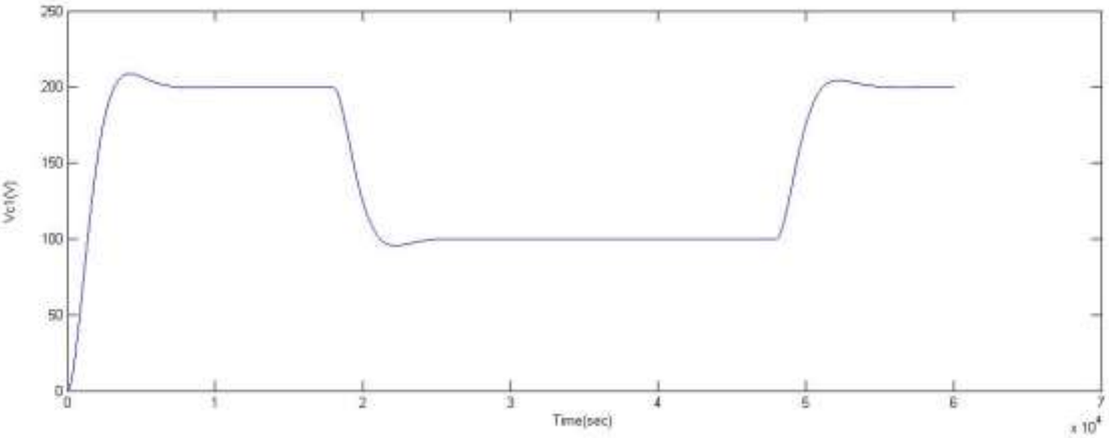

Fig :9 Zeta converter input voltage

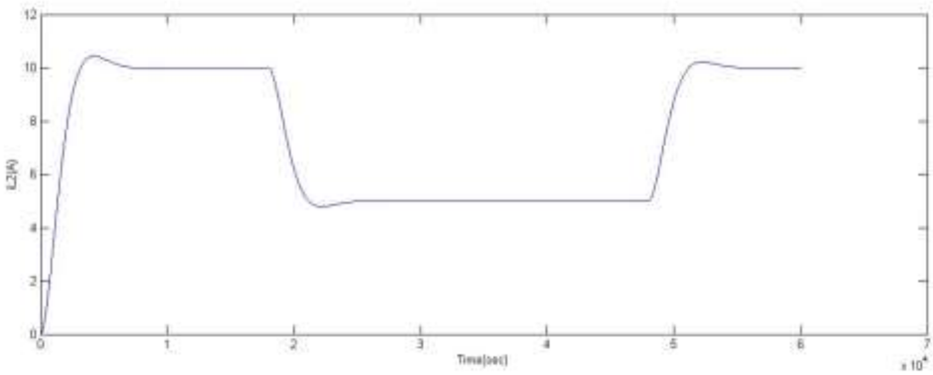

Fig :10 Zeta converter output current

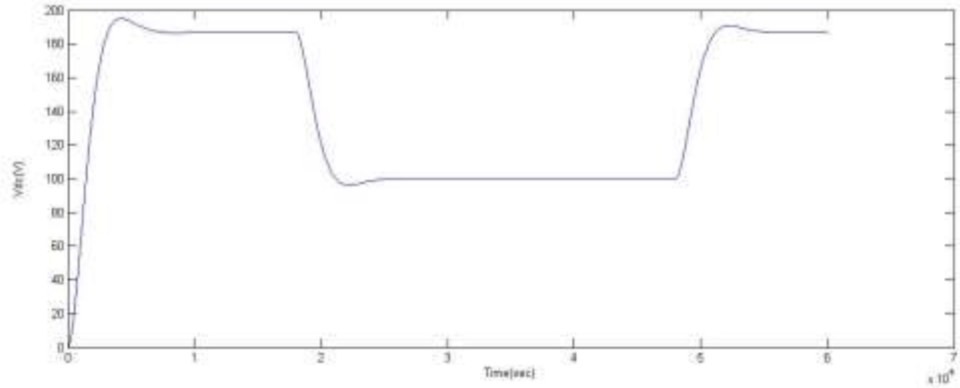

Fig:11 Zeta converter output voltage

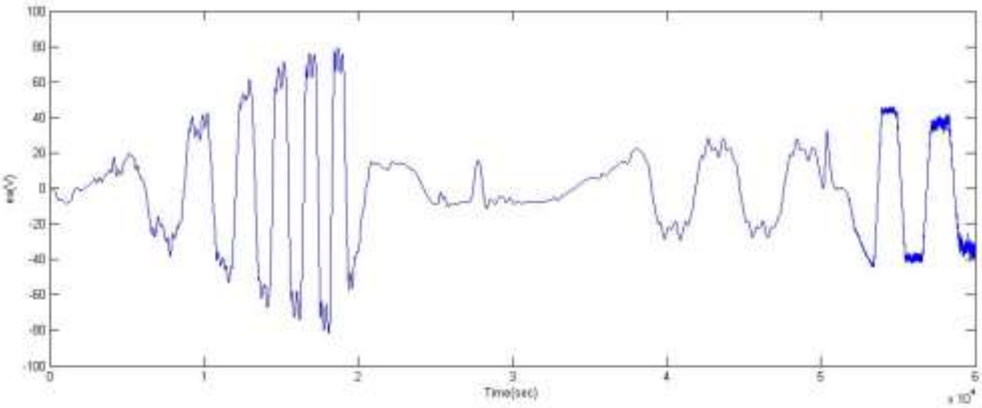

Fig:12 BLDC Motor output voltage

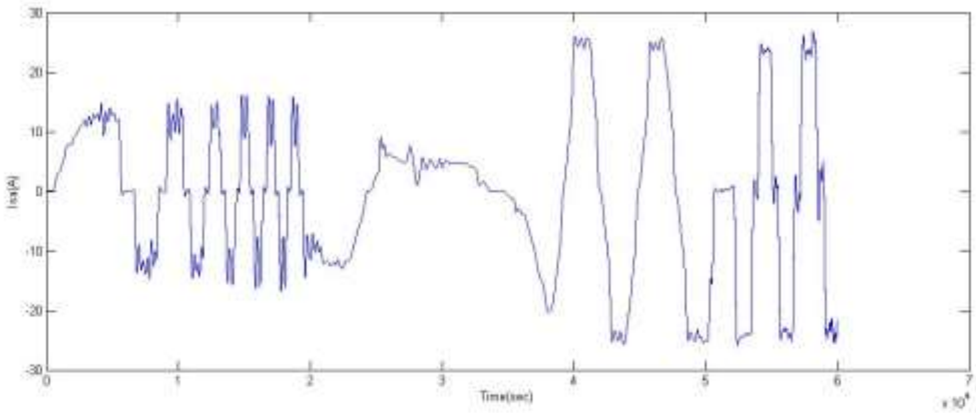

Fig:13 BLDC Motor output current

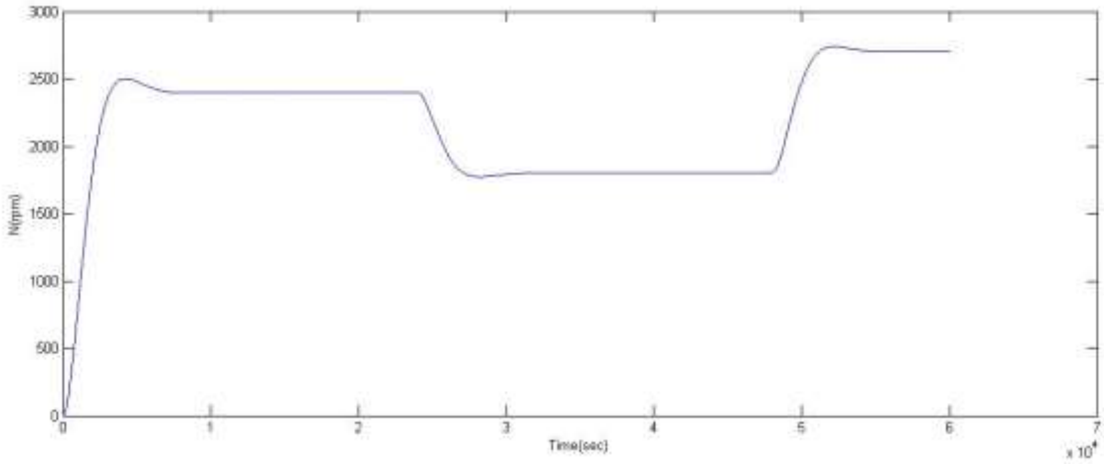

Fig:14 BLDC Motor speed

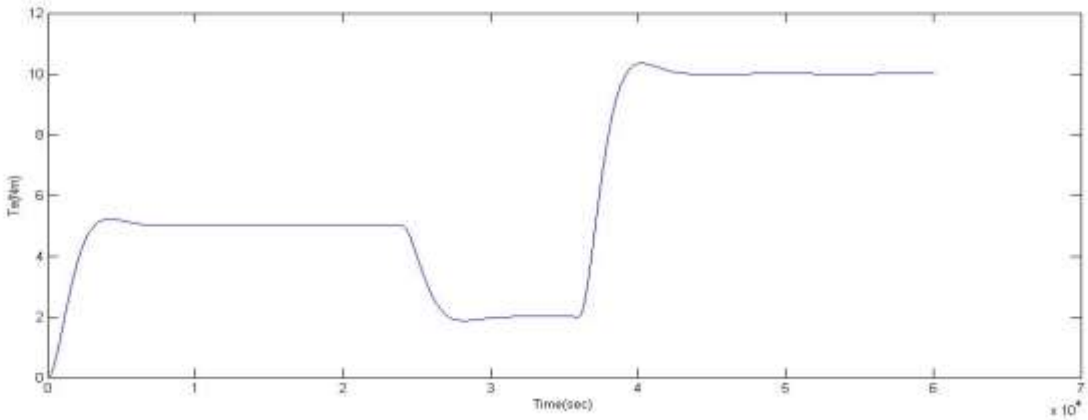

Fig :15 BLDC Motor Torque

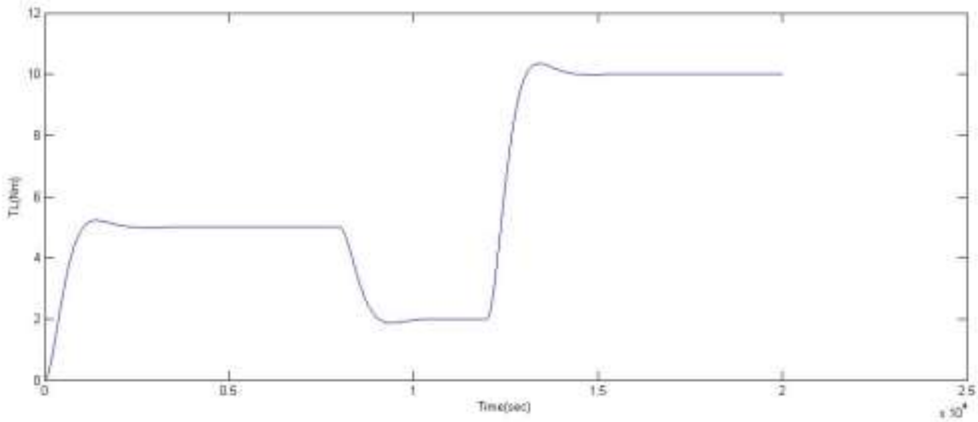

Fig 16 BLDC Motor Load Torque

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Table 1 Esteemed efficiency without zeta converter

Without Zeta Converter			
S(W/m^2)	P_{pv} (W)	P_m (W)	n (%)
400	360	255	65
500	450	326	62.3
650	585	438	64.7
800	720	565	75.9
900	810	660	82.5
1000	900	746	81

Table 2 Esteemed efficiency with zeta converter

With Zeta Converter			
S(W/m^2)	P_{pv} (W)	P_m (W)	n (%)
400	360	255	71
500	450	326	72.4
650	585	438	74.8
800	720	565	78.5
900	810	660	81.5
1000	900	746	83

Solar irradiance (S): S(W/m2)

Photovoltaic power output (Ppv): Ppv (W)

Motor power output (Pm): Pm (W)

Overall system efficiency (η): n (%)

This comparison is conducted with the absence of the Zeta Converter, and the specified parameters are used to evaluate and contrast the system's performance against scenarios where the Zeta Converter is implemented.

Solar Irradiance (S): Measured in Watts per square meter (W/m2), solar irradiance represents the amount of solar power received per unit area. It is a key factor in determining the overall power output of a photovoltaic (PV) system. Photovoltaic Power Output (Ppv): Represented in Watts (W), Ppv denotes the electrical power generated by the photovoltaic cells in response to the incident solar irradiance. This output is influenced by factors such as panel efficiency, shading, and environmental conditions. Motor Power Output (Pm): Expressed in Watts (W), the motor power output signifies the electrical power delivered by the system's motor, which is typically used for tasks such as water pumping in solar PV-fed systems. The efficiency of the motor contributes to the overall effectiveness of the system. Overall System Efficiency (η): Percentage-wise, the overall system efficiency (η) provides an assessment of how effectively the solar power is converted into usable electrical energy, accounting for losses in various components such as the PV array, inverter, and other system elements. In comparing the system without the Zeta Converter to scenarios where the Zeta Converter is employed, it is essential to analyze how the introduction of the Zeta Converter influences these parameters. This may involve evaluating changes in efficiency, power output, and overall system performance to determine the advantages or disadvantages of incorporating the Zeta Converter technology. Such a comparative analysis is crucial for assessing the impact of the Zeta Converter on the efficiency and functionality of the solar power system.

Conclusion

The appropriateness of the suggested SPV array zeta conversion fed VSI-BLDC motor pump has remained proved through simulation outcomes. The suggested scheme has remained suitably planned and modelled to achieve the intended goals, also it has been verified to look at different outcomes in initial, dynamic, & steady-state scenarios. For SPV array-built water pumping, the addition of a BLDC motor as well as zeta converter has been validated by its efficiency assessment. Several desired functions have been demonstrated by the system under study, including the MPP removal of the SPV array, soft preliminary of the BLDC motor, basic occurrence changing of the VSI leading to a reduction in converting sufferers, rapidity controller of the BLDC motor deprived of the need for supplementary regulator, and the removal of phase existing & DC link voltage sensing, which reduces the level of complexity and cost. Even with very little solar irradiation, the suggested approach has shown to function well.

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