PV-Hybrid Energy Storage System Fed BLDC Driven Water Pumping Scheme with Fuzzy Logic Controller

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ABSTRACT
In present life non conventional energy sources are most powerful in the automotive field sector involve the use of solar photovoltaic (PV)-fed water pumping scheme driven by a brushless DC (BLDC) motor drive. To overcome the difficulty among DC-DC converters and minimize the power processing with employed zeta converter .Duty ratio of zeta converter is controlled to extract the maximum power from the solar system with help of particle swam optimization(PSO) based maximum power point tracking(MPPT) method. Hybrid energy storage system (HESS) is connected to PV system in order to maintain constant voltage at the input of BLDC motor drive and also mitigate the PV output variations.A robust power management algorithm is employed for proper control of PV-HESS system. The overall MPPT with power management control facilitates the zeta converter to meet smooth performance of the water pumping system with help of fuzzy logic controller.The performance of the proposed controller is demonstrated using MATLAB/SIMULINK for variation in atmospheric condition.

Keywords—Brushless DC (BLDC) motor; hybrid energy storage system (HESS), maximum power point tracking (MPPT), particle swarm optimization (PSO), photovoltaic (PV) system, zeta converter, Fuzzy logic controller.

I.INTRODUCTION

The increasing worldwide electricity demand attracts scientists' interest in the efficient use of renewable energy sources. This same solar energy network, which is safe and environmentally friendly, is very popular among the numerous renewable sources of power. Given that solar energy is sporadic in existence, it requires the full power point could monitor the output from the solar electricity system. Throughout the literature [1] several MPPT algorithms are mentioned for monitoring the solar pV system's potential capacity. This same traditional MPPT algorithms include: Perturb & observe (P&O), incremental conductance (INC), short circuit current as well as open circuit voltage. Throughout order to resolve limitations of modern

algorithms, ongoing work proceeds to develop MPPT technology[2]. Non-uniform solar separation in the PV network is known as just a partial shadowed condition (PSC) because of the rain, colors of the trees and houses.

In PV characteristics, PSC may cause multiple peaks. The traditional MPPT algorithms may be connected to the local peak which is not the actual MPP of the P-V functionality. PSO dependent MPPT algorithm[3] has been one of the latest and efficient MPPT technique for the optimum extraction of both the maximum energy from either the solar photovoltaic device. The supply of solar pv includes backup including such energy storage device to preserve its output. A combination between battery and super condenser has becoming the most common hybrid energy storage device. That battery will provide stable, state sufficient power to assist intermittent cases as just a super condenser.

A bidirectional DC-DC converter will load or unload either HESS. Based on the correct power management algorithm, changing pulses for both the two-way DC-DC converter could be produced. Traditionally, the bidirectional buck-boost converter has been used to this end. PV output voltage is enhanced with the converter DC-DC. That literature introduces many DC-DC converter topologies, amongst which zeta converter requires that researchers ' attention that can be used in many applications such as MPPT, power factor correction (PFC), and enhanced power efficiency [4]-[6]. A) limitless area of MPPT could be reached unlike conventional buck-and-boost converters[7], b) inductor existence on the output side induces constant and free ripple power output, c) some negative voltage-sensing components are present with the zeta-converter, because it generates non-inverted output voltage.

The usage of both the BLDC motor transformer has the benefit of soft start[8] and is ideal for an efficient water pumping device. In this project a solution has been proposed for even an efficient and independent water pumping system; i.e., a PSO-based MPPT algorithm is used to generate switching pulses to both the zeta converter as well as an algorithm for dual circuit power management would be applied [9, 10].

II. SYSTEM DESCRIPTION

That BLDC motor-driven PV-HESS piping system device is provided in Fig.1 to PSO-based MPPT algorithm. Solar pv system is indeed a main source of water pumping systems driven by BLDC motor as well as HESS has been used to handle control intermittent system response to fluctuations in atmospheric conditions. The Zeta-Converter becomes activated either by PSO-based MPPT controller produced pulses. Their battery & super condenser are responsible for both the power control of the device with various ambient conditions. Throughout a stable state, your battery handles the voltage shifts while working as a mega capacitor through the transience. The ultimate goal here would be to preserve constant voltage throughout the entire BLDC engine even under various atmospheric conditions accomplished by the correct algorithm for power management. That electric balance would be as follows, if another solar system's produced PPV is; PM, that power provided either by motor drive BLDC; PSC then PB, respectively, seem to be the immediate power of both the super condenser & battery bank. The SR flip-flops relative power technique is used with this device and tested using the Zinc ZC 702 FPGA package.

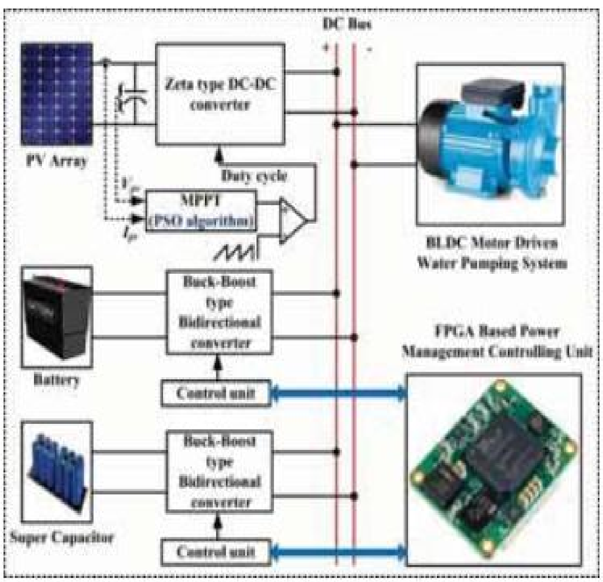


Fig.1 Hybrid PV-ESS fed BLDC motor driven water pumping system.

$$P_M = P_{PV} + P_{SC} + P_B \tag{1}$$

where P_{PV} is the generated power of the solar energy system; P_M is the power demanded by BLDC motor drive; P_{SC} and P_B are the instantaneous powers of the super capacitor and battery bank respectively.

In this work, solution of an effective and standalone water pumping system is proposed, i.e., PSO-based MPPT algorithm is employed to generate switching pulses for the zeta converter and dual loop power management algorithm is employed for controlling the overall PV-HESS system. The real-time operation of the power management controller is validated through fuzzy logic controller. The fuzzy controller is applied to the DC-DC converter and the dynamics of the system have been improved by using fuzzy logic controller.

A.Design and operation of zeta converter

Through proper switches like such a buck-boost converter, that zeta converter will improve or indeed the output voltage. When compared to both the bucks boost transformer, the current voltage is not changed as well as the negative voltage controls are omitted. Image2. Displays that zeta converter circuit diagram.

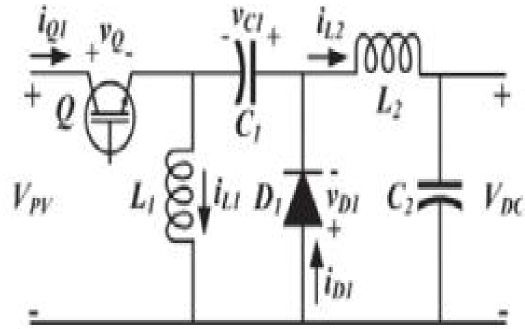


Fig. 2 Zeta converter topology.

That zeta converter consists of Q, Diode D1, AC coupling capacitor C1, L1, L2, then C2. That AC coupling converter becomes constructed from a power semiconductor. The specification specifications for the zeta converter are listed in table I. The energy stored onto L1 &L2 once switch Q becomes activated. Therefore L1 & L2 will be in charge status during this process. Once turn Q will be off L1, its compressed energy is discharged into the condenser C1 as well as the inductor L2 provides the remaining electricity for the output. Each C2 binding DC condenser is chosen depending mostly on motor rpm, and optimal value among C2min and C2rated is now to be provided.

TABLE I. DESIGN PARAMETERS OF ZETA CONVERTER

Parameter	Expression	Selected value
Duty cycle (D)	$D = \frac{V_{DC}}{V_{DC}+V_{PV}}$ (2)	0.76
Inductor ($L_1 = L_2$)	$L_1 = L_2 = \frac{DV_{PV}}{f_{sw}\Delta i_L}$ (3)	6 mH
Capacitor (C_1)	$C_1 = \frac{DI_{DC}}{f_{sw}\Delta V_{C1}}$ (4)	20 µF
DC link capacitor (C_2)	$C_{2min} = \frac{I_{DC}}{6 * w_{min} * \Delta V_{DC}}$ (5) $C_{2rated} = \frac{I_{DC}}{6 * w_{rated} * \Delta V_{DC}}$ (6)	850 µF

III. CONTROL STRATEGIES

The operation of DC-DC electricity converters is also an essential part of a single, powerful water pumping device. Each zeta converter becomes powered by either a PSO-MPPT model to find full power through PV devices, while a dual loop power storage technique is used to monitor the symmetric DC-DC converters.

3.1 PSO algorithm and application in MPP tracking:

In terms of power device issue optimization, electronics applications, harmonically energy harvesting converters[13], etc, it was noticed that PSO [12] was extremely useful. Many parametric calculations are required for genetic algorithms, colonic computation and other related biological algorithm. When contrast to many other biological optimization computation, PSO is simple to implement although time-consuming. Their particles throughout PSO travel throughout the space of the question, consider the best answer and store this in the brain. The highest health in the community as well as in the entire cycle is alluded to as the highest personal benefit as well as the leading international interest. Growing particle travels until a certain pace towards the best professional and global principles and updates them during each iteration. That pace and location of both the particle were modified as follows.

$$\emptyset_{id}(k+1) = \emptyset_{ij}(k) + c_1 r_1 \left[P_{b_{ij}}(k) - \rho_{ij}(k)\right] + c_2 r_2 \left[P_{g_i}(k) - \rho_{ij}(k)\right] \quad (7)$$

$$\rho_{ij}(k+1) = \rho_{ij}(k) + \emptyset_{ij}(k+1) \quad (8)$$

where i = 1, 2, …., n; j = 1, 2, …., d; k is the recapitulation number then k+1 index means the next repetition..ଢand.ରୀ are the rushing coefficients consistent to personality weight then sociality weight correspondingly(both are taken as 2.05 in this article), $r_1$and $_2$r are the consistently circulated random quantity between [0, 1].,is the individual best practice of separately particle,, is the greatest particle in the group found so remote it signifies the location and velocity of i[th] particle correspondingly.

$$\chi = \frac{2}{\left|2 - \varphi - \sqrt{\varphi^2 - 4\varphi}\right|}, \varphi = c_1 + c_2 \text{ and } \varphi > 4 \quad (9)$$

$$\emptyset_{id}(k+1) = \chi[\emptyset_{ij}(k) + c_1 r_1 \left(P_{b_{ij}}(k) - \rho_{ij}(k)\right) + c_2 r_2 \left(P_{g_i}(k) - \rho_{ij}(k)\right)] \quad (10)$$

Throughout the MATLAB 2009a setting, the MPPT-based PSO-based technology is applied to determine the optimal operating cycle perhaps to optimize control. The MPPT regulates the V pv & Ipv via sensors and calculates power production. The process begins with such a random selection of the velocity as well as the particles throughout the minimal to full service period (operation period of both the Zeta converter). MPPT was known as its fitness function (FF).

$$FF = \max P_{pv}(D) \quad (11)$$

The perfect period of service. The duty period varies from 0 to 1. Since the last review, the original service period and minimum workout values are assigned as that of the appropriate national and global roles. The particles throughout the swarm are modified at time, location and place at the very next level of both the algorithm so according (10) but (8). Thanks to either the stochastic existence of PSO, that modified particle location was not quite similar to previous one. When this happens too easily in D, that Q function would be filled with high voltage.

The dc voltage is then ordered by last value reached and also the closest duty period is chosen to minimize the changeover burden. Iteration proceeds in the very same manner till the counter exceeds the full fixed value because after the number of times the possible answers are picked. When not, the repetition rate will be through and the performance factor reassessed. If shifts throughout the shading sequence are observed, the particles throughout the swarm are reset. The full number of iterations is 50 and the code has 5 particles. That proposed MPPT controller effectively controls global maximum output both during standardized and selective shading of both the PV collection.

3.2. Power management control strategy :

The symmetric DC-DC converters can be operated to sustain continuous DC voltage throughout the BLDC drive only under varying conditions throughout the atmosphere. The power control algorithm used in this analysis comprises of 2 loops for producing the reference current (I_{ref}). The Iref becomes created for both the HESS method using a proportional integral (PI) regulator. Therefore, the term for a comparison current is broken up for both the battery including super condenser to monitor the equation

$$I_{ref} = \left(K_P + \frac{K_I}{s}\right) * V_{error} \tag{12}$$

KI are both the additive and functional profits. The Ziegler-Nicholus process [16] is used to approximate the importance of K p and K_I.

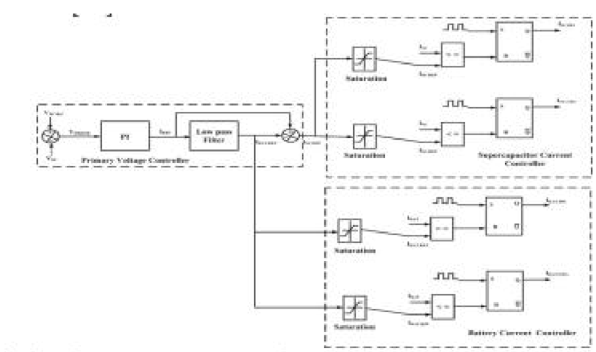


Fig. 3. Power management control strategy.

Just one low pass filter separates the achieved reference current from either the battery but instead super condenser. The resulting reference current. That error caused by contrasting reference versus current is supplied to both the SR flip-flop restore board. Whenever the current significantly meets the sampling rate, that battery&super condenser is transferred to the discharge state and becomes compensated until the real current reaches the comparison amount. Image. 3 provides a detailed description of both the approach for power management.

IV FUZZY CONTROLLER

Lotfi A. Zadeh describes the term flush over vagueness and this occurs whenever the piece's borders addresses the issue. This method was used in 1965 to increase productivity and showed enormous complexity in the framework mostly on fuzzy theory of collection. Fuzzy set is also an essential method for mathematically improving that treats certain data because of its vagueness. This comprehension of people's expression and strengthen the text to remember in fleetingness the instance of specific characters.

Fuzzy analytic geometry is a supplement that seeks to define classical theory, whereby elements lead to the development of various membership rates. To order to explain human thinking, Fuzzy logic utilizes the whole cycle between O and 1. It method combines the input vector which is transformed to boost functions by both the sets of membership and often called FUZZY SETS.The fuzzy collection contains an associate attribute that could be described as both a variable parameter. A sum from o to 1 adjusts the values throughout the ambiguous collection during membership. The techniques are regarded as "fuzzification" for transforming the crisp data with growing solvent. The Fuzzier module effects are interfaced with various laws. This are central to both the FLC's varying function in order to minimize the gap and adjust the mistake in order to monitor the behavior by way of ambiguous management laws generally. The following calculation is based mostly on fuzzy board. The product of both the variable regulation in phase is the mix of both the crisp but DEFUZZIFICATION.

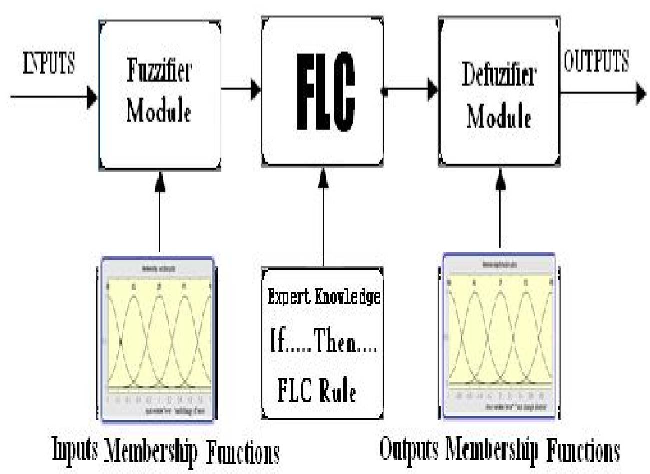


Fig 4: Block diagram fuzzy logic

4.1 Fuzzy rules:

The machine with both the inlet and outlet vector in these fuzzy monitors the scale of terms to evaluate them in specific ways. The basic terminology to describe the variables is chosen. In the large medium and low are commonly used. Each inlet and outlet variable of the controller is needed for these 3 terms. The need to maintain their plus between negatively, and to strengthen the Process in framework additionally differs from zero { negative big, negative medium, negative small, zero, positive small, middle, CT }, the general terms used in the English abbreviation prefix: {NB, NM, NS, ZE, PS, PM, PB}.

V SIMULATION DESIGN AND RESULTS:

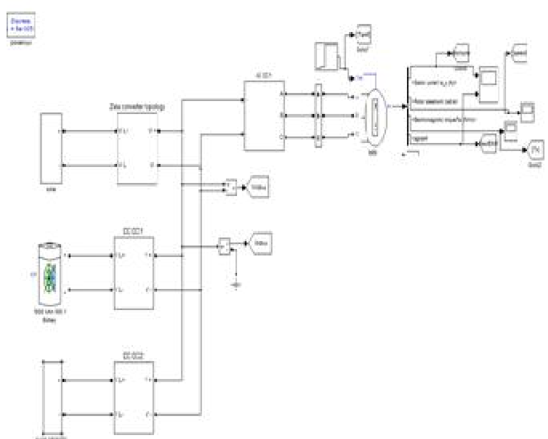


Fig5.1: Simulation Block Diagram

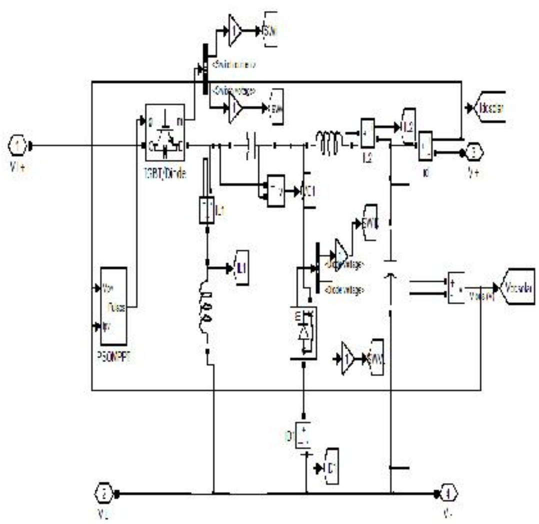


Fig 5.2: Simulation of Zeta Converter

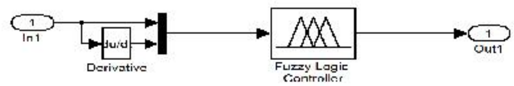


Fig5.3: Fuzzy Logic Controller

Simulation Results:

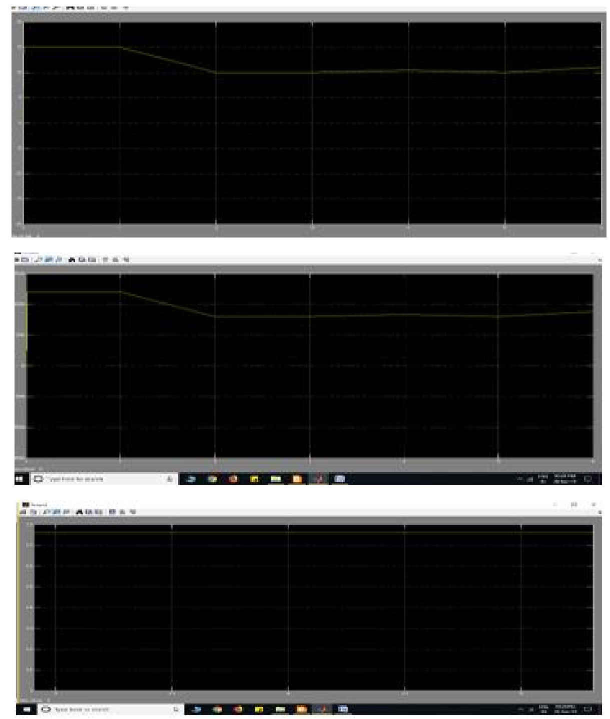


Fig. 5.4 Tracking curves obtained during uniform shading

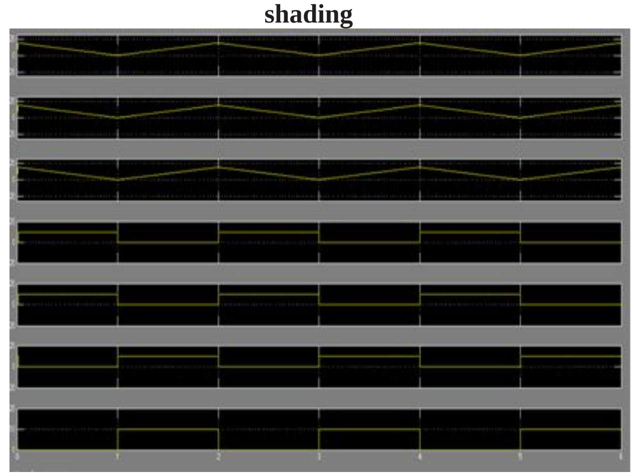


Fig. 5.5. Zeta converter variables during steady state

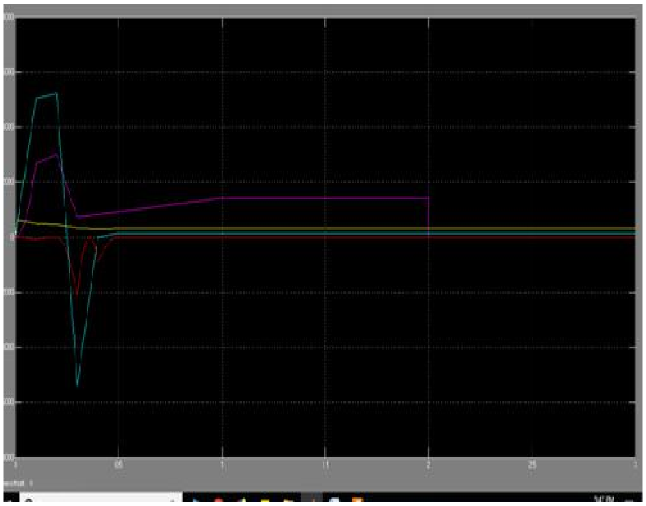
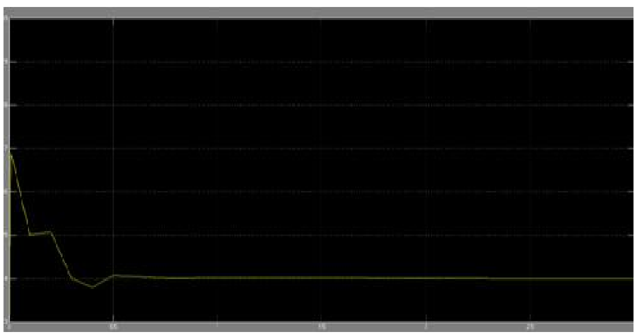
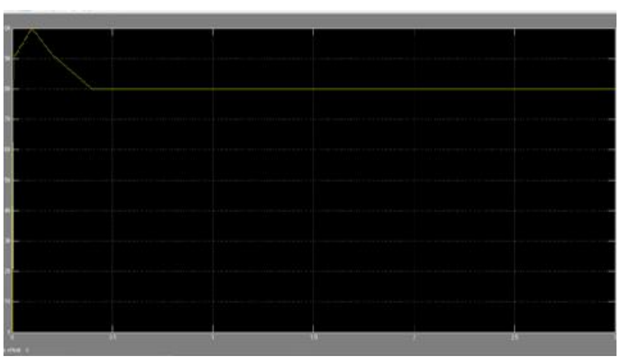


Fig. 5.6. Power management curves for a step change of 1000 W/m2 to 0 W/m2at 2 s



(a)



(b)

Fig.5.7. Load parameters (a) Current, (b) Voltage

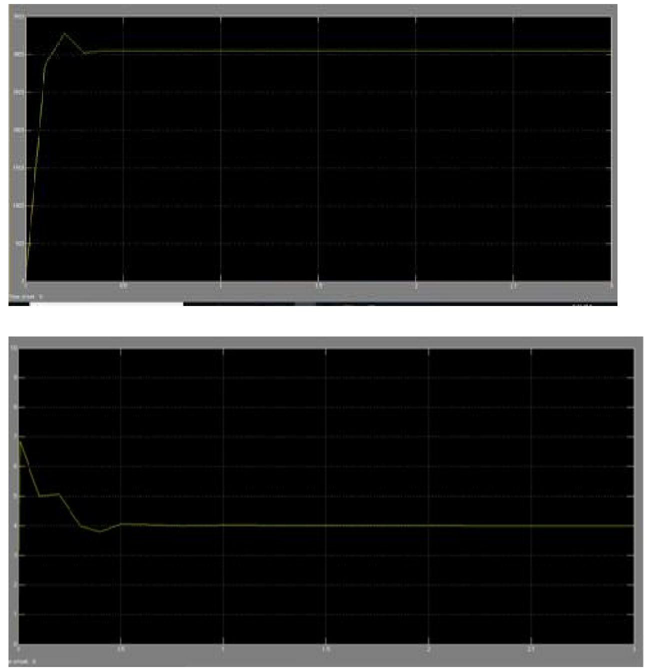


Fig 5.8. (a) Speed, (b) Torque of BLDC motor

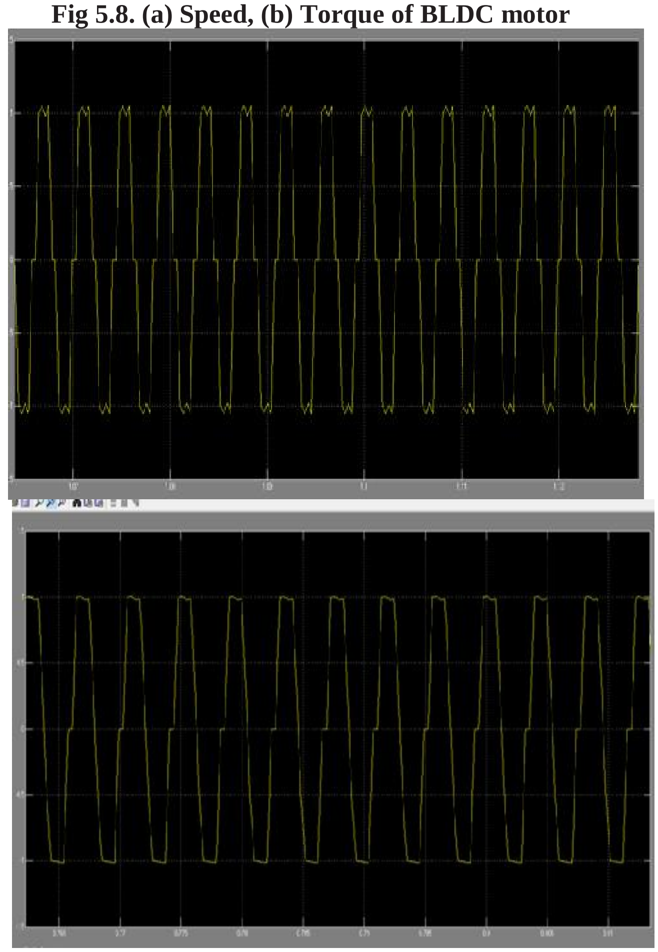


Fig. 5.9. (a) Stator current, (b) Back EMF of BLDC motor.

CONCLUSION

The PV fed BLDC drive using zeta converter assisted by HESS has been validated as an effective solution for replacing the usage of conventional energy sources. The zeta converter employed has the better performance in terms of MPPT implementation, smooth operation of motor drive for water pumping. Also, the power management algorithm used for the HSS system is capable of maintaining constant voltage to BLDC motor. In this paper fuzzy logic controller is stabilize the system response fast. Various desired performances such as PSO-based MPPT under varying atmospheric condition, operation of zeta converter, dynamic performance of overall system has been demonstrated using MATLAB/Simulink platform. The results shown in this study confirm the accuracy of the control algorithm.

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