Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 5, May : 2023

Controlling of PV fed BLDC Motor with Optimization Technique

Mr. P. Subhani Khan[1], Mrs. R. Jaya Lakshmi[2]

[1, 2]Assistant Professor, Department of EEE, PSCMRCET, Vijayawada, Andhra Pradesh, India

ABSTRACT

The goal of this study is to soft start a permanent magnet brushless DC motor and increase the efficiency of an SPV array using a buck-boost converter-driven solar photovoltaic array that is used to pump water. Current sensors, which are typically used to regulate the speed of BLDC motors, are entirely removed. A voltage-source inverter's changing DC-link voltage controls the BLDC motor's speed (VSI). This study examines how the interleaved DC-DC converter, which serves as a transitional DC-DC converter between the solar PV array and soft starting of BLDC motors.The output ripple current of the intermediate converter with semiconductor switches is reduced, and it offers an indefinite region for recording maximum power (MPPT). In this project, the speed of a brushless DC motor has been managed utilising a variety of control approaches, including PI, FUZZY, and PSO Optimization techniques. To get the most efficiency out of the solar array, the system is powered by a solar PV array and the MPPT technology.

Key Words: BLDC Motor, FUZZY Controller, PSO Technique, VSI Converter, PV System and DC-DC Converter

1. INTRODUCTION

A BLDC Motor is a type of synchronous motor that uses Direct Current (DC) to produce AC that may be used to drive each of the motor's phases. In terms of structure, brushless motors are comparable to permanent magnet synchronous motors, but they can also be converted into switching reluctance motors. Industrial engineering, consumer electronics, electric vehicles, motion control systems, positioning and actuation systems' aero modelling, and many more fields find many uses for BLDC motors [1]. The BLDC motor is superior to other motors in a variety of ways, including high power-to-weight ratio, greater speed, electronic controllability, dependable operation, and low maintenance requirements [2].

In order to avoid the challenges of providing current to the moving armature, brushless motors typically use a fixed armature and rotating permanent magnets. Instead of employing the brush/commutators method, the controller carries out a comparable timed power distribution using a solid-state circuit [3]. The efficiency of high-quality brushed and brushless motors under heavy mechanical loads is comparable. High speeds, maintenance-free operation, and operation where sparking is dangerous (i.e., in explosive situations) are all conditions and demands that brushless-type DC motors must meet [4].

D. Shobha Rani, created a potential start-up technique with a high starting torque and sensorless procedures based on a hysteresis comparator is advised [5]. The hysteresis comparator prevents numerous output transitions brought on by noise or ripple in the terminal voltages in addition to compensating for back EMF phase delay brought on by a low-pass filter (LPF).

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 5, May : 2023

2. DESIGNING OF BLDC MOTOR

Brushless DC motors, for example, do not experience the "slide" that is commonly noticed in induction motors since they have a permanent magnet rotor. Magnetism that is permanent Mechanical commutators and brushes are commonly used in DC motors to complete the commutation process [6]. Initially, the magnetic field is created by the stator winding of a brushless DC motor, and the rotor begins to rotate as a result of this field. And the Hall effects presents in this type of drive is used for sensing the position of rotor as in the form of commutating signals. Figure 1 shows the structure of BLDC motor with PV system [7].

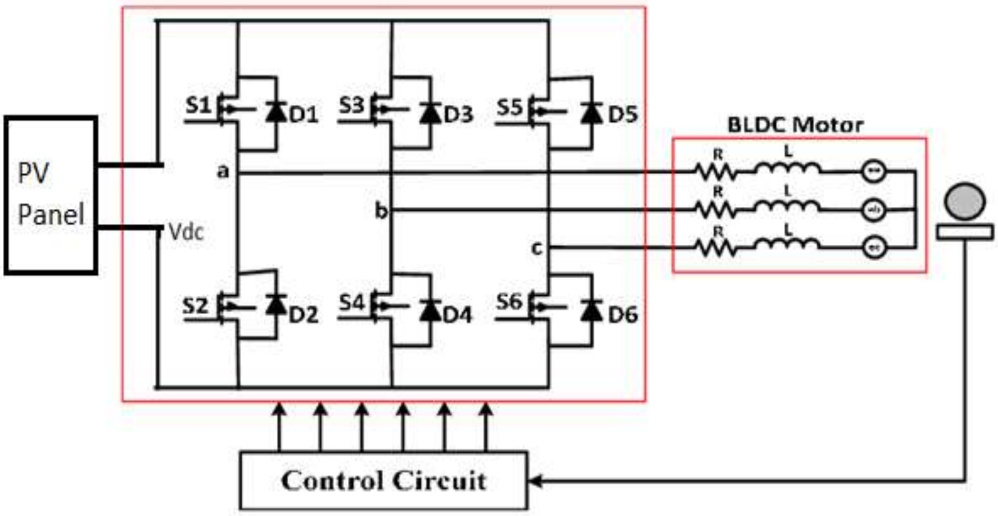

Figure 1: Basic schematic diagram for BLDC

The mathematical model analysis using KVL equations for figure 1.

$$V_{a1} = i_{a1} r_a + L \frac{di_{a1}}{dt} + e_{a1} \quad 1(a)$$

$$V_{b1} = i_{b1} r_b + L \frac{di_{b1}}{dt} + e_{b1} \quad 1(b)$$

$$V_{c1} = i_{c1} r_c + L \frac{di_{c1}}{dt} + e_{c1} \quad 1(c)$$

In this study, we applied a line-to-line parks transformation technique to these equations [8]. The two-phase coordinators created by these parks translate the three phase voltages as follows:

$$\begin{bmatrix} Vab1 \\ Vca1 \end{bmatrix} = \begin{bmatrix} -\frac{1}{3} & -\frac{1}{3} \\ \frac{\sqrt{3}}{3} & -\frac{\sqrt{3}}{3} \end{bmatrix} \begin{bmatrix} Va1 \\ Vb1 \\ Vc1 \end{bmatrix} \quad (2)$$

The alpha and beta components of voltage and current are expressed below,

$$\psi_{\alpha 1} = \frac{1}{L_\alpha}(V_{\alpha 1} - i_{\alpha 1} r_a) \quad 3(a)$$

$$\psi_{\beta 1} = \frac{1}{L_\beta}(V_{\beta 1} - i_{\beta 1} r_a) \quad 3(b)$$

The total phase angle is obtained by using the two flux linkages of alpha and beta coordinates as shown in figure 4,

$$\psi = \psi_{\alpha 1} + j\psi_{\beta 1} \quad 4(a)$$

$$\theta 1 = \tan^{-1}(\psi_{\beta 1} / \psi_{\alpha 1}) \quad 4(b)$$

$$\begin{bmatrix} i_{d1} \\ i_{q1} \end{bmatrix} = 0.66 \begin{bmatrix} -\sin(\theta 1 - 30) & \sin(\theta 1 + 30) \\ \cos(\theta 1 + 30) & -\cos(\theta 1 - 30) \end{bmatrix} \begin{bmatrix} i_{\alpha 1} \\ i_{\beta 1} \end{bmatrix} \quad (5)$$

For error tolerance, these measured currents are compared to reference direct and quadrature axis currents. The electromagnetic torque generates the reference current signals [9].

$$T_{e1} = T_{m1} + J\frac{dw_{m1}}{dt} + Bw_{m1} \quad (6)$$

The generated electromagnetic torque is expressed as,

$$T_e = \frac{e_{a1} i_{a1} + e_{b1} i_{b1} + e_{c1} i_{c1}}{w_{m1}} \quad (7)$$

a. Sensorless Control Methods of BLDC

A BLDC motor drive typically uses one or more location sensors to maintain synchronisation. Such a design results in a higher driving cost due to sensor wiring and motor installation. Additionally, sensors cannot be used in compressors, where the rotor is encased in a closed housing with a restricted number of electrical entry points, or in some pumps, where the motor is submerged in a liquid [10]. Therefore, the BLDC sensorless drive is a crucial feature of a brushless motor controller for both practical and financial reasons. Figure 2 shows the circuit diagram for BLDC motor with sensorless controller [11].

Making the equation for one phase is challenging because the BLDC motor’s neutral point is not provided. As a result, the following line-to-line equation takes into account the unknown input observer [12]:

$$i'_{ab} = \frac{2R}{2L} i_{ab} + \frac{1}{2L} v_{ab} - \frac{1}{2L} e_{ab} \quad (8)$$

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 5, May : 2023

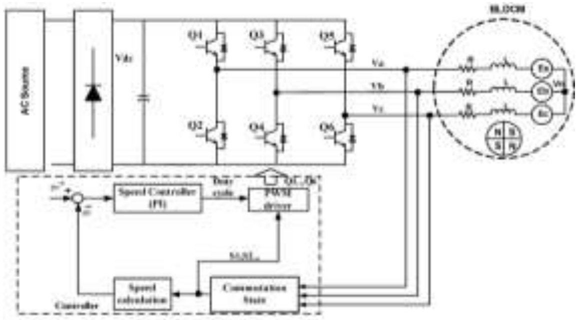

Figure 2: Sensorless Control Method of BLDC

a. Fuzzy Logic Controller:

To more effectively control the reactive power, a FUZZY controller is added to the synchronous condenser controller. Fuzzification, membership function, rule-base construction, and defuzzification are the four processes in which a FUZZY logic system can operate [13]. The structure of Fuzzy inference system is shown in figure 3. The error and change in error are selected as the inputs for the FUZZY logic controller. The number of members selected in this case for the inputs error and change in error are LN, MN, Z, MP, and LP [14]. Additionally, there are 25 rules that make up this system's regulations as shown in table-1.

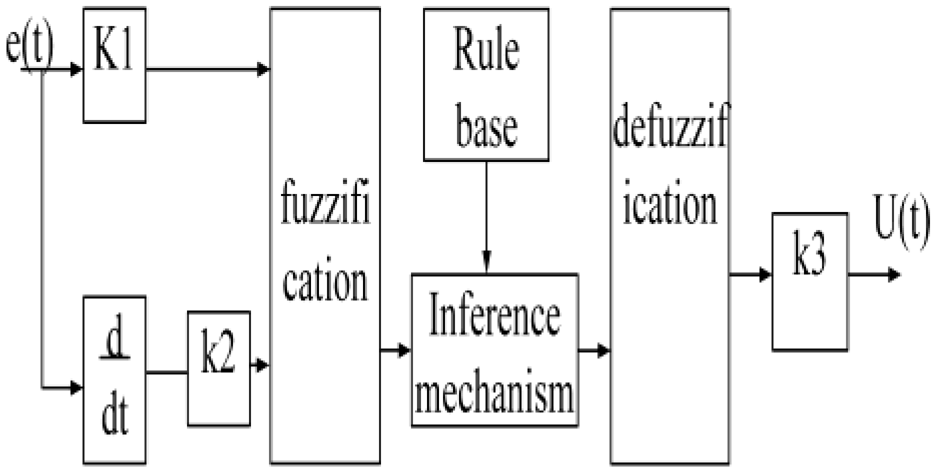

Figure 3: Structure of FIS Editor

Table-1: FIS Editor Rule base formation

E/ΔE	N-M	N-S	Z	P-S	P-M
N-M	N-M	N-S	N-M	N-S	N-S
N-S	N-M	N-S	M-N	Z	P-S
Z	N-M	N-S	Z	Z	P-S
P-S	N-M	N-S	Z	N-S	P-M
P-M	N-M	N-S	Z	P-S	P-S

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 5, May : 2023

b. Analysis of PSO Technique:

The conventional PSO algorithm's as shown in figure 4, convergence criteria look for the best answer or the maximum number of successful rounds. As a result, anytime the following criteria are met, the proposed PSO algorithm [15] will re-initialize and optimise the best settings of Kp and Ki:

$$|v_1(i+1) < \Delta v_1| \quad (9)$$

$$(p_{i1}(k+1) - p_{i1}(k) / p_{i1}(k) > \Delta p_1) \quad (10)$$

Pi (k) represents the old parameters, while pi (k+1) represents the new values. Stand for the agent's rapid change in insolation and detection of convergence from the aforementioned equations, respectively.

The choice of speed reference affects two things: 1) improved error firmness at the expense of a poor tracking reaction at lower values; and 2) faster tracking reaction at the expense of more oscillations at higher values. As a result, a balanced rate needs to be chosen [16]. The second restriction, however, may not be satisfied when P is large due to reduced variance in real power; as a result, the initialization rate of the agents is low [17].

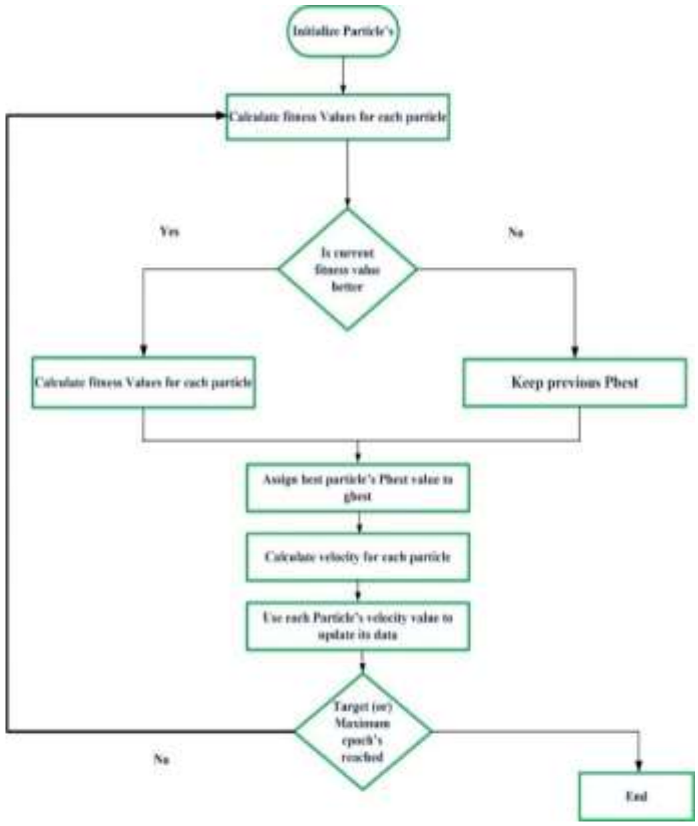

Figure 4. Flowchart for PSO Technique

Step 1: Parameter selection: For the proposed VSI Converter, the calculated speed error of the BLDC motor is defined as the particle position, and speed and torque is chosen as the fitness value evaluation function.

Step 2: PSO initialization: In a standard initialization, PSO particles are usually randomly initialized. For the proposed controller, the particles are initialized at fixed, equidistant points, positioned around the GP.

Step 3: Fitness evaluation: The fitness evaluation of particle i will be conducted after the digital controller sends the PWM command according to the gate signal, which also represents the position of particle i.

Step 4: Determination of individual and global best fitness: The new calculated individual best fitness (P_{best}) and the global best fitness (g_{best}) of each particle value are compared with previous ones. They are then replaced according to their positions, where necessary [18].

3. SIMULATION AND RESULT ANALYSIS:

A fixed voltage source has been provided for the entire system in this. The Kp and Ki PI controller parameters in this model, which help to regulate the speed of the BLDC motor using a 3-inverter, have been determined using a PSO. With a greater reliance on renewable energy sources, there are various disadvantages to give energy. The system has been connected to a solar PV array, which will power the entire setup. The maximum power technique allows for the extraction of efficiency of maximum from solar system. For the 3-inverter to produce the appropriate output, a bidirectional converter has also been used.

Table 2: Simulation Parameters

Parameter	Range
Resistance	0.7 Ohm
Inductance	2.72 mH
Inertia	0.8 mkg.m^2
Friction	1m N.m.s
Kp	0.8
Ki	2.3

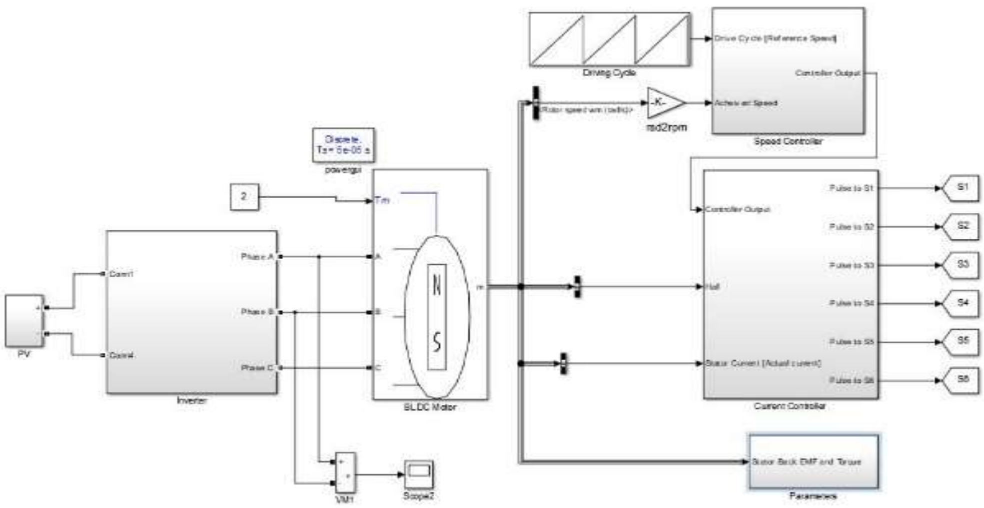

Figure 5: Simulation Diagram for Proposed BLDC

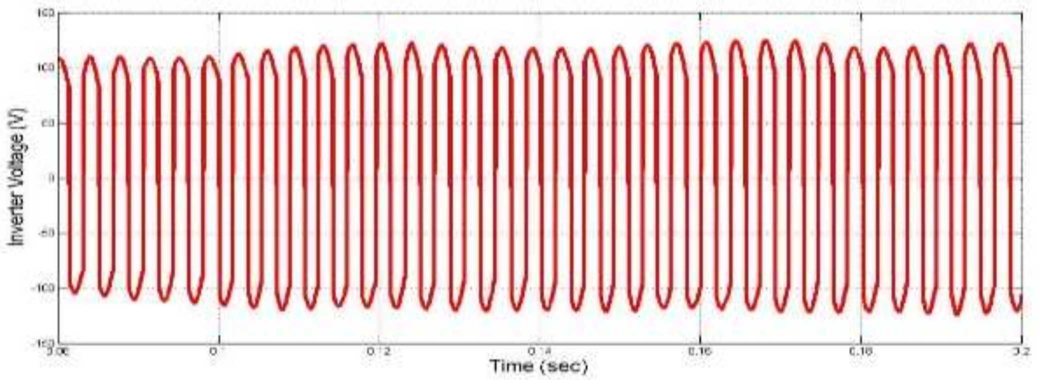

Figure 6: Inverter voltage with FUZZY Technique

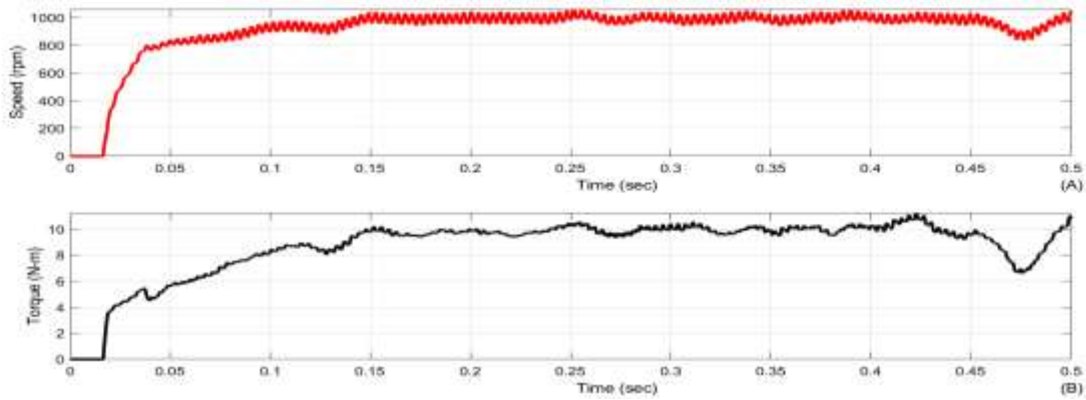

Figure 7: BLDC Waveforms (A) Speed, (B) Torque with FUZZY Controller

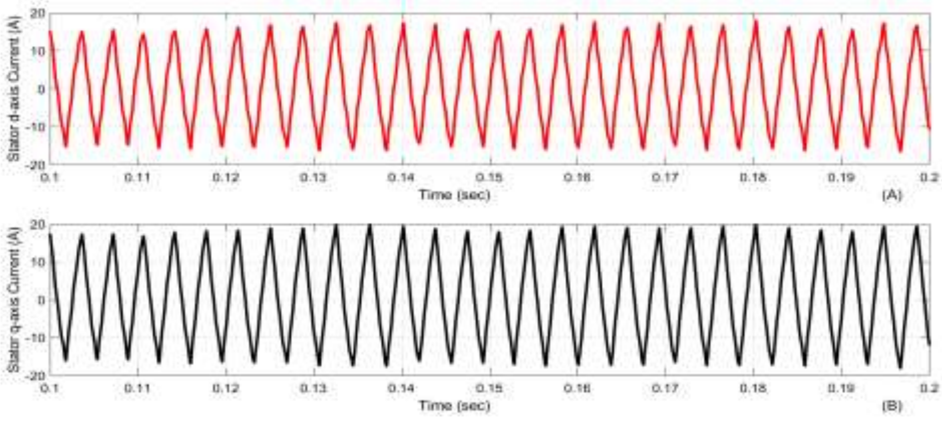

Figure 8: BLDC Current Waveforms (A) Stator d-axis, (B) Stator q-axis with FUZZY Controller

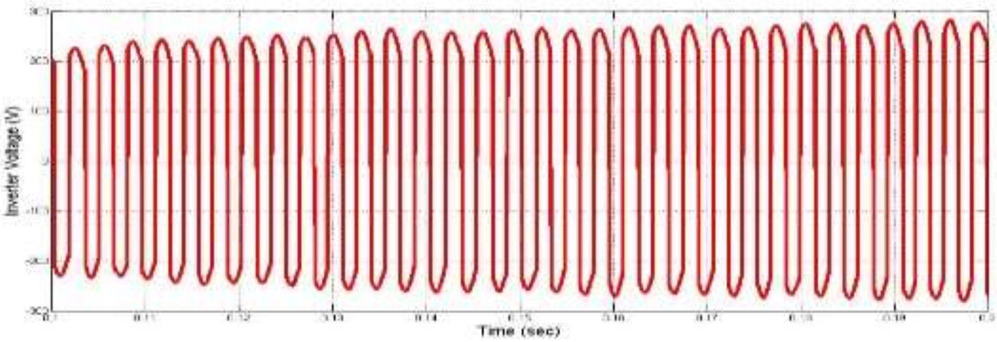

Figure 9: Inverter voltage with PSO Technique

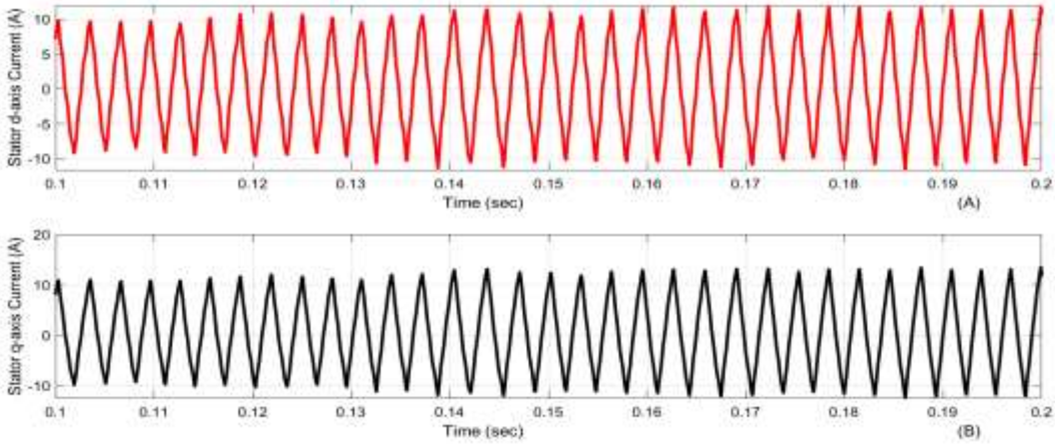

Figure 10: BLDC Current Waveforms (A) Stator d-axis, (B) Stator q-axis with PSO Controller

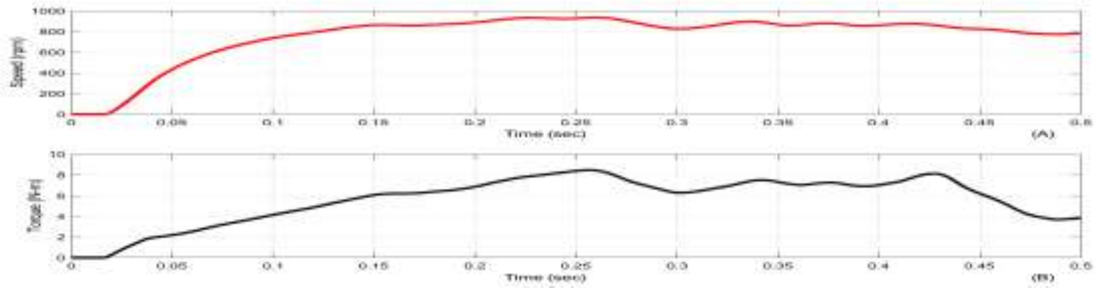

Figure 11: BLDC Waveforms (A) Speed, (B) Torque with PSO Controller

Table 3: Comparative Analysis between FUZZY and PSO

Parameter	**FUZZY**	**PSO**
Inverter Voltage	100V	120V
Speed Distortions	15%	8%
Torque Distortions	18%	7%

4. CONCLUSION

This study compares PSO and FUZZY approaches for fine-tuning a PI controller to control the speed of a BLDC motor. The results of the simulation of the BLDC motor reveal that the suggested controller is capable of efficiently searching for the PI controller's ideal gains. By contrasting the PSO approach and the

FUZZY technique, it can be seen that the PSO method can more effectively enhance the dynamic performance of the system.

REFERENCES

1. Mohamad Ridwan, Dedet Candra Riawan and Heri Suryoatmojo "Particle Swarm Optimization-Based BLDC Motor Speed Controller with Response Speed Consideration" IEEE conference on Intelligent Technology and its Application (ISITIA), pages 193-198, Surabaya, Indonesia,2017:

2. Sariki Murali, Kaibalya Prasad Panda and Gayadhar Panda "PVHESS fed BLDC Driven Water Pumping System with PSO-based MPP Tracking Employing Zeta Converter" IEEE Innovative Smart Grid Technologies-Asia (ISGT-Asia), Pages:196-201, 2018:

3. V.Maheskumar, M.Bhuvanesh, S.Govindasamy, M.Yogaraj "Design and Implementation Of Solar PV fed BLDC Motor driven water pump using MPPT" International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-4, Issue-03, March 2018:

4. S.Sakunthala, R.Kiranmayi, P.Nagaraju Mandadi "A study on industrial motor drives: Comparison and applications of PMSM and BLDC motor drives" International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), 2017:

5. D. Shobha Rani, M. Muralidhar "BLDC Motor Driven for Solar Photo Voltaic Powered Air-Cooling System" World Academy of Science, Engineering and Technology (IJEPE), Vol:11, No:9, 2017

6. Prakash Salawria, Rakesh Singh Lodhi and Pragya Neeema "Implementation of PSO-Based Optimum Controller for Speed Control of BLDC Motor" International Journal of Electrical, Electronics and Computer Engineering 6(1): 104-109(2017):

7. S.Sarada, C.Ganesh and K.Aparna "Brushless DC (BLDC) motor drive for solar photovoltaic (SPV) array fed water pumping system by using FUZZY Logic controller" International Journal of Electrical Engineering. ISSN 0974-2158 Volume 10, Number 3 (2017), pp. 289-305:

8. Atef Saleh Othman Al-Mashakbeh **"**Proportional Integral and Derivative Control of Brushless DC Motor" European Journal of Scientific esearchVol.35 No.2 (2009), pp.198- 203

9. Aishwarya Kokare, Sangita Patil, Lalit Bacchav "Implementation of a Highly Efficient MPPT Technique for a PV System Using SEPIC Converter" International Conference on Information, Communication, Instrumentation and Control (ICICIC), IEEE, 2017:

10. Jubaer Ahmed, Zainal Salam "A Modified P&O Maximum Power Point Tracking Method with Reduced Steady State Oscillation and Improved Tracking Efficiency" IEEE Transactions on Sustainable Energy Volume: 7 Issue: 4, Oct. 2016:

11. Rajan Kumar and Bhim Singh "BLDC Motor Driven Solar PV Array Fed Water Pumping System Employing Zeta Converter" IEEE Transactions on Industry Applications, Year: 2016 Volume: 52, Issue:3 Pages: 2315 – 2322.

12. 21. K.Ang, G.Chong, and Y. Li, "PID control system analysis, design, and technology," IEEE Trans. Control System Technology, vol.13, pp 559-576, July 2005.

13. Salih Baris Ozturk, Member, IEEE, and Hamid A. Toliyat, Fellow, "Direct Torque and Indirect Flux Control of Brushless DC Motor" in IEEE/ASME TRANSACTIONS ON MECHATRONICS, VOL. 16, NO. 2, APRIL 2011

14. AS, Upama; BISWAS, Pabitra Kumar. Closed Loop speed control of BLDC Motor Drive by using classical controllers with Genetic Algorithm. Journal of Power Technologies, [S.l.], v. 100, n. 2, p. 161-170, june 2020. ISSN 2083-4195.

15. Das, U., & Biswas, P. (2021). Relative study of Classical and fuzzy logic Controllers in Closed Loop BLDC Motor Drive with GA and PSO optimization techniques. Journal of Applied Research and Technology, 19(4), 379-402.

16. Gwo-Rueyyu and Rey-Chue Hwang "Optimal PID Speed Control of Brushless DC Motors Using LQR approach" IEEE International Conference on systems, Man and Cybernetics, 2004, pp.473-478.

17. Yu-kun Wang, Jie-sheng Wang "Optimization of PID Controller Based on PSO-BFO Algorithm" IEEE Chineese Control and Decision Conference, Yinchuan, China 2016, DOI: 10.1109/CCDC.2016.7531820.

18. Bergh, L.G. MAC Gregory. J.F. constrained minimum variance- Internal model structure and robustness properties.IND. Eng chem. Res.1986, 26, 1558.