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Speed Control of BLDCM using Meta-Heuristic Algorithm PSO Tuned PI Controller

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ABSTRACT: In modern industrial, automobile, and home appliance drives needs a more economical, energy efficient motor. Among the special machines, the Brushless DC Motors (BLDCM) are more attractive to the application engineer because they offer a high power to weight ratio, compact construction, do not require consistent maintenance, an efficiency margin of 85–90%. This study particle swarm optimization (PSO) tuned PI based speed control for a three-phase brushless DC motor with transient time domain characteristics. The PSO based controller algorithm is implemented which receives the actual speed by position sensor located inside the BLDCM. It calculates the duty cycle of the Pulse Width Modulation (PWM) signal that is applied to the driver system of the BLDCM drive to achieve the reference speed. Performance characteristics of a BLDC motor drive such as steady state error, peak overshoot, speed drop under loaded conditions, restoration time after loaded conditions were analysed using MATLAB/Simulink 2014.

KEYWORDS: Brushless DC Motor (BLDCM); steady state error; peak overshoot; Particle Swarm Optimization(PSO) ;Proportional Integral contrller (PI); Pulse Width Modulation (PWM)

I. INTRODUCTION

In several conventional control algorithms, like P, PI, PID based controllers used to control the BLDCM, the control variables that can be optimised are only one single variable. This limits the application to only the linear model based controllers that are used in BLDCM [1-5]. But in many practical applications where the applications are non- linear and the controller needs to control more than one variable simultaneously to achieve the desired performance, the adaptive Meta Heuristic algorithms has proven to be an effective methods[6].

In industrial drives application like variable adjustable speed operation is needed, such applications requires controlling of both the Kp and Ki parameter which is not possible in the case of P, PI, PID controller based control algorithms. Online tuning process for multivariable control in BLDCM where the above two problems one is tuning problem for PI controlling preparation and the other non-adaptive nature of the PI controllers. The Meta heuristic algorithm finds a better method [7-9].

In this research address, the above stated problem is solved by using evolutionary optimization techniques like Particle Swarm Optimization (PSO) based PI, is applied to the BLDCM and their performance characteristics are presented[10].

II. PSO TUNED PI CONTROLLER BASED SPEED CONTROL OF THE BLDCM

The Eberhart and Kennedy first created the PSO technique in 1995 as a population-based optimization approach and a form of evolutionary computation tool. The technique was shown to be robust in addressing problems with nonlinearity and no differentiability, high dimensionality, and several optima, using adaptation, which is based on social-psychological theory. The next are the technique's properties: The approach is straightforward to implement, with great computational efficiency and a stable convergence characteristic, and it depends on swarm research, like bird flocking and fish schooling. Particles are a population of possible solutions that the PSO flow through search space [11].

In the PSO method, particles have a variable velocity which affects how far they travel in search space. Every one of the particles has a memory as well, which allows it to recall the optimal solution in every one of the search spaces it has visited. In addition, pbest refers to the place with the best fitness, whereas gbest refers to the overall best of the population's particles. In this work, PSO was utilized for tuning the weight coefficients in order to obtain an optimal controller. In PSO, a swarm of randomly selected individuals referred to as particles is produced. Each one of the particles represents a possible solution to the problem of optimization [12].

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The precise algorithm for PSO is as follows:

1. Construct a "population" of agents (particles) that are evenly distributed throughout X.
2. Consider the objective function while assessing the positions of each particle (say the below function).
3. Update a particle's position if it is currently in a better location than it was previously.
4. Determine the best particle (based on the particle's most recent best locations).
5. Adjust the speeds of the particles (Velocities for Particle Swarm Optimization).
6. Transfer particle to its new locations.

As soon as the halting requirements are met, move on to step 2[13].

III. CONTROLLER ALGORITHMS

A. PI Controller

In The basic diagram of speed control of a BLDCM drive using a PSO based PI controller (Figure 1) is made up of three phase inverter, current regulator, speed controller, BLDC and Hall sensors. The speed of the BLDCM is measured using a Hall sensor[15].

TABLE 1 INITIALIZE PARAMETERS OF PI AND PSO TUNED PI CONTROLLER

Initialize parameters	Values
Population size (n)	100
Dimension (dim)	4
Lower Bound (lb)	0.01
Upper Bound (ub)	400
Acceleration co-efficient (C2)	1.2
Social co-efficient (C1)	0.12
Inertia weight (w)	0.9

It is calculated from the output of the Hall sensor, which senses the information of the rotor position of the BLDCM. The error between the reference speed and actual speed of the BLDCM is given to the speed controller, which generates the command or reference current.

The initial Kp and Ki values are arbitrarily selected as the initial population. The Kp and Ki values are optimized by using the following objective function[14].

The objective function in the current research work is the minimisation of the Integral Time Absolute Error (ITAE) which represents the difference between the reference speed and the actual speed of the BLDCM.

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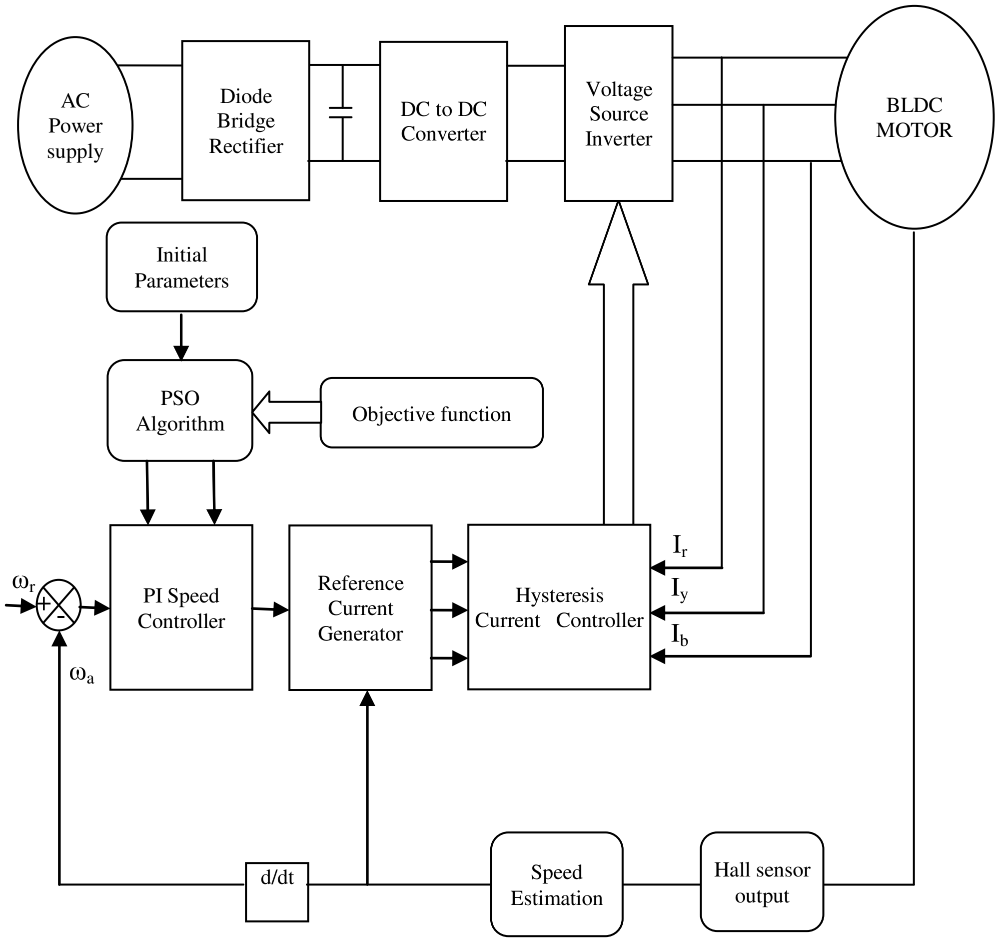

FIG 1Proposed block diagram of 3-phase BLDCM control

The ITAE is minimised to obtain the gain settings of the PI controller by using the following expression:

$$ITAE = \int_0^t t|e(t)|\ dt \qquad (1)$$

Where t is the time period taken by the system to reach the stable state and e(t) is the error between the reference speed and the actual speed.

The optimized Kp and Ki values are then applied to the reference current regulator, which provides the firing currents to the inverter whose output is generated based on the difference between the actual phase currents and reference currents. Based on this, the desired speed control is achieved by the BLDCM. The optimized Kp = 2.554 and Ki = 250.89 values for speed controller is evaluated from the proposed PSO algorithms. The flowchart of PSO algorithm shown in Figure 2.

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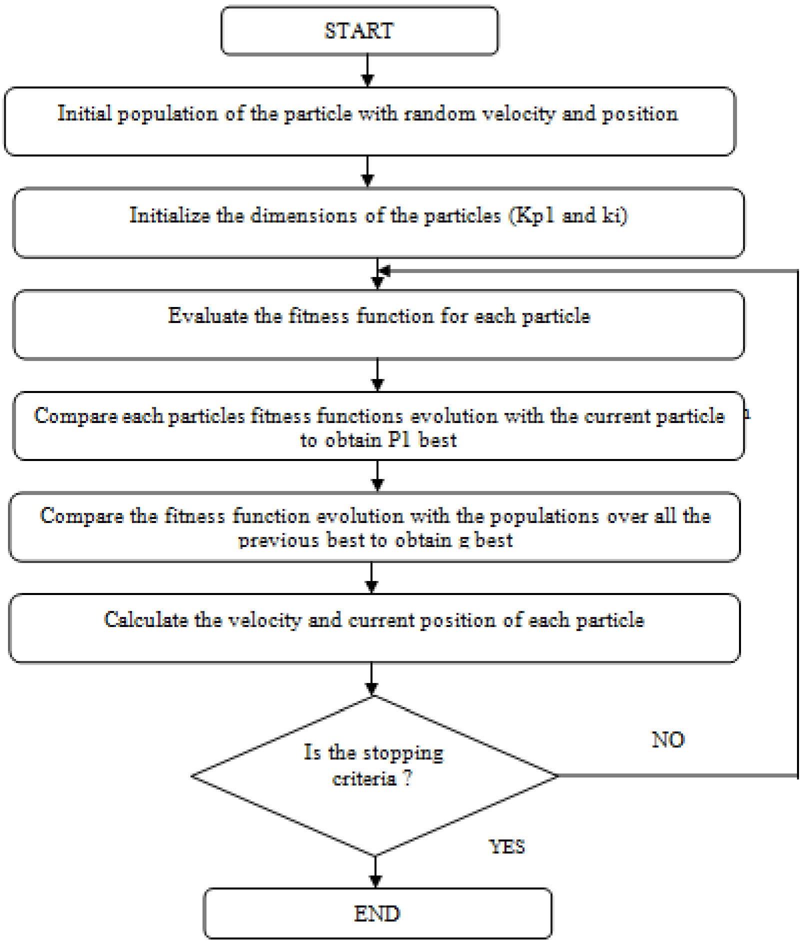

The PSO tuned PI controller based BLDCM is simulated using the following MATLAB/simulink model (Figure 3). The sub block of the simulink model executes the PSO-PI controller function.

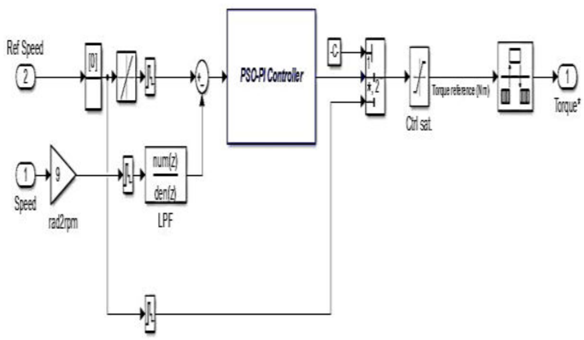

Fig. 2. Simulink model for PSO-PI controller

Analysis of performance characteristics of PSO tuned PI controller based BLDCM

The steady state performance of the PSO tuned PI controller based BLDCM is obtained by simulating the motor under no load condition. The steady state characteristics of peak overshoot and settling time are obtained. The performance characteristics of the BLDCM at no load obtained (Table II) based on the PI tuned by the PSO algorithm is shown in Figure 3. From the characteristics, it is observed that the peak overshoot is 1053 RPM (5.3 %) and the settling time is 0.35 seconds for 1000 RPM.

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The study of the steady state performance of PSO tuned PI controller based BLDCM as shown in the above Table II.

TABLE 2 STEADY STATE RESPONSE OF PSO TUNED PI CONTROLLER BASED BLDCM

S.No	Controller	Peak overshoot (%)	Settling time (sec)
1	PSO tuned PI controller BLDCM	5.3	0.35

To study the transient response of the PSO tuned PI controller based BLDCM, the load is varied in steps of 20% and the level of a speed drop from the rated speed due to the application of load and the restoration time for different loads from 20% to 80% are obtained and plotted in the graph. From the Table II, it is identified that the load level significantly influences the level of speed drop and also increases the restoration time as it is displayed in the following Figure 4.

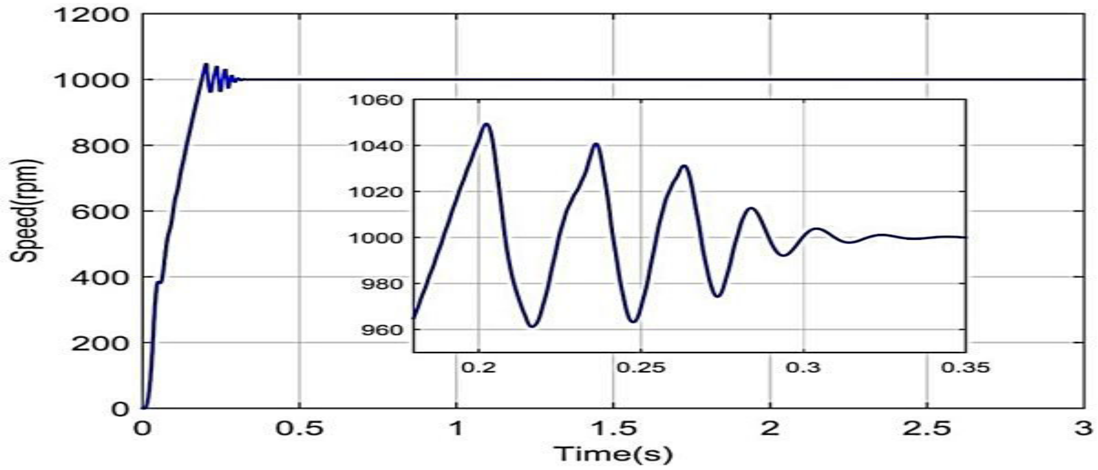

Fig.3. Steady state performance characteristics of PSO tuned PI controller based BLDCM

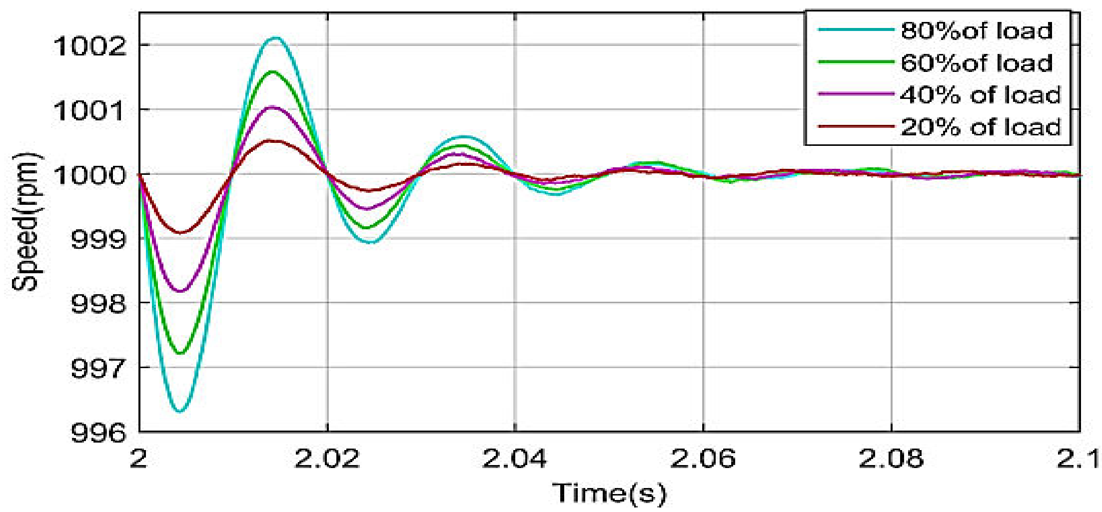

Fig. 4. Transient response of PSO tuned PI controller

The transient performance of the PSO tuned PI controller for different load condition is presented in the Table III. From the Table III, it is demonstrated that as the load on the BLDCM increases, the speed drop also increases and also the restoration time also increases.

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TABLE 3TRANSIENT RESPONSE OF PSO TUNED PI CONTROLLER FOR DIFFERENT LOAD CONDITIONS

S.No	Load (%)	Speed drop (RPM)	Speed drop (%)	Restoration time (sec)
1	80	996.3	0.37	0.09
2	60	997.2	0.28	0.07
3	40	998.2	0.18	0.06
4	20	999.1	0.09	0.05

To study the impact of PSO algorithm in enhancing the transient performance of the PI tuned BLDCM is presented in the above Table III showing the transient performance of the PSO tuned PI controller.

From the Figure 5, it is evident that the application of PSO based PI tuned controller significantly enhances the ability of the BLDCM, in maintaining the speed of the motor almost nearer to the rated base speed of 1000 RPM irrespective of changes in the load.

BLDCM has the ability to deliver almost a stable performance irrespective of change in load. And also the restoration time is also significantly enhanced in the case of a PSO based PI tuned controller. Integral Time Absolute Error (ITAE) analysis for PSO-PI controller

Till now in the above section of the chapter enumerately discusses about various performance analysis for different dynamics of the BLDCM like peak overshoot, settling time, speed drop and restoration time for both loaded and unloaded conditions. Even though clarity has been achieved on analyzing results of the above dynamics, it is felt necessary a thorough analysis is required to understand the integral error component in the performances of the PSO tuned PI controller.

It is necessary for the reason the main objective function is to completely understand the performance of the different controller. To meet out the objective function of the understanding the error component present in PSO tuned PI controller a procedural methodology available in MATLAB,ITAE tool is explored and fixed over the PSO-PI controller in analysing its error component. To analysis the error component of PSO-PI controller, the motor is made to run at 1000 rpm for 3 seconds, At the instant of 2 seconds from its start 80% of load value is applied over the BLDCM drive and using ITAE tool available in MATLAB. The error component is recorded as 2.724. This 2.724 is error index, which indicates that deviating from the zero with magnitude of 2.724. The error index value 2.724 has to be understood it has no unit it is integral component of absolute error of the PSO-PI tuned PI controller.

IV. CONCULSION

From the above study, it is proved that the application of heuristic PSO algorithm significantly improves the steady state and transient performances of the BLDCM.The peak overshoot is 5.3% and settling time is 0.35s under steady state performance of the BLDCM using PSO tuned PI controller.At 80% of load value the speed drop is only 0.37% and restoration time is 0.09s which significant breakthrough found using PSO tuned PI controller.

The Integral Time Absolute error of 2.754 for PSO tuned PI controller.
The PSO tuned PI is proposed for use in designing an optimum PI controller for the BLDC motor speed regulation in this study. A PI controller was used for controlling the BLDC speed. BLDCM speed is controlled using a fuzzy logic which surpasses the PSO method in this research. Yet, PSO has some drawbacks, such as being easy to slip into a local optimum in a high-dimensional environment and having a slow rate of convergence. Several types of research were undertaken in the previous few decades for improving PSO. The data suggest that the machine settles down in a shorter time than the PSO-based method. In the PSO approach, the significant improvements in time domain performance justify its adoption. The suggested approach could give the field of BLDC motor drive system controller design a new dimension.

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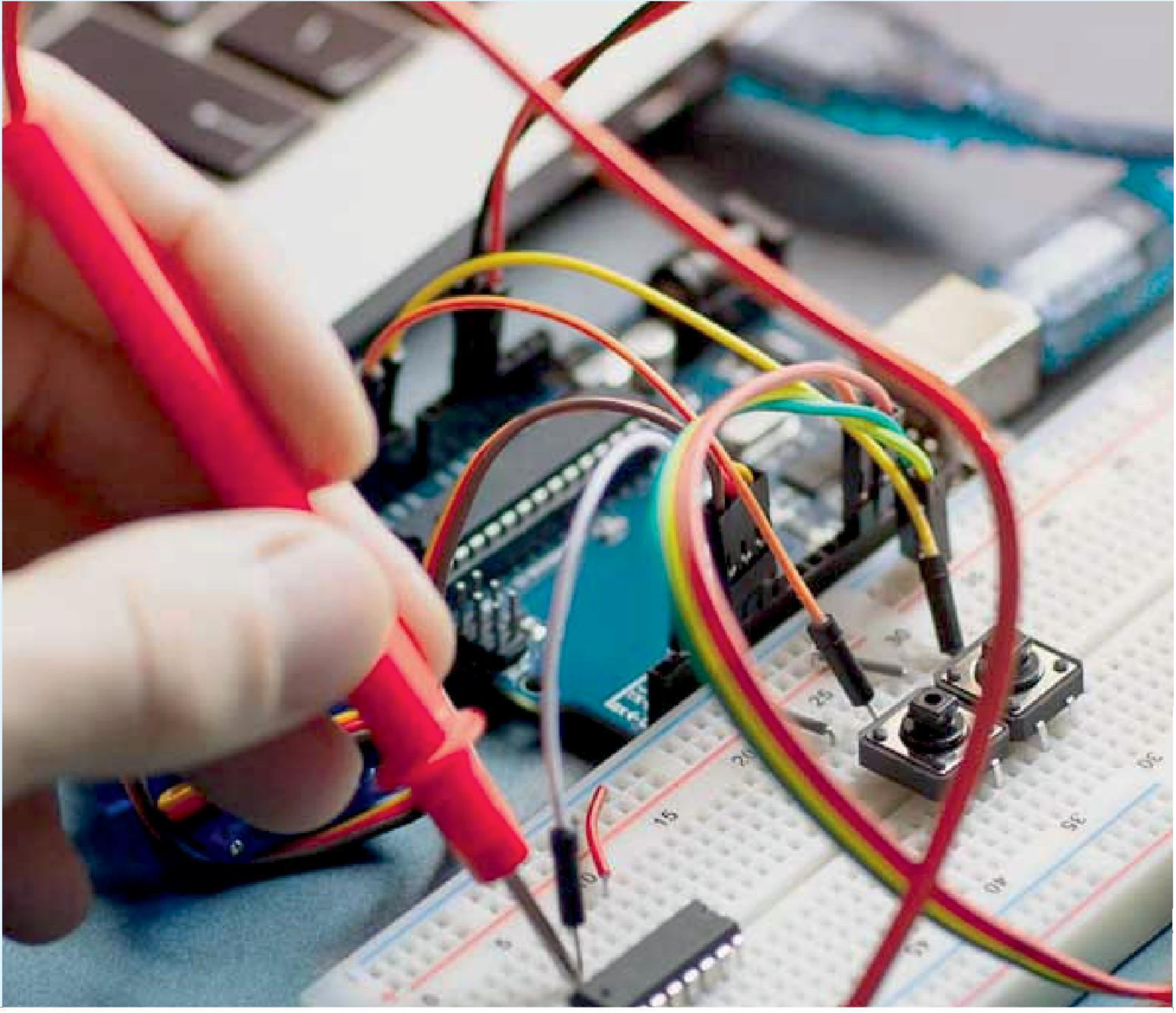
REFERENCES

1.Emadi, Handbook of Automotive Power Electronics and Motor Drives. Boca Raton, FL: CRC Press, 2005.
2.C. -L. Huang, F. -C. Lee, C. -J. Liu, J. -Y. Chen, Y. -J. Lin and S. -C. Yang, " Torque Ripple Reduction for BLDC Permanent Magnet Motor Drive Using DC-Link Voltage and Current Modulation," in IEEE Access, vol. 10, pp. 51272-51284, 2022.
3.X. Wang et al., " Stray Flux-Based Rotation Angle Measurement for Bearing Fault Diagnosis in Variable-Speed BLDC Motors," in IEEE Transactions on Energy Conversion, vol. 36, no. 4, pp. 3156-3166, Dec.2011.
4.ImadElomary, Abbou Ahmed and Idoumgha rLhassane, "Optimization Design of the BLDC Motor Using Backtracking Search Algorithm," International Review of Electrical Engineering (IREE), vol 16, No 2 ,2021
5.C. Alexander, and H. A. Toliyat, "Direct torque control of four-switch brushless DC motor with non-sinusoidal back EMF," IEEE Transactions Power Electronics, vol. 2, pp. 263–271, Feb. 2010.
6.M. Ebadpour, N. Amiri and J. Jatskevich, " Fast Fault-Tolerant Control for Improved Dynamic Performance of Hall-Sensor-Controlled Brushless DC Motor Drives", IEEE Transactions on Power Electronics, vol. 36, no. 12, pp. 14051-14061, 2021.
7.M. Perotti and F. Fiori, "A Closed Loop Delay Compensation Technique to Mitigate the Common Mode Conducted Emissions of Bipolar PWM Switched Circuits", IEEE Transactions on Power Electronics, vol. 36, no. 5, pp. 5450-5459, 2021.
8.M. Karthik et al., "Evaluation of electromagnetic intrusion in brushless DC motor drive for electric vehicle applications with manifestation of mitigating the electromagnetic interference, " International Journal of Ambient Energy, pp. 1-8, 2020.
9.Wei Xie, Jie-Sheng Wang, Hai-Bo Wang, "PI Controller of Speed Regulation of Brushless DC Motor Based on Particle Swarm Optimization Algorithm with Improved Inertia Weights", Mathematical Problems in Engineering, pp 1-12. 2019.
10.E, Monmasson, M, N, Cirstea, "FPGA design methodology for industrial control systems -a review," IEEE Transactions on Industrial Electronics, vol. 54, no. 4, August 2007.
11.S. Raja, Dr. M.Rathinakumar and A. S. Viswanathan, "Performance Analysis of Digital Controller for BLDC Motor Drive System," International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, Issue 6, June 2017.
12.T Wang, H. Wang, C Wang and H Hu., "A novel PID controller for BLDCM speed control using dual fuzzy logic systems with HSA optimization", International Journal of Scientific Reports, Vol. 4, pp.1-12,2022.
13.Jun Shi, QingtaoMi, Weifeng Cao, and Lintao Zhou,"Optimizing BLDC motor drive performance using particle swarm algorithm-tuned fuzzy logic controller", SN Applied Sciences, Vol. 4, pp. 293-302, 2022.
14.U. Das, and P. Biswas, "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, Vol.19, pp.379-402,2021.
15.S. Raja, M. Rathinakumar, Transient analysis of the fuzzy logic based speed control of three-phase BLDC motor, Engineering, Technology & Applied Science Research, vol. 13, no. 1, February 2023, pp. 9855-9860.



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