International Journal of Computational and Experimental Science and ENgineering (IJCESEN)

Vol. 9-No.1 (2023) pp. 17-19
http://dergipark.org.tr/en/pub/ijcesen

ISSN: 2149-9144

Research Article

Disturbance Rejection Performance Comparison of PSO and ZN Methods for Various Disturbance Frequencies

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Article Info:

DOI: 10.22399/ijcesen.1202255
Received : 10 November 2022
Accepted : 17 January 2023

Keywords

PID control
Ziegler-Nichols
Particle Swarm Optimization

Abstract:

In this study Proportional-Integral-Derivative (PID) control of brushed DC Motor is analysed. The parameters of the PID controller are tuned with two different approaches, namely Ziegler-Nichols (ZN) and Particle Swarm Optimization (PSO). The system is tested under sinusoidal disturbance of varying frequencies in order to evaluate and compare disturbance rejection performances. It is shown that PSO approach has clearly higher performance compared with ZN approach for all disturbance frequencies. Simulations are done using Python programming language with trapezoid rule for differentiation and integration. Comments are done on results and future study is planned.

1. Introduction

DC motor is one of the most widely used electrical machines in industry. Speed control of DC motor has several applications including robotics, CNC and automation and electrical vehicles. Controlling speed of DC motor with no load is relatively simple problem which is studied quite exclusively. In real applications, DC motor is run with varying amount and types of loads. The logic lying behind PSO is to search the parameter space by considering the most successful points found. K. Khandani, A. A. Jalali and M. Alipoor designed PID controllers for time delay systems. PSO technique has been used to obtain optimal parameters of 2-DOF PID controller and compared with Genetic Algorithm (GA). Results has been shown that PSO has more performance than GA [1]. Krohling and Rey designed a PID controller for optimal disturbance rejection. The method which is used for study has handled the methodology as a constraint optimization problem. Servo motor has used for simulation and GA approach has used for optimize parameters [2]. Ibrahim, Hassan and Shomer compared Bacterial Foraging (BF) technique and PSO for determining the optimal parameters of PID controller in speed control of brushless dc motor. The proposed technique is shown that PSO method has more performance than BF especially in dynamic performance of the system [3]. Song, Xiao and Xu designed a random vibration PSO- Gravitational Searh Algorithm (GSA) based Fuzzy PI controller for brushless dc motor control. Results has given in study both simulation and experimental [4]. In this study, sinusoidal disturbance is used as a load to brushed dc motor for speed control. PSO and ZN methods are compared for various frequencies of disturbance and it is seen that PSO clearly has more performance than that of ZN especially in higher frequencies.

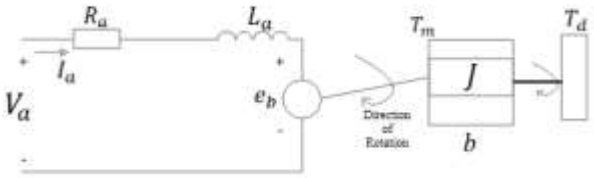

Figure 1: *Dc Motor Electrical and Mechanical Model*

Illustrative diagram of DC motor is shown in Figure 1. According to Kirchhoff, the sum of the voltages dissipated in a closed circuit is equal to the sum of the source voltages.

$$V_a = R_a i_a + L_a \frac{di}{dt} + e_b \quad (1)$$

In a conductor moving in a magnetic field, a reverse induced voltage of magnitude inversely proportional to the speed of movement occurs.

$$e_b = K_b w \qquad (2)$$

A force proportional to the magnitude of the current is applied to a current-carrying conductor while in a magnetic field.

$$T_m = K_m i_a \qquad (3)$$

Newton's Second Law of Motion is used to derive the mathematical model of the mechanical part.

$$T_m - T_d = J\frac{dw}{dt} + bw \quad (4)$$

Equation 5 is obtained when the transfer function of equation 4 is found.

$$\frac{w(s)}{T_m(s) - T_d(s)} = \frac{K_m}{1 + K_m J s} \quad (5)$$

Equation 6 is obtained when the transfer function of Equation 1 is found.

$$\frac{i_a(s)}{V_a(s) - e_b(s)} = \frac{1}{R_a + L_a s} \qquad (6)$$

The block diagram obtained for the DC Motor using Equations 5 and 6 is shown in Figure 2.

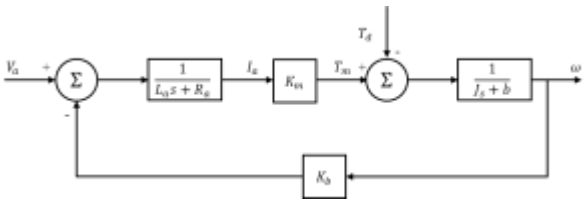

Figure 2: *DC Motor Block Diagram*

2. Material and Methods

PSO is a successful optimization technique, which is shown in literature [5], used especially for problems those are very hard or impossible to be solved analytically [6,7].

In this study position of each particle is a three-dimensional vector including Kp, Ki and Kd of the PID controller. For simulation Python programming language is used with Spyder IDE. Discrete time derivatives are calculated using trapezoid rule. DC motor parameters are taken realistically. Sinusoidal disturbance of various frequencies is given and sinusoidal reference input is used.

3. Results and Discussions

The motor has been tested under different loads and frequencies for performance evaluation. Results for various disturbance frequencies are shown in Figure 3, Figure 4, Figure 5 and Figure 6.

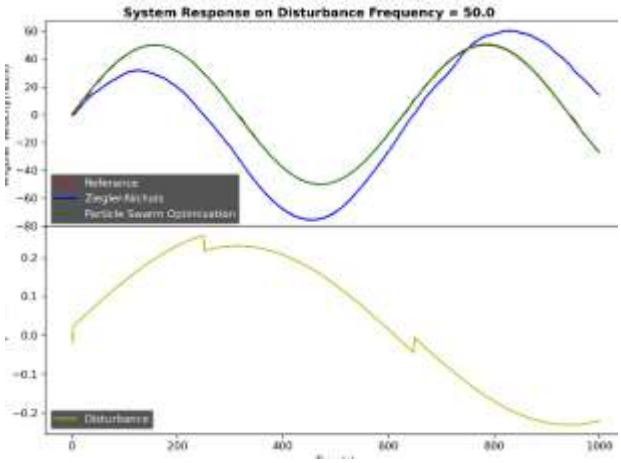

Figure 3: *System Response Under Disturbance Frequency = 50*

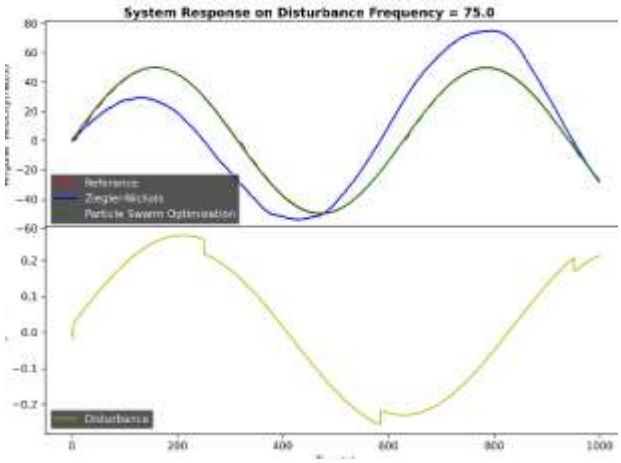

Figure 4: *System Response Under Disturbance Frequency = 75*

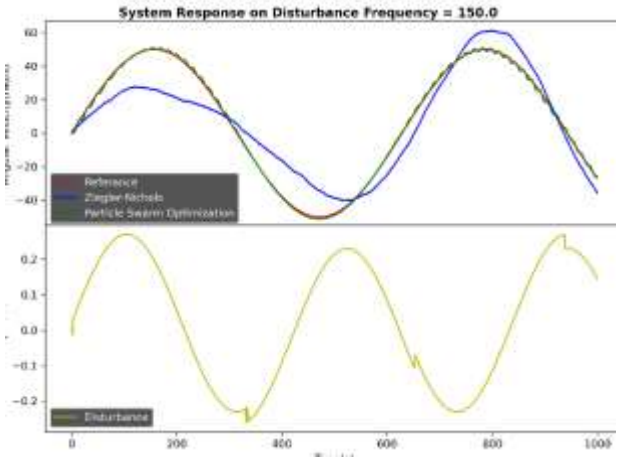

Figure 5: *System Response Under Disturbance Frequency = 150*

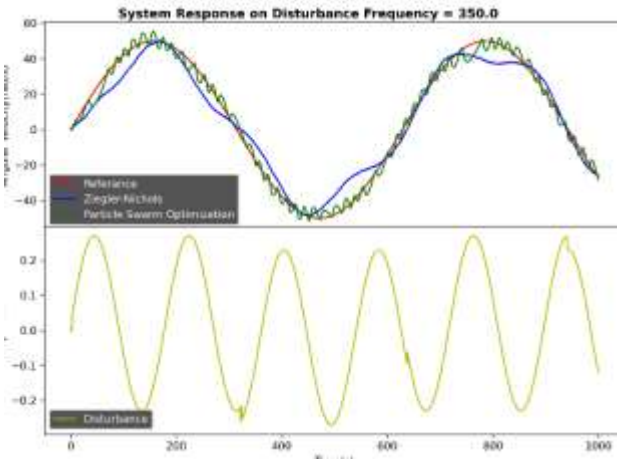

Figure 6: *System Response Under Disturbance Frequency = 350*

4. Conclusions

It is clearly seen that PSO has better disturbance rejection performance especially in higher disturbance frequencies. One of the reasons for the high success of the PSO algorithm in sinusoidal reference can be explained as the ease in which the reference value changes more slowly and the motor follows the reference. As a result, in all amplitudes and frequencies, the PSO algorithm outperformed the ZN method

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
- **Acknowledgement:** The authors declare that they have nobody or no-company to acknowledge.
- **Author contributions:** The authors declare that they have equal right on this paper.
- **Funding information:** The authors declare that there is no funding to be acknowledged.
- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

[1] K. Khandani, A. A. Jalali and M. Alipoor, (2009). Particle Swarm Optimization based design of disturbance rejection PID controllers for time delay systems. *IEEE International Conference on Intelligent Computing and Intelligent Systems*, pp. 862-866, doi: 10.1109/ICICISYS.2009.5358043.

[2] R. A. Krohling and J. P. Rey, (2001). Design of optimal disturbance rejection PID controllers using genetic algorithms. *IEEE Transactions on Evolutionary Computation*, 5(1);78-82. doi: 10.1109/4235.910467.

[3] H.E.A.Ibrahima, F.N.Hassan, Anas O.Shomer. (2014) Optimal PID control of a brushless DC motor using PSO and BF techniques. *Ain Shams Engineering Journal*, 2(5);391-398.

[4] Baoye Song, Yihui Xiao and Lin Xu (2020). Design of fuzzy PI controller for brushless DC motor based on PSO–GSA algorithm, *Systems Science & Control Engineering*, 8(1);67-77. DOI: 10.1080/21642583.2020.1723144.

[5] Yazgan H, Yener F, Soysal S, Gür A, (2019). Comparison Performances of PSO and GA to Tuning PID Controller for the DC Motor, *Sakarya University Journal of Science*, 23(2); 162-174.

[6] Ziegler J G, Nichols N B, 1942, Optimum Settings for Automatic Controllers, *Transactions of the American Society of Mechanical Engineers*, 64(11);759-765.

[7] Akyol S, Alataş B, (2012). Current Swarm Intelligence Optimization Algorithms. *Nevşehir University Journal of Graduate School of Natural and Applied Sciences*, 1(1);36-50.