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Social Ski-Driver Algorithm Based Optimal Design of a PID Controller for a Linear BLDC Motor

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Abstract— *This paper provides an approach with a Social Ski Driver Algorithm (SSD) to evaluate the best PID gains for a linear brushless DC speed control system (BLDC). The approach suggested has superior characteristics, such as fast distribution, simple convergence and high device performance. The brushless DC motor is modeled on open-loop and shut-off transmission functions and the SSD is in MATLAB. The approach presented was successfully optimized in both transient and stable situations as opposed to the initial model.*

Keywords— linear brushless Dc motor, speed control, PID controller, optimization, social ski-driver algorithm.

1. Introduction

The brushless DC motor is widely used for industrial applications, and provides many advantages over other traditional engines such as higher power, higher dynamic torque, higher efficiency, high speed, noise and a high speed/weight ratio [1]. Two main motor types are used by the industry. (i) DC current flow motors made from the stationary polar structural field spiral, (ii) DC air gap (PMBLDCM) permanent brushless magnet motors, required for EMFs [2] instead of wire wound field poles, with the Permanent Magnet. Brushless DC motors have no brushstroke similar to traditional DC motors. Unlike standard DC motors, the conversion takes place electronically.

BLDCM is a trapezoidal synchronous permanent magnet (PMSM). The most widely used controls for the speed of the BLDC engine are standard PI and PID controllers. The plant has numerous uncertainties under realistic supervision. Changes of payload, pressure and other external interruptions may be due to this. The PI controller is the perfect linear control, but it is easier because the mechanism is not a linear and difficult choice to run with an intelligent controller. As the robust characteristics of BLDCM make for more control possibilities, it has an SSD-based PID controller. The BLDCM is turned without brushes electronically. The stator magnet typically consists of a magnet of steel. In slots or wounds the stator windings are fixed to the poles. In order to generate torque ripples, the trapezoid form of the BLDCM emf requires rectangular tension. Inverted DC motors, whose rotation the magnet and remain [3] are almost similar to BLD CM. The briquettes are introduced to counter the current polarity on the DC generator, but with a semiconductor switch the BLDCM reversal is achieved. The BLDCM modeling is similar to a synchronous three-stage computer, since it has the same features of its permanent magnet. The flow of the rotor relies on the used magnetic material. The brushless DC motor of this article suggests a new SSD solution for an optimal design of the PID controller.

2. Linear Brushless DC Motor:

Permanent magnet DC motors use mechanical commutators and brushes to accomplish commutation. However, BLDC engines adopt Hall Effect sensors instead of mechanical commutators and brushes [4]. The BLDC motor stators are coils, and the rotors are permanent magnets. The stators produce magnetic fields to spin the rotor. This article analyzes a three-phase and two-pole BLDC motor. A three-phase and one-half-bridge pulse width (PWM) inverter controls the speed of the BLDC motor. Fig. 1 displays the block diagram of the open loop model for the BLDC generator.

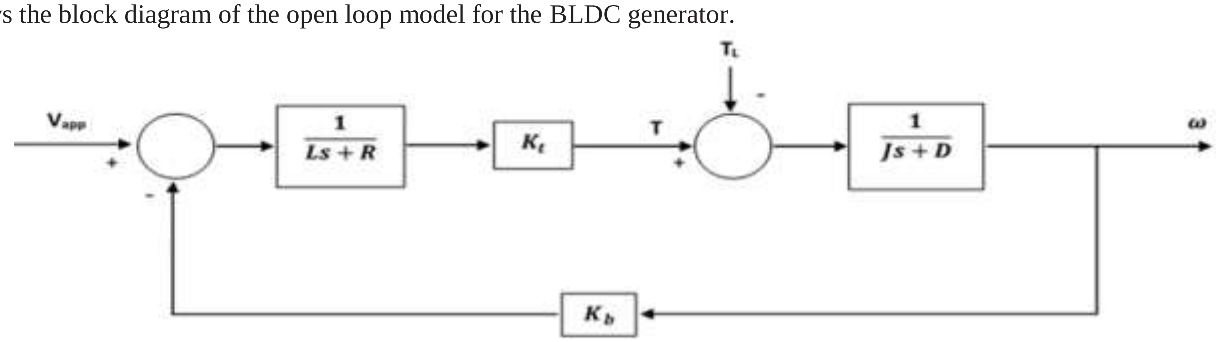

Fig. 1. BLDC model

The open loop transfer function for the speed model is:

$$G_p(s) = \frac{\omega(s)}{V_{app}(s)} = \frac{K_t}{L.J\,s^2 + (L.D + R.J)s + K_t K_b} \#(1)$$

Where:

ω = Motor speed
V_{app} = Applied voltage
K_t = Motor torque constant
L = Inductance of the stator
J = Moment of inertia
D = Viscous coefficient
K_b = Back electromotive force constant
R = Resistance of the stator
The parameter values used in this paper are given in table (1) [9].

Table 1: Parameter values and units

Parameter	**Value with unit**
K_t	0.1433 Kg-m/A
K_b	0.1433 V-s/rad
L	0.052 H
J	$1*10^{-5}$ Kg-m s^2/rad
D	$1*10^{-4}$ Kg-m s/rad
R	21.2 Ω

3. Social Ski-Driver Algorithm:

The SSD algorithm has recently been proposed in [5] as a new optimization algorithm. It displays the track of downhill skiers. The SSD components are defined briefly as follows:

- *Agents' locations* ($\boldsymbol{X}_i \in \mathcal{R}^n$): These locations are used to calculate the cost function.
- *Previous optimal place* $\boldsymbol{P}_i$: The fitness value for all agents is defined via the fitness function. The fitness value of each agent is then compared to its actual location and the best position is taken care of. PSO is the same [6] algorithm.
- *Mean global solution* $\boldsymbol{M}_i$: As with the Grey Wolf Optimizer (GWO) [7], agents change to the global stage in the algorithm, suggesting the strongest three best solutions:

$$\mathbf{M}_i^t = \frac{X_\alpha + X_\beta + X_\gamma}{3} \#(2)$$

where X_α, X_β, and X_γ are the best three solutions obtained.

- *The agents' velocity* ($\mathbf{V}_i$): The agents' locations are updated by the following velocity $\mathbf{V}_i$ as:

$$\mathbf{X}_i^{t+1} = \mathbf{X}_i^t + \mathbf{V}_i^t \#(3)$$

Where

$$\mathbf{V}_i^{t+1} = \begin{cases} c\sin(r_1)(\mathbf{P}_i^t - \mathbf{X}_i^t) + \sin(r_1)(\mathbf{M}_i^t - \mathbf{X}_i^t) \\ \quad if\ r_2 \le 0.5 \\ c\ \cos(r_2)(\mathbf{P}_i^t - \mathbf{X}_i^t) + \cos(r_2)(\mathbf{M}_i^t - \mathbf{X}_i^t) \\ \quad if\ r_2 > 0.5 \end{cases} \#(4)$$

Where V_i is the velocity of X_i, r_1 and r_2 are randomly generated numbers with a range of [0,1], $\mathbf{P}_i$ is the best solution, M_i is the mean global solution, and c is a parameter used to combine production and discovery and is calculated by $c^{t+1} = \alpha c^t$, where t is the current iteration, and $0 < \alpha < 1$ is used to reduce the c [5].

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4. Implementation of SSD based PID controller Design:

4.1 Fitness Function

In this paper, a time domain criterion [8] is used to test the PID controller. The P, I and D control parameters are a range of good measures, which reduce time domain performance. Therefore, the performance criterion is defined as follows [8]:

$$\text{Min of } W(K) = \left(1 - e^{-\beta}\right)\left(M_p + E_{ss}\right) + e^{-\beta}(t_s - t_r) \#(5)$$

Where K= $[K_p, K_i, K_d]$, β is a factor for a weighting within a range of [0.5,1.5], which here is set as 1.0.
The fitness function is reciprocal of the performance criterion, in the other words:

$$F = \frac{1}{W(K)} \#(6)$$

4.2 Proposed SSD-PID Controller

In this work the SSD algorithm is used to design a PID controller for BLDC as shown by the following block diagram.

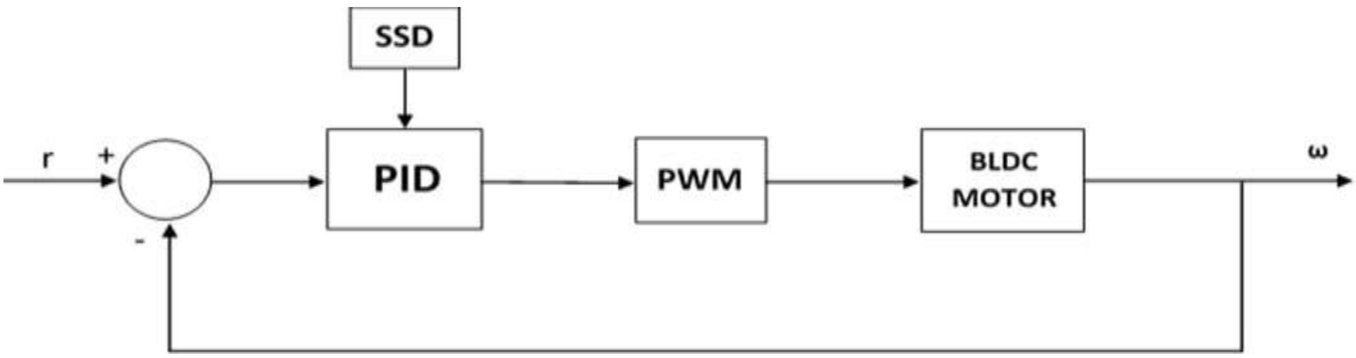

Fig. 2. SSD based PID controller design block diagram

5. Simulation Results and Discussion

5.1 Results

The closed loop transfer function for a speed control of linear BLDC with a unity feedback system is given after substitute different parameter values from table 1 by:

$$G(s) = \frac{0.1433}{0.053 \times 10^{-5}\, s^2 + 0.0002172\, s + 0.1638} \#(7)$$

This original system has a step response as shown in Fig 3.

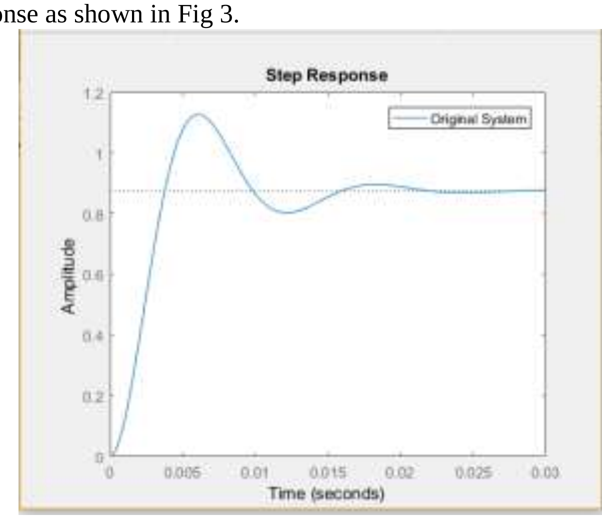

Fig. 3. Unit step response for the original system

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Time domain characteristics for this response are shown in table 2.

Table 2: Time domain specifications for original system

	M_p *(%)*	*Steady state*	t_r *(sec)*	t_s *(sec)*
Original system	28.8	0.875	0.00255	6.99

A PID controller is designed using social ski-driver algorithm (SSD) and the gains are determined as shown in table 3.

Table 3: SSD-PID gains

	K_p	K_i	K_d
SSD-PID controller	167.7102	49.0617	0.8236

The unit step response for speed control of linear BLDC motor after optimized by the SSD-PID controller is shown in Fig. 4.

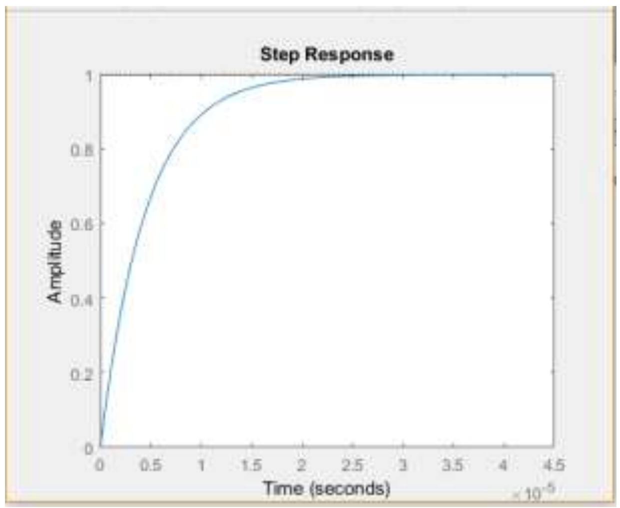

Fig. 4. Unit step response for the optimized system

Transient and steady state characteristics are shown in table 4.

Table 4: Transient and steady state characteristics

	M_p *(%)*	*Steady state*	t_r *(sec)*	t_s *(sec)*
Optimized system	0	1	$9.89*10^{-6}$	$1.78*10^{-5}$

5.2 Discussion

The SSD is used to design the PID controller which gives gains shown in table 3 above. From table 2 and table 4 we can observe that the designed controller has a powerful effect in optimize speed control for the linear BLDC motor where overshoot is improved by 100% from 28.8% to 0%, rise time is improved by 99.612%, settling time improved by 99.91%, and steady state is improved by 14.29%.

As shown by above percentages, it is clear that the designed controller proves its effectiveness in enhance the performance of such systems.

6. Conclusion

This paper introduces a new architectural strategy to use the SSD approach to evaluate PID control parameters. The results from the BLDC simulation show that the proposed controller will find the optimal PID controller successfully. It reveals that this approach increases the system's dynamic efficiency, unlike the original system.

7. References

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