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# PID Controller Tuning for Speed Control of DC motor using Optimization Techniques

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***Abstract***— *This paper proposes a strong natural algorithm to optimize the strength of a PID controller used with a DC motor control speed. The PID is designed for a modern DC system and the evolutionary algorithm is used to optimize the controller based on a Krill Herd Optimization (KHA) algorithm. The best PID parameters of Optimization in a MATLAB / Simulink setting are used to achieve desired transient and steady state characteristics. The obtained characteristics by this optimization algorithm are compared with original system outcomes and the suggested optimization - an algorithm based on the DC motor speed control has been demonstrated to optimize its effectiveness.*

**Keywords—** DC motor, speed control, PID controller, optimization techniques, Krill Herd Optimization, step response.

## 1. INTRODUCTION

In applications requiring adjustable speed, DC motor drives are commonly used. Applications include rolling presses, paper machines, traction systems, presses, garment mills, and many others. Fractional DC motors are commonly used for positioning and tracking servo motors. While AC drives are expected to overtake DC drive drives, today, DC drives dominate variable speed applications, due to lower cost, reliability and easy control. There are several methods for regulating the speed and the location of the engine based on the DC engine power. The aim of the motor speed control is to signal the speed needed and to drive a motor at this speed. One of the earlier control strategies is PID (proportional integrated derivative). There are many algorithms and approaches used to control speed of the DC motor, among them the PID control has proven to be satisfactory and already has a wide variety of industrial control applications [1].

PID regulation is a long-standing effective control technique. Any of the factors that make the PID controller very important in academia and industry include versatility, robustness, a wide variety of applicability and near-optimum performance. Recently, PID controllers were frequently badly tuned and attempts were made to address this problem systemically. Since several process plant operated with PID controllers have similar dynamics, it has been shown that the controller parameters of the plants with less than a full mathematical model are satisfactory. PID monitoring is now an active subject for many years. The technology emerged because the control parameters were to be modified with limited effort and because mothering the mathematical models could be complicated and cost-effective [1].

In 2012, the krill herd algorithm (KH) is suggested on the basis of a simulation of the herding success of krill individuals [20]. The KH algorithm is a modern algorithm inspired by biology to solve problems of optimization process. There are three main factors formulating KH's time-dependent location of the krill individuals: (1) movement caused by other individuals' presence; (2) movement to be foraged; The KH-algorithm is a remarkable benefit compared with other natural-inspired algorithms. For several optimization and engineering problems, it can also be successful [1].

## 2. KRILL HERD ALGORITHM

The KH algorithm implemented a new type of swarm-based approach to optimization problems [2]. The position can be changed in three stages during the KH process which are movement inspired by neighboring krills, foraging activities and distribution.
The above steps can be modeled into Eq. (1).

$$\frac{dX_i}{dt} = N_i + F_i + D_i \#(1)$$

Where the corresponding steps for the *i*th krill individual are: $N_i$, $F_i$ and $D_i$.
First step can be modeled by Eq. (2).

$$N_i^{new} = N^{max} \times \alpha_i + \omega_n \times N_i^{old} \#(2)$$

in which $N^{max}$=induced motion at maximum, $\omega_n$ = induced motion's inertia weight [0,1]; and $N_i^{old}$=induced motion at past.
Second step is affected by two factors which are now and past food locations, which are described by for the ith krill:

$$F_i = V_f \beta_i + \omega_f F_i^{old} \#(3)$$

Where:

$$F_i = \beta_i^{food} + \beta_i^{best} \#(4)$$

and $V_f$ represents foraging speed, $\omega_f$ is the foraging motion's inertia weight in [0, 1],$F_i^{old}$ is the past foraging motion.
The third step is modeled by:

$$D_i = D^{max} \delta \#(5)$$

where $D^{max}$ is the diffusion speed at its maximum, and $\delta$ is the random directional vector and its arrays are random values in [–1, 1].

### 3. DC MOTOR MODEL

The model for a DC motor that is separately excited is shown in Figure 1.

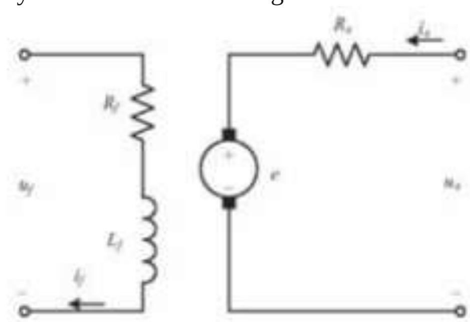

**Fig. 1.** Separately excited DC motor circuit [3]

Speed control for such motor has the following closed loop transfer function [3]:

$$G(s) = \frac{\omega(s)}{u_a(s)} = \frac{K_t.K_b}{L_a.J\, s^2 + (L_a.B + R_a.J)s + K_t.K_b} \#(6)$$

The used values are shown in table (1) for different variables [3].

**Table 1:** Parameter values

| ***Parameter*** | ***Meaning*** | ***Value*** |
|---|---|---|
| $R_a$ | Armature resistance | 1 Ω |
| $L_a$ | Armature inductance | 0.5 H |
| $J$ | Rotor inertia | 0.01 kg.m$^2$ |
| $B$ | Friction coefficient | 0.00003 N.m.sec/rad |
| $K_b$ | Back EMF constant | 0.023 V. s/rad |
| $K_t$ | Torque constant | 0.023 N.m/A |

### 4. PID CONTROLLER

A PID controller is a three-term controller used commonly in industrial control systems for various reasons. The PID controller has a transfer function that is given by:

$$G_{PID}(s) = K_p + \frac{K_i}{s} + K_d s \#(7)$$

This PID controller is used here after careful tuning using KHA to optimize performance of a separately excited DC motor as shown in Figure 2.

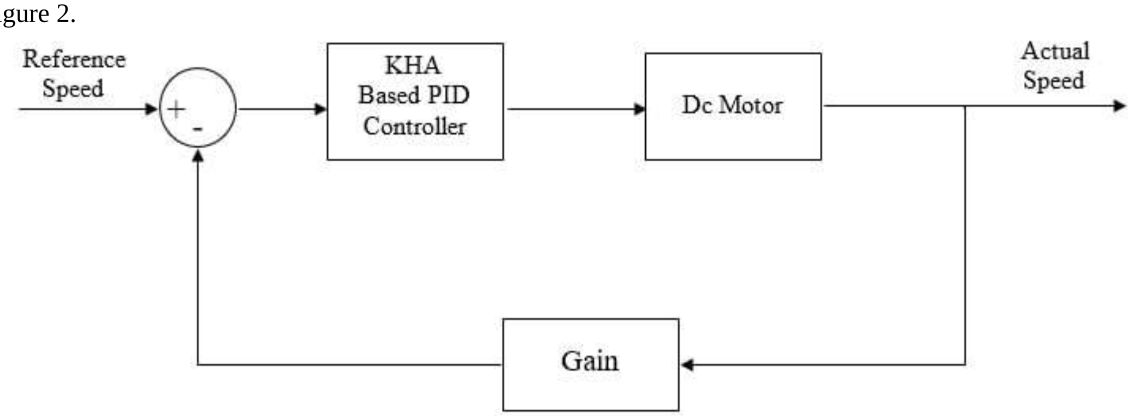

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**Fig. 2.** General block diagram for KHA based PID controller tuning for DC motor

## 5. MATLAB SIMULATION AND RESULTS

The original system without any tuning has the following step response:

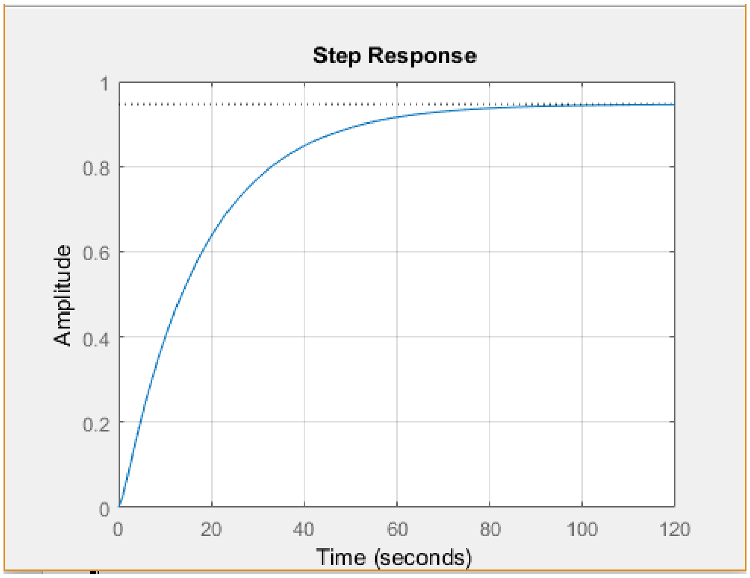


**Fig. 3.** Step response for original system

The PID gains after optimizing by KHA are given by table (2).

**Table 2:** PID optimized gains

| $K_p$ | $K_i$ | $K_d$ |
|---|---|---|
| 99.999929587102130 | 0.000000374792381 | 48.805002458563493 |

The step response for the optimized system is shown in Figure 4.

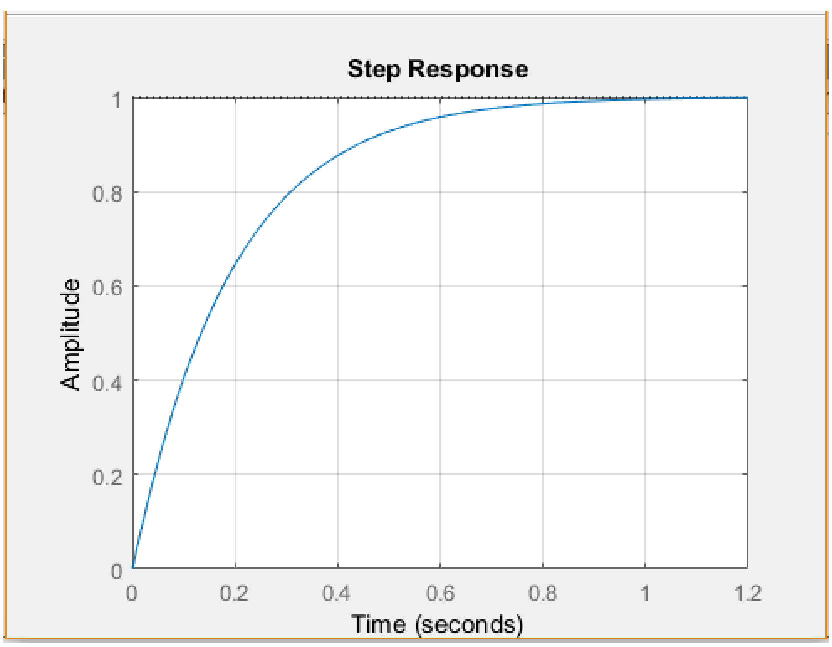

**Fig. 4.** Optimized performance

The performance characteristics for both cases are shown in table (3).

**Table 3**: Step response characteristics

| ***Case*** | $M_p$ ***(%)*** | $t_r$ ***(sec)*** | $t_s$ ***(sec)*** | ***Steady state*** |
|---|---|---|---|---|
| Original system | 0 | 38.2 | 68.6 | 0.946 |
| Optimized system | 0 | 0.418 | 0.727 | 1 |

It is obvious from these results that the KHA algorithm is very effective to optimize PID control tuning for the speed control of a DC motor to ensure optimum efficiency in any function.

## 6. Conclusion

The PID controllers are a standard control solution thanks to their compact design, very fair control efficiency and ease of use. This was achieved using the Krill Herd Optimization Algorithm, which simulated the DC motor speed control system. (KHA). The KHA algorithm for tuning the PID controller has been shown to be more effective than the original system output in terms of system overshoot, settling time, rise time and steady state.

## 7. References

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