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# A Method for Optimal Tuning of Fractional Order PID Controller for DC Motor Speed Control using PSO Algorithm

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**ABSTRACT:** This paper an innovative tuning method for determining fractional order PID ( $PI^{\lambda}D^{\mu}$ ) controller parameters and improved performance of DC motor using particle swarm optimization algorithm (PSO) is presented. The performance of PSO FOPID controller is compared with Genetic Algorithm (GA) optimized FOPID controller. The comparison is made based on time domain performance index Integral of time absoluteerror (ITAE). This paper presents how to employ the particle swarm optimization to seek efficiently the optimal parameters of  $PI^{\lambda}D^{\mu}$  controller. Finally, it has been shown that the response and performance of the closed loopsystem with PSO FOPID controller is much better than GA FOPID controller for the samesystem and with better robustness.

**KEYWORDS:** Fractional Order PID Controller, Genetic Algorithm, MATLAB Simulink, Particle Swarm Optimization (PSO)

## I.INTRODUCTION

In the past decades, modern control theories have made great advances. Control techniques including optimal control, H1/H2 control, fuzzy control, neural network control, predictive control, and so on, have been developed. Nevertheless, the Proportional-Integral-Derivative (PID) control technique has still been widely utilized in many industrial applications such as process control, motor drives, flight control, etc.

Recently, there are increasing interest to enhance the performance of PID controller by using the concept of fractional calculus, where the orders of derivative and integrals are non-integer. Fractional calculus in non-local makes it able to emphasize mathematically the long-memory. Fractional Order PID controller (FOPID or, where and are the integrating and derivative orders and they are non-integers) proposed by Podlubny [9] is a generalization of the PID controller using fractional calculus. A FOPID controller is characterize by five parameters, i.e., the proportional gain, the integrating gain, the derivative gain, the integrating order and the derivative order. Over the last years, FOPID controllers find many applications in irrigation canal control [10], temperature tracking [11], motion control of DC motor [12], [13]. From the above results we have known that FOPID controller has better performance than conventional PID controller.

Tuning of parameters of PID controllers is one of the fields which has been took the interest many researchers. Well known tuning methods like Ziegler-Nicholas do not give optimum performance. Meta-heuristic optimization approachs like Genetic Algorithms and Particle swarm Optimization are very popularly used for tuning PID controller parameters. These techniques are very useful in achieving the global optimum solution. In this paper particle swarm optimization is employed to tune the FOPID controller. In this paper comparative study of GA FOPID and PSO based FOPID is performed.

The organization of the paper is in the following way. Section 2 deals with mathematical modelling of DC motor. The concept of FOPID controller is given in section 3. Rational approximation technique for fractional order derivative and integral is discussed in section 4. Section 5 discusses about the PID and FOPID design by minimizing a chosen time domain integral performance index IATE using PSO technique. In section 6, the simulated waveforms and the comparative tables of the proposed and past techniques are depicted. Paper ends with conclusion in section 7.



**II.DC MOTOR CONTROL**

A DC Motor works on the principal of rotational motion, achieved through attraction and repulsion of magnetic poles of permanent magnet and the electromagnet. Electrical energy is converted into mechanical energy by means of passing the Direct Current through the coil windings, generating electromagnetic poles, which interact with poles of permanent magnet making the motor rotate and hence generating mechanical energy. Current speed is the main factor in attaining the desired outputs, which can be attained either manually by means of voltage variation armature resistance and field flux or by means of automated control devices, wherein controllers are used to regulate the current speed for attaining (Figure 1).



**Fig.1 TF model of DC motor.**

**III.PARTICLE SWARM OPTIMIZATION**

Particle swarm optimization technique was introduced by Kennedy and Eberhart in 1995. It is an evolutionary optimization technique and stochastic method, developed by studying the social movement of swarms such as bird flocking and fish schooling. This method is robust in determination issues that includes non differentiability, nonlinearity, multiple optima and high dimensionality. It has stable convergence characteristics with smart computational efficiency and easily implementable. Unlike alternative evolutionary strategies where the evolutionary operators manipulate the particle, every particle in PSO flies within the search space with speed that is dynamically adjusted in keeping with its own flying experience and flying experience of its companions.

Initially PSO algorithm randomly considers N number of particles. For all the N particles in the swarm, the objective function is obtained.

$$V_{t+1} = W * V_t + C_1 * rand(0, 1) * (pbest - X_t) + C_2 * rand(0, 1) * (gbest - X_t) \dots (1)$$

$$X_{t+1} = X_t + V_{t+1} \dots (2)$$

Where: gbest = Global Best Position.

Pbest = Self Best Position.

C1 and C2 = Acceleration Coefficients.

W = Inertial Weight.

Vt = Velocity.

Xt = Particle.

Once the particle computes the new Xt it then evaluates its new location. If fitness (Xt) is better than fitness (pbest), then pbest = Xt and fitness (pbest) = fitness (X t), in the end of iteration the fitness (gbest) = the better fitness (pbest) and gbest = pbest.

**IV.FRACTIONAL ORDER PID CONTROLLER**

In fractional calculus, the order of derivatives and integrals can be any real value. The FOPID consist of five parameters to tune while PID has only three parameters. Due to more parameters, FOPID increases flexibility and robustness to the system.

The differential equation of FOPID is given by:

$$u(t) = K_p e(t) + K_i D^{-\lambda} e(t) + K_d D^{\mu} e(t) \quad (3)$$

The Laplace transform of equation (3) is given by

$$C(s) = K_p + K_i s^{-\lambda} + K_d s^{\mu} \quad (4)$$

In a graphical manner, the control possibilities using a fractional-order PID controller are shown in fig.2, extending the four control points of the classical PID to the range of control points of the quarter-plane defined by selecting the values of λ=1 and μ=1.

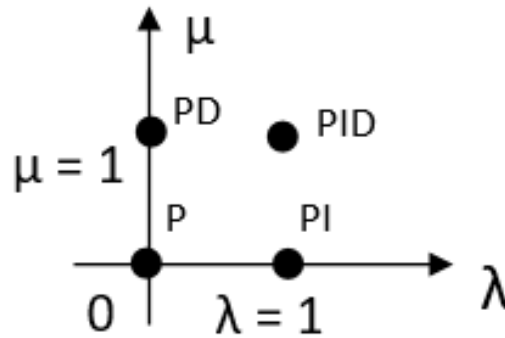


Fig. 2: Point to Plane Expansion.

V.OPTIMIZATION OF FOPID CONTROLLER PARAMETERS

The negative unity feedback control system with MATLAB simulation which is shown in Figure(3), where the fractional order PID (FOPID) controller  $G_c(s)$  implemented by using fractional control toolbox, the integral of time weighted absolute error (ITAE) as objective function (fitness function) and the plant  $G(s)$  were implemented by MATLAB toolbox.

$$G_c(s) = K_p + \frac{K_i}{s^\lambda} + K_d s^\mu \dots \dots \dots (5)$$

$$G(s) = \frac{1}{(s^3 + 3s^2 + 2s)} \dots \dots \dots (6)$$

$$ITAE = \int_0^\infty t|e(t)|dt \dots \dots \dots (7)$$

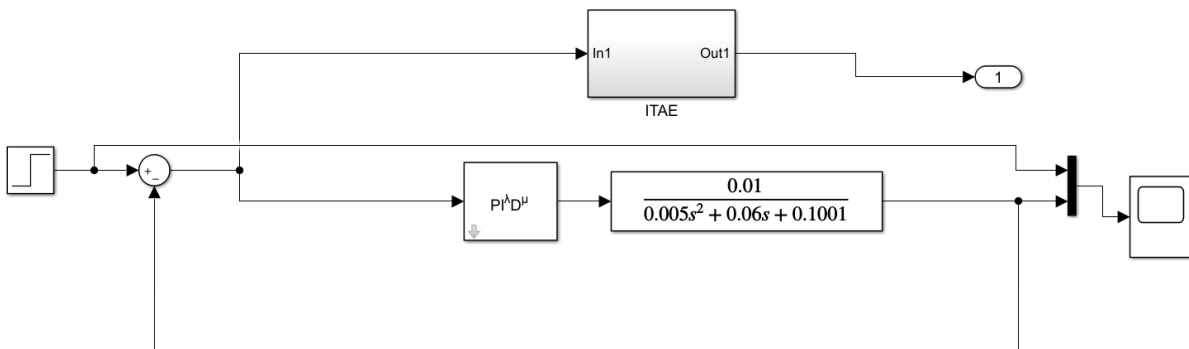


Fig. 3. SIMULINK Model of DC Motor Speed Control

VI.SIMULATION RESULTS

The PSO algorithm method has been implemented as M file which interconnected to Simulink model where the FOPID controller parameters are computed and feed to the GUI of the controller. The optimization performed with this initial parameter, number of particles (50), number of dimensions (5), maximum iteration (50), C1=1.5, C2=1.5, with the objective function (fitness function) (ITAE). The step response curves of the DC motor control are depicted in the Fig.4 from where we can observe that the overshoot of the GA FOPID is larger than PSO FOPID.



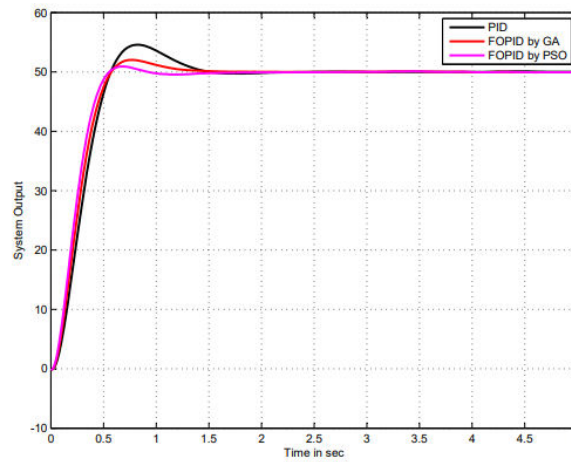


Fig.4. Step response curves of PSO-FOPID and GA-FOPID controllers.

The obtained results shown in the Table 1 which compares the controller parameters which are obtained when optimized by two different algorithms Particle swarm optimization and Genetic Algorithm.

Table 1. System Response controller parameters

Controller type	Kp	Ki	$\lambda$	Kd	$\mu$
PSO-FOPID	100	100	1.0209	10.5506	1.3896
GA-FOPID	76.5432	81.0690	1.0360	5.6356	1.3327

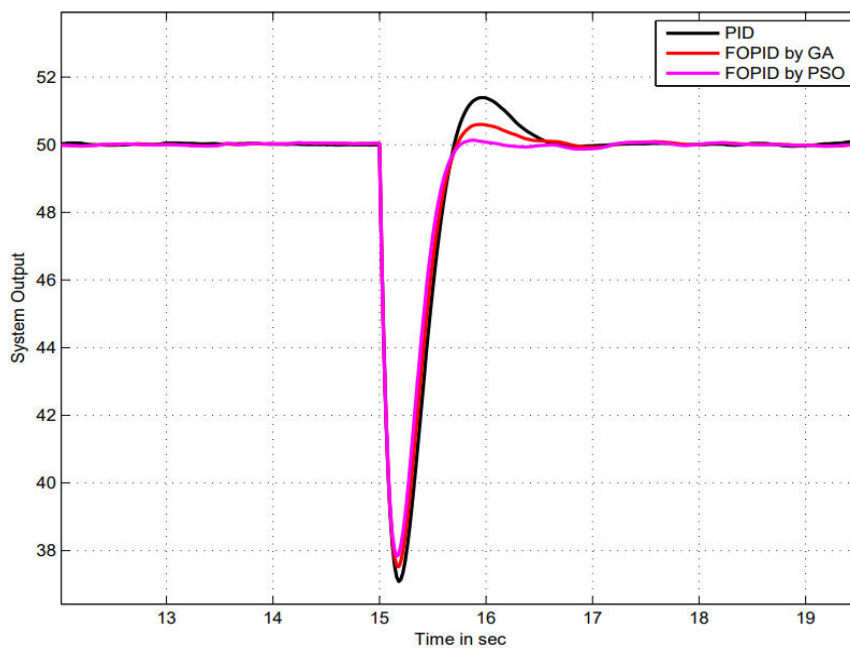


Fig.5 Step response curves of PSO-FOPID and GA-FOPID controllers for an applied load.



A comparative study of various time domain parameters of step response of the proposed and previous methods is shown in the Table 2.

**Table 2. System Response performance indexes.**

Controller type	Rise time	Steady state time	Peak time	Overshoot
<b>PSO-FOPID</b>	0.56s	2.2756s	0.68s	1.84%
<b>GA-FOPID</b>	0.5689s	3.5898s	0.76s	4.04%
<b>PID</b>	0.5761s	4.6652s	0.82s	9.16%

## VII.CONCLUSION

In this paper, a design method of FOPID controller parameters using the PSO algorithm by minimizing the ITAE is presented. Five parameters of fractional order PID controller are debugged and solved by PSO algorithm. The proposed FOPID controller is compared with GA optimized FOPID controller and Conventional PID controller. From the simulation results, it is concluded that PSO optimized FOPID controller has better response against GA FOPID controller. The presented FOPID controller design will find wide application in the future controller design.

## ALGORITHMS

### Algorithm 1. Particle Swarm Optimization Algorithm

```

No of iteration
No of population size
For i=1: no of iteration
    evaluate the particle by generating random value
For i=1: particle
    sorting the value of data = [group data]
    local best = min (sort) (E)
    fitness ← fitness updation
End
    If current value < global best
        update value = gbest
        outdata ← store
value
    calculating error
Else if
    check for global best
End if
    overall value global best
End if
    overall value ← global value
    matrix best ← store value
    velocity ← velocity updation
    error out ← error update + velocity
End

```

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