Performance Analysis of DC motor using PID controller tuned by Metaheuristic Techniques

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Abstract: The use of DC motor is very wide in industrial applications. The choice of motor depends on its performance characteristics like speed, torque and its response time to input variations. It is essential to control its performance with the help of input variations or can be achieved by controller. The Proportional - Integral - Derivative are very popular for its simplicity in tuning and implementation. The controller tuning can be achieved manually or automatically. Manual tuning is arduous job which requires knowledge of the domain and expertise in same. A latest improved grey wolf optimization (IGWO) technique is compared with Particle swarm optimization (PSO) which obtain satisfying and desired results.

Keywords: DC motor, PID Controller, IGWO, PSO, Performance characteristics.

I.INTRODUCTION

DC motor drives are prime in engineering and its applications like electric traction, elevators, position control and robotics etc. DC motor drives have some important advances, such as: their simplicity, high reliabilities ease of application, flexibilities have long been a main instrument for home appliances, engineering applications and robot manipulators where it's necessary to control position and speed of motor. DC motors are also more superior to that of AC motors about the speed torque characteristics. Generally, the minimum settling time is required without getting peak overshoots either motor is armature driven or field driven. The control of DC motor is also possible by adaption of neural networks [2]. PID controller is very popular in every control application because of its ease in learning and implementation [3].

In world, a large share of control application is run by PID controller. 95% of controller's applications are based on PID because of its simplicity, easy functioning and applicability.

Parameters fine-tuning are applied by some expert humans by utilizing a trial and error approach and some practical rules; this perform makes the high cost and difficult activity. Like particle swarm optimization, genetic algorithm can be used to solve many of the same kinds of problems [11]. Optimization Algorithms like GA, PSO, etc. have proved their efficiency in giving good results by developing the steady states characteristics and performance indices.

In this paper, Improved Grey Wolf Optimizer is preferred as a latest optimization algorithm for optimally designing the PID controller in a DC motor and then the results are compared by PSO algorithm. The main purpose is to use optimal methods include IGWO and PSO to design a suitable controller for DC motors is efficiency of algorithms. PSO has already proved its reliability in power system major problems like economic load dispatch etc. [4-5] afterwards, a comparison between these two methods will be illustrated the best method. Performance Characteristics in DC motors is the most significant factor. Particle Swarm Optimization is a popular renowned algorithm which is utilized in different optimization problems and is given good result for more problems [12].

Improved Grey Wolf Optimizer (IGWO) algorithm is an enhanced form of optimization method which is employed to solve optimization problems of different varies like other heuristic algorithms in the area of evolutionary

computation. IGWO also evades the deficiency of early converges of GA in EELD problem in power system [14] and helps in solving approximation in link manipulator [13]
IGWO a mathematical model and the computer simulation which impersonates the management hunting and hierarchy mechanism of grey wolves in nature.

II.DC MOTOR MATHEMATICAL MODEL

DC motor dynamic behavior is given by following set of relations and its block diagram is shown in Fig 1. A simplified linear model is presented for this work ignoring the nonlinearities like the backlash and dead zones to simplify the application of metaheuristic techniques. Consider

$$T_m(s) = K_m I_a(s),$$

$$U_a(s) = (r_a + Ls) I_a(s) + U_b(s),$$

$$U_b(s) = K_b \dot{\theta}(s),$$

$$I_a(s) = \frac{U_a(s) - K_b \dot{\theta}(s)}{(r_a + Ls)}$$

$$T_l(s) = J_m s^2 \theta(s) + B_m s\theta(s),$$

$$T_l(s) = T_m(s) - T_d(s) \qquad (1)$$

where U_a = armature applied voltage,
U_b = back-emf,
K_m = motor constant,
K_b = back emf constant,
J_m = inertia of rotor,
B_m = viscous damping,
T_m = developed motor torque,
T_l = torque delivered to load,
T_d = disturbance torque (neglected),
r_a = armature resistance,
L = armature inductance,
I_a = armature current and s is s-plane.

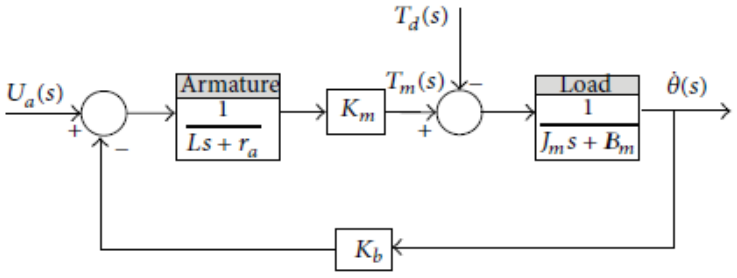

Figure 1. Block diagram of DC Motor [13]

By using (1) the transfer function of DC motor is [13]

$$\frac{\dot{\theta}(s)}{U_a(s)} = \frac{K_m}{(r_a + Ls)(J_m s + B_m s) + K_m K_b} \qquad (2)$$

The open loop step response of DC motor without PID controller is shown in Figure 2.

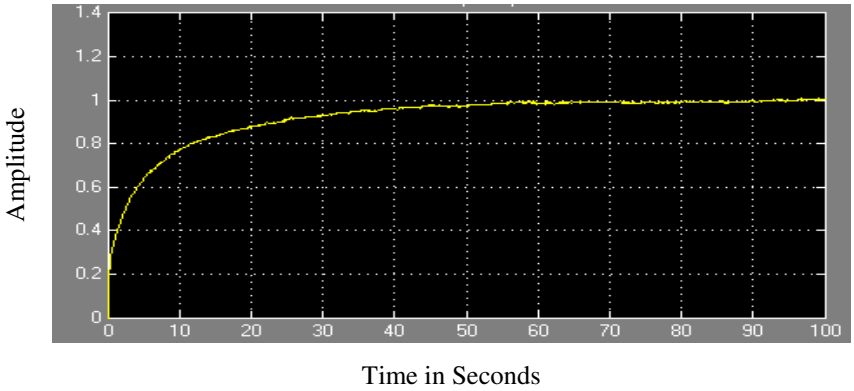

Figure 2. Open loop response of DC motor

III.METHODOLOGY

2.1 *Particle swarm optimization*

In the last decades, natural based algorithms have been attention paid to solve optimization problem. Optimization techniques such as: Evolutionary programming, genetic algorithm, particle swarm optimization, imperialist competitive algorithm are some of these popular methods that have already been employed.

Particle Swarm Optimization (PSO) algorithm is utmost popular optimization algorithm which has been developed [1]. PSO algorithm is inspired by the fish schooling and social behavior of birds flocking. In this approach optimal solution to a mathematical optimization problem is restricted of birds behave in the moment the food pursue, the escape from hunters and the search for mates. In the last few years, PSO has been employed in extensive variety of applications ranging from classical method problems to scientific optimization problems and highly proprietary engineering [5-6].

Traditional PSO algorithm performs by an initial population (swarm) of candidate solution (elements). These elements are searched around in the search-space in order to a few definite formulations. The elements searching and their moving are followed up to their own best identified position in the search-space and the whole swarm's best identified position. A flowchart for PSO algorithm is shown in figure 3.

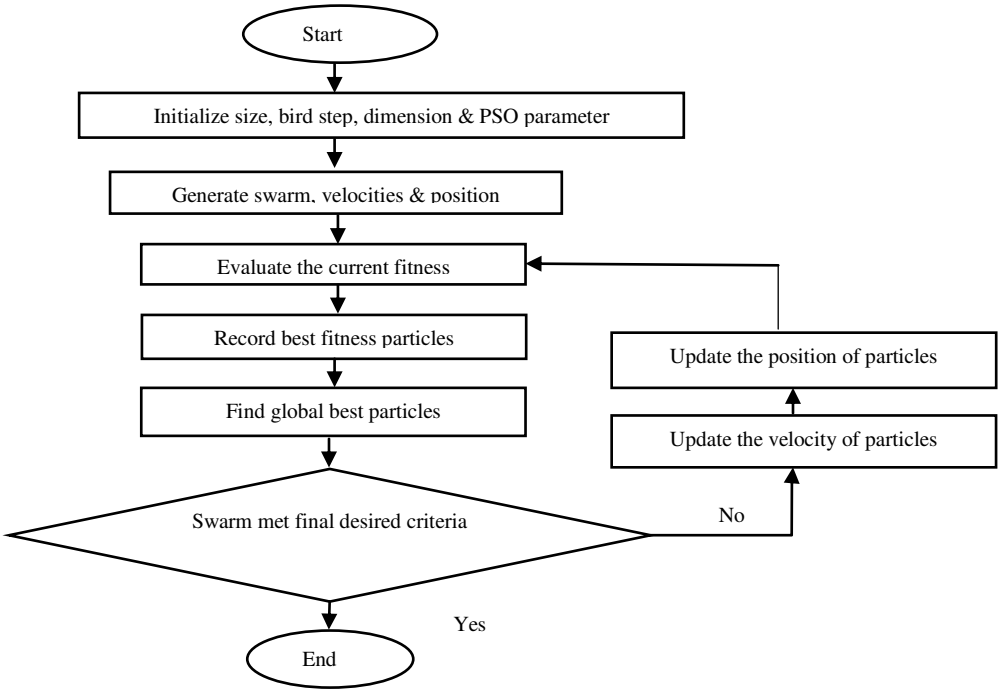

Figure 3. Flow chart of PSO

2.2 *An improved grey wolf optimization*

An improved grey wolf optimization (IGWO) is the enhanced form of grey wolf optimization (GWO) algorithm. GWO algorithm was proposed in 2014, which impersonate the hunting technique and social hierarchy of grey wolves in nature. This algorithm is grounded on three important steps

1. Follow the prey
2. Encircle the prey until it stops moving
3. Finally, attacking the prey

According to the headship hierarchy of wolves, we predict first best solution as alpha, second best solution as beta and third best solution as delta. The rest of the solutions are assumed as omega as per hierarchy of grey wolves [16]. The flow chart of IGWO is shown in fig 4.

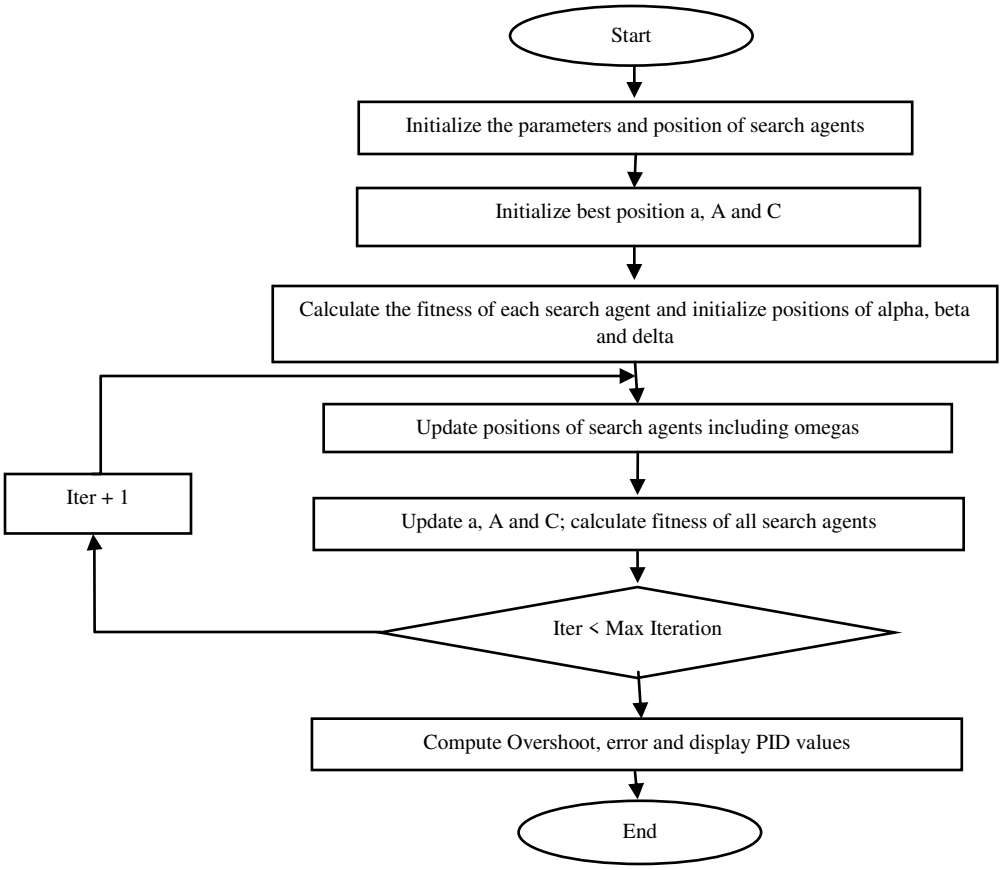

Figure 4. Flow chart of IGWO

IV.IGWO AND PSO BASED PID CONTROLLER

An IGWO and PSO algorithm based PID controller is designed to obtain optimum performance characteristics of DC motor. The parameters which are used to verify the performance characteristics of PID controller using IGWO and PSO algorithm is shown in table 1.

Table 1. IGWO and PSO Parameters

Parameters	Values in IGWO	Values in PSO
No. of population	50	50
Maximum iterations	50	50

The obtained values of PID controller constants using IGWO and PSO algorithm is shown in table 2.

Table 2. PID controller constants using IGWO and PSO

PID controller constants	K_P	K_I	K_D
IGWO	0.9543	0.2920	1.2173
PSO	1.0038	1.0057	1.5066

V.SIMULATION

To minimize the peak overshoot, settling time, steady state error of DC motor and improve its efficiency as well as response time simulation in MATLAB is done. The basic steps for simulation are:

Step 1: The development of linear mathematical model for DC motor and by using motor parameters a new transfer function is obtained.

Step 2: In Simulink, the obtained transfer function values are inserted and actuator model is designed

Step 3: A bench marking controller is designed and it used as input of actuator. The output is collected from actuator and fed to scope for graphical representation of signal.

Step 4: A feedback signal is taken from output and fed to PID controller in summation with step input.

Step 5: The PID controller is tuned with the help of IGWO and PSO technique.

Step 6: To perform simulation using MATLAB/SIMULINK for PID, PSO and IGWO controllers and Comparative study of the controllers is done.

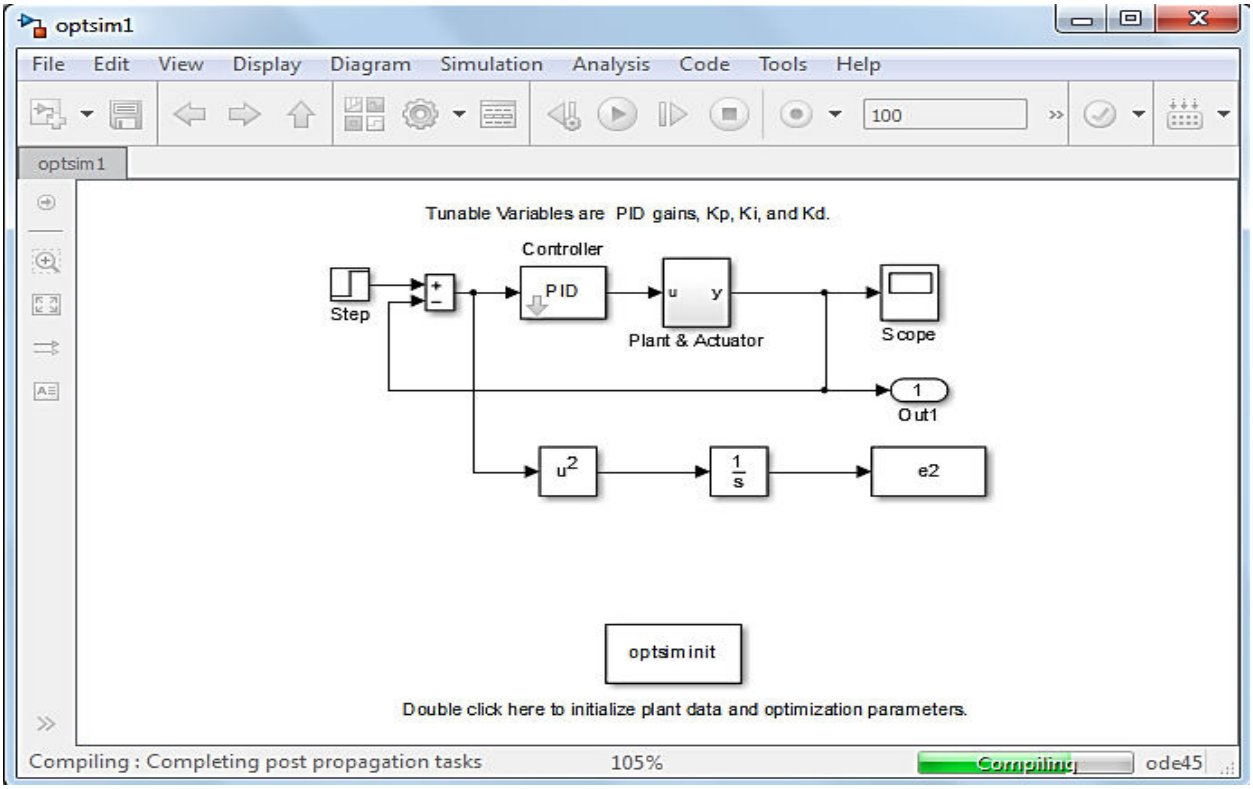

Figure. 5. Simulation Model

VI.RESULTS AND DISCUSSION

A benchmarking PID controller is designed using simulation and tuning is done by IGWO and PSO algorithm. To obtain desired response, tuning of control loop is organized in a manner so that control parameters provide the optimum value. Stability is serious concern in control system but the different systems possesses their own requirements and behaviors which might not be compatible with each other. For stable output, disturbances should not oscillate the process or output behavior of the system. Marginal stability can be accepted in some cases with bounded oscillation condition. The simulation output of PID controller tuned with IGWO and PSO is shown in fig 6 and 7 respectively. The performance characteristics of PID controller is also shown in table 3.

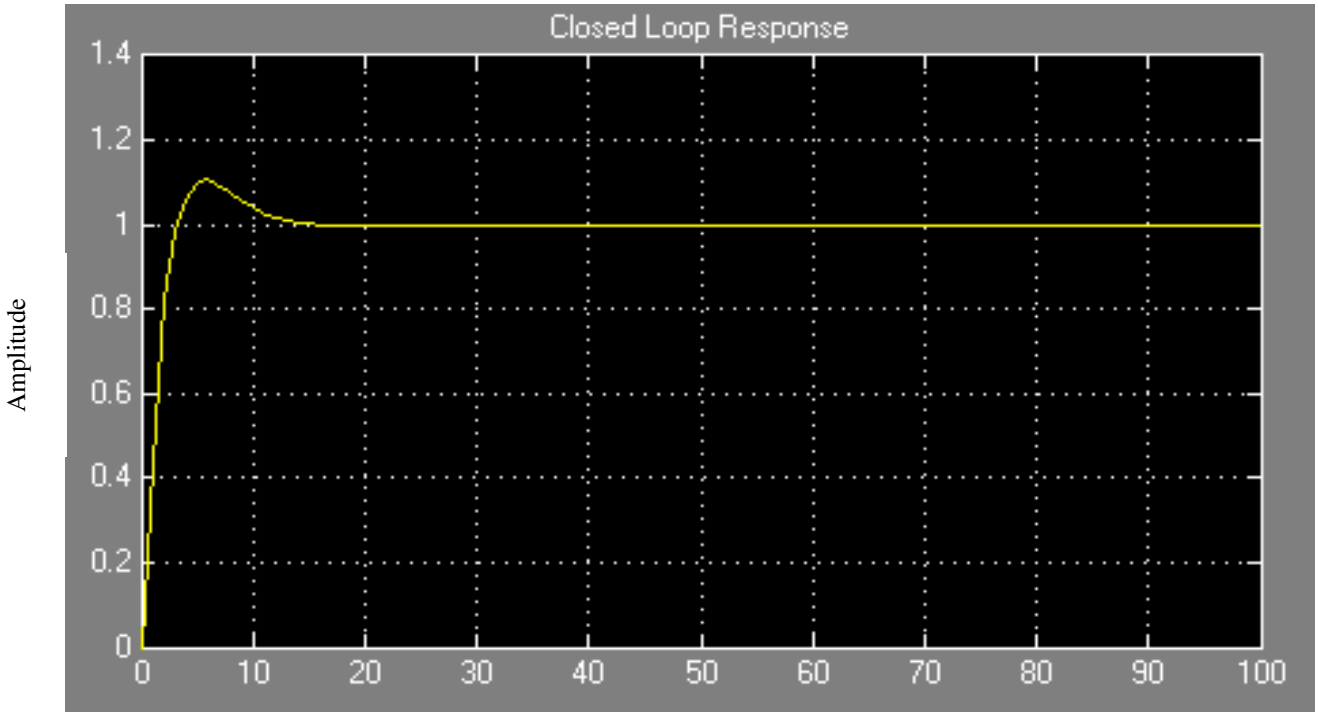

Figure 6. Closed loop response of PID controller tuned with IGWO

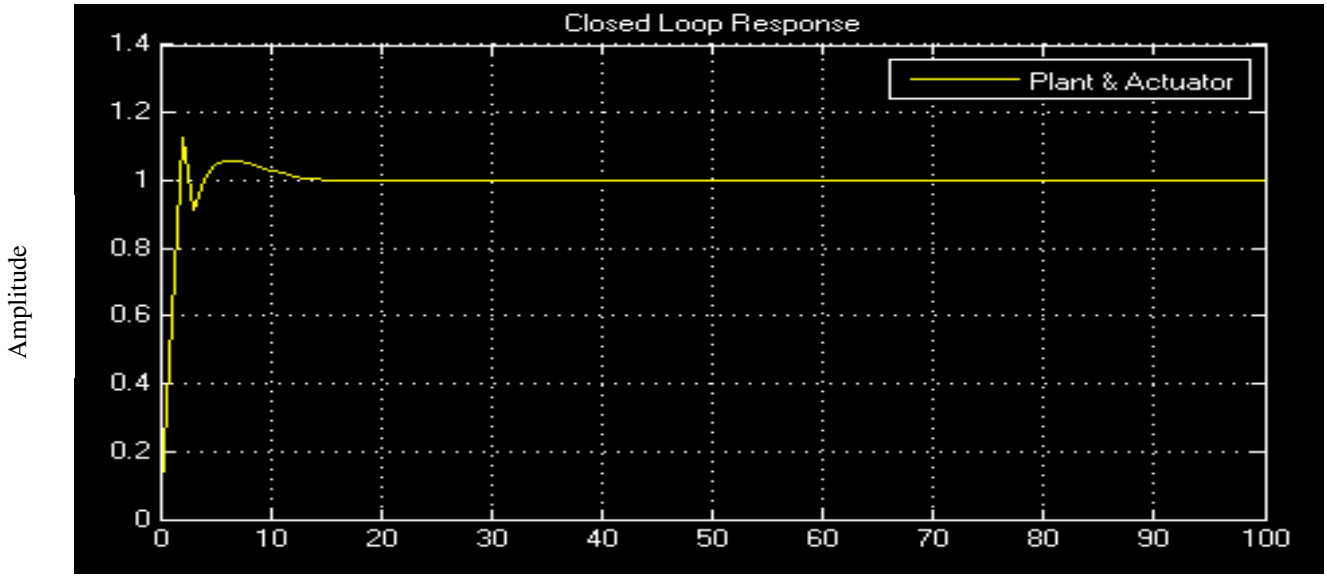

Figure 7. Closed loop response of PID controller tuned with PSO

Table 3. Performance characteristics of DC motor using PID controller

S. No.	Maximum peak overshoot (M_P)		Settling Time (T_S)		Steady state error e_{SS}	
	IGWO	PSO	IGWO	PSO	IGWO	PSO
1	1.115	1.142	15.02	15.24	0	0

VII.CONCLUSION

The performance characteristics of DC motor is obtained using PID controller which is programmed by IGWO and PSO algorithm. The performance characteristics of DC motor is shown in table 3. The optimum results show that the designed controller can be employed as proficient PID controller. The comparison between PID controller tuned by IGWO and PSO, shows that the proposed technique can advances the performance characteristics of the system in a well manner. The PID controller using IGWO is the finest which proved acceptable performances and owns good robustness toward PSO.

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