PID Controller optimization using Metahuristic Controller with Different Nonlinearities

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Abstract: This paper mainly explains the application of Metaherustic controller for tuning the parameter of PID controller. The minimization of error function has been done by improving the static and dynamic performances of the system like steady state error, Peak Overshoot, and Settling Time. This could be possible by means of applying metaherustic controller like GA in tuning the PID controllers under different Nonlinearities. The main intention of this paper is to support the specifications of PID controller at various Nonlinearities such as sinusoidal and saw tooth noise. The projected scheme derives the wonderful closed-loop response of second order system and then, it provides the effectiveness of the proposed method compared to the conventional methods.
Keywords: PID Controller, GAPID Controller, Conventional Controller, Sawtooth Noises, Nonlinearities

1. Introduction

In all systems, controller is an essential preliminary observe. Countless work has been approved by researchers and many controllers have been provided for linear and nonlinear, stable and unstable processes. Consequently, these systems produce unwanted overshoot. Previously, PID controllers with the assistance of Z-N method (Prathibanandhi, 2018; Aroulanandam, V. V., 2019) have been used to tune the controller. However, they have some limitations to get an optimal solution. Hence, the metaherustic approach such as GA has been used for tuning the PID controller parameters (Ibtissem, 2012; Shankar, 2020; Sekaran, 2020).

The DC motor drive which has the rated speed of 1000 rpm, 240V, 15A has been considered for evaluation. The PID controller has been initially designed for the machine by using Z-N method (Latchoumi, 2013). Then, the performances are obtained. Later by using GA methods, PID controller has been designed and its performances are analyzed. For those controllers, different disturbances such as sinusoidal and sawtooth are given and their performances are obtained.

2. Modelling of Separately Excited Dc motor

DC motor includes three parts like an armature; a circuit for attractive topic supplied by magnets of poles; and a commutator. In order to build the DC automobiles switch, `its easy arithmetical version has been used. Accordingly, these motors have great velocity and torque to manage.

Torque developed by the motor is given by flux and armature current (Younis, 2018; Ranjeeth, 2019).

$$\text{Torque} = Kt\ Ia \quad (1)$$

Back Emf is directly proportional to the change in Angular velocity

$$\text{Back emf} = Kb\ d\theta/dt \quad (2)$$

Torque equation $d\theta/dt2 = 1/J\ [\ Kt\ Ia - B(d\theta/dt) + Tl]$ (3)

The differential equation of the armature circuit is

$$dIa/dt = 1/L[-R\ \ Ia + Va - Kb\ (d\theta/dt)] \quad (4)$$

By using have been designed through the above two basic equations, The armature resistance, friction, force, inductance, back emf, inertia of motor the mathematical model. The following TABLE-I shows the corresponding DC motor parameters.

Table 1. DC Motor Parameters

Parameters	Values

Armature Inductance- La	0.121H
Armature Resistance -Ra	11.2Ω
Rotor Inertia-J	0.02215kgm2
Armature Voltage-Va	240V
Viscous friction constant-B	0.002953
orque constant -K_t	1.28Nm/A
Back emf constant-K_b	1.28Vs/rad
Speed -N_{ref}	1000rpm

3. Conventional Controller

The PID controllers are mostly used in controllers for speed control of Drive. The proportional, integral and derivative actions are the three main functions of the conventional controllers. The Fig.1.represents the pictorial representation of PID controller

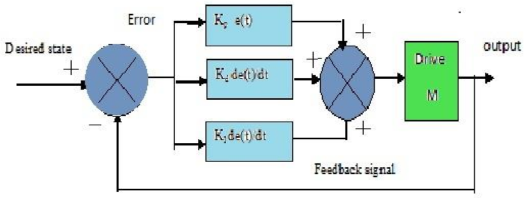

Figure 1. Pictorial Representation of PID Controller

$$U(t) = Kp+ Ki [\int e(t)d] + Kd \quad (5)$$

4. Genetic Algorithm

The convergence of this algorithm provides the association between the most excellent robustness value and the common fitness value (Umesh, 2013; Latchoumi, 2017). A simple GA is derived by using primary operators like reproduction, crossover and mutation. Here, large probabilities of Fitter chromosomes are elected. Hence, it is begun with an initial population (Prathibanandhi, 2018). The GA derives the information from the initial population; generates the new individuals by using genetic operators that can replace the content of the old information, and then from the new population, another generation is reproduced. After a number of generations, the algorithm will be on the way to the best chromosome, which represents the optimum solution or near optimal (Thirupura Sundari, 2019; Ranjeeth, 2020). This process can be visualized by Fig.2.

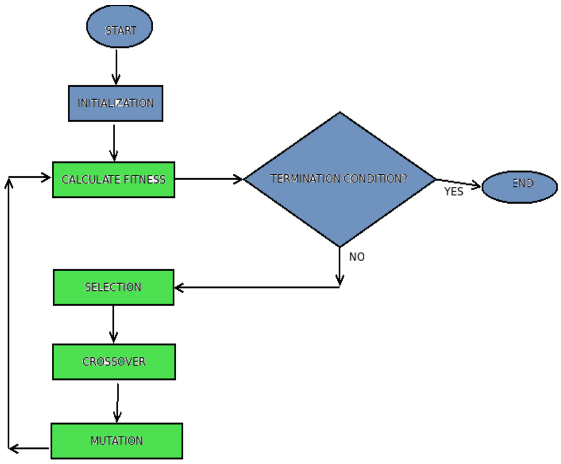

Figure 2 Chromosome structure

4.1. Problem illustration

The parameters of the PID controllers can be represented as each individual population. For the speed control problem under consideration, the controller parameters are represented in binary form as follows:

1010111010	100011011	1001000100
K_p	K_i	K_d

4.2. Population Initialization

Population Initialization is needed for any GA. The most common method is to create solutions randomly for the entire population and it is the normal method in GA (Hong-Gui , 2018). In order to control the speed of the drive under various considerations, all the individuals are initialized arbitrarily using an identical arbitrary number of binary strings (i.e) ones and zeros.

4.3. Evaluation function

GA finds the optimal solution by minimizing the given fitness function which gives the value of the problem solution. In the speed control, the intention is to minimize the

Integral Absolute Error (IAE) of PID controller by satisfying the constraints. Now, the new objective function becomes

$$IAE = \sum_{t=0} \left| Nref(t) - Nact(t) \right| \quad (6)$$

Here tsim =simulation time

Nref (t) = Desired speed of motor at any instant

Nact (t) = the actual speed of motor at any instant.

4.4. Genetic Operator

The genetic operator emphasizes good solutions and destroys the bad solutions by maintaining population constant. The objective is to permit the "fittest" individuals, on the way to be selected to reproduce. In this work, "tournament selection" is selected. Bit mutation and two point crossover are used on the selected members to get a fresh population. Thus, the Genetic algorithm approach has been implemented for tuning PID parameters to the speed control problem and the results obtained are given.

The parameter settings of GA are given in TABLE II

Table 2: GA Parameters settings

Genetic Parameters	Values
Bit number	8
Rate of cross over	0.75
Rate of mutation	0.06
Population size	10
Generations	100

5. Simulation Results

The PID controller of DC motor is tuned by means of Ziegler-Nichols method (Harion, 2019). The tuning results are given below. The tuning values from this algorithm are

Kp = 0.8531; Kd = 0.0047; Ki = 38.7769

After the PID controller parameters are tuned for the following Nonlinearities such as sinusoidal, Sawtooth Noises, the speed control of the DC motor has been obtained as shown in fig.3.a and fig.3.b.

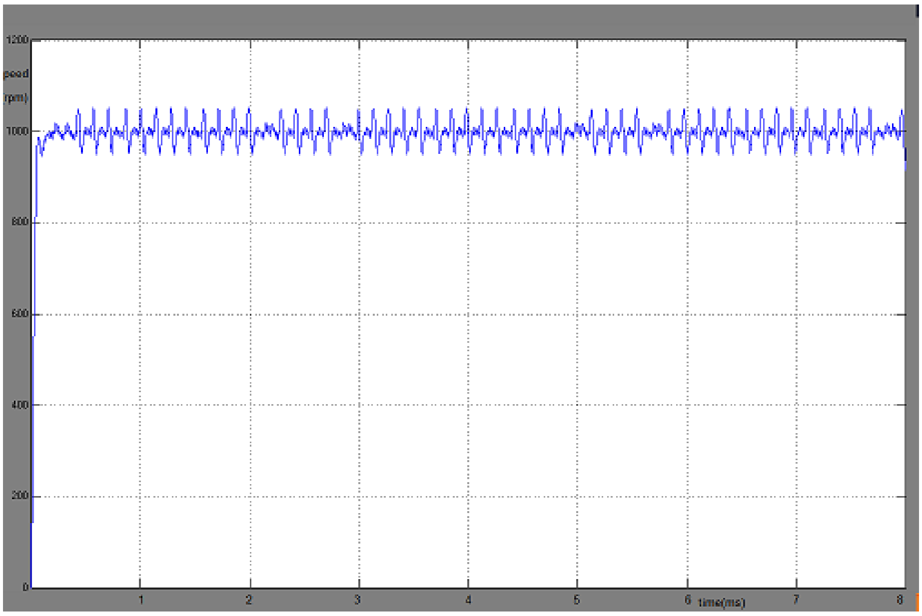

Figure 3.a.Conventional PID controller response for sinusoidal   Nonlinearity(Speed of DC drive(rpm) Vs\time(ms)

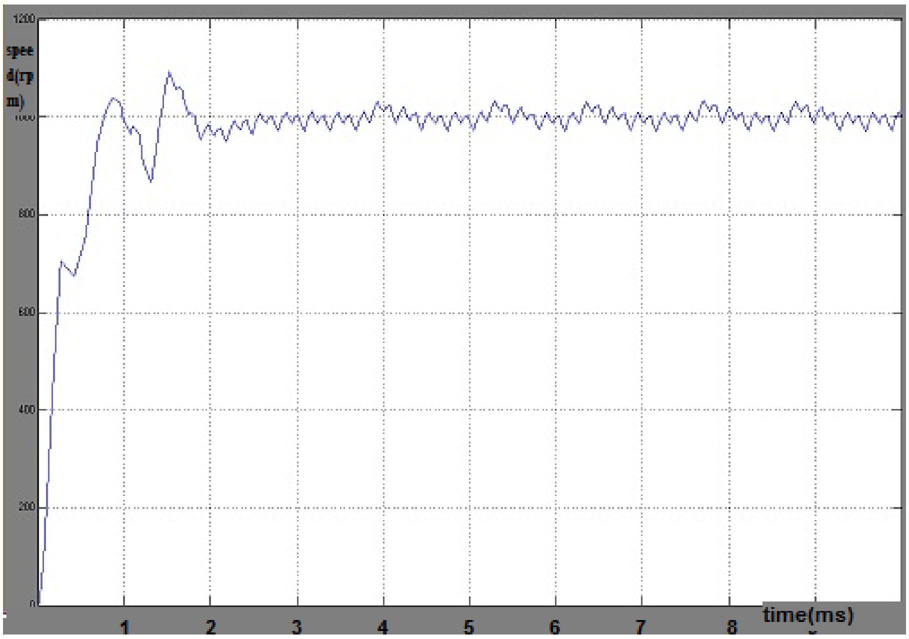

Figure.3.b.Conventional PID controller response for Saw tooth Nonlinearity(Speed of DC drive(rpm) Vs\time(ms)

The suitability of the proposed method is demonstrated and GA based method has been applied to obtain the optimal solution. The parameter settings of GA are given in TABLE-II. These parameters are constant across all runs. The convergence of this algorithm provides the association between the most excellent robustness value and the common fitness value and the graphical representation of the simulation results is shown in fig.4. From the graph, it is very clear that after 30 generations, there is no significant reduction in the objective function value and the corresponding parameter values are the optimum parameter values of the PID controller.

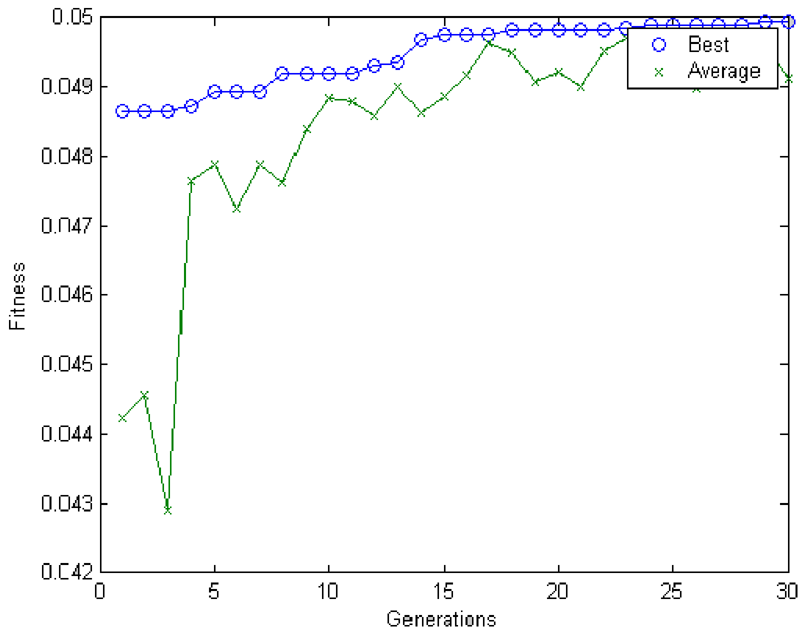

Figure.4.Convergence of GA-PID controller

The Convergences of GA-PID controller are Kp = 0.8531; Kd = 0.0047; Ki = 38.7769. The optimum Kp, Kd, Ki values are given to the PID controller of the simulation circuit and the speed control of the DC motor is obtained under the following circumstances as given in fig.4.a and fig.4.b.

a) At Sinusoidal Noise

b) At saw tooth noise

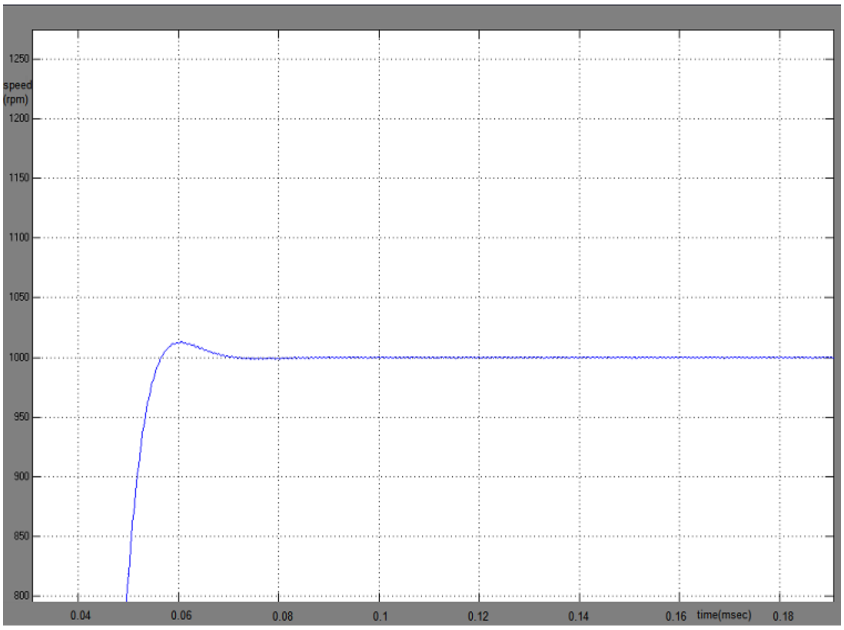

Figure.4.a.GA-PID controller response for sinusoidal Nonlinearity (Speed of DC drive(rpm) Vs time(ms)

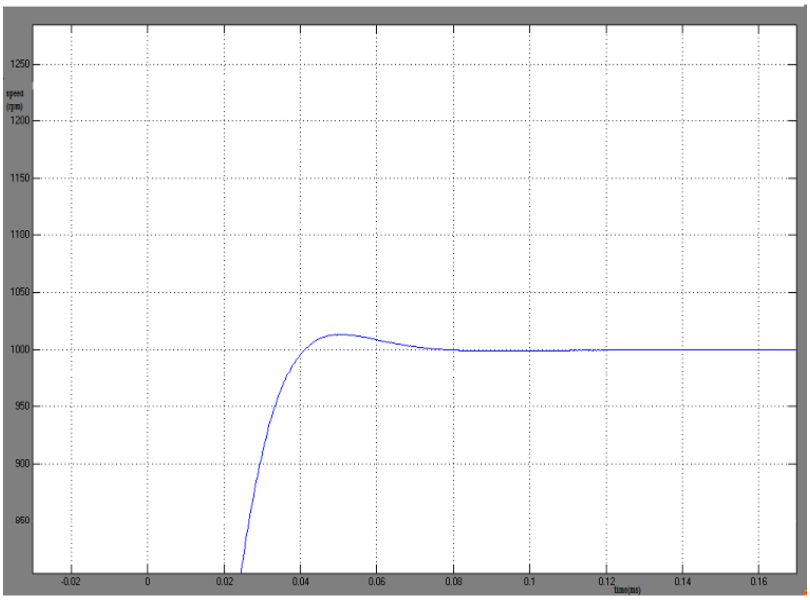

Figure.4.b.GA-PID controller response for Saw tooth Nonlinearity (Speed of DC drive(rpm) Vs time(ms)

The performance of GA-PID controller is carried for any second order drive and it is compared with the conventional controller in MATLAB computer simulation. The suitability of the proposed method has been demonstrated and the speed control of the drive has been obtained under the following nonlinearities. The comparison tables TABLE-III and TABLE-IV for conventional controller, GAPID controller at different nonlinearities are listed.

Table 3 Comparison Table for Sinusoidal Nonlinearity

Controller	Steady state error (rpm)	Steady state value (rpm)	Settling time (msec)	Peak over Shoot (rpm)
Conventional controller	100	1050	Infinite	1050
GAPID controller	0.2	1002	0.08	1010

Table 4: Comparison Table of Sawtooth Nonlinearity

Controller	**Steady state error (rpm)**	**Steady state value (rpm)**	**Settling time (msec)**	**Peak overshoot (rpm)**
Conventional controller	50	1005	Infinite	1095
GAPID controller	0.1	1000	0.12	1010

6. Conclusion

In this paper, Metaherustic algorithm, which is capable of providing good speed regulation with stability along with minimum settling time, steady state error and overshoot (Chin- Hung, 2018), has been proposed and demonstrated for tuning the PID controller. In this paper, initially, the PID Controller has been tuned by the Ziegler Nichols met hod (Akbarzadeh, 2019) which is suitable only for linear process. Then, the same has been adjusted to the optimum values by means of better speed control under various nonlinearities like sinusoidal as well as sawtooth in such a way that the settling time, steady state error and peak overshoot are reduced[3]. Finally, it is evident that the GA-PID controller has provided better performance than the conventional controllers[2].

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