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Design and Implementation of PID Controller using Genetic Algorithm

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***Abstract*:-Proportional-Integral-Derivative (PID) Controllers play a significant role in many industrial and commercial applications. Design of PID controller is always a challenging problem especially for high order systems. Genetic algorithm (GA) is a stochastic global adaptive search optimization technique based on the mechanism of natural selection. GA is expected to be superior in avoiding local minima which plays a significant role in case of a non-linear system. The studies based on GA Based PID Controller are used to highlight its effectiveness for better optimization.**

1. INTRODUCTION

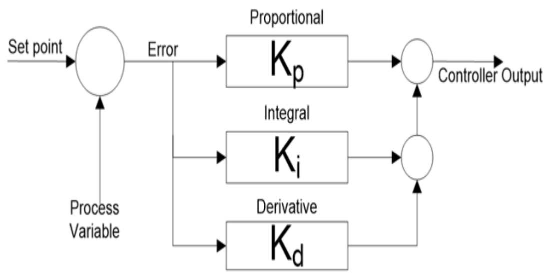
A proportional–integral–derivative controller or commonly known as PID Controller is a generic control loop feedback mechanism (controller) widely used in industrial control systems. The PID Controller algorithm consists of three distinct stable parameters, and is consequently termed as three-term control, they are proportional, integral and derivative values, denoted as *P, I,* and *D*. The optimization algorithms search is to find the set of inputs to an objective function those results in optimum outputs.

In order to achieve better performance parameters there is need for implementation of optimization techniques to obtain some satisfactory results, but still many more have to be tested to achieve optimization. According to increasing system complexity and work expansion, the optimization of motor control and hence the rotor velocity control is required to be more optimized. Many optimization technologies like conventional optimization as well as other techniques have been employed. But in order to improve the performance, a few optimization techniques like GA and Interactive Evolutionary algorithms (EA) have also been implemented.

The Genetic Algorithm performs a multi-directional search through a sample space of potential solutions. During the process, not only does it maintain the population of potential solutions but also randomly creates new solutions within this population. The creation of new solutions is achieved by the adoption of certain operators (mutation, crossover, selection, reproduction), which mimic the process of natural selection and evolution.

2. PID CONTROLLER

A proportional–integral–derivative controller or commonly known as PID Controller is a generic control loop feedback mechanism (controller) widely used in industrial control systems. Therefore, a PID is the most commonly used feedback controller. Such type of controller estimates fault rate as the difference between a considered method variable and a required set-point. The designed controller tries to reduce the error by correcting the process control inputs.



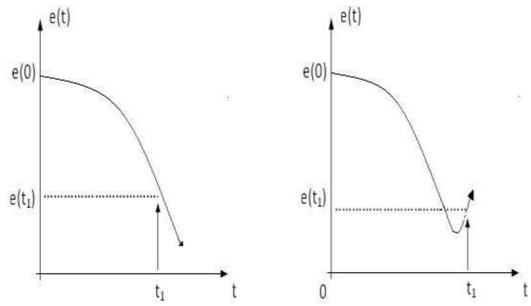
Block diagram of a PID Controller

PID Controller is one of the versatile multivariable controllers used for many process applications. The role of derivative control is illustrated in Fig. 1.2., which can be analyzed with two different situations where one can expect different actions performed by the controller is illustrated. However, if PI controller is used then control signal will be the same in moment t_1: u (t_1). Proportional will be proportional to error in t_1: and is given by

$$u_p(t_1) = Ke(t_1)$$

Integral part of the signal will be proportional to the area under error curve till moment t_1 and is given by

$$u_p(t_1) = \frac{K}{T_i}\int_0^{t_1} e(\tau)d\tau$$



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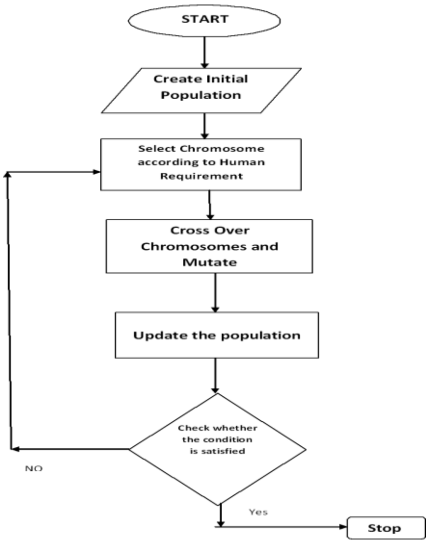
3. GENETIC ALGORITHM:

GA is a stochastic global adaptive search optimization technique based on the mechanism of natural selection. It is a heuristic mimicking the natural evolution process and is routinely used to generate useful solutions of an optimization problem. In GA, a population of strings called chromosomes encode the possible solutions of an optimization problem and evolve for a better solution by process of reproduction. The process of evolution starts from a population of randomly generated individuals. Optimization is achieved in generations where in each generation, fitness function evaluates each individual in the population and multiple individuals are selected stochastically based on their fitness. These selected individuals are modified to form a new population. The algorithm terminates when either produces a maximum number of generations, or a satisfactory fitness level has been reached for the chosen population.GA starts with an initial population containing a number of chromosomes where each one represents a solution of the problem, the performance of which is evaluated by a fit ness function. Basically, GA consists of three main stages, they are Selection, Crossover and Mutation. The application of these three basic operations allows the creation of new individuals, which may be better than their parents. This algorithm is repeated for many generations and finally stops when reaching individuals that represents the optimum solution of a problem.

We know that the performance parameter for any DC Motor can be optimized by employing the PID Controller and then optimizing or lowering the error functions. In the present work, GA is used to derive the PID Controller parameters by optimizing the error in the DC Motor angular velocity.

The flow chart presented in Fig. 4.6 above represents real implementation of GA so as to optimize the relative output of the parameters which are responsible for the motor control and hence the velocity / speed control.

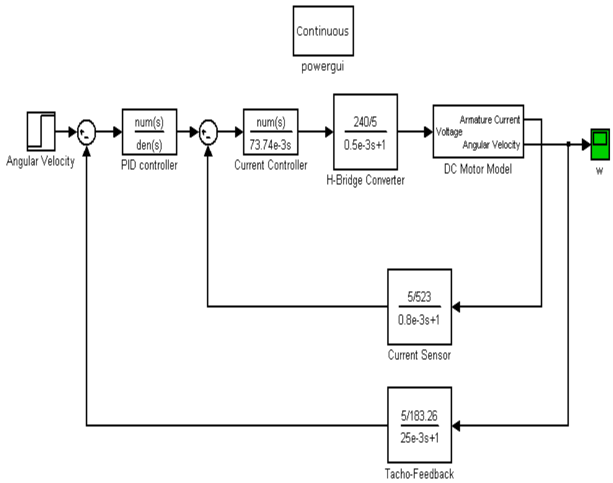


Architecture for Genetic Algorithm

PID Controller : A proportional–integral–derivative controller (PID Controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems – a PID is the most commonly used feedback controller. A PID Controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs.

4. OPTIMIZATION OF PID CONTROLLER PARAMETERS USING GENETIC ALGORITHM (GA)

In this implementation mode, it is found that the input is taken as angular velocity component and this value which has to be optimized for better performance and control for each type of error model using GA. The input is fed to PID Controller where for each iteration the error is calculated and then PID Controller tries to minimize the error value. The output of the controller is in the current form which is then passed through the H-Bridge converter. H-Bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC Motors to run forward and backward. H-bridges are available as integrated circuits, or can be built from discrete components.



SIMULINK model for the complete system

The output of converter is then fed as input to the DC Motor module. The DC Motor module has two components like armature current and the angular velocity. Armature current is fed back to the PID Controller via current sensor. And again the PID Controller controls the parameters output by employing filtering and then optimizing the performance parameters. This process continues until the system reaches the optimized stability and functionalities.

5. RESULTS:

Fitness function in the GA structure is configured to optimize different types of errors. These errors are the return values from fitness function. The GA uses the return values as the fitness parameter to evaluate individuals in the population and hence select the best candidates.

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Different optimization functions and the resulting PID Controller transfer functions are listed below. Result of the motor speed optimization for various Error models are presented in figures below. The results obtained for PID Controller values with GA implementation for different error models are presented in Table along with number of generations required.

1. *ITSE (Integral Square Error)*

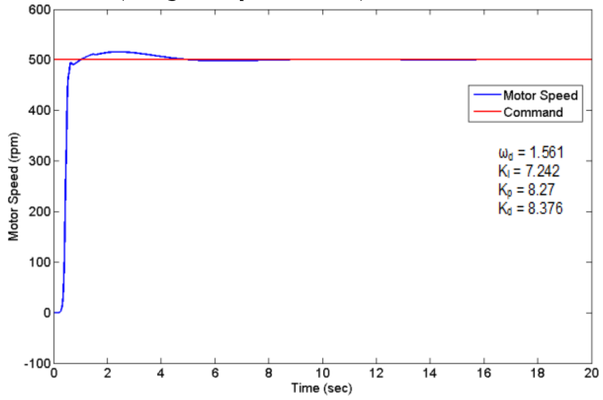

Fig: Motor Speed optimized for ITSE

```
For i=1: length (velocity)
Temp = (183.26/5)*command;
f= f+abs((temp-velocity (i)^2)*tout(i));
end
```

The transfer function for ITSE value is given below:

$$\text{PID}=\frac{8.376s^2+8.27s+7.242}{s(s+1.561)}$$

2 *ITAE (Integral Time Absolute Error):*

```
for I= 1: length (velocity)
temp = (183.26/5) * command;
f= f + abs (temp-velocity(i))*tout (i)
end
```

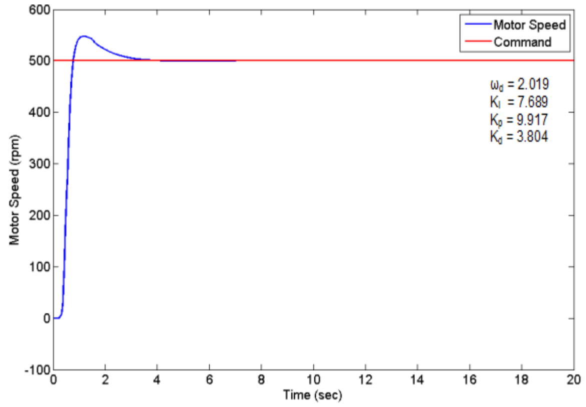

Fig: Motor Speed optimized for ITAE

The transfer function of IATE value is given below:

$$\textbf{PID} = \frac{3.804s^2+9.917s+7.689}{s(s+2.019)}$$

3. *Peak Overshoot:*

f = max(velocity);

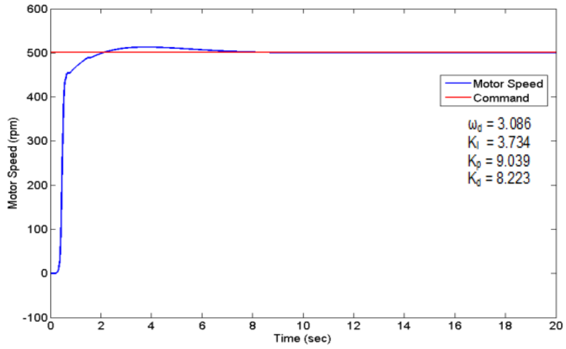

Fig: Motor Speed optimized for Peak Overshoot

The transfer function of Peak Overshoot value is given by:

$$\textbf{PID} = \frac{8.223s^2+9.039s+3.7342}{s(s+3.086)}$$

4. *Absolute Error:*

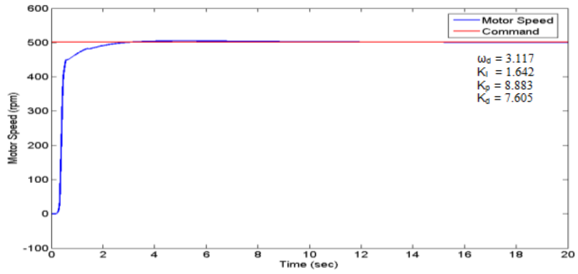

Fig: Motor Speed optimized for Absolute Error

F = abs((max(velocity   183.26/5* command))

The transfer function of absolute error value is given by

$$\textbf{PID} = \frac{9.643s^2+9.87s+2.26}{s(s+2.032)}$$

5. *Squared Error:*

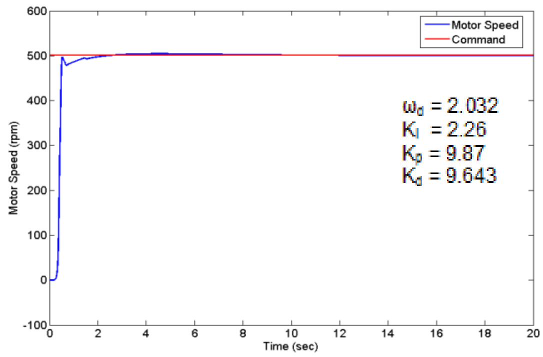

Fig: Motor Speed optimized for Squared Error

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```
for i = 1: length(simout)
temp = (183.26/5)*command;
f = f+(temp simout(i))^2;
end
```

The transfer function of Squared error is given by:

$$\text{PID} = \frac{9.643s^2 + 9.87s + 2.26}{s(s + 2.032)}$$

The optimized parameters obtained after applying the GA are listed in the table. The results show that the PID-GA Controller offers better performance than other techniques used.

Table Optimized PID parameters for 500 rpm in GA

Parameter	ω_d	K_i	K_p	K_d	Generations
ITSE	1.561	7.242	8.27	8.376	62
ITAE	2.019	7.689	9.917	3.804	67
Peak Overshoot	3.086	3.734	9.039	8.223	51
Absolute Error	3.117	1.642	8.883	7.605	24
Squared Error	2.032	2.26	9.87	9.643	35

After implementing the proposed algorithm, the various error functions are obtained for a set command speed of 500 rpm. The comparative study of data output for the parameters like ITSE, ITAE, peak overshoot, absolute error and the squared error values, which do play a vital role for deciding the best and optimized performer algorithm for the speed control has been carried out. The results obtained from the implemented algorithm for different values of error functions are presented in the Table 3.4. The table shows the various gains of the controller, angular speed and the number of generations to optimize the results. The table consists of the relative values of function parameters for each PID components. The study of various error functions like ITSE, ITAE, overshoot value, absolute value and the squared value have been obtained with various number of generations.

Here, we found that the number of the generations required for ITAE & ITSE was higher and the relative values of the gain parameters for PID Controller are also not much lower as expected for the optimum optimization. But in fact these values signify that the GA implementation has the better performance than the conventional or less efficient optimization technique.

6. CONCLUSIONS AND FUTURE WORK:

PID Controller plays a significant role in varieties of industrial applications. The tuning of the controller parameters is a complex part of the system. The GA based algorithm adopted to tune the controller parameters for various error models mentioned above shows that the optimization of the speed has been achieved with various number of generations required for convergence to obtain the controller parameters. The study can be carried out to keep the tuning rules as simple as possible implementing the Fuzzy Logic along with GA.

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