Optimum Tuning Algorithms for PID Controller A Soft Computing Approach

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ABSTRACT

PID controllers are widely used in industrial plants because it is simple and robust. Industrial processes are subjected to variation in parameters and parameter perturbations, which may be significant and even, make the system unstable. So the control engineers are on the lookout for automatic tuning procedures. In this paper, the parameters of PID controller are tuned for controlling the armature controlled DC motor. Trial and error method, Continuous cycling method, Z-N step response method & Kappa-Tau method are the conventional methods whose performance have been compared and analyzed with the intelligent tuning techniques like Genetic algorithm and Evolutionary programming. GA and EP based tuning methods have proved their excellence in giving better results by improving the steady state characteristics and performance indices.

Keyword-Kappa-Tau, EvolutionaryProgramming, Genetic Algorithm& performance indices.

1. PID CONTROLLER

The general equation of PID controller is

$$Y(t) \quad [kpe(t) \quad Kd\frac{d(e)}{d(t)} \quad Ki\int_0^t e(t)d(t)]$$

The variable e(t) represents the tracking error which is the difference between the desired input value and the actual output. This error signal will be sent to the PID controller and the controller computes both the derivative and the integral of this error signal. The signal U(t) from the controller is now equal to the proportional gain (Kp) times the magnitude of the error plus the integral gain (Ki) times the integral of the error plus the derivative gain (Kd) times the derivative of the error[2].

2. Characteristics of PID control action:

A proportional controller will have the effect of reducing the rise time but never eliminate, the steady-state error. An integral control will have the effect of eliminating the steady-state error, but it may make the transient response worse. A derivative control will have the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response.[7]

3. Need for controller tuning:

The design of a control system is an attempt to meet a set of specification which defines the overall performance of the system in terms of certain measureable quantities. These measurable quantities are referred as performance indices like Integral Absolute error (IAE), Integral square error (ISE), Integral Time absolute error (ITAE) and Mean Square error (MSE).If the performance Indices increases, control system can perform poorly and even become unstable. So it needs to tune the controller parameters to achieve good control performance with the proper choice of tuning constants [7].

3.1 Methods for PID Controller Tuning

The PID control algorithm is used for the control of almost all loops in the process industries, and is also the basis for many advanced control algorithms and strategies. In order to be able to use a controller, it must first be tuned to the system. This tuning synchronizes the controller with the controlled variable, thus allowing the process to be kept at its desired operating condition. Standard methods for tuning controllers and criteria for judging the loop tuning have been used for many years. Mathematical criteria, Cohen- coon Method, Trial and error method, Continuous cycling method, Relay feed back method and Kappa-Tau tuning method.From the above mentioned methods, four have been selected, tuned, designed and the results obtained were compared. These results thus show which method is the better one [3].

4. Reason for Selecting Soft Computing Techniques.

1. Model type: Many methods can be used only when the process model is of a certain type, for example a first order plus dead time model (FOPDT). Model reduction is necessary if the original model is too complicated. [8]
2. Design criteria: The methods aim to optimize some design criteria that characterize the properties of the closed-loop system. Such criteria are, for example, gain and phase margins, closed-loop bandwidth, and different cost functions for step and load changes [8].
3. Approximations: Some approximations are often applied in order to keep the tuning rules simple [8].

Each of these can be considered as a limitation that can cause problems in tuning. Model reduction causes process/model-mismatch, and it is possible that the controller design based on the reduced-order model does not work properly with the full-order process. The available design criteria may not be expressive enough to guarantee that the closed-loop system behavior is exactly what the designer has in mind.

Approximations can cause errors that deteriorate controller performance. The aforementioned problems can be avoided if the tuning method uses the full-order model, has a rich set of different design criteria, and does not make any harmful approximations. In practice, this means that a multi-objective criterion that depends on the dynamic behavior of a possibly high-order closed-loop system has to be optimized. Such an optimization task

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can be difficult and time-consuming to solve using conventional methods. In this paper a method based on the ideas of evolutionary computation is used to optimize the parameters of a PID controller.

The purpose of this research is to investigate an optimal controller design using the Evolutionary Programming. In this paper a new PID tuning algorithm is proposed by the Evolutionary Programming to improve the performance of the PID controller. The ultimate gain and the ultimate period were determined from a simple relay feedback experiment. The new tuning algorithm for the PID controller has the initial value of parameter KP, TI, TD by the Ziegler-Nichols formula that used the ultimate gain and ultimate period from a relay tuning experiment. And we compute the error of plant response corresponding to the initial value of parameter. The new proportional gain (KP), the integral time (TI) and derivative time (TD) were determined from a Evolutionary Programming. This Evolutionary Programming tuning algorithm for a PID controller considerably reduced the overshoot and rise time as compared to any other PID controller tuning algorithms, such as Ziegler-Nichols tuning method, Trial and error method and continuous cycling method. The process of EP and GA is explained in the figure.1.

In this project, the objective function is required to evaluate the best PID controller for the system. An objective function could be created to find a PID controller that gives the smallest overshoot, fastest rise time or quickest settling time. However in order to combine all of these objectives it was decided to design an objective function that will minimize the performance indices of the controlled system instead. Each chromosome in the population is passed into the objective function one at a time. The chromosome is then evaluated and assigned a number to represent its fitness, the bigger its number the better its fitness . The genetic algorithm uses the chromosomes fitness value to create a new population consisting of the fittest members. Each chromosome consists of three separate strings constituting a P, I and D term, as defined by the 3-row bounds declaration when creating the population . When the chromosome enters the evaluation function, it is split up into its three Terms. The newly formed PID controller is placed in a unity feedback loop with the system transfer function. This will result in a reduce of the compilation time of the program. The system transfer function is defined in another file and imported as a global variable. The controlled system is then given a step input and the error is assessed using an error performance criterion such as Integral square error or in short ISE. The chromosome is assigned an overall fitness value according to the magnitude of the error, the smaller the error the larger the fitness value.

5. Flow Chart of EP and GA:

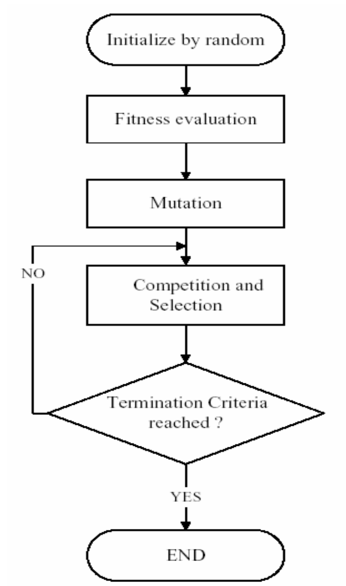
6. RESULTS AND DISCUSSION

The transfer function of the electric DC motor is in equation below [1]

$$\frac{(s)}{V(s)} \quad \frac{K}{L_a J s^3 \quad (R_a J \quad B L_a) s^2 \quad (K^2 \quad R_a B) s}$$

La = armature Inductance
Ra = armature resistance
K = motor constant
J = moment of inertia
B = mechanical friction

The parameters of the electric DC motor have the following value respectively, J=0.042, B=0.01625,



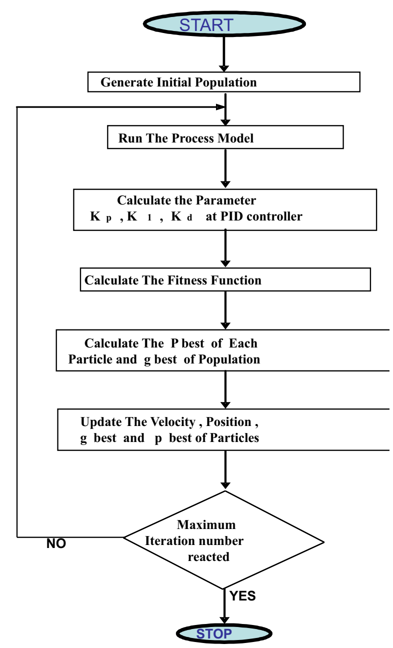


Figure:1 Flow Chart of EP and GA

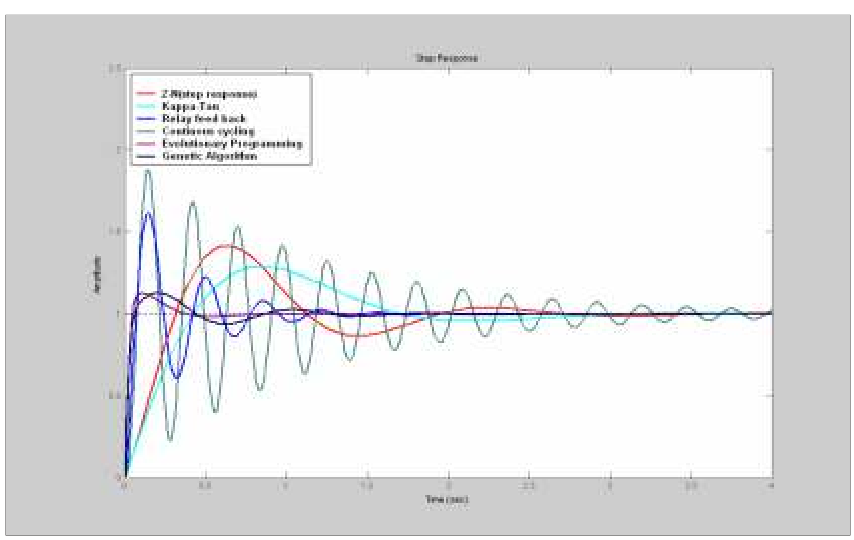


Figure2: Comparisons of All above Methods

K=0.9, L=0.025, R=5 as a nominal value.

The transfer function of the electric DC motor is[1]

$$P\ s \quad \frac{0.9}{0.00105s^{3} \quad 0.2104s^{2} \quad 0.8913s}$$

All the conventional methods of controller tuning lead to a large settling time, overshoot, rise time and steady state error of the controlled system. Hence an intelligent controller viz., Evolutionary programming is introduced into the control loop. Initially a population of 5 with 100 generations was used. The success rate of settling, rise time and peak overshoot was poor. Then the population was increased to 10 with 100 generations for a good success rate. Performance characteristics of process model were indicated and compared with the intelligent tuning methods as shown in the figure.2 and values are tabulated in table-I.

Performance Indices	Z-N (step response)	Kappa-Tau	Continuous cycling	Evolutionary programming	Genetic Algorithm
ITAE	3.3805	3.3113	7.82	0.0721	0.3781
IAE	0.5176	0.5188	0.56	0.4891	0.7712
ISE	2.3467	2.2503	3.2	1.0277	1.0435
MSE	0.0117	0.0112	0.016	0.0051	0.0052

Table1 Comparison of Performance Indices

Conclusion

The Soft Computing algorithm (GA&EP) for PID controller tuning presented in this research offers several advantages. One can use a- high-order process model in the tuning, and the errors resulting from model reduction are avoided. It is possible to consider several design criteria in a balanced and unified way. Approximations that are typical to classical tuning rules are not needed. Evolutionary programming is often critized for two reasons: algorithms are computationally heavy and convergence to the optimal solution cannot be guaranteed. PID controller tuning is a small-scale problem and thus computational complexity is not really an issue here. It took only a couple of seconds to solve the problem. Compared to conventionally tuned system, GA & EP tuned system has good steady state response.

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