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# IMPLEMENTATION OF EVOLUTIONARY ALGORITHM BASED PID CONTROLLER

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***ABSTRACT***

*Proportional-Integral-Derivative (PID) controllers are the most popular controllers in process control and most widely used controllers in industry because of their simplicity of architecture; easy theoretical analysis and implementation.PID have three adjustable parameters so different values of them make different step response, so an increasing cost of literature is devoted to proper tuning of PID controllers. The problem merits further investigation as traditional tuning methods make very large control signal and because of large control signal system can damage but evolutionary algorithms based tuning methods improve the factors of the closed loop performance and also amplitude of the control signal. In this paper studied evolutionary algorithms based tuning methods that is GENETIC ALGORITHM. To examine the validity of GA tuning method studied the DC motor plant. Simulation results reveal that evolutionary algorithms based tuning method have improved control signal amplitude and quality factors of the closed loop system such as rise time, integral absolute error (IAE) and maximum overshoot.*

***Keywords: Evolutionary Algorithm, Genetic Algorithm, Particle Swarm Optimization, PID Controller.***

## I. INTRODUCTION

PID controllers have three adjustable parameters, i.e. $K_P$ as proportional gain, $K_I$ as integral gain and $K_D$ as derivative gain. Through the years many methods have been proposed for tuning of PID controller parameters such as:

A). Traditional methods

B). Evolutionary Algorithms based methods

There are many traditional methods for tuning of PID controllers like Ziegler and Nichols tuning method and damped oscillation tuning method [1]. But using traditional tuning methods the performance of the closed loop system cannot be optimized. There are some evolutionary algorithms based tuning methods such as Genetic Algorithms (GA) [2], Ant Colony Optimization (ACO) [3] and Particle Swarm Optimization (PSO) [4]-[6]. Basically, GAs are inspired by biological systems' improved fitness through evolution [2]. A solution to a given problem is represented in the form of a string, called 'chromosome', consisting of a set of elements, called 'genes', that hold a set of values for the optimization variables [11].

In the case of genetic algorithm solutions of the optimization problem which is Kp, Ki and Kd are encoded to 0 and 1 bits. In this paper using GA based tuning methods in addition to reducing output error, making a faster response and optimizing quality factors of the system like rise time, maximum overshoot and settling time, control signal of the system is optimized.

The remainder of this paper is organized as follows, in section 2 Ziegler and Nichols tuning method which is a traditional method of PID tuning, genetic algorithms is discussed which is evolutionary method of pid tuning; in section 3 results and discussions will be taken where traditional methods and evolutionary algorithms based tuning methods are compared, and finally this paper is concluded in section 4.

## II. ZIEGLER AND NICHOLS TUNING METHOD

One of the most important traditional tuning methods is Ziegler and Nichols tuning method. This tuning method which is based on closed loop system first was proposed by Ziegler and Nichols [8]. In this method initially a proportional controller is set and its value is increased slowly to oscillate the system, this value of proportional controller and period of its oscillation respectively is called Ku and Pu. Using Ku and Pu the parameters of controller can be tuned as shown in Table I:

**Table I Ziegler and Nichols Closed Loop Tuning Method**

| Controller | parameters |
|---|---|
| P | $K_p = K_u/2$ |
| PI | $K_p = 0.45 * K_u$ , $\tau_i = 5/6 * P_u$ |
| PID | $K_p = 0.6 * K_u$ , $\tau_i = P_u / 2$ , $\tau_d = P_u /8$ |

where $\tau_i$ and $\tau_d$ are respectively called integral time constant and derivative time constant and $K_i = K_p / \tau_i$ and $K_d = K_p * \tau_d$.

In 1942 Ziegler and Nichols, both employees of Taylor Instruments, described simple mathematical procedures, the first and second methods respectively, for tuning PID controllers. These procedures are now accepted as standard in control systems practice. Both techniques make a priori assumptions on the system model, but do not require that these models be specifically known. Ziegler-Nichols formulae for specifying the controllers are based on plant step responses.

A).The first method:

The first method is applied to plants with step responses of the form displayed in Figure 4. This type of response is typical of a first order system with transportation delay, such as that induced by fluid flow from a tank along a pipe line. It is also typical of a plant made up of a series of first order systems. The response is characterised by two parameters, *L* the delay time and *T* the time constant. These are found by drawing a tangent to the step response at its point of inflection and noting its intersections with the time axis and the steady state value.

The plant model is therefore

$$G(S) = \frac{ke^{-sL}}{Ts+1} \qquad (1)$$

B). The second method:

The second method targets plants that can be rendered unstable under proportional control. The technique is designed to result in a closed loop system with 25% overshoot. This is rarely achieved as Ziegler and Nichols determined the adjustments based on a specific plant model.

The steps for tuning a PID controller via the 2nd method is as follows:

Using only proportional feedback control:

1. Reduce the integrator and derivative gains to 0.
2. Increase *Kp* from 0 to some critical value *Kp=Kcr* at which sustained oscillations occur. If it does not occur then another method has to be applied.
3. Note the value *Kcr* and the corresponding period of sustained oscillation, *Pcr*

## III. GENETIC ALGORITHM

In the case of genetic algorithm solutions of the optimization problem which is $K_P$ , $K_I$ , $K_D$ are encoded to 0 and 1 bits. In the first generation a population of chromosomes is generated initially and in each generation GA searches for the best solutions in the solution space. In each generation three main operators which are mutation, crossover and selection operates on the algorithm. Selection operator moves the best solutions of the generation which have the minimum value of cost function $f$ to the next generation so it helps the algorithm to converge to the optimum solution of the algorithm.

Cost function = min $f(K_P, K_I, K_D)$

Note that $f$ *is* a general function in terms of Integral Absolute Error, Integral Square Error, Maximum Overshoot and control signal. In section three, $f$ is introduced in three forms of minimizing ISE, ISE + Mp and ISE + Mp + Control signal. Crossover combines two individuals and produces two new individuals and moves them to the next generation while mutation operates on one individual to produce a single new individual. In each generation after operating mutation, crossover and selection operator, the solutions are applied to the specified cost function.

PID controller parameters will be optimized by applying GA. Here we use Matlab Genetic Algorithm Toolbox [6] to simulate it. The first and the most crucial step is to encoding the problem into suitable GA chromosomes and then construct the population. Some works recommend 20 to 100 chromosomes in one population. The more the chromosomes number, the better the chance to get the optimal results. However, because we have to consider the execution time, we use 80 or 100 chromosomes in each generation. Encoding is done in real number rather than binary encoding because the latter discards the parameters value if it exceeds its precision capability. Each chromosome comprises of three parameters, *Kd, Kp, Ki*, with value bounds varied depend on the delay and objective functions used.

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## IV. RESULTS AND DISCUSSIONS

A frequently cited case study i.e. DC motor is considered, so transfer function of that

$$G(s) = \frac{\theta(s)}{V(s)} = \frac{0.9}{0.00105s^3 + 0.2104s^2 + 0.8931s}$$

The following PID coefficient is calculated by Ziegler and Nichols tuning method:

$K_P = 119.07$

$K_I = 1102.5$

$K_D = 3.22$

In genetic algorithms and particle swarm optimization case we have chosen three different cost functions which are:

1). Optimizing Integral Square Error (ISE)

$$f = \sum_{i=1}^{\inf} (y(i) - y_{sp})^2 \qquad (2)$$

2). Optimizing integral square error and maximum overshoot(ISE + MP)

$$f = c_1 * \sum_{i=1}^{\inf} (y(i) - y_{sp})^2 + c_2 * \text{abs}(\max(y) - y_{sp}) \qquad (3)$$

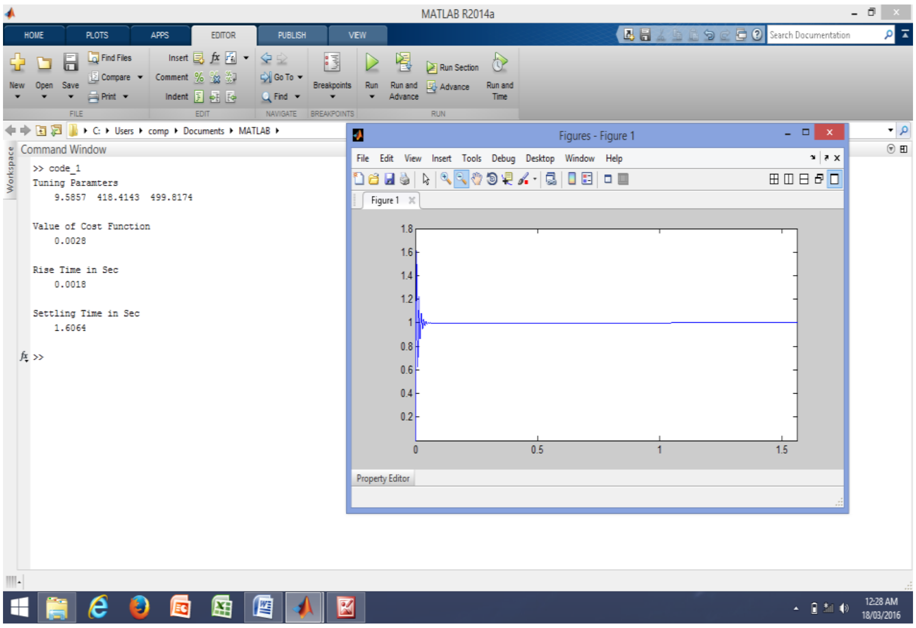


**Figure 1 – Optimization Based On 1).**

3). Optimizing Integral Square Error, Maximum Overshoot and Control Signal (ISE + Mp + Control Signal)

$$f = c_3 * \sum_{i=1}^{\inf} (y(i) - y_{sp})^2 + c_4 * \text{abs}(\max(y) - y_{sp}) + c_5 * \sum_{i=1}^{\inf} (u(i) - u_{sp})^2 \qquad (4)$$

Where $C_1$ , $C_2$ , $C_3$ , $C_4$ and $C_5$ are constant weights.

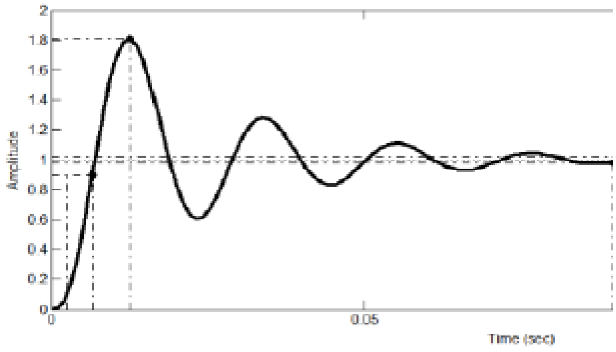


**Figure 2 – Output of Z & N Method**

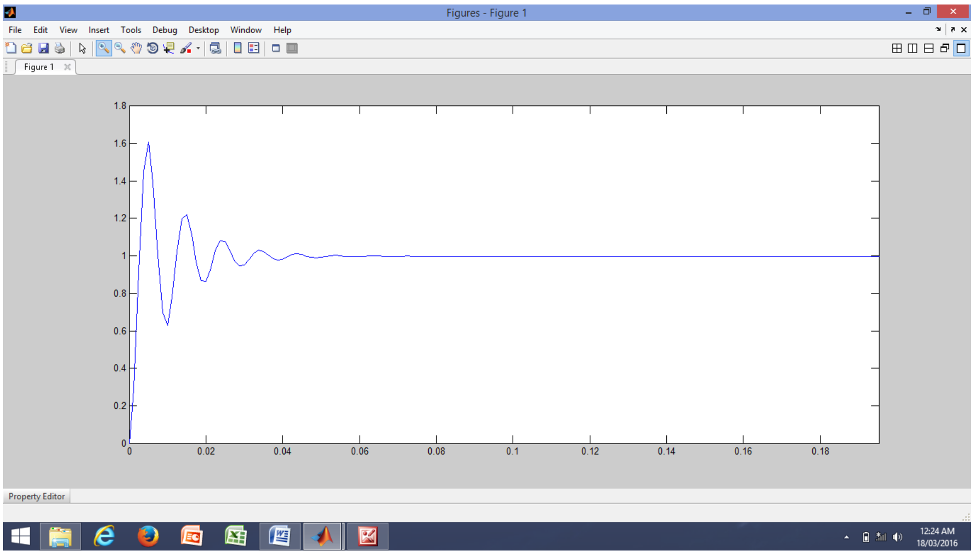


**Figure 1.1**

Based on fig 1). & 2)., it is observed that Ziegler and Nichol tuning methods make a large settling time and overshoot whenever GA makes small.also makes a fast response in the comparison with Z&N tuning method.

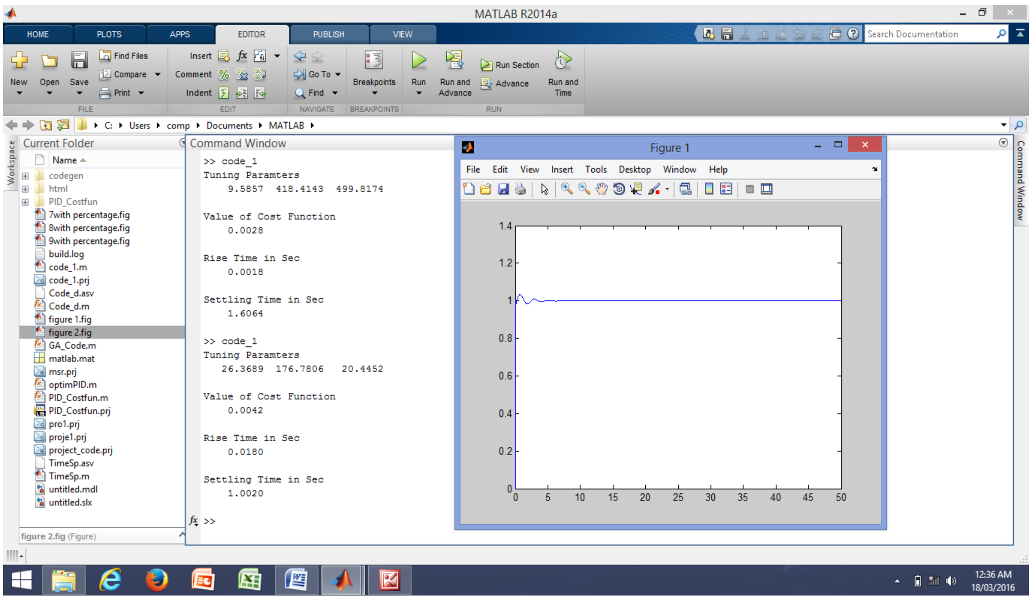


**Figure 3 – Optimization Based on 3).**

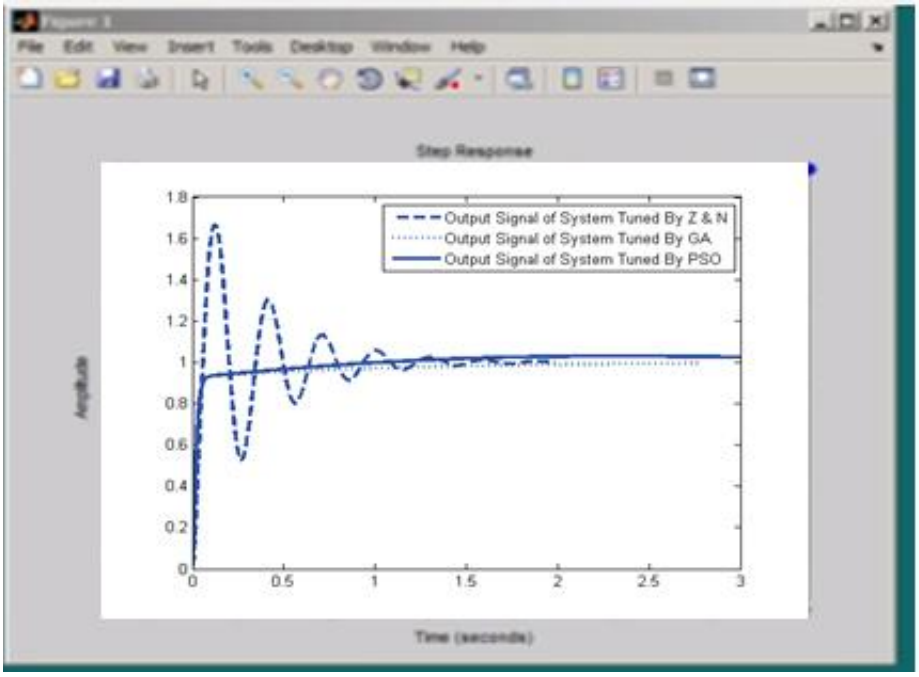


**Figure 4 – Comparision of Tuning Methods**

According to fig. 3) , this is optimized with integral square error and maximum overshoot.In fig. 4).,comparision of three tuning method observed that Ziegler and Nichols tuning method have made a large overshoot and settling time while GA and PSO based tuning method are fast and perfectly optimize settling time, overshoot.

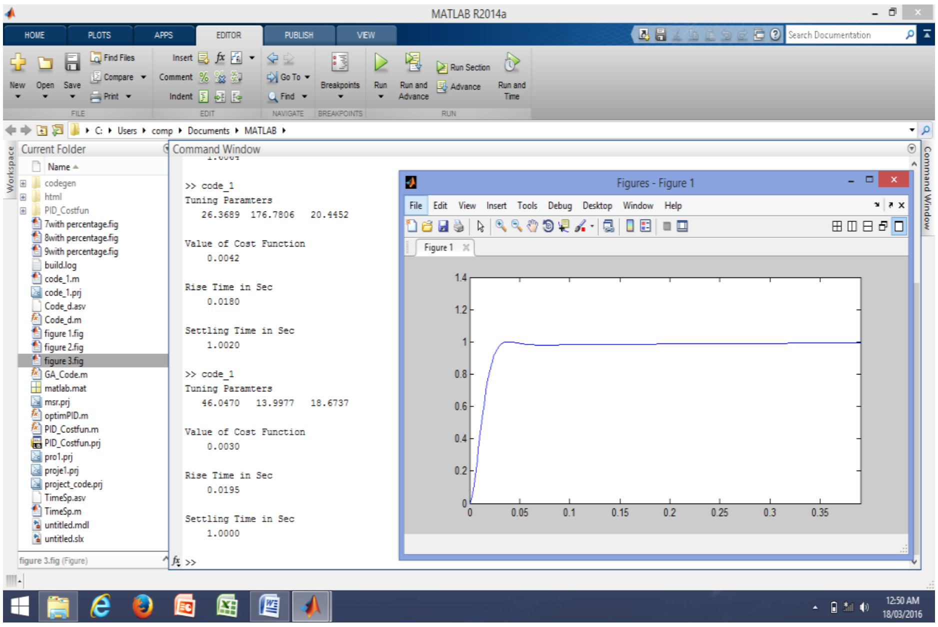


**Figure 5 – Optimization Based on 5).**

From fig. 5). It is obvious that $k_i$ & $k_d$ decreases because of the this is optimizing with the integral square error, maximum overshoot and control signal.GA is really a perfect optimizing for quality factors.

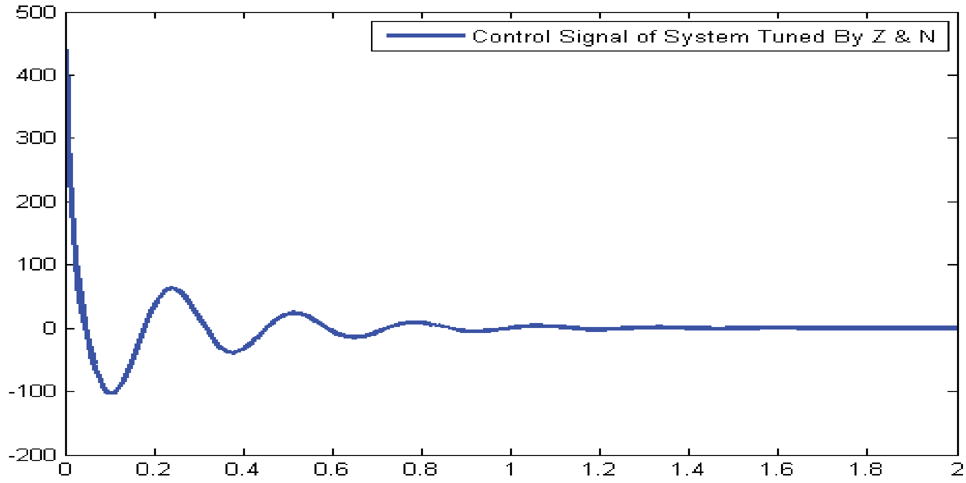


**Figure 6 – Control Signal of System Tuned By Z &N**

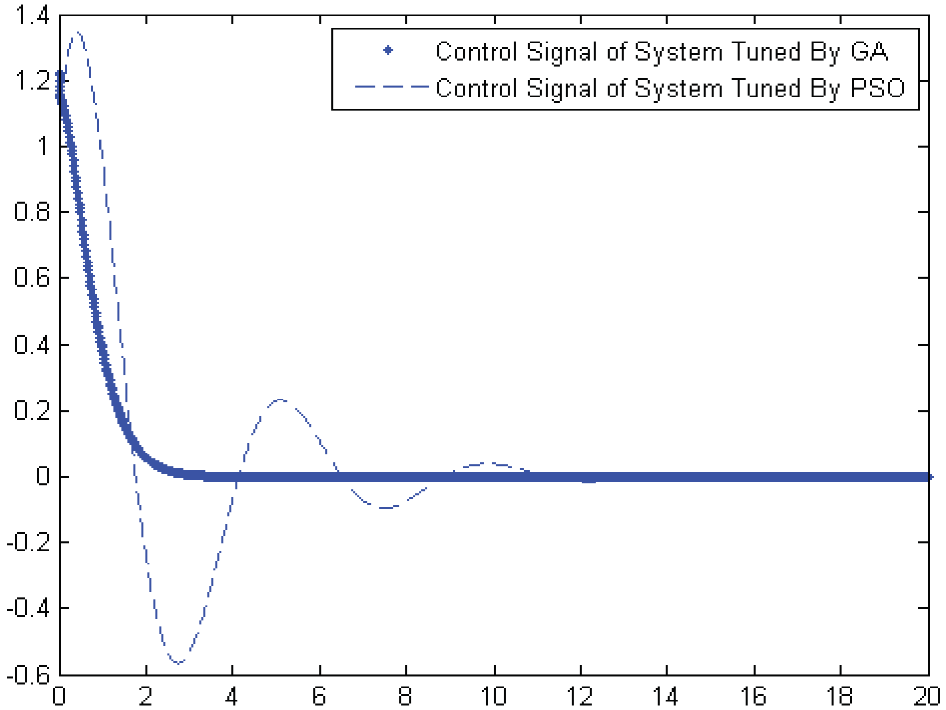


**Figure 7 – Control Signal of System Tuned By Ga & Pso**

Fig. 6 shows that Z&N tuning method made a large control and its range of variation is about 500 which can damage the system so Z&N tuning method is poor in optimizing control signal while as shown in Fig. 7 the evolutionary algorithms based tuning method made a smooth control signal which its range of variation is about 2. Control signal of Z&N tuning method is 250 times larger than evolutionary algorithms based tuning method so evolutionary algorithms based methods can be used for optimizing control signal.

## V. CONCLUSIONS

Ziegler and Nichol which is traditional method and genetic algorithm which is evolutionary algorithm based PID tuning is studied in this paper. In this traditional tuning method needs a first order plant or small order while evolutionary algorithm uses a higher order plant model. In this paper using GA based tuning methods in addition to reducing output error, making a faster response and optimizing quality factors of the system like rise time, maximum overshoot and settling time, control signal of the system is optimized. Finally, it can be concluded that GA based tuning method provides better results compared to the traditional especially in terms of settling time and maximum overshoot.

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