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Smart Controlling Technique For Rotating Electrical Machine Using Genetic Algorithm With Multi-Objetive Function

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Abstract— The requirement of better control strategy for electric motor drives is speedily increasing in every field like electrical vehicles, traction and all the processing industries. Controller based on artificial intelligence technique could be the best controller for better transient as well as steady state response of the motor. The main objective of this paper is to analyse and implement the Artificial intelligent technique i.e Genetic Algorithm using multi-objective function to tune PID controller parameters and estimate their advantages over conventional tuning techniques. This technique is applied and analysed on a third order plant of a DC servo motor with main focus on developing a speed controller. Objective functions used are ITSE (integral time square error), MSE (mean square error), ISE (integral square error) and Vectored fitness function. Results obtained from GA with multi-objective functions are compared with conventional methods like Ziegler-Nichols method. It was found that GA with multi-objective function outperformed GA with single objective function and traditional tuning practices of Ziegler-Nichols tuning of PID controllers.
Keywords—DC servo motor, Genetic Algorithm (GA), multi-objective function, PID controller tuning, Ziegler-Nichols (ZN)

I. INTRODUCTION

In most of the process control industries, mostly loops of control systems are based on Proportional-Integral-Derivative (PID) controllers. The basic and simple design of PID controller makes it easygoing to regularize the response of the system. PID controllers are being broadly used in every field where control action is required because it is easy to tune, less requirements, simplicity and its less maintenance. Moreover well-ordered fine-tuning and design methods leads to an efficient and optimal operation of the PID controller in order to regularize the different parameters of process to be controlled and are economically important for process industry.

The chief objective of this paper is to employ and analyze the intelligent technique that is Genetic Algorithm using multi-objective (GA-MO) function for optimal tuning of parameters of PID controller and enumerate its advantages over conventional tuning methods[1]. Moreover Genetic Algorithms are well-organized and quick choice at obtaining the optimal solution among the space of all best results[2] . We are using Genetic Algorithm with multi-objective function (vectored fitness function) in this paper to find the optimal parameters of the PID controller: K_p (proportional gain), K_d (derivative gain) and K_i integral gain. Genetic Algorithm (GA) is an adaptive heuristic search and optimization technique grounded on evolutionary approximations of natural selection genetics. Concept of GA is based on Darwins theory of survival of the fittest [3]. We are using Performance indices like ITSE (integral time square error) and MSE (mean square error) and ISE (integral square error) to make single multi-objective function in the form of vectored sum to minimize the error to give better response[4]. We are using a third order transfer function of a DC servo motor in this research to get better steady-state as well as transient response. DC servomotor (Armature controlled) is fed with GA-PID controller to control its operation where the desired performance parameters assigned by the user successfully satisfied, so the fitness functions used for determination of the optimum controller parameters are as follows

$$\text{MSE } (E_1) = \frac{1}{N}\sum_{i=1}^{n}(e(t))^2 dt \quad (1)$$

$$\text{ISE } (E_2) = \int_0^t (e(t))^2 dt \quad (2)$$

$$\text{ITSE } (E_3) = \int_0^t t(e(t))^2 dt \quad (3)$$

$$J\ (K_p\ K_i\ K_d) = w_1E_1 + w_2E_2 + w_3E_3 \quad (4)$$

Where, E is the new multi-objective function that is vectored fitness function. It is sum of product of weights given w_1, w_2, w_3 and performance indices E_1, E_2, E_3 given in equations (1), (2) and (3). Here, we are putting weights w_1= 0.2, w_2= 0.2, w_3= 0.6.

II. DC SERVO MOTOR MODELING

As for reference, armature controlled DC servo motor shown in Fig.1 is considered from the point view of control system it is third order linear single input single output system.

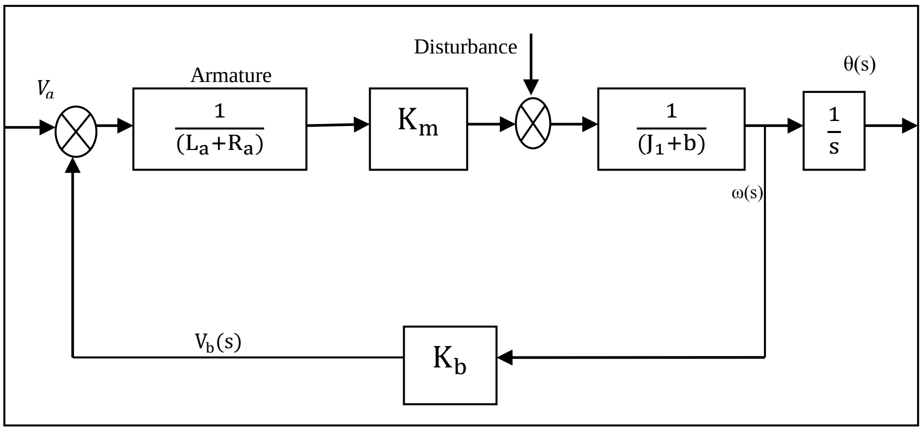

Figure 1.Block Diagram of DC Servo Motor

It has been proved that DC servo motor has better position and speed control. We can easily find the relationship between the voltage input '$V_a(s)$' and motor speed 'ω(s)' and in between voltage input '$V_a(s)$' and shaft angular position 'θ(s)' after converting the mechanical constants into electrical constants with the help of force voltage analogy.

The transfer function of DC servo motor for angular position control is shown below:

$$\frac{\theta_1(s)}{V_a(s)} = \frac{K_m}{s[(L_a+R_a)(J_1S+b)+(K_mK_b)]} \quad (5)$$

or

$$\frac{\theta_1(s)}{V_a(s)} = \frac{K_m}{L_aJ_1s^3+(L_ab+R_aJ_1)s^2+(R_ab+K_mK_b)s} \quad (6)$$

Here, $\theta(s)$ is the output in the form of angular displacement and $V_a(s)$ is the input armature voltage to the system.

Several parameters shown in equation(6) are as follows:-

J_1 Moments of inertia	(0.02kg.m^2)
b Viscous friction constant of motor	(0.1-N.m.s)
K_b Back emf gain constant motor	(0.1-V/rad/sec)
K_m Torque gain constant motor	(0.01-N.m/Amp)
R_a Resistance of armature core	(2.0-Ohm)
L_a Inductance of armature core	(0.5-H)

After putting all these parameter values in equation(6) we got the overall transfer function of the plant system given below:

$$\frac{\theta_1(s)}{V_a(s)} = \frac{0.1}{s(0.01s^2 + 0.09s + 0.21)} \quad (7)$$

or

$$\frac{\omega_1(s)}{V_a(s)} = \frac{0.1}{(0.01s^2 + 0.09s + 0.21)} \quad (8)$$

III. THE PID CONTROLLER

The PID controller determines the value of controlled variable, compares the actual value of the desired value (reference), computes the deviation and produces a control signal that will melt off the deviation to zero or to a smallest possible value. The method by which the PID controller produces the command signal is called mode of control or control action. PID controller is a combination of three controller actions namely the proportional controller, derivative controller and integral controller. These are denoted by K_i, K_p and K_d and Values of these parameters will improve the overall steady state as well as transient response of the system i.e. settling time, reduce overshoot, rise time and steady state error. The transfer function of PID controller is shown:-

$$C(s) = \frac{U(s)}{E(s)} = K_p + \frac{Ki}{s} + K_d s \quad (9)$$

Block diagram of a general PID controller is demonstrated in Fig.2 given below. Input to this controller is an error signal which is the remainder of actual and set value, actuate the PID controller with the resulting signal weighted and summed to form the control signal U(s), to control the plant. We will get the new control signal and again new error signal will be computed. Then new control signal will be sent to the plant contineously until the steady state response reduces to tollerence band of 2% to 5%.

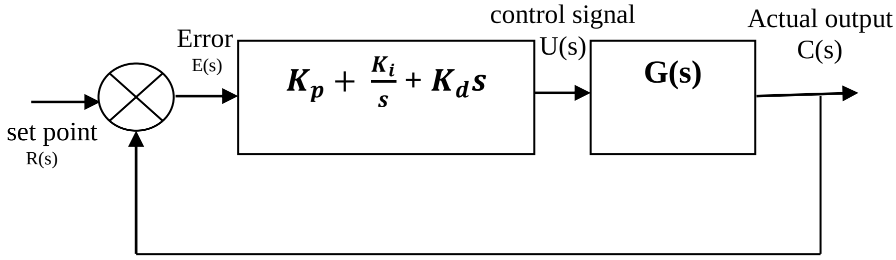

Figure 2. PID Controller Representation

IV. METHODOLOGY

4.1 Ziegler-Nichols Method

Ziegler-Nichols scheme for PID controller tuning is the classical method which is widely practiced for designing several controllers. Ziegler and Nichols confronted two methods of designing a controller, one is step response method and another one is frequency response method. In this paper step response method is used to tune the controller.

4.2 Implementation

In this scheme integral time T_i will be specified to infinity (∞) and derivative time will be specified to the zero (0). This is done to set out the initial setting of the initial setting of the system. After putting all these parameter values we have to increase the proportional gain until the point of instability is achieved i.e. sustained oscillation occurs, so we can achieve the critical gain value K_c. Thereafter we need to compute the oscillation frequency which can easily find with the help of Routh-Hurwitz stability criterion T_c.

$$T_i = \frac{1}{K_i} \quad (10)$$

$$T_d = K_d \quad (11)$$

Moreover the values of PID controller gains parameters K_p , K_d, K_i can easily be computed with the help of ZN-Table below:

Table 1- Ziegler-Nichols Tuning Table

Controller	**K_p**	**T_i**	**T_d**
P	0.5 K_c	∞	0
PI	0.45 K_c	0.833T_c	0
PID	0.6 K_c	0.5 T_c	0.125 $_c$

4.3 Genetic Algorithm

The idea of evolutionary computing was innovated in 1960 by scientist I.Rechenberg in his research work 'Evolutionary Strategy'. Genetic algorithms are computerized search and optimization algorithm grounded on the mechanics of natural genetics and natural selection. Prof Holland of university Michigan projected the concept of these algorithms in the mid sixties and brought out his seminal work. Genetic algorithm are advantageous at taking a larger, potentially vast, search spaces and navigating them looking for optimal compounding of things and results which we might not find ever.

GA starts with multiple points which contain number of chromosomes to a problem and its functioning is appraised based on some fitness function. Grounded on its fitness value, chromosomes belongs to parents are selected to undergo three natural stages i.e. selection, crossover, and mutation.
While implementing Genetic Algorithm, first thing we have to do is specification of all necessary initializing GA parameters like lower bounds, upper bounds, number of iterations required, population size, cross over fraction, mutation fraction etc. Table 2 gives the initial GA parameters considered in this work.

Table 2- GA Initialization

Parameters	**Values**
Lower bound[K_p, K_i, K_d]	[0 0 0]
Upper bound[K_p, K_i, K_d]	[50 50 50]
Stopping criteria(iterations)	100
Population Size	40
Crossover Fraction	4
Mutation Fraction	0.08

The step wise implementation of the GA algorithm for PID parameter tuning is given as under:-

Step 1. Establish initial population P(t).

Step 2. Evaluate the fitness of each chromosome or string in population P(t). Evaluate the fitness function which can be inverse of error function.

Step 3. Select the best fit solution. Select next iteration population P(t+1) of previous stage from population according to their fitness value.

Step 4. Apply crossover to selected member pairs off and mate individuals in P(t+1) as parents to generate new off springs.

Step 5. Apply mutation by slightly changing some random solution.

Step 6.Repeat step 2-5 until the number of iterations has been reached to max value. Note down the optimized 'K_p, K_i, K_d', values.

Step 7. Now perform the closed loop operation with GA-PID and plant system and calculate the time domain specification for the system.

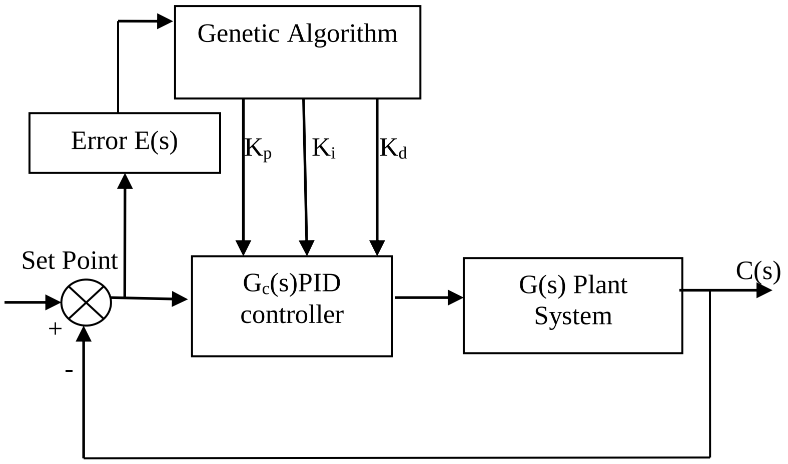

Figure 3. Block diagram for GA-PID controller

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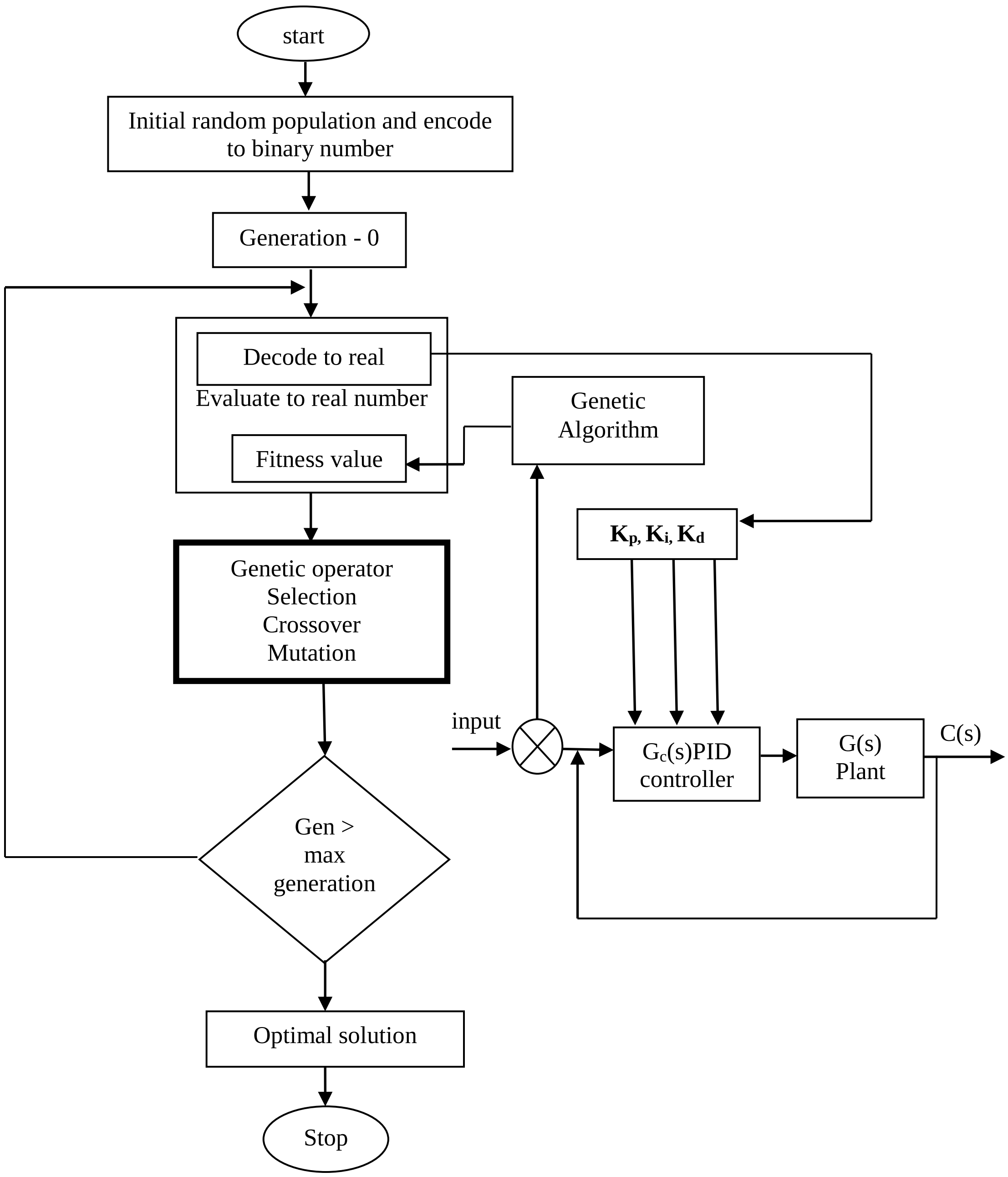

Figure 4. Flow chart of genetic algorithm for PID tuning

V. RESULTS

The Genetic algorithm based PID controller tested on the given plant. The parameters which is to be optimized are the PID gains i.e proportional gain, Integral gain and Derivative Gain. The Genetic algorithm required a fitness function which is to be optimized with respect to the given parameter. Three single objective functions and two multi-objective functions are considered one at a time. Single objective function includes the ITSE, ISE and MSE. There are basically two way to use multi-objective genetic algorithm one is to use vectored fitness function and second is to be as separate fitness function and used for Pareto Optimal solution. The comparison of time responses is given in figure 5 and the time specifications are given in table 3. It is clear from the figures that vectored objective function gives best result as compaired to the other objective function. However ISE gives best settling time for tollerence band 2% but slower rise time. The Vectored objective function gives

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best settling time if we consider 5% tolerance band and faster rise time as compaired to the other fitness function

Table3. Comparison of Results

	Conventional Topologies		**Proposed Topologies**				
Paremeters	*ZN*	*PSO*	*MSE*	*ITSE*	*ISE*	*Pareto solution*	*Vectored Function*
Rise time	0.0813	0.343	0.0863	0.0897	0.1004	0.0570	0.0486
Settling time	2.3630	7.190	0.4604	0.4679	0.4324	0.5048	0.4840
Settling min	-	-	0.9017	0.9023	0.9015	0.9019	0.9018
Settling max	-	-	0.9977	1.0010	1.0008	0.9966	0.9977
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

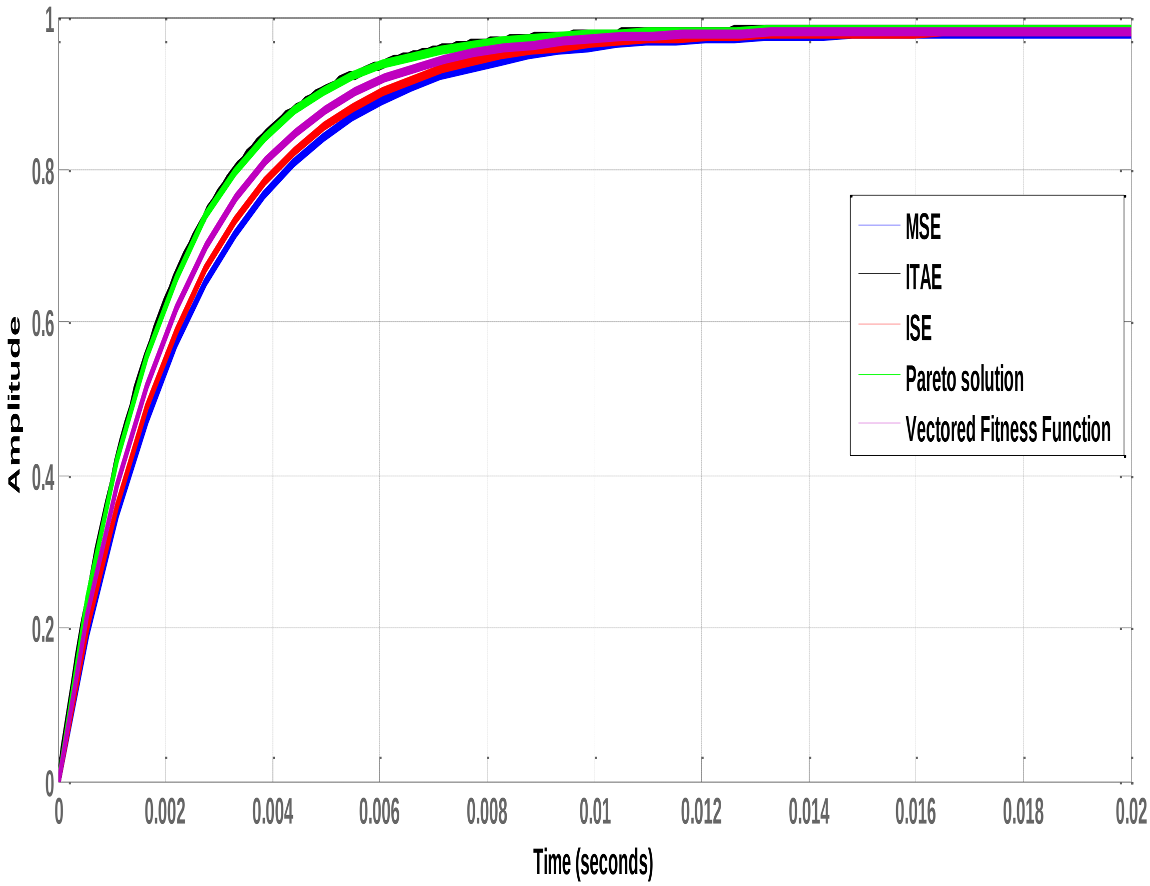

Figure 5 .Comparison of Step Response For Different Objetive Functions

VI. CONCLUSION

In this paper, we used Genetic Algoritm technique to minimize the single and multi-objective functions to get optimiezed value of PID controller gains. Results compared with conventional tuning. It is found that application of Genetic Algorithm with multi-objective fitness function gave better steady-state as well as transient response than conventional techniques.

REFRENCES

[1] Aishwaya Yadav, Sulochana Wadhwani,” Genetic Algorithm Based Intelligent Control Technique for Rotating Electrical Machine”, *International Journal of Engineering Research and application*, ***13****(3),* 2014, ISSN:2448-9622.

[2] Aishwaya Yadav, Sulochana Wadhwani, “PSO Based Intelligent Tuning Of PID controller for DC servomotor”, *International Journal of scientific Engineering and technology Research*, ***15****(3),* 2014, ISSN:2319-8885

[3] S. Rajasekaran, Vijaykakshmi Pai, *Neural Networks, Fuzzy logic, and Genetic Algorithm synthesis and Application* (PHI Learning Pvt. Ltd., New Delhi, 2012).

[4] K. J. Astrom and T. Hagglund, “Automatic Tuning of PID Controllers*”*. 1988: Instrument Society of America.

[5] J. G. Ziegler and N.B. Nichols, “Optimum Settings for Automatic *Controllers”*. *ASME Transactions*. **64**(8): p. 759–768, 1942.

[6] G. Saravanakumar, R.S.D. Wahidhabanu, and V.I. George, Robustness and Performance of Modified Smith Predictors for Processes with Longer Dead-Times. *International Journal on Automatic Control and System Engineering*. **6**(3), 2006

[7] K. J. Astrom, Automatic Tuning and Adaptation for PID Controllers - A Survey. *Control Engineering Practice*. **1**(4): p. 699-714, 1993.

[8] T. Jain and M.J. Nigam, “Optimisation of PD-PI Controller Using Swarm Intelligence. *Journal of Theoretical and Applied Information Technology*, **4**(11): p. 1013-1018, 2008.

[9] J. S. Kim,“Auto Tuning PID Controller Based on Improved Genetic Algorithm for Reverse Osmosis Plant”. In Proceedings of the World Academy of Science and Engineering. 2008.

[10] P. B. De Moura Oliveira, “Modern Heuristics Review for PID Control Optimization: a Teaching Experiment*”*. In Proceeding of International Conference on Control and Automation. 2005. Budapest, Hungary.

[11] G. H. Cohen and G. A. Coon, “Theoretical Consideration of Retarded Control”. *ASME Transactions*. **75**: p. 827–834, 1953.