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A Method to Determine the Optimal Parameters for PID Controller

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***Abstract* — PID parameters optimization is the most important problem in control field. Applying Genetic algorithms promises of a better future. This paper presents a new method for determining PID controller parameters using Genetic Algorithm (GA) and apply this method for fan-and-plate model. The result shows the good control quality of the system**

***Index Terms* — PID controller, Genetic Algorithm, Fan-and-plate model**

I. INTRODUCTION

The fan-and-plate system includes a hinged rectangular plate and a variable speed fan. The angular orientation of the plate is controlled by blowing an air stream from the fan, using a DC motor. The rotation angle of the rectangular plate is determined through a low-friction potentiometer

Figure1. Fan-and-plate system

This fan-and-plate system contains rich dynamics: model has a strong nonlinear, because the plate acts as pendulum, the air stream contact area changes based on the angle of the plate… The important dynamics of the system: fan motor time constant; air transportation lag; non-minimum phase response. By varying the position of the fan relative to plate, the lag time constant and the load of the plate can be changed, which affect the dominant time constant of the system. Also, the fan-and-plate system is easily be influenced by the air turbulence around the plate and the air stream through the plate itself. These bring many challenges to the plate angular orientation control problem. The model also can be used to practice many other control algorithms.

The evolution of technology enables us to create new modern algorithms with the high control quality, robustness to noise and model variance but, they often require the complex control structure, causing the difficulties in implementation of the controller. The PID controllers although can not guarantee a high stability and quality control for the complex system, strong nonlinear, but provides a simple structure, easy implementation and robustness, so was applied in almost all the industrial processes.

There are so many methods to determine the PID controller parameters: Ziegler – Nichols method, Cohen-Coon method, using Genetic Algorithm … Each of them have different advantages and applications. In this paper, a transfer function model of fan-and-plate system is constructed through experiment, after that, applied the GA to find the optimal parameters for the PID controller of the system.

II. FAN AND PLATE DYNAMIC MODEL

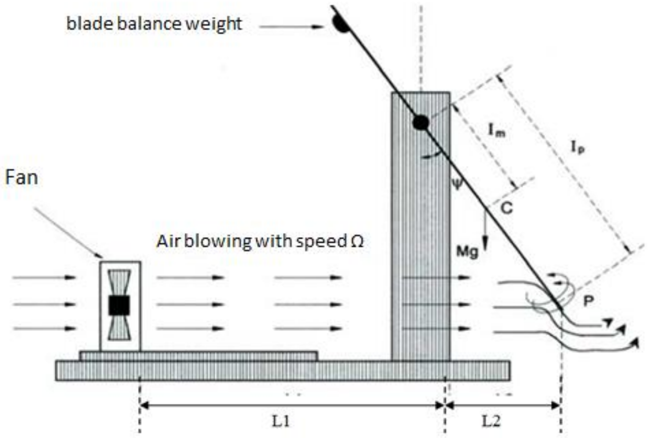

Figure 2. Diagram of fan and plate system

Where:

Ψ : The angle formed by the plate and the vertical axis

M_g : Mass of the plate (with counterweight)

C: centroid of the system

P: applied pressure to the plate

Ω: air stream velocity

Fan and plate model comprises 3 main parts: fan block, air stream dynamic block and plate block

* Fan block are expressed:

$$T_1 \frac{d\Omega(t)}{dt} + \Omega(t) = K_1 V(t) + C_1 \quad (1)$$

Where: T_1 the time constant

K_1 steady state gain

C_1: initial condition constant

* The air stream dynamic block: express the relationship between air stream velocity Ω and the pressure applying to the plate. When Ω changes, there are 2 parameters need to be taken care of: plate rotation lag, the air turbulence under and around the plate. We consider these parameters as

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transportation lag, a square-root nonlinear and orientation-dependent dynamic.

* Plate block: express the relationship between Ψ and P. Consider plate as physical pendulum. The plate dynamic model:

$$J\frac{d^2\Psi}{dt^2} = -Mgl_M \sin\Psi - b\frac{d\Psi}{dt} + PAl_p\cos\Psi \qquad (2)$$

Where:

J: rotational inertia of hinge

A: Effective area of plate

b: Damping coefficient

It can be seen from the equation that the fan-and-plate system dynamic model is very complex. To design the PID controller, we need the linear dynamic model of the system. We use the System Identification Toolbox in Matlab.

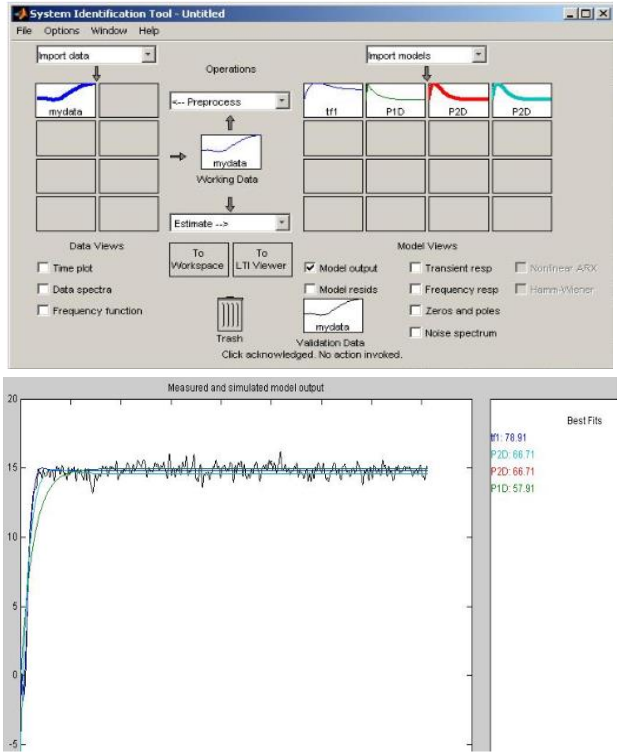

Figure 3. *Identify fan and plate system.*

we obtain the fan-and-plate system transfer function:

$$G(S) = \frac{-0,939S + 1,84}{S^2 + 1,823S + 0,6633} \qquad (3)$$

III. PID PARAMETERS OPTIMIZATION

3.1 GA genetic algorithm

GA [1-5] is a global random search method inspired by the basic principles of natural evolution processes. Genetic algorithms are commonly used to generate high-quality solutions to optimization and search problems by exploiting the evolution process (selection, crossover and mutation).

By starting at some individuals and parallel implementation, GA avoids the local minima as well as the convergence to sub-optimal solutions. For this reason, GA can provide the high performance location in complex spaces without any difficulties related to the dimension of the space as gradient techniques, or derivative-based optimization methods.

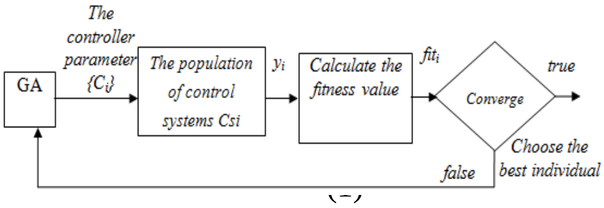

Figure 4. Parameter optimization using GA

A genetic algorithm is generated with a random initial population including 20-100 individuals. Each individual is expressed by a sequence of real number or binary number called chromosome. Each chromosome in the population is evaluated by the objective function. The objective function assigns each chromosome a value, called a fitness value. In this way, the algorithms can be applied to find the optimal chromosome (selection, crossover and mutation).

Figure 4 describe the use of GA to find the optimal parameters for the controllers. Chromosome *{Ci}* represents a parameter of the controller *{CSi}*. The chromosome adaptation is evaluated by fitness function through the values fit_i. Chromosome C_i will be the most optimal if its value fit_i is smallest. If the convergence is guaranteed, we will obtain the chromosome providing the most optimal parameter for the controller.

Here, the adaptation functions are expressed:

$$\text{IAE: } J_1 = \int e^2(t)dt \to \min \qquad (3)$$

$$\text{MSE: } J_3 = \frac{1}{N}\sum_{i=1}^{N} e_i^2(t) \to \min \qquad (4)$$

In which, IAE, MSE are the controller performance metrics, e(t) is the difference between the set-point and the feedback signal.

3.2. PID parameter optimazation using GA

Run GA with 50-100 individuals for PI controller, to get two parameters K_1 and K_2 , respectively.

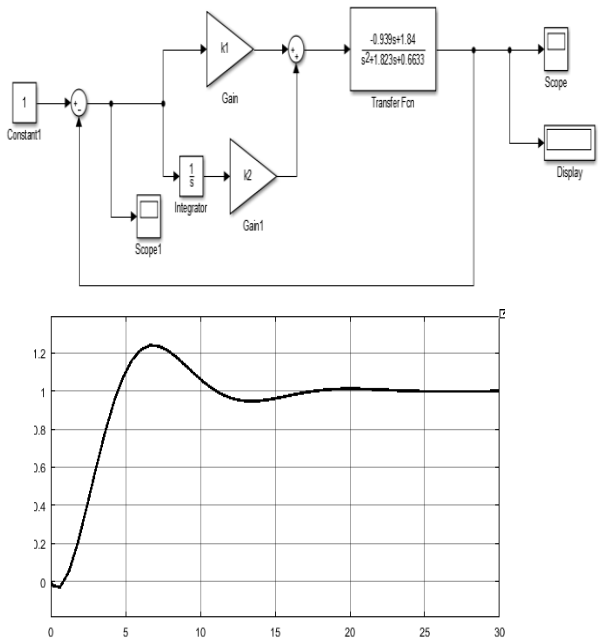

Figure 5. PI Parameter optimization using GA

We obtain the optimization value is 9,79641 and the optimal function is at:

$$x = [K_1 \ \ K_2] = [0,2705 \ \ 0,0847] \qquad (6)$$

IV. Experimental Results

Apply the parameters above for the real model, the result is as follows:

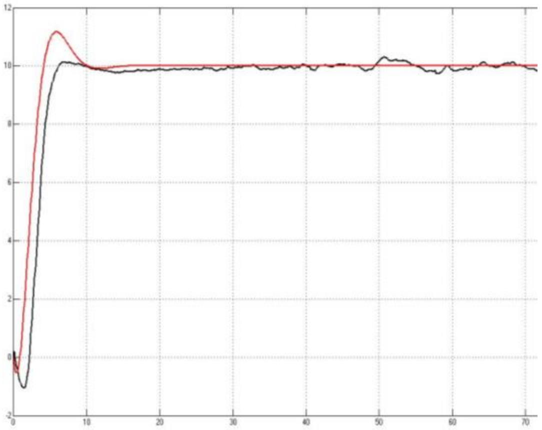

Figure 6. The setpoint value is 10^o

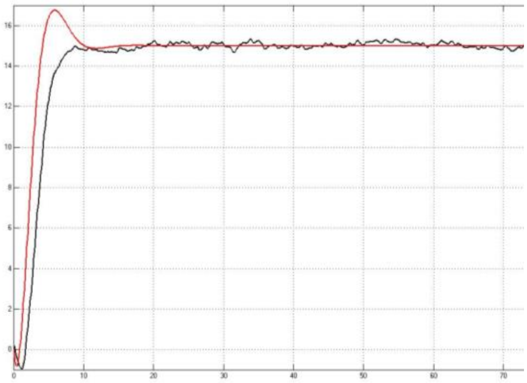

Figure 7. The setpoint value is 15^o

Comment: The experimental results on the real fan-and-plate model show the good quality of the acquired controller

V. Conclusion

This paper illustrate a method to determine the optimal parameters for the PID controller using GA, experimental results indicate that the presented approach works effectively, and provides a good dynamic response of the fan-and-plate system.

These experimental results reveal that the use of GA in determining the optimal parameters for the PID controller is effective. Hence, the proposed method seems to be particularly appropriate to use as one of the PID parameters optimization methods.

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