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# Analysis and Simulation of PI and PID Control Systems Using Xcos Scilab

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**Abstract.** Research has been conducted to analysis and simulation of PI and PID control systems using Xcos-Scilab. It focused on the constant value of kp, ki, and kd in the P, PI and PID control system simulation. The system output was set into a step signal so it will be analyzed with transient response method. For comparison, the PID control system with the Ziegler-Nichols tuning method was also used. It has been done in order to find out whether the Trial and error method is more appropriate to use in the in the PID control system simulation or not. The plant used is the Servo Motor Model with transfer function $G(s) = 1.74/0.0268s^2 + s$. The results from the analysis of the variation of simulated control system constants, the best parameters are: P (P variation): Kp = 7, PI (P Variation): Kp = 8; Ki = 2, PI (I Variation): Kp = 5; Ki = 5, PID (P Variation): Kp = 60; Ki = 5; Kd = 2, PID (I Variation): Kp = 50; Ki = 1; Kd = 5, PID (D Variation): Kp = 50; Ki = 10; Kd = 2.

**Keyword:** PID, plant, system response, trial and error, Xcos-Scilab, Ziegler-Nichols.

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## 1 Introduction

Control systems or control systems have a very important role in every application of technology in life. Humans need control of the machines to get the results they want. But there are times when humans can't always be present to control machines. Therefore, an automatic control system was developed [1-7].

One of the most widely used control systems in the industry is PID control (Integral Proportional and Derivatives). PID control is a combination of three kinds of controls, namely proportional controller, integral controller, and derivative controller. Third parameter P, I and D each have different actions to the system response and are influenced by the controlling constants (Kp, Ki, and Kd) [8-12]. Based on this, the authors conducted research on the

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simulation of control system and control system that will be compared with the response, namely control system P (P variation), PI control system (P variation to I), PI control system (variation I to P), PID control system (P variation of I and D), PID control system (variation I to P and D), PID control system (D variation of P and I) , and tuning PID parameters with Ziegler-Nichols.

The responses obtained in this case are rise time, settling time, peak time, and maximum overshoot. The selection of the right constants from the combination of control systems is expected to eliminate each other's weaknesses and be able to contribute to the excess of these parameters. This simulation program is expected to be the basis for determining the parameters needed in the realization process in a plant. PID control characteristics that have complexity in mathematical modeling, intuitively relatively elusive [13-16]. That's why the use of additional software is included as a simulation deviceOne popular and easy-to-obtain device is Scilab. Xcos is part of the Scilab-based Graphical User Interface (GUI) which is used for modeling and simulation of mixed dynamic systems (hybrids) including continuous and discrete models. Xcos has a graphical editor that makes it easier to portray models into block charts by connecting one block of diagrams with another. Each block represents a basic function that has been provisioned or according to user settings. Xcos consists of three elements: Editor, Browser Palette and Simulator [17-18].

## 2 Methods

This research was conducted from 03 March 2020 - 02 June 2020. The place of research is The Center for Physical Research (P2F), Indonesian Institute of Sciences (LIPI), Serpong Science and Technology Research Center (PUSPIPTEK), Building 440-442, South Tangerang. Research tools and materials used for this research include Laptops and Software Scilab Xcos 6.1.0. This research only uses 1 tool and material because this research is only a simulation program.

The observed variables include:

1. Proportional gain (Kp)
2. Integral gain (Ki)
3. Derivative gain (Kd)
4. Rise time (Td)
5. Peak time (Tp)
6. Settling time (Ts)
7. Maximum overshoot (Mp).

Data retrieval is done by simulating P control system (P variation), PI control system (constant P and I variation), PI control system (constant P and I variation), PID control system (P variation, I and D constant), PID control system (constant P, constant I and D variation), PID control system (constant P, constant I and D variation) and parameter PID tuning with Ziegler-Nichols. The data collection is done with Scilab-Xcos software. Simulation results are given in the form of graphs.

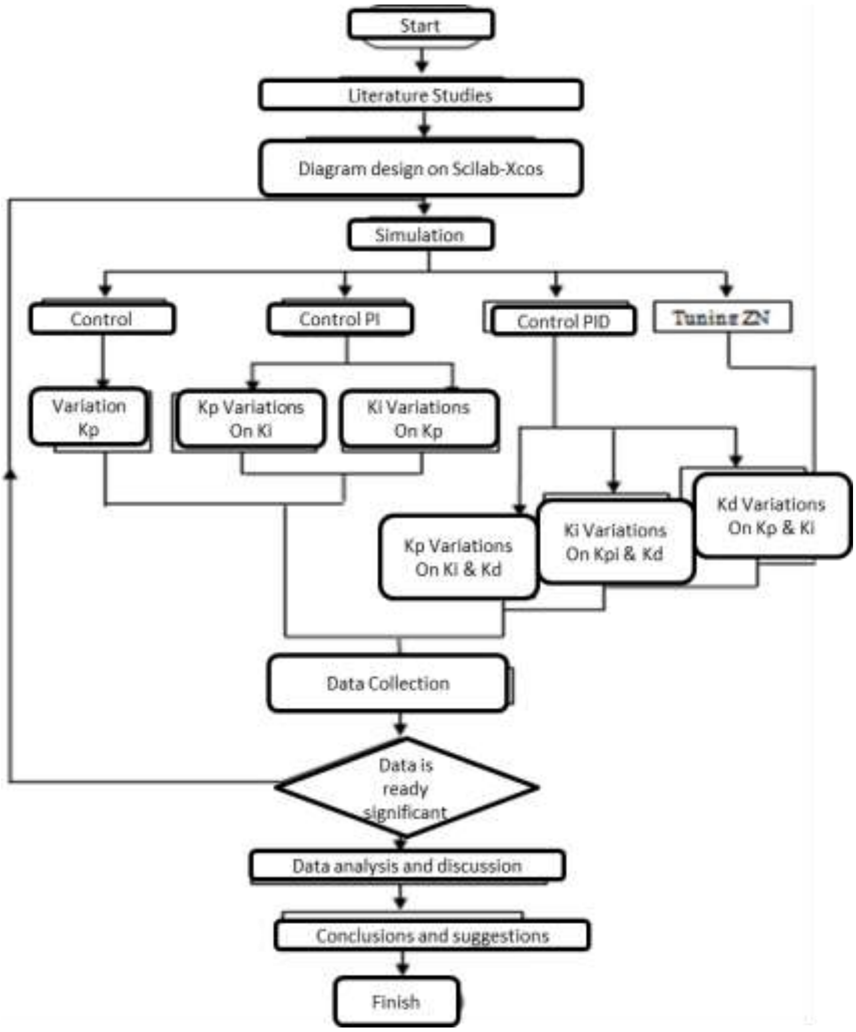


**Figure 1.** Research Flowchart

## 3 Result and Discussion

### 3.1 Proportional Control System Simulation (Variation P)

**Table 1.** Proportional control system response to parameter changes

| P | *Rise Time* (Tr) | *Overshoot* (Mp) | *Peak Time* (Tp) | *Settling Time* (Ts) |
|---|---|---|---|---|
| 1 | 2.289 | 0 | 0 | 3.174 |
| 2 | 1.628 | 0 | 0 | 2.043 |
| 3 | 1.404 | 0 | 0 | 1.666 |
| 4 | 1.295 | 0 | 0 | 1.475 |
| 5 | 1.239 | 0 | 0 | 1.362 |
| 6 | 1.192 | 0 | 0 | 1.283 |
| 7 | 1.175 | 0 | 0 | 1.223 |
| 8 | 1.160 | 0.6 | 1.299 | 1.191 |
| 9 | 1.143 | 2.2 | 1.200 | 1.211 |
| 10 | 1.123 | 3.1 | 1.200 | 1.237 |

*Best Response*

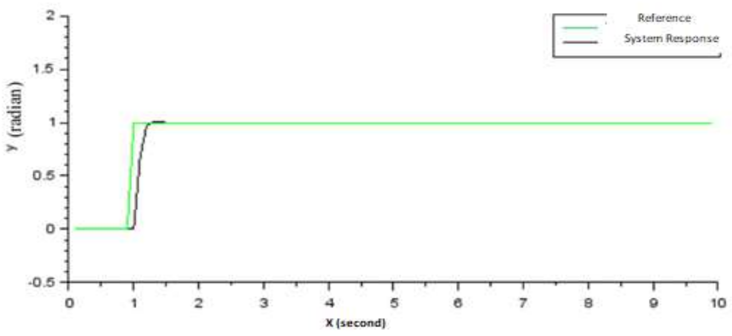


**Figure 2.** Graph of Proportional Control Simulation Results with Kp = 7

### 3.2 PI Control System Simulation (Constant P, Variation I)

**Table 2.** Integral Proportional control system response to parameter changes

| P | I | *Rise Time* (Tr) | *Overshoot* (Mp) | *Peak Time* (Tp) | *Settling Time* (Ts) |
|---|---|---|---|---|---|
| 5 | 5 | 1.194 | 8.9 | 1.500 | 2.878 |
| 5 | 10 | 1.180 | 15.0 | 1.400 | 2.255 |
| 5 | 15 | 1.168 | 21.0 | 1.400 | 1.923 |
| 5 | 20 | 1.159 | 26.0 | 1.300 | 1.758 |
| 5 | 25 | 1.151 | 31.1 | 1.300 | 1.656 |
| 5 | 30 | 1.145 | 35.4 | 1.300 | 1.585 |
| 5 | 35 | 1.139 | 38.9 | 1.300 | 1.877 |
| 5 | 40 | 1.134 | 41.6 | 1.299 | 2.033 |
| 5 | 45 | 1.129 | 43.0 | 1.290 | 2.052 |
| 5 | 50 | 1.125 | 44.9 | 1.280 | 2.032 |

*Best Response*

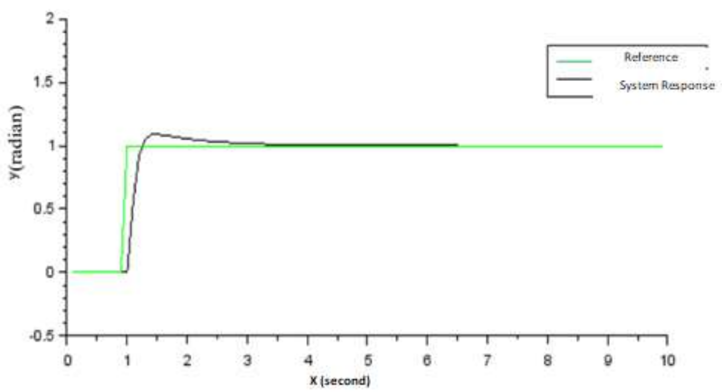


**Figure 3.** Graph of Proportional Control Simulation Results with Kp = 5, Ki = 5

### 3.3 PI Control System Simulation ( Variation P, Constant I)

**Table 3.** Integral Proportional control system responses to parameter changes

| P | I | *Rise Time* (Tr) | *Overshoot* (Mp) | *Peak Time* (Tp) | *Settling Time* (Ts) |
|---|---|---|---|---|---|
| 2 | 2 | 1.423 | 16.0 | 2.000 | 3.770 |
| 4 | 2 | 1.265 | 5.8 | 1.698 | 3.760 |
| 6 | 2 | 1.185 | 3.0 | 1.400 | 2.607 |
| 8 | 2 | 1.155 | 2.4 | 1.299 | 1.362 |
| 10 | 2 | 1.118 | 4.3 | 1.200 | 1.277 |
| 12 | 2 | 1.094 | 4.0 | 1.200 | 1.256 |
| 14 | 2 | 1.187 | 5.1 | 1.100 | 1.220 |
| 16 | 2 | 1.083 | 8.6 | 1.100 | 1.183 |
| 18 | 2 | 1.080 | 12.5 | 1.100 | 1.179 |
| 20 | 2 | 1.078 | 15.3 | 1.100 | 1.176 |

*Best Response*

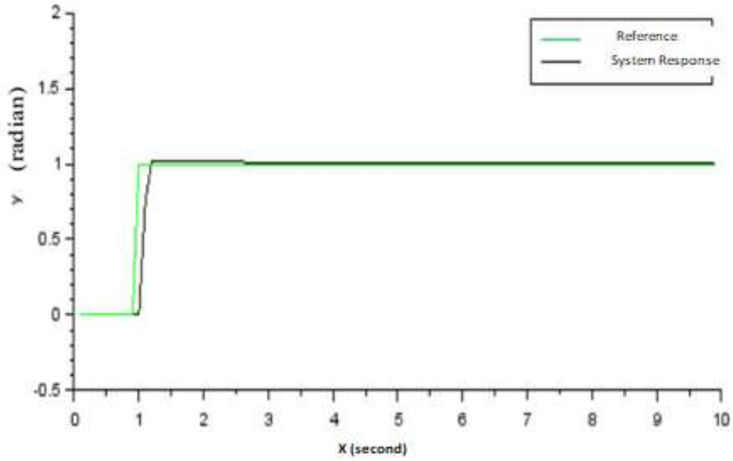


**Figure 4.** Graph of Proportional Control Simulation Results with Kp = 8, Ki = 2

### 3.4 PID Control System Simulation (Variation P, I and Constant D)

**Table 4.** Integral Derivative Proportional control system response to parameter changes

| P | I | D | *Rise Time* (Tr) | *Overshoot* (Mp) | *Peak Time* (Tp) | *Settling Time* (Ts) |
|---|---|---|---|---|---|---|
| 15 | 5 | 2 | 1.349 | 4.6 | 1.995 | 4.520 |
| 20 | 5 | 2 | 1.275 | 2.8 | 1.798 | 3.255 |
| 25 | 5 | 2 | 1.226 | 1.9 | 1.699 | 1.338 |
| 30 | 5 | 2 | 1.190 | 1.3 | 1.692 | 1.289 |
| 35 | 5 | 2 | 1.174 | 1.1 | 1.500 | 1.263 |
| 40 | 5 | 2 | 1.158 | 0.8 | 1.497 | 1.230 |
| 45 | 5 | 2 | 1.140 | 0.6 | 1.485 | 1.198 |
| 50 | 5 | 2 | 1.120 | 0.6 | 1.397 | 1.190 |
| 55 | 5 | 2 | 1.100 | 0.5 | 1.392 | 1.183 |
| 60 | 5 | 2 | 1.097 | 0.4 | 1.361 | 1.175 |

*Best Response*

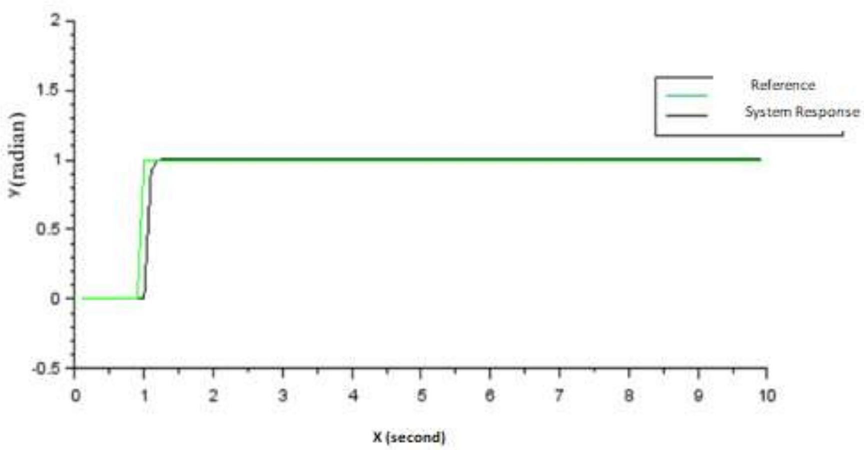


**Figure 5.** Graphs of PID Controller Simulation Results with Kp = 60, Ki = 5, Kd = 2

### 3.5 PID Control System Simulation ( Constant P ,Variation I, D Konstan)

**Table 5.** Responses to Integral Derivative Proportional control system against parameter changes

| P | I | D | *Rise Time* (Tr) | *Overshoot* (Mp) | *Peak Time* (Tp) | *Settling Time* (Ts) |
|---|---|---|---|---|---|---|
| 50 | 1 | 5 | 1.263 | 0.2 | 1.947 | 1.427 |
| 50 | 2 | 5 | 1.262 | 0.4 | 1.943 | 1.414 |
| 50 | 3 | 5 | 1.260 | 0.6 | 1.693 | 1.401 |
| 50 | 4 | 5 | 1.259 | 1.0 | 1.674 | 1.396 |
| 50 | 5 | 5 | 1.257 | 1.2 | 1.565 | 1.391 |
| 50 | 6 | 5 | 1.256 | 1.4 | 1.691 | 1.387 |
| 50 | 7 | 5 | 1.254 | 1.7 | 1.598 | 1.382 |
| 50 | 8 | 5 | 1.253 | 1.8 | 1.697 | 1.378 |
| 50 | 9 | 5 | 1.252 | 2.0 | 1.695 | 1.373 |
| 50 | 10 | 5 | 1.250 | 2.9 | 1.776 | 1.369 |

*Best Response*

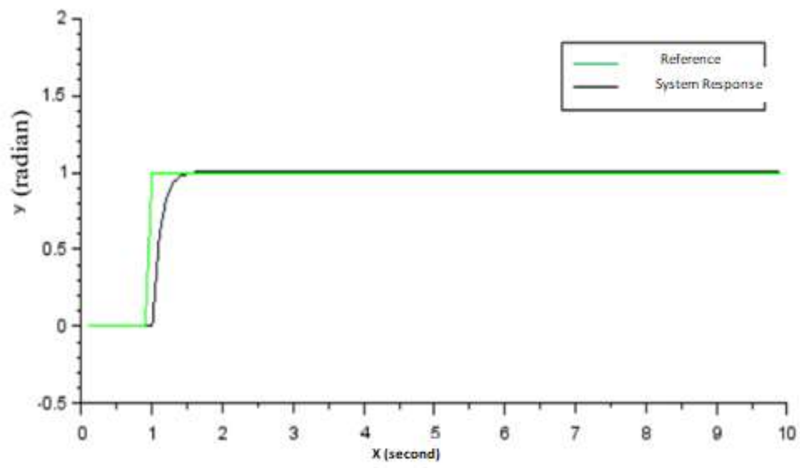


**Figure 6.** Graphs of PID Controller Simulation Results with Kp = 50, Ki = 1, Kd = 5

### 3.6 PID Control System Simulation (Constant P, Constant I, Variation D)

**Table 6.** Responses to Integral Derivative Proportional control system against parameter changes

| P | I | D | *Rise Time* (Tr) | *Overshoot* (Mp) | *Peak Time* (Tp) | *Settling Time* (Ts) |
|---|---|---|---|---|---|---|
| 50 | 10 | 2 | 1.117 | 1.2 | 1.400 | 1.187 |
| 50 | 10 | 4 | 1.198 | 1.7 | 1.500 | 1.289 |
| 50 | 10 | 6 | 1.286 | 2.3 | 1.800 | 3.100 |
| 50 | 10 | 8 | 1.367 | 2.9 | 2.197 | 3.937 |
| 50 | 10 | 10 | 1.425 | 3.4 | 2.197 | 4.964 |
| 50 | 10 | 12 | 1.490 | 3.9 | 2.496 | 5.888 |
| 50 | 10 | 14 | 1.557 | 4.4 | 2.625 | 6.627 |
| 50 | 10 | 16 | 1.610 | 4.8 | 2.796 | 7.225 |
| 50 | 10 | 18 | 1.687 | 5.3 | 2.996 | 7.807 |
| 50 | 10 | 20 | 1.754 | 5.8 | 3.098 | 8.327 |

*Best Response*

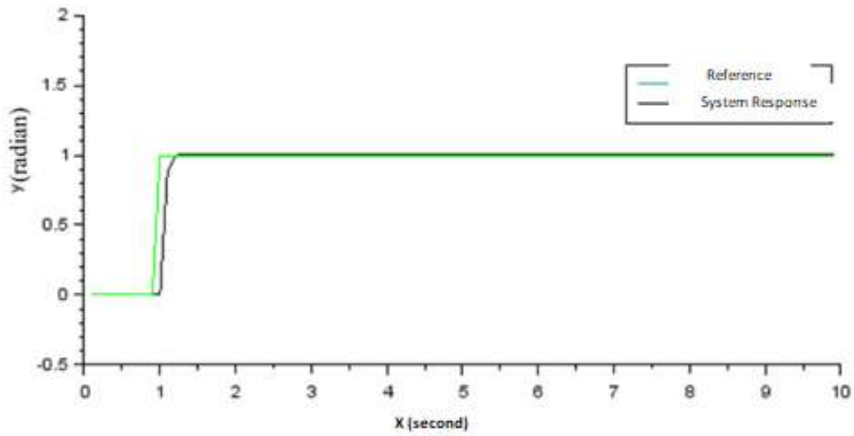


**Figure 7.** Graphs of PID Controller Simulation Results with Kp = 50, Ki = 10, Kd = 2

**Table 7.** Comparison of Tuning results of Ziegler-Nichols PI and PID parameters

| Type Controller | Kp | Tr (second) | Mp (%) | Tp (second) | Ts (second) |
|---|---|---|---|---|---|
| PI | 55 | Continuous oscillations | | | |
| | 1 | 2.429 | 83.7 | 4.081 | 56.24 |
| PID | 73 | 1.165 | 74.7 | 1.3 | 2.995 |
| | 10.000 | 1.093 | 12.8 | 1.2 | 1.625 |

Using the calculation Routh Hurwitz obtained the value Kcr = 121.67. With this value obtained continuous graphs. Tuning PID parameters using Ziegler-Nichols method obtained results for Integral Derivative Proportional Controller with Kp = 73, Ti = 0.23, Td = 0.057: maximum overshoot of 74.7%, peak time of 1.3 seconds, rise time of 1.165 seconds and settling time of 2.995 seconds. Kp value is raised little by little until there is a system response that has a small overshoot. It appears that at the time of proportional controller worth 10,000 can form a good performance in the system, where the overshoot value is 12.8%, peak time is 1.2 seconds, rise time is 1.093 seconds, and settling time is 1.625 seconds.

In Proportional-Integral controller obtained value Kp = 55, Ti = 0.38. With this value obtained continuous graphs. Kp value is raised little by little until there is a system response that has a small overshoot. It is seen in Table 4.7 that at the time the proportional controller is 1 system has not formed a good performance, where the maximum overshoot is 83.7%, the peak time is 4.081 seconds, the rise time is 2.429 seconds and settling time of 56.24 seconds.

From the two types of controllers according to the Ziegler – Nichols method, the controller that provides a fairly good system response is the PID controller because it has the maximum overshoot, peak time, rise time, and settling time which is the least compared to the PI control so that the system is more stable faster.

## 4 Conclusion

The effect of adding P constants to the simulation process of P control, PI control, and PID control is to shorten the rise time, peak time, and settling time to achieve a stable state. The effect of adding constant I to the simulation process of PI and PID control is to produce significant improvements in the value of rise time, peak time, and settling time. The effect of adding D constants to the PID control simulation process is resulting in slower rise time, peak time, and settling time. Overshoot increases with the increasing value of D. Ease of use Scilab Tool is an open source software licensed GPL that is free to download and use. The benefit of Ziegler-Nichols tuning is that it provides an optimal initial value of Kp, Ki, and Kd parameters, which can still be optimized according to the needs of the system.

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