

Control Systems

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Control System Design

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Abstract

A closed loop control system was designed using MATLAB and Simulink capable of controlling the angular positioning for an automatic CIWS turret. This system was designed and ran using the theoretical values $a=2$ $b=6$ $c=6$ for the transfer function. The report investigates some of the basics of control systems and how they apply to this control system. The systems preference was required to bring the process under control in 2 seconds with an overshoot of less than 5% then found the closed loop transfer function was found and inputted into the control system these results were then compared to a single transfer function, to validate the effectiveness of the simulation overall.

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2 Intro

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3 duction

3.1 What is a Control system

A control system is a network of mechanical or electrical devices that using control loops regulate or produce an output for other devices and wider systems. It can be broken down into containing a system

input, which could be target value, a controller that processes the input the output of the system and a error signal for difference between calculated and real. Although some controllers can also have a feedback system that adjust to minimise error. There are two main types of control systems closed and open. [1]

Control systems are used over a wide variety of industries, for example it is used during autopilot systems on aircraft to help maintain altitude and direction. The medical industry also uses control systems on infusion pumps to help deliver medical doss at required rates. [2]

A CIWS Turret requires precision targeting the control system can allows the turret to move and position itself in front of a target at high speeds with low room for error. It should be able to adapt depending on its position to the target against its goal.

3.2 Closed loop vs open loop

Closed loop and open loop are the two main type of control system. An open loop tends to be much simpler and cheaper to design there is no feedback from the output back to the system therefor the system is not monitored so there is a low accuracy and would have to be manually adjusted. [3]

A closed loop system which is most suitable for the turret system as it contains the feedback loop allowing it to adapt depending on the given output and the required output crating a more stable system overall with a higher precision in its movement, however this can be very complex and costly to design on a larger scale. [4]

3.3 Poles and zeros

In a control system poles are values represented by 's' that make the overall denominator transfer function = to 0, It determines the natural response and stability of the overall system. The location of the poles determines the stability of the overall systems and shows the natural frequency ad damping of the system that impact the response speed and oscillation [5]

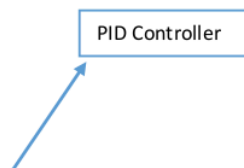
Zeros are values of 's' that make the numerator of the transfer function equal to 0, this effect transient response and frequency characteristics. Zeros affect the transient response ie rise time, overshoot and oscillations. And affects the response shape of the systems. PID Controllers when tuned modify the pole zero locations to create stability. [6]

4 Equipment

Using MATLAB, the following components were used to create the control system

- Step - The step is created to set the initial time step for the simulation [7]
- Subtract
- PID Controller - PID controller stands for proportional, integral and derivative control [8]
- Transfer function - A compact way of showing the relationship between the input and output [9]
- Scope – A way to view results graphically [10]

The layout of this system is shown in figure 1



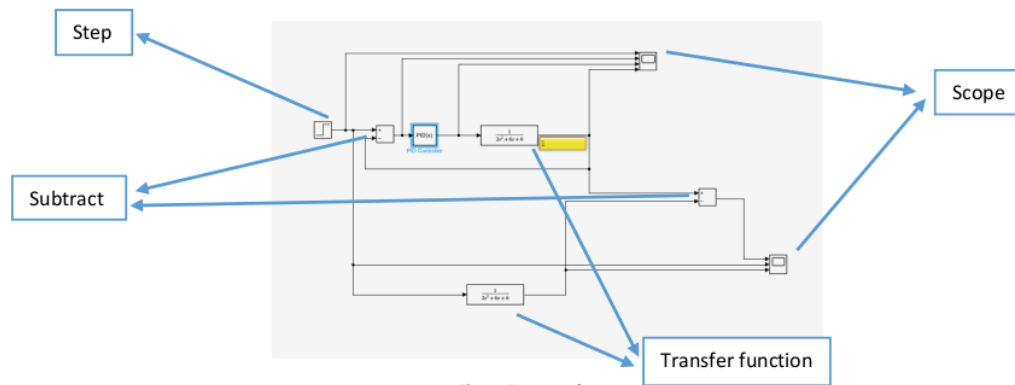


Figure 1 - control system

4.1 Why choose PDI Controller

This control system was designed with the option to use one of the three possible controllers out of many possible options, these are PD (Proportional-Derivative), PI (Proportional-Integral), and PID (Proportional-Integral-Derivative controller). [11]

- Proportional – This corrects the error instantly, cannot control correct steady-state error
- Derivative – Predicts future errors reacting to the rate of change to help with stability to prevent overshoot
- Integral –corrects steady-state error however if not tuned properly has high likelihood of overshoot [12]

PD and PI controllers although tend to be quicker they both focus on an individual area whereas a PID controller brings both the advantages of the two controllers into one controller, its ideal for achieving specific requirements of the system while maintaining a desired output. [13]

Overall, the PDI controller once turned can help the system meet target goals of the under two seconds poisoning with 5% overshoot where most mathematical errors are approached and corrected by the system where other controllers would not.



5 Method

Figure 1 shows the set-up of the components of the simulation, The transfer function contains the equation:

$$G(s) = \frac{1}{as^2 + bs + c}$$

The values of a, b and c they were taken from the last three digits of the student's university number plus 1 (2223155) so in this case a=2 b=6 c=6 creating the equation below:

$$G(s) = \frac{1}{2s^2 + 6s + 6}$$

This was used for the transfer function when tuning the design in the PDI controller

5.1.1 MATLAB PID Tuning

As this design is a closed system then once it is designed the controller can be tuned to reach the requires settling time of 2 seconds and the 5% overshoot, the graph should look like what is shown in figure 2 bellow

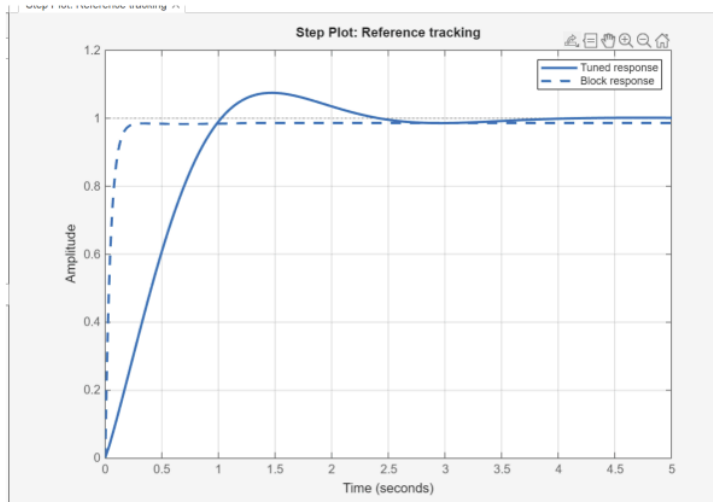


Figure 2 - tuned system

Values of the PDI and N are shown bellow

P - 118.279932213476 – 118.280

I - 68.891521235636 – 68.892

D - 41.8637766299333 – 41.864

N - 2399.37092810534 – 2399.370

These where then inputted into the following equation:

$$K_p + K_i \frac{1}{s} + K_d \frac{s}{\frac{1}{N}s + 1}$$

Then using this result, it was then placed in the following equation

$$TF = \frac{G}{1 + GH}$$

Thee resulting equation was taken out and added to matlab in the following controller as bellow

$$\frac{201130.017037542s^6 + 483756638.344829s^5 + 2812594929.72051s^4 + 6330269466.29553s^3 + 6467238395.51364s^2 + 2379643011.14889s}{4s^6 + 19218.9674248427s^5 + 23344283.2241349s^4 + 622212175.271491s^3 + 3158359326.17238s^2 + 6744944842.24822s + 6674489706.13657s^2 + 2379643011.14889s}$$

Transfer Fun1

6 Results

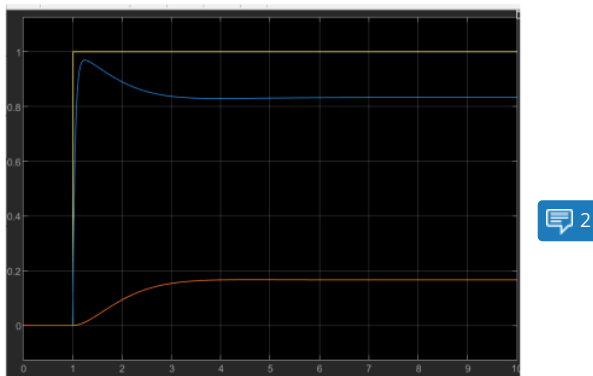


Figure 3 - initial run of system



Figure 4 - Transfer function of the whole system

7 Discussion

As seen in figure 3 the system is far more unstable with a very high overshoot whereas the tuned and input value for the transfer function system shown in figure 4 has a very low overshoot and is a fairly stable system, showing that the transfer function for the entire system is the most precise of the two systems and the simulated control system will work for the CIWS system

8 Conclusions

For the turret the closed transfer system is proven to be the best option for the systems. When running the simulation, it can be found that tuning the PID then using the overall transfer function is the most efficient way to create the system with the highest degree of accuracy.

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

40/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4



Comment 1

Excellent background information



Eqn. No.

You should include an equation number to allow you to identify the equation in your text e.g. "this can be calculated using equation 2".

PAGE 5

PAGE 6



Comment 2

What do each of the colours represent? You should label your data to allow you to explain it more easily.

PAGE 7



Ref Qual

You should try to use more high quality reference sources, such as textbooks from reputable academic publishers and articles from peer reviewed journals.

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GRADING FORM: SMU GENERIC_SMOSEY

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57.90

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



"Inclusion of a wide range of research-informed literature, including sources retrieved independently.

Selection of relevant and credible sources. Very good use of referencing conventions, consistently applied."

6.5

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



Knowledge is accurate with a good understanding of the field of study.

17.4

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.



Evidence of some logical, analytical thinking and synthesis. Can analyse new and/or abstract data and situations without guidance. An emerging awareness of different stances and ability to use evidence to support the argument.

Valid conclusions and recommendations, where relevant.

More analysis, maybe through the use of pole-zero plots to prove stability would have got you more marks here.

17.4

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A good and appropriate application of standard methods, materials, tools and/or techniques.

Good appreciation of the context of the application, with some use of examples, where relevant.

11.6

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate effectively in a suitable format, but may have minor errors.

Mostly coherent work and is in a suitable structure.

5

As this work was submitted late, without a differentiated deadline, it has been capped at 40%. You would have scored 58%