Summary Report for Control System

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Report Module: Control System

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1.Introduction

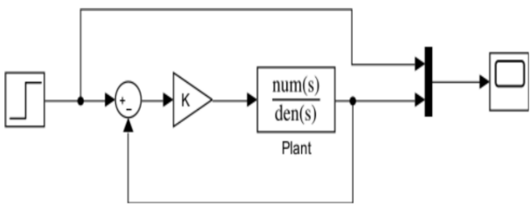
The control system is the system that assign or standardize the behavior of other systems to reach target results. The feedback control system, which the rest of the report will be discussed is one of the examples in control system. This system will reduce disturbance significantly by returning the output signal as one of the input signals.

The aim of this lab experiment is to build and simulate feedback control system models in Simulink in order to inspect and observe the behavior of the system. Also, it is asked to relate feedback control theory to simulation and numerical results using widely-used software tools like Matlab and Simulink. After the lab experiment, more machines and devices related to feedback control systems should be analyzed proficient in later study and research period.

The report begins with further information about the lab, with methods to approach the results. After that, the results will be fully displayed and explained. Following this, the impact of the results and the potential future expansion will be discussed. Finally, a conclusion will be given.

2.Approaches and Methods Used

Two models of feedback control systems were provided for this lab experiment as shown in Figure.1 and Figure.2 which were Feedback Control System of a Plant and Simplified Aircraft Landing System repectively. After building the systems, 5 tasks for each systems were required to complete in order to test and analyze the systems step by step.



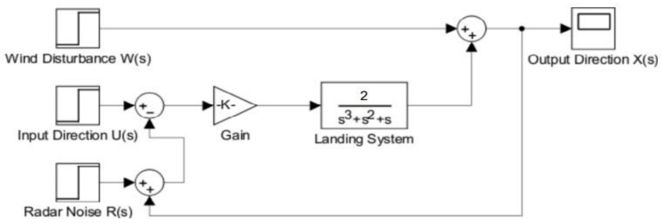


Figure.1: Feedback control system of a Plant

Figure.2: Simplified Aircraft Landing System

For the Feedback Control System of a Plant in Figure.1, the function of Plant was given as where num(s) = s+1 and den(s) = $s^2 - 4s$ and inputting Step signal. After the model was built in Simulink and the function was set, it was required to check the stability of the open-loop system. It was done by removing the feedback signal in the system and checked the output being generated in oscilloscope experimentally. Also, by solving the equation in den(s) which was $s^2 - 4s$ could also show the stability theoretically. Then the critical value of K (gain) was expected to determine for a stable closed-loop system by derivation of routh-hurwitz table and testing on the built model. Likewise, plots of the Locus root of the closed-loop system could also determine the critical value. Subsequently, replaced the Step signal input into Ramp signal input, substituted values of K between 2 to 10 to check the stability of the system. Finally, to find the steady-state error of the system when it is asymptotically stable by importing the data into Matlab for accurate calculation.

For the Simplified Aircraft Landing System in Figure.2, firstly, it was crucial and challenging to derive the transfer functions using Superposition for Wind Disturbance and Radar Noise as $G_W(s)$ and $G_R(s)$ respectively. Then it was required to transform the transfer functions into normalized sensitivity equations. Following this, two feedback control system models were constructed in Simulink based on the normalized sensitivity equations. Finally, by adjusting values of K, the stabilities of the systems and uncertainties or variations in ‘Landing System’ could be illustrated.

3.Results

For Feedback Control system, figure.3 was obtained from the open loop system experimentally with Step Input, and the graph shows an unstable circumstance as time domain in x-axis went to infinity, the output of the system in y-axis also went to infinity. Theoretically, the den(s) function was 0 when s = 4, as 4 is a positive and real number, it could prove that the system was unstable.

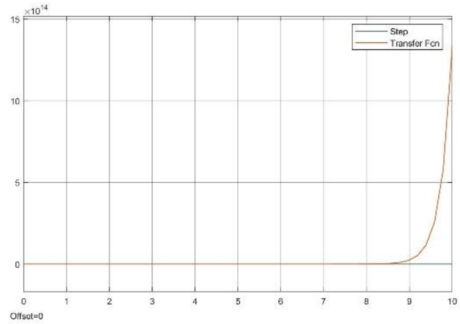
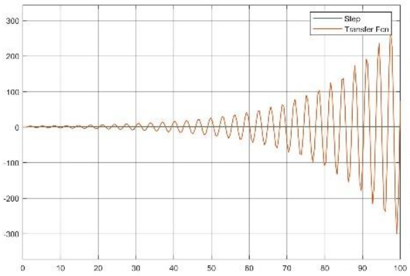
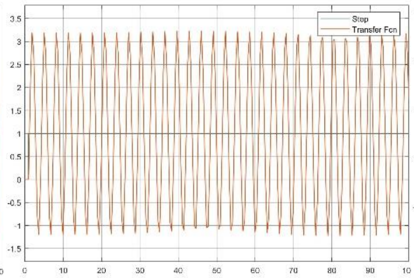


Figure.3: Open-loop system plotting

After derived the routh-hurwizt table and had been tested in Simulink with Step Input, when K was 4, the system was marginally stable, as the average output was constant; when K was smaller than 4, the system was unstable, as the output tends to infinity; when K was greater than 4, the system was stable, as the output tends to a constant. Therefore, the critical value of K was 4 in the system. Figures.4,5,6 shows the graphs when k = 3.9, 4 and 4.1 respectively.





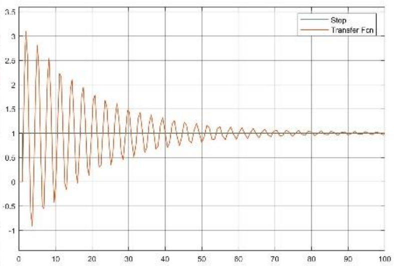
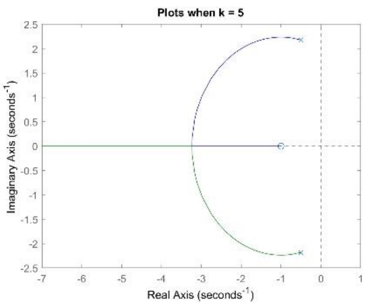
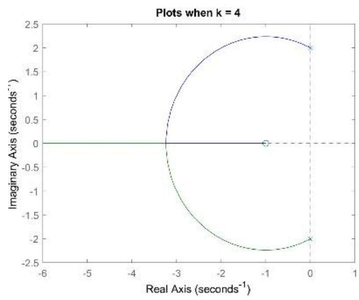


Figure.4: K = 3.9 Figure.5: K = 4.0 Figure.6: K = 4.1

The plot of Locus root of the closed-loop system shown in Figures.7,8 and 9 could prove the critical value was 4 even further. If the system was stable, the Locus root would be visible in Second and Third Quadrants (Figure.7). Also, if the system was marginally stable, the Locus root would occur in the Imaginary Axis (Figure.8). Otherwise, if the system was not stable, the Locus root would appear in the First and Forth Quadrants (Figure.9).





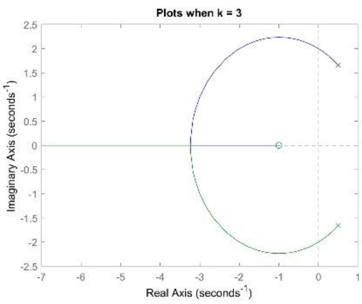


Figure.7: K = 5 Figure.8: K = 4 Figure.9: K = 3

Likewise, the system was tested by Ramp Input. The outputs are shown in Figures.10, 11 and 12 when K was 3, 4 and 7 respectively. The graph illustrated similar results as Step input and deduced the same conclusion as before that when K was smaller than 4, the system was unstable; when K was 4, the system was marginally stable; when K was greater than 4, the system was stable.

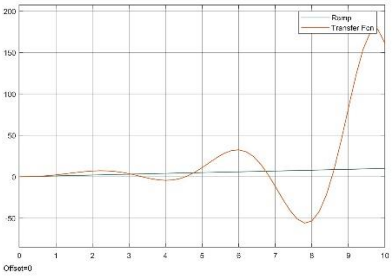


Figure.10: K = 3

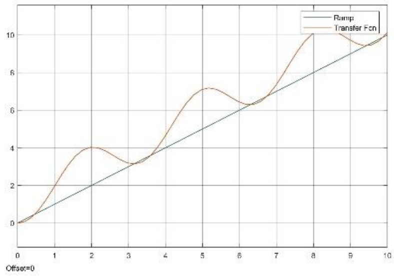


Figure.11: K = 4

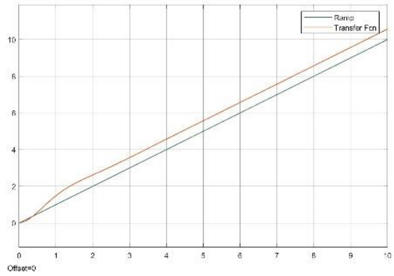


Figure.12: K = 7

Finally, when the system was asymptotically stable, the steady-state error was 0.5180 when K was 7; the error was 0.3375 when K was 10 and the error was 0.2761 when K was 12. Therefore, it was deduced that as the gain increased, the steady-state error in the system decreased exponentially.

For the Simplified Aircraft Landing System, the transfer function after derivation were, $G_W(\mathrm{s}) = \left(1 + \frac{2K}{s^3+s^2+s}\right)^{-1}$ (1) and $G_R(\mathrm{s}) = \frac{\frac{2K}{s^3+s^2+s}}{1+\frac{2K}{s^3+s^2+s}}$ (2). Then normalized sensitivity function could be deduced as $E_W(s) = -\frac{2K}{2K + G_o}$ (3) and $E_R(s) = \frac{G_o}{2K + G_o}$ (4), where $G_o = \frac{2}{s^3+s^2+s}$ (5). The feedback control system models were both constructed as shown in Figure.13.

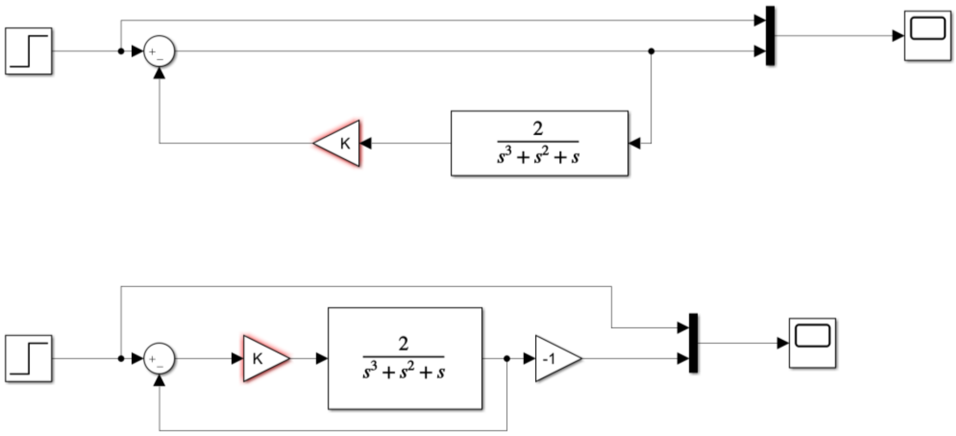


Figure.13: Feedback control system models for $E_R(s)$ (top) and $E_W(s)$ (bottom)

Set K to the value of 0.1, 0.5 and 7.

K = 0.1:

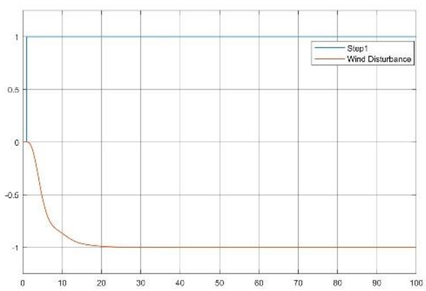


Figure.14: Wind Disturbance

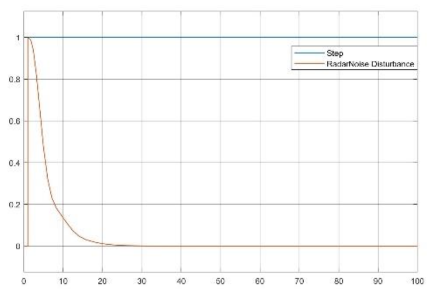


Figure.15: Radar Noise Disturbance

When K was 0.1, both Wind Disturbance sensitivity system and Radar Noise sensitivity system were stable.

K = 0.3

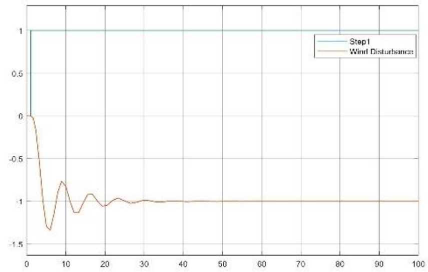


Figure.16: Wind Disturbance

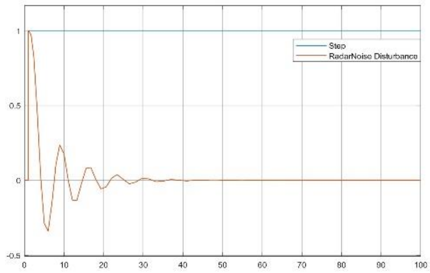


Figure.17: Radar Noise Disturbance

When K was 0.3,both Wind Disturbance sensitivity system and Radar Noise sensitivity system were becoming more stable in shorter period of time.

K = 0.5:

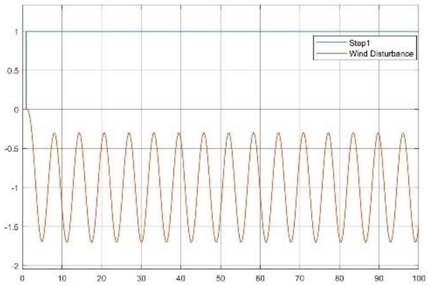


Figure.18: Wind Disturbance

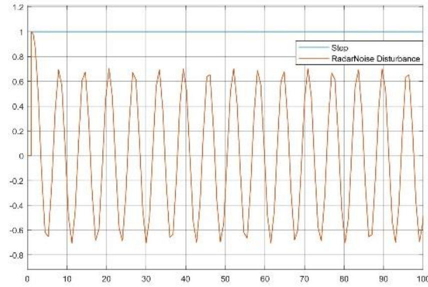


Figure.19: Radar Noise Disturbance

When K was 0.5, both Wind Disturbance sensitivity system and Radar Noise sensitivity system were marginally stable.

K = 7:

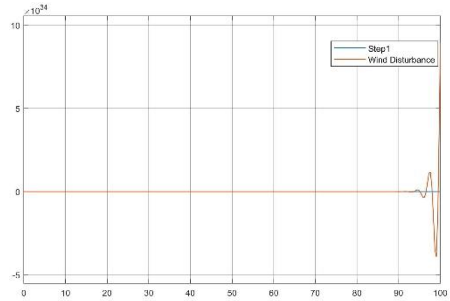


Figure.20: Wind Disturbance

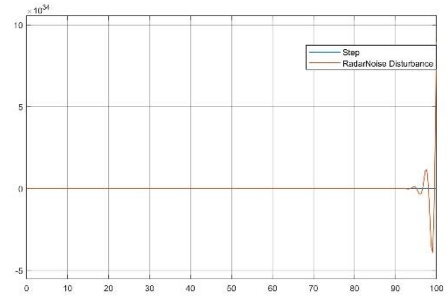


Figure.21: Radar Noise Disturbance

When K was 7, both Wind Disturbance sensitivity system and Radar Noise sensitivity system were unstable.

Overall, both Wind disturbance sensitivity system and Radar Noise sensitivity system were stable when K was smaller than 0.5 and they were marginally stable when K was exactly 0.5. Otherwise, they were unstable when K was greater than 0.5. Likewise, it could be concluded that as the gain, K approached to 0.5 from the region smaller than 0.5, the sensitivity increased for both system and the settlement time dropped fairly. (The settlement time is the time required to output to approach 2% of the final steady-state value.) Therefore, K should be as close as possible to 0.5 without equal or exceed it to achieve best sensitivity and shortest settlement time.

4.Impacts

Afterall, the outcomes from the lab experiment could deduct certain applications and future potentialities. In the case of Feedback Control System of a Plant, by adjusting the gain of the system, the stability of the system could alter. Also, the steady-state error could be mostly eliminated if gain achieves a certain large value. It could be used to control temperature and humidity in certain issue, for example, cabinets for Cigar and wine or Greenhouses for crops. In the case of the Simplified Aircraft Landing System, the stability and sensitivity of noise and disturbance were determined by the gain. Therefore, the effects of noise and disturbance in a control system could be reduced to minimum if the gain of the noise and disturbance could rise to its maximum under an approval value. Other than the Aircraft Landing System, it could be also used in designing and modifying auto-parking for vehicles.

In the future, I will use the results to design feedback control systems which are stable and might be sensitive, depends on the application. Also, the results could be used in control system analysis in my later study and research.

5.Conclusions

The process of the lab experiment showed a significant progress in building and simulating Feedback Control System models. The study and analysis of two models had related feedback control theory to simulation and numerical results using Matlab and Simulink. More complicated control systems could be analyzed proficient in the future.

Reference:

Electrical4U. (2019). *Control System | Closed Loop Open Loop Control System | Electrical4U*. [online] Available at: https://www.electrical4u.com/control-system-closed-loop-open-loop-control-system/ [Accessed 29 Nov. 2019].

C.L. Phillips and R.D. Harbor, Feedback Control Systems, Prentice Hall, ISBN 0130161241.

P. Antsaklis, and A.N. Michel, Linear Systems, McGraw Hill, ISBN 0070414335.

DECLARATION

I have read and understood the College and Department's statements and guidelines concerning plagiarism.

I declare that all material described in this report is all my own work except where explicitly and individually indicated in the text. This includes ideas described in the text, figures and computer programs.

Name: …………Lixuan Yang………

Signature: ………………………………

Date: ….29th November, 2019…………