EEE342 Feedback Control Systems-Preliminary Work 3

Ezgi Demir

Department of Electrical and Electronics Engineering, Bilkent University, 06800 Ankara, Turkey

1. Introduction

At the start of this lab, I set out to integrate multidisciplinary analysis with practical control design: first assessing and justifying optimal sites for a gas storage facility, then identifying and mitigating both technical and community risks, and finally modeling the tank dynamics to develop a stable feedback controller in MATLAB.

2. Laboratory Content

Part 1

After thorough analysis, I recommend situating the gas storage/distribution facility in Tekirdağ or Edirne rather than in Kırıklareli or Istanbul because these are the only suitable locations with the reason of geographical properties of the landscape and being closed to European area. These areas provide flatter, more accessible terrain, avoiding the mountainous complications of Kırıklareli and the extreme urban congestion and heightened risks found in Istanbul.

Fig. 1: Physical Map of the Marmara Region [3]

Economically, both Tekirdağ and Edirne offer significant cost efficiency and robust industrial infrastructure that facilitates construction and operational logistics while also attracting regional and international investments. Socially, choosing these sites minimizes disruptions in densely populated areas and fosters community acceptance by leveraging existing industrial zones, which are better equipped to manage industrial risks. Environmentally, these locations allow for more sustainable development; the relatively flat terrains reduce the need for extensive land alterations, and integration with pre-existing industrial areas helps limit ecological disturbance [6][7].

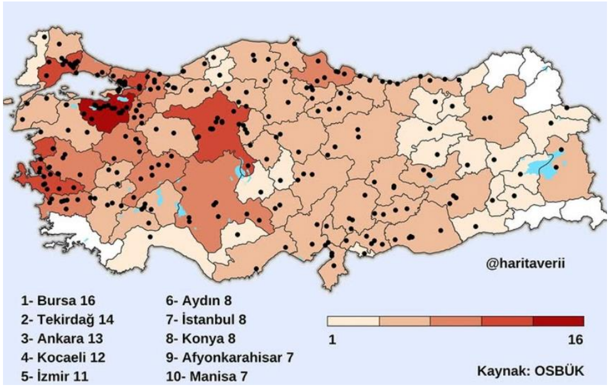

Fig.2: Map of the Ranking of Turkey's Organized Industrial Zones [5]

Additionally, Tekirdağ's proximity to the Marmara Sea provides critical maritime access that enhances logistical connectivity and supports efficient distribution, making it an ideal candidate for a sustainable and secure energy infrastructure project.

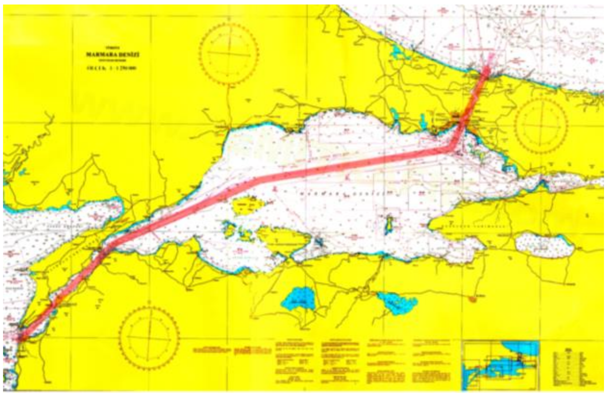

Fig. 3: Turkey's Straits and Connecting Regions [4]

Part 2

Engineering Problem

Problem: Safety and Risk of Gas Leaks or Explosions

Issue:
Due to the flammable nature of natural gas, any leakage in storage or distribution lines can lead to catastrophic explosions, endangering life, property, and the environment.

Engineering Solutions:
Advanced Sensor and Monitoring Systems: Install state-of-the-art gas detection sensors and continuous monitoring systems that can promptly detect leaks and automatically trigger emergency protocols. [7]

Automated Shutdown and Isolation Mechanisms: Implement redundant safety valves and automated shutdown systems that quickly isolate sections of the network in the event of a leak.

Problem 2: Social Acceptance and Community Opposition

Issue:
Local communities may oppose the facility due to concerns over health risks, environmental pollution, and potential disruptions to local lifestyles, leading to delays and increased costs.

Non-Engineering Solutions:

Community Outreach and Education Programs: Develop initiatives that transparently communicate the safety measures in place and the economic benefits, such as job creation and regional development. Hosting public forums and information sessions can build trust

Part 3

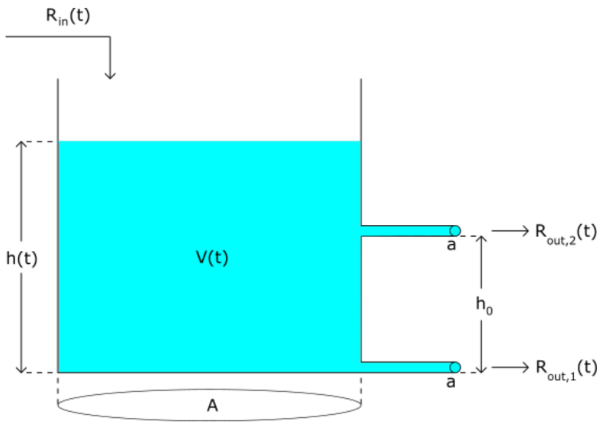

Fig. 4: Gas storage System

In the figure, incoming gas $R_{in}(t)$ and the output to both Turkey and Europe ($R_{out,1}(t)$ and $R_{out,2}(t)$ respectively)

Specifications of our Transfer Function of a controller:

• A: Square of sum of numbers in your student ID

ID: 22103304 → A $=(2+2+1+0+3+3+0+4)^2 = 225\ m^2$

• a: Mean of numbers in your student ID

$$a = \frac{2+2+1+0+3+3+0+4}{8} = 1.875\, m^2$$

• h_0: Height of the second pipe → 5 m

• V_0: = A × h(0) = A × 9 m^3

$$G_C(s) = \frac{K(s+a)}{s(s+b)} \quad (Eq.1)$$

From the tank model we are given in the lab manual we started to formulize (from Fig.4),

$$R_{out,1}(t) = a\sqrt{2gh(t)} \quad (Eq.2)$$

$$R_{out,2}(t) = a\sqrt{2g(h(t)-h_0)} \quad (Eq.3)$$

Therefore, since we know that the input and ouput should be conserved at a time t , we can write the below equations:

$$A \times h(0) + \int_0^t (R_{in}(t) - R_{out,1}(t) - R_{out,2}(t))dt = A \times h(t) \quad (Eq.4)$$

When we take the derivative of the both sides,

$$\frac{dh(t)}{dt} = \frac{1}{A}\left(\left(R_{in}(t) - a\sqrt{2gh(t)} - a\sqrt{2g(h(t)-h_0)}\right)\right) \quad (Eq.5)$$

We call this above function f(h, R_{in}). From using Taylor Series,

$$h(t) = h_0 + \triangle h \quad (Eq.6)$$

$$R_{in}(t) = R_{in}(0) + \triangle R_{in} \quad (Eq.7)$$

Assume c and d random real numbers,

$$\frac{dh(t)}{dt} \triangle h = c \triangle h + d \triangle R_{in} \quad (Eq.8)$$

$$c = \frac{df}{dh}\Big|_{h=h_0, R_{in}= R_{in}(0)} = \frac{a\sqrt{2g}}{2A\sqrt{h_0}} \quad (Eq.9)$$

$$= \frac{1.875\sqrt{2\times 9.81}}{2\times 225\sqrt{5}} \approx 0.00826$$

$$d = \frac{df}{dR_{in}}\Big|_{h=h_0, R_{in}= R_{in}(0)} = \frac{1}{A} \approx 0.004444 \quad (Eq.10)$$

When we take the Laplace Transform we derived the linearized version,

$$G_P(s) = \frac{d}{s-c} \quad (Eq.11)$$

And Eq.1 is given us in the lab manual, when we combine these two [1],

$$G(s) = \frac{G_P G_C}{1+G_P G_C} = \frac{Kd(s+a)}{s(s+b)(s-c)+Kd(s+a)} \quad (Eq.12)$$

From Root Hurwitz Criterion I found that I shoul select b> 3 and I choose 10. After chosing b value I continue with K and it turns out that I have to chose K> 32. In order to not to take risk and stay in the stable region I chose K=50 [1].

When I try to derive the plot of my transfer function after pluging in the parameters I found, I see below results.

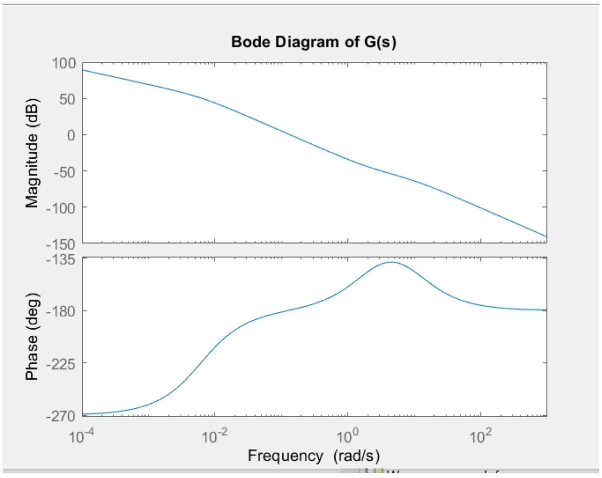

Fig. 5: Bode Plots of Overall Transfer Function

```
 GainMargin: [0.3408 Inf]
GMFrequency: [0.1192 Inf]
PhaseMargin: 3.3375
PMFrequency: 0.2047
DelayMargin: 0.2845
DMFrequency: 0.2047
     Stable: 1
```

Fig. 6: Parameters of my Transfer Function

By looking at the value stable, it confirms that the values I picked satisfied the stability condition.

Matlab Code

```
a = 1.875;
g = 9.81;
Area = 225;
h_0 = 9;
c = a*sqrt(2*g)/(2*Area*sqrt(h_0));
d = 1/Area;
G_p = tf([d],[1 -c]);
G_c = tf([50 93.75],[1 10 0]);
bode(G_p*G_c)
title("Bode PLot of G(s)")
allmargin(G_p*G_c)
```

3. Conclusion

Tekirdağ and Edirne stand out for their flat terrain, existing industrial infrastructure, maritime links, and low social/environmental impact. We've addressed leak-and-safety risks with advanced detection and isolation systems, and built local support through formal benefit agreements and advisory boards. Together with a robust feedback controller that ensures stability, this makes for a secure, efficient gas storage and distribution solution.

I learned how to tackle a real-world engineering problem from end to end: evaluating and justifying a site using economic, social, political, and environmental criteria; identifying both technical and community-related risks; and developing solutions—like leak-detection systems and formal benefit agreements—to address them. On the control side, I gained hands-on experience modeling a physical system, linearizing it, deriving its transfer function, and using MATLAB to design and tune a feedback controller for stability. Overall, this lab showed me how to blend technical analysis with stakeholder engagement to create a robust, practical solution.

REFERENCES

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