Nabucco Gas Pipeline Project

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1. Introduction

The aim of this laboratory work is to encourage the students to think about, as well as to improve their ability in identifying and formulating, real life engineering problems and to propose possible solutions for them considering various issues. The project that is analyzed in this report is Nabucco Gas Pipeline Project.

2. Laboratory Content

2.1 Nabucco Gas Pipeline Project and Locations

Nabucco gas pipeline project is a project about natural gas distribution and storage pipeline, which is proposed in Turkey in 2002 and cancelled in 2013 [1]. The aim of the project was to diversify the natural gas suppliers and delivery routes for Europe, therefore reducing European dependence on Russia.

Figure 1: Location of the Nabucco Pipeline [1]

To maximize the profits of the project, we can propose geographical locations and regions where the economic status and wealth are low, as well as the unemployment rate is relatively higher than other regions. The figure below shows the average income of regions in Turkey:

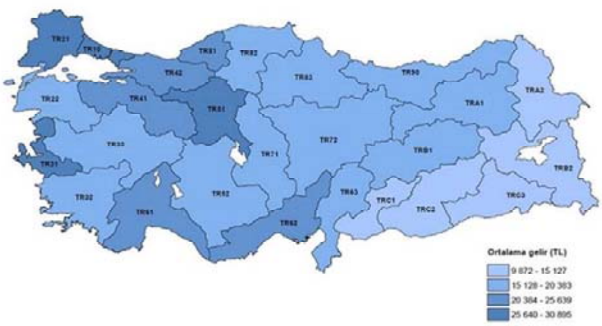


Figure 2: Average Income of Certain Regions in Turkey [2]

An issue related to the proposing a location for gas storage tank is security and terrorism. As the tank must be secured in order to prevent any disaster or demolish, the tank must be installed in a region where the security is high and risk of terror is low.

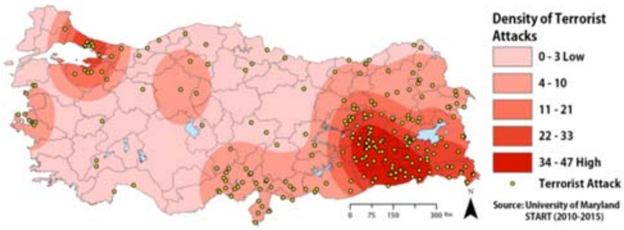


Figure 3: Turkey Terror Map [3]

Another issue to consider proposing a location for the gas storage tanks is the risk of natural disasters and earthquakes, which may eventually result in dramatic disasters due to the gas storage tank facility.

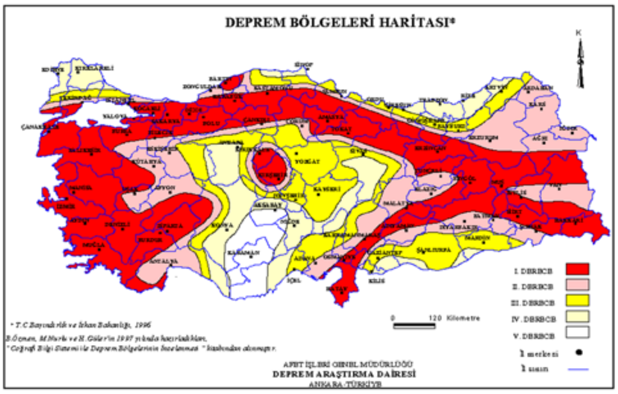


Figure 4: Turkey Earthquake Risk Map [4]

According to the considerations and issues stated above, the proposed locations for gas storage tank are Yozgat, Kayseri and Karaman, where average income and risk of natural disasters are low and security is relatively high.

2.2 Possible Problems about the Process of Gas

There may arise various problems in the gas distribution and storage process. One of them is fire hazard, which may eventually destroy the whole project and may cause the death of people living around the tank and pipelines. This fire hazard problem can be solved with an engineering approach. Fire-resistant materials can be used in the tank and pipelines. Another problem about the material of the project is corrosion, which occurs to metallic materials and shortens the life of the material that it affects. Using corrosion inhibitors therefore reduces the effect of corrosion and keeps the used material strong and healthy.

There may occur problems whose solutions are not related to engineering or technical work. One of them is, the residents of the location that the gas storage tank is proposed to be built may protest this project as they may think their lives are in danger due to this project. This solution may be solved by convincing these protesters about the benefits of the project to their city and Turkey, as well as the high security conditions.

2.3 Gas Storage Tank Design

In this section, the gas storage and distribution tank system that has incoming gas and two outputs to both Turkey and Europe and related controller are designed.

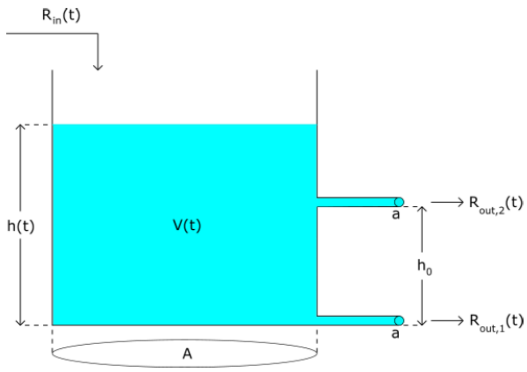


Figure 5: Gas Storage Tank Model

The parameters of the tank model are given below:

$$A = (2+1+6+0+0+9+6+6)^2 = 900\ m^2$$

$$a = \frac{2+1+6+0+0+9+6+6}{8} = 3.75\ m^2$$

$$h(0) = 9\ m$$

$$h_0 = 5\ m$$

$$V_0 = 9A = 9 \times 900 = 8100$$

$$R_{out1} = a\sqrt{2gh(t)}$$

$$R_{out2} = a\sqrt{2g(h(t)-h_0)}$$

The starting point is to use conservation of the mass. The mass is preserved, so that:

$$\frac{d(Ah)}{dt} = R_{in} - a\sqrt{2gh(t)} - a\sqrt{2g(h(t)-h_0)}$$

$$\frac{dh}{dt} = f(h, R_{in}) = \frac{1}{A}(R_{in} - a\sqrt{2gh(t)} - a\sqrt{2g(h(t)-h_0)}\,)$$

We can express this derivative as the function of h and R_{in}:

$$f(h, R_{in}) = \frac{1}{A}(R_{in} - a\sqrt{2g}(\sqrt{h-h_0} + \sqrt{h}))$$

At this point, we need to linearize this function in order to design the plant and controller.

$$\frac{d}{dt}\Delta h = a_1 \Delta h + a_2 \Delta R_{in}$$

where the a_1 and a_2 are defined as

$$a_1 = \frac{\partial f}{\partial h} = \frac{-a\sqrt{2g}}{A}(\frac{1}{2\sqrt{h-h_0}} + \frac{1}{2\sqrt{h}})$$

$$a_2 = \frac{\partial f}{\partial R_{in}} = \frac{1}{A}$$

We now linearize the function that we obtained around the initial state points.
At the time t = 0, according to the mass of conservation, the rate of change in the height is zero. Using this fact, we obtain:

$$\frac{dh}{dt}\ at\ t = 0 = f(h(0), R_{in}(0))$$
$$= \frac{1}{A}(R_{in}(0) - a\sqrt{2g}(\sqrt{h(0)-h_0} + \sqrt{h(0)}))$$

$$a_1 = \frac{-a\sqrt{2g}}{A}\left(\frac{1}{2\sqrt{9-5}} + \frac{1}{2\sqrt{9}}\right) = \frac{-5a\sqrt{2g}}{12A}$$

$$a_2 = \frac{\partial f}{\partial R_{in}} = \frac{1}{A}$$

Putting the a_1 and a_2 into the equation above, we obtain:

$$\frac{d}{dt}\Delta h = \frac{-5a\sqrt{2g}}{12A}\Delta h + \frac{1}{A}\Delta R_{in}$$

which is a linearized system.

At this point, we take Laplace transform of this linear equation and obtain (assuming initial conditions that arose in the transform process are zero):

$$sH(s) = \frac{-5a\sqrt{2g}}{12A}H(s) + \frac{1}{A}R_{in}(s)$$

$$(s + \frac{5a\sqrt{2g}}{12A})H(s) = \frac{1}{A}R_{in}(s)$$

Finally, we can define the transfer function of this plant:

$$G_p(s) = \frac{H(s)}{R_{in}(s)} = \frac{1}{A(s + \frac{5a\sqrt{2g}}{12A})} = \frac{1/A}{s + \frac{5a\sqrt{2g}}{12A}}$$

The controller has the following form:

$$\mathrm{G_c}(s) = \frac{\mathrm{K(s + a)}}{s(s+b)}$$

The interval for K, a and b values are very large, so we choose these values as anything we want as long as the closed loop system is stable.

Choosing $\mathrm{a} = 1$ $\mathrm{b} = 2$ and $\mathrm{K} = 1$, we can check the closed loop stability using Root Locus:

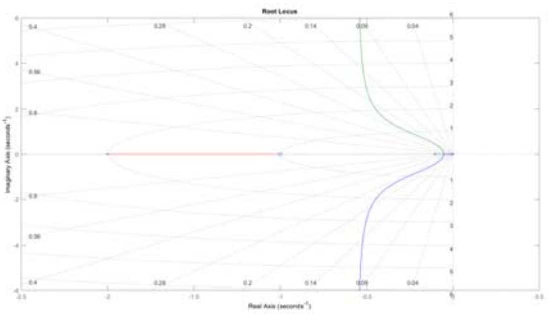


Figure 6: Root Locus for Controller

As it can be see from the Root Locus, the system is stable for all K>0. I choose K = 400 and proceed.

The Bode plot of open loop system $\mathrm{G_c}(s)\mathrm{G_{p(s)}}$ is:

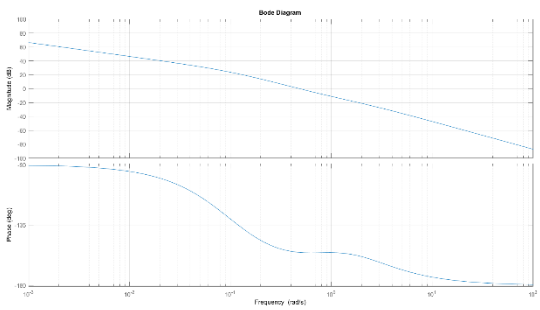
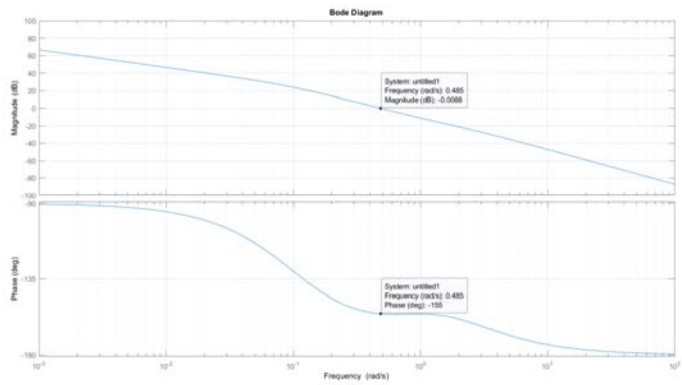


Figure 7: Bode plot of for Open Loop System

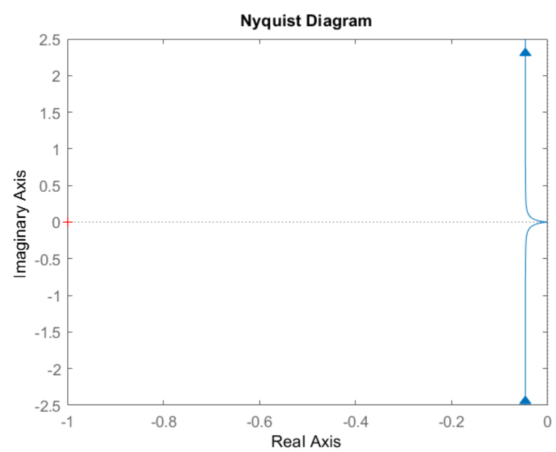
For phase margin, we look at the frequency where the magnitude is 1, i.e. 0 dB. This frequency is observed on the Bode plot as $\omega = 0.485\,\frac{\mathrm{rad}}{\mathrm{sec}}$. At this frequency, on the phase plot, the corresponding phase is $\phi = -155°$. Then the Phase Margin (PM) is:



$$\phi_{PM} = 180° - 155° = 25° = 0.139\pi \; in \; rad$$

Figure 8: Bode plot for Calculation of Margins

To calculate the Gain Margin (GM), we find the frequency where the phase is $\phi = -180°$ and find the corresponding gain on this frequency. As it can be seen from the Bode phase plot, the phase becomes $\phi = -180°$ at the $\omega = \infty$ and the gain is also



diverges to $-\infty$. Thus, the Gain Margin is infinite. This can also ben seen from the Nyquist plot as:

Figure 9: Nyquist Plot of Open Loop

The real axis cross is at origin. As $GM = 1/d$ where d is the real axiss crossing point, $GM = 1/0$, the GM diverges and is infinite.

Delay Margin (DM) is $DM = \frac{\phi_{PM}}{\omega_x}$ where ω_x is the frequency where the gain is 0 dB. In our case, ω_x is found as $0.485\,\frac{\mathrm{rad}}{\mathrm{sec}}$. Therefore, delay margin is:

$$DM = \frac{\phi_{PM}}{\omega_x} = \frac{0.139\pi}{0.485} = \; 0.287\pi \; in \; rad$$

3. Conclusion

First, the possible geographical location of the gas storage tank is proposed based on various parameters such as economic, political and environmental issues. Then, the possible problems and issues, during the gas storage/distribution process are identified and solutions for these problems are presented. Consequently, the model of gas tank, where the input is incoming gas and the two outputs are for gas distribution to Turkey and Europe is shown and analytical solutions are made. The mathematical model, using linearization, is presented and related plant and controller for this control system are designed. Finally, the Bode plot is drawn and the gain margin, phase margin and delay margin of the system are calculated.

REFERENCES

1. The planned route of the Nabucco pipeline. [Art]. Wikimedia Commons, 2009.
2. Gelir ve Yaşam Koşulları Araştırması Bölgesel Sonuçları, 2017 [Art]. TÜİK, 2017
3. Hojun Song, Vulnerability Assessment: Syrian Refugees in Turkey in 2017.
4. Türkiye Yeni Deprem Haritası [Art]. AFAD, 2014.

APPENDIX

```
A = 0;
id = zeros(1,8);
id = input("Enter your ID: ",
's');
for i = 1:8
    u(i) = str2double(id(i));
end

for i = 1:8
  A = A+str2double(id(i));
end
A = A*A;
a1 = mean(id);

h_0 = 5;
h_in = 9;
g = 9.81;
K = 1;
a2 = 1;
b = 2;

gp = tf([1/A], [1
5*a1*sqrt(2*g)/(12*A)])
gc = tf([K K*a2], [1 b 0])

figure
rlocus(400*gp*gc)
grid on
figure
sys = feedback(400*gp*gc,1);
bode(400*gp*gc); %% I chose gain K
= 400 where the closed loop system
is stable
grid on
disp(a1);
disp(A);
```