Lab-3 Preliminary Work

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1. Introduction

This preliminary lab assignment consisted of investigating on a real-life problem and understand how engineering on a broader perspective is done. The main problem was to discover and propose a solution that considers many aspects of the problem. The problem proposed is the Nabucco gas pipeline project proposed by BOTAŞ, Turkey to Austria in 2002. The project was eventually aborted in 2013[1]. The aim was to build a gas pipeline from four source countries to Turkey and Europe in order to reduce the dependency of Europe to Russia in terms of energy [2]. The initially considered pipeline routing is given below.

Fig. 1: The Nabucco Gas Pipeline Route[3]

2. Laboratory Content

2.1. Possible Geographical Locations for the Gas Storage Tank

In order to investigate this problem, as requested we should approach to the problem from several different perspectives. For this type of international projects, there are five main aspects that should be considered: Security, Accessibility, Increasing the Regional Employment and The Risk of any type of Natural Disaster and of course the Cost of the pipeline that will be built.

2.1.1. Security

Security of the area that the project will be built is a top priority in the consideration of a project. Since this is an intercontinental energy-based project, the tank that contains the gas should be in an area possibly away from any form of terrorism. Hence, we look at the map for the terrorist attacks in Turkey. The map is given below.

Fig. 2: Density of Terrorist Attacks in Turkey[4]

It is easier to observe that the project location should exclude the South East regions of the country.

2.1.2. Accessibility

In construction, the accessibility is a primary topic since the project cost can increase extremely with the choice of an inaccessible location since that would require more road time for the trucks and also the location should be chosen in a location that is relatively close to the factories that the construction materials will be obtained from, primarily iron. In order to observe this, we look at the Turkey Land Routing Map and the Map for the locations of iron factories.

Fig. 3: Turkey Land Routing Map [5]

Bu looking at this map, in terms of highway transition, there are some amount of intersection nodes which can possibly create a better choice in terms of supplying materials from separate areas. If we compare this with Fig. 1, the possible regions that we can use are given below.

- Tokat
- Erzincan
- Sivas
- Erzurum
- Kırıkkale
- Ankara
- Eskişehir
- Kastamonu
- Kayseri

Then, by looking at the locations of factories, we can eliminate pick the best five and converse more on the other perspectives that we are required to approach.

Fig. 4: Turkey Iron/Steel Map [6]

Here, we can see that the part sectioned as "Karadeniz Bölgesi" will be the primary source of iron and steel for the pipeline project. Hence, we can decrease the list into the following,

- Ankara
- Eskişehir
- Erzincan
- Sivas
- Kırıkkale

These cities were selected due to the fact that there are at least two factories that are at a hand’s reach, furthermore, Sivas and Kırıkkale have their own factories.

2.1.3. Employment

Although the cities are picked for project construction accessibility, to move further we have to examine the employment/unemployment rates for each of those cities and determine the location that would benefit its habitants the most. In order to do that, we have observed the employment rate map of Turkey with respect to their populations in each city.

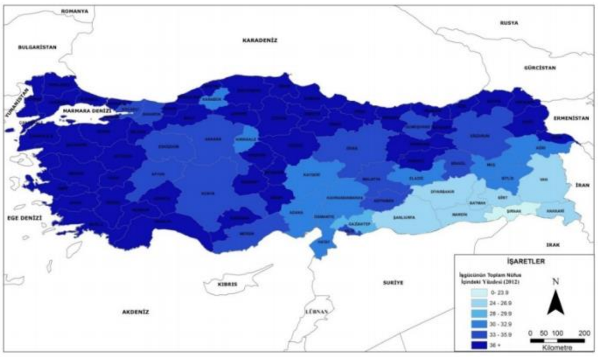

Fig. 5: Map for the employment rate in Turkey[7]

Here we can see that most of the cities that we have observed have a high amount of employment, however one city that we can see that can use a global scale project is Kırıkkale. However, we must observe the city we have chosen from a natural stand point too.

2.1.4. Risk of Natural Disaster

The most prevalent type of natural disaster that we can observe in Turkey is earthquake. Hence, we can observe the map for the earthquake risk in Turkey to decide if the city is the right location.

Fig. 6: Map for the Earthquake Danger in Turkey [8]

Here, we see that Kırıkkale is not on both of Turkey’s main earthquake fault lines. Hence, we can conclude that Krıkkale is the best option for the Nabucco gas line Gas Storage Tank. Then we, investigate the Google Earth and decide on a specific location for a Storage Tank. After some observations, I have concluded that Balışeyh county is the best choice since it’s close to the center with some transportation routes and it is a rural area with empty space and a flat space, hence can be used as a construction site.

2.2. Identifying the Problems that May Occur During the Process

As with all these types of projects, there may be some problems in terms of functionality and some errors. One possible problem might be the pressure drop due to some unexpected temperature fluctuations on the gas volume. This can be resolved by designing some feedback control systems on various control stations along the pipeline. Also, the pressure is expected to change constantly since the pipeline is fed by four distinct sources with different pressure capabilities. Also, evaporation occurs on different conditions to the gas and the seals designed for this functionality must be engineered exclusively.

However, there are always some amount of politics involved in these types of intercontinental projects. Political and economical decisions and the problems caused by them are generally can’t be fixed by engineering procedures.

2.3. Modelling the System and Designing a Controller

The system given in the Preliminary Lab assignment will be analyzed and approximated with a model in this section. The storage tank that is assigned to be done has one input and two separate outputs.

We start by calculating the parameters that are required. My ID number required to compute parameters is 21601531. Hence,

$$A = (2+1+6+1+5+3+1)^2 = 361$$

$$a = \frac{2+1+6+1+5+3+1}{8} = 2.375$$

Also, we are given that the initial height at time zero is 9 and height of the upper pipe to be 5m. The given system is below.

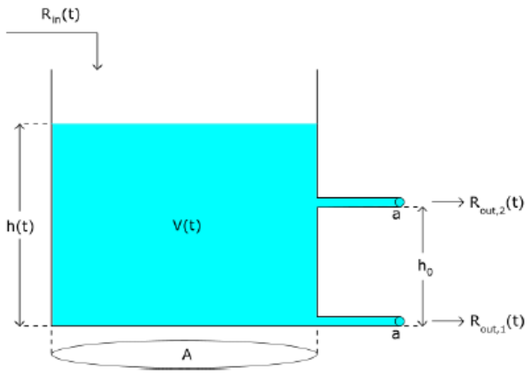

Fig. 7: The given gas tank system

Also, we are given the equations for the outputs which are also given as,

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

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

Hence, we can define the conservation of mass in this system as.

$$Ah(t) = V(0) + \int_0^t [R_{in}(t) - R_{out,1}(t) - R_{out,2}(t)]dt$$

Then, we can take the derivative of both sides.

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

If we rename the derivative of h(t) with respect to t as f, we can approximate f as a first order Taylor Series expansion given as,

$$f = \frac{dh(t)}{dt} = \frac{\partial f}{\partial h(t)}|_{t=0}h(t) + \frac{\partial f}{\partial R_{in}(t)}|_{t=0}R_{in}(t)$$

Which also corresponds to

$$f = \frac{dh(t)}{dt} = \frac{\partial f}{\partial h(t)}|_{h=h0,Rin=Rin0}h(t) + \frac{\partial f}{\partial R_{in}(t)}|_{h_{ho},Rin=Rin0}R_{in}(t)$$

We take the partial derivatives.

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

$$\frac{\partial f}{\partial R_{in}(t)} = \frac{1}{A}$$

When replaced with our values, the approximation takes on the form

$$\frac{dh(t)}{dt} = \alpha h(t) + \beta R_{in}(t)$$

We can then take the Laplace transform of this equation

$$G_P(s) = \frac{\beta}{s - \alpha}$$

Hence, α and β coefficients become as

$$\beta = \frac{1}{A},\ \alpha = \frac{-5a\sqrt{2g}}{12A}$$

The α and β coefficients are found via MATLAB and then defined as a transfer function; the code is given below.

```
close all
h_pr = 9;
h_0 = 5;
A = 361;
a = 2.375;
g = 9.81;
% f = dh/dt = alpha*h(t) + beta*rin(t)
alpha = (a*sqrt(2*g)/(2*A))*(-power(h_pr,-
1/2)-power(h_pr-h_0,-1/2));
beta =  1/A;
% H(s)/RIN(s) = beta/(s-alpha)
num = [beta];
denum = [1 -alpha];
G_p = tf(num,denum);
```

Then, we are asked to implement a controller in the form

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

The values I have picked, and the transfer function constructed is given below within the MATLAB code.

$$a = 10$$

$$b = 20$$

$$K = 10$$

```
% define Gc coefficients
Kc = 10;
a_c = 10;
b_c = 20;
% Controller
c_num = [Kc Kc*a_c];
c_denum = [1 b_c 0];
G_c = tf(c_num, c_denum);
```

Then, we have plotted the bode diagram of the transfer function $G_P(s)G_C(s)$ using the bode() function via MATLAB. The plot is given below.

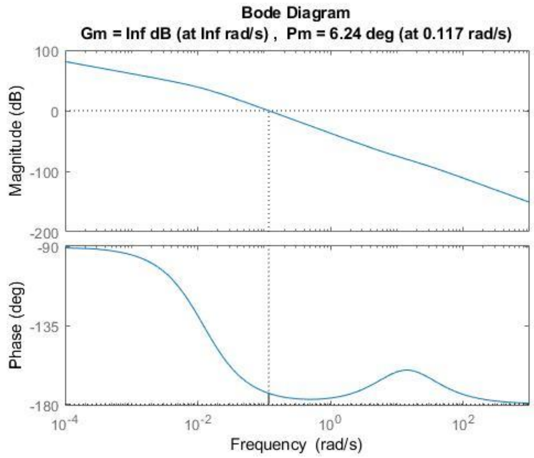

Fig. 8: The Bode Plot of the Designed System

Furthermore, we have used the MATLAB command allmargin() to determine the gain margin, delay margin and phase margin of the system. The following output then was received.

```
GainMargin: Inf
GMFrequency: Inf
PhaseMargin: 6.2449
PMFrequency: 0.1173
DelayMargin: 0.9290
DMFrequency: 0.1173
Stable: 1
```

The Last line in this output snippet says that the system is stable, hence the coefficients we have picked are valid. These outputs are constructed via this code.

```
% draw the bode plot
figure();
bode(G_p*G_c)
% margins
figure()
margin(G_p*G_c)
allmargin(G_p*G_c)
```

3. Conclusion

This preliminary lab assignment was a highly multidimensional one since, we were not only required to design a system and work on it, first we have identified and investigated on a real-life problem and came up with engineering solutions. The solution that we have reached was backed by many different perspectives such as economic, political, social, environmental. Then, we have transformed the physical system given to us into an approximated transfer function. We transformed the time-domain system into the Laplace domain in order to observe the system better and design a controller for that system easily. We also have learned how to use the bode(), margin() and allmargin() functions in order to observe a system's margin characteristics easily. Overall, this preliminary lab was a successful and instructive one.

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