Homework Assignment 1

General guidelines:

- ✓ Try to submit this assignment within three weeks.
- ✓ You may work alone or in pairs.
- ✓ Submit the results as a PDF file to yoashl@ee.technion.ac.il.
- ✓ Clearly state your name(s) and ID(s) at the top of the first page and in the Email.
- ✓ If you need help with Matlab or Simulink please contact me.

The objective of this exercise is to analyze the dynamics of a simple power system in the Matlab/Simulink environment. You will simulate the two-machine system we discussed in class, and test the validity of the DC power flow approximation.

Consider the two machine system shown in Fig. 1.

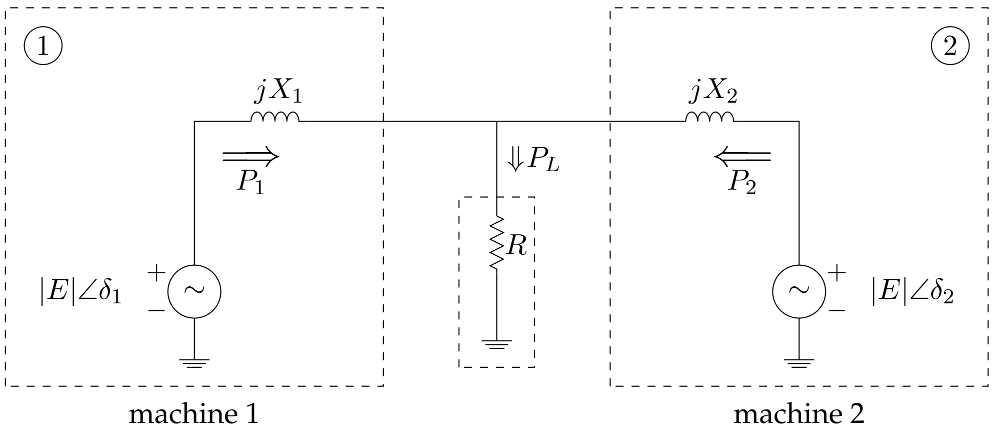

Figure 1: Two synchronous machines feeding a resistive load, single-phase diagram.

First define the system parameters. Open a new Matlab script named “HW1_data.m”, and type (or copy) the following text:

```
ws = 2*pi*50; % [rad/sec] nominal system frequency
Prt = 150e3; % [W] machine rated power (three-phase)
E = 10e3; % [Vrms] induced EMF at nominal frequency (rated voltage)

J = 12*Prt/ws^2; % [kg*m^2 = W*s^3] rotor moment of inertia
D = 0.04*ws/Prt; % [1/(W*s)] damping factor

X1 = 4*E^2/Prt; % [Ohm] synchronous reactance
X2 = X1; % [ohm] synchronous reactance

K = 1/(J*ws); % [1/(W*s^2)] swing equation constant

Pref1 = 0.4*(Prt/3); % [W] reference power (droop control)
Pref2 = 0.3*(Prt/3); % [W] reference power (droop control)

PL = 0.7*(Prt/3);  % [W] load power (single-phase)
R = E^2/PL; % [Ohm] load resistance
```

Run the file to store the variables in the Matlab workspace.

Now build a Simulink model named "HW1_sim", which looks like this

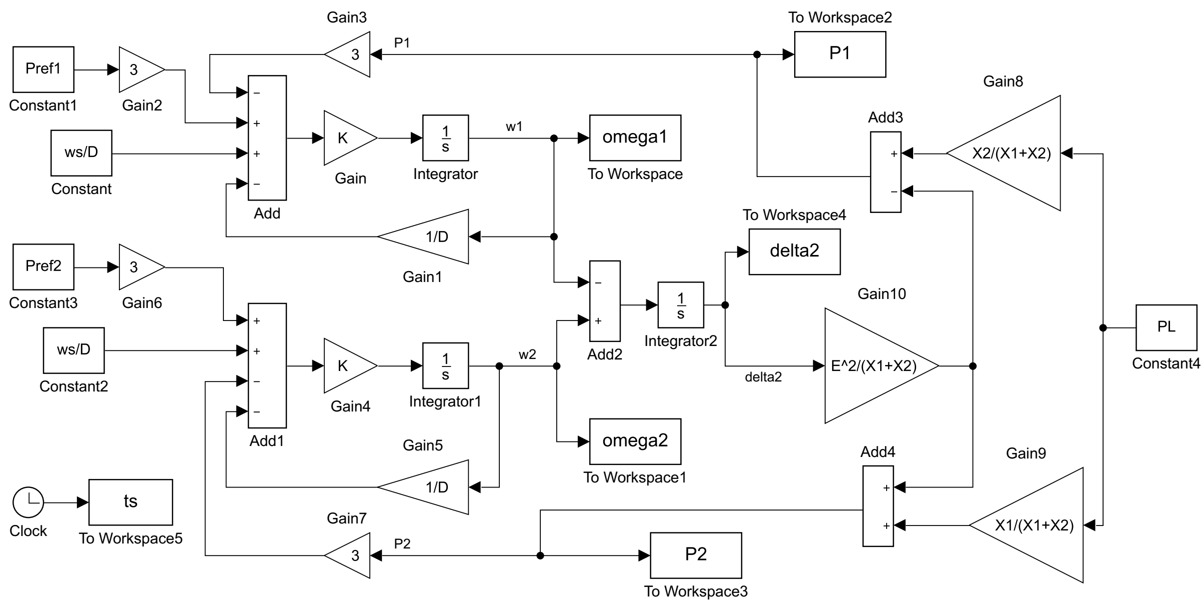

Figure 2: Basic simulation.

Edit the simulation as follows:

- ✓ In the **To Workspace** blocks, define "Save format" as "Array".
- ✓ In Simulation - Model Configuration Parameters - Solver - Addition Options:
  - Max step size = 1e-3
  - Relative tolerance = 1e-5
  - Stop time = 12

Question 1: Run the model, and plot the signals. What is the operating point $\bar{\delta}_2$, $\bar{\omega}_1$, $\bar{\omega}_2$? Specify the appropriate units for each of the variables.

Question 2: Compute the admittance matrix $Y_{2\times 2}$ (analytically) using the basic definition $I = YV$. Show the symbolic expression and compute the numeric values.

Notes:

- ✓ The network has 2 buses. The load resistor R is modeled as part of the network.
- ✓ Recall that the jth column of Y may be found by connecting a unity voltage source to bus j, and grounding the other buses. Then $y_{i,j}$ is the current injected into bus i.

Question 3: Using the AC power flow equations express the powers P_1 and P_2 as a function of δ_2 and the elements of Y.

Question 4: In the same Simulink file, copy and paste the original system to obtain two identical systems (which will run in the same simulation). Now edit the second system such that the network is represented by the AC power flow equations, instead of the DC power flow equations.

Notes:

- ✓ In the copied system, remember to edit the variable names in the **To Workspace** blocks. For instance, use “omega1_B” instead of “omega1”.
- ✓ To implement the AC power flow equations you may use the “**Fcn**” block, which may be found in the “User-Defined Functions” library.

Run the model, and plot the signals.
What is the operating point of the new system?
Is it identical to the operating point of the original system? Explain.

Question 5: In both systems replace the constant “Pref2” with a **step** block, which is defined as follows:

- ✓ Step time = 5
- ✓ Initial value = Pref2
- ✓ Final value = 1.5*Pref2

Run the model and compare the results for the two systems.
Is the DC power flow a good approximation in this case? Explain.

Question 6: In the **step** block, change Final value to 3.5*Pref2.

Run the model again and compare the results for the two systems.
Is the DC power flow a good approximation in this case? Explain.