Project 1 for chapters 1 and 2
Design of Smart Power Grid Renewable Energy Systems
Wiley 2011

Simulation Problem 1. Write a report and a general Matlab M-code to solve the problem below. Your report should have the following sections.

1. Problem statement.
2. Mathematical formulation
3. Solution in a tabular form.
4. Appendix for your Matlab M-Code

Problem: The operation of AC machines (in particular, transformers and induction machines) can be studied with the aid of the T-circuit shown in Fig. 1 below.

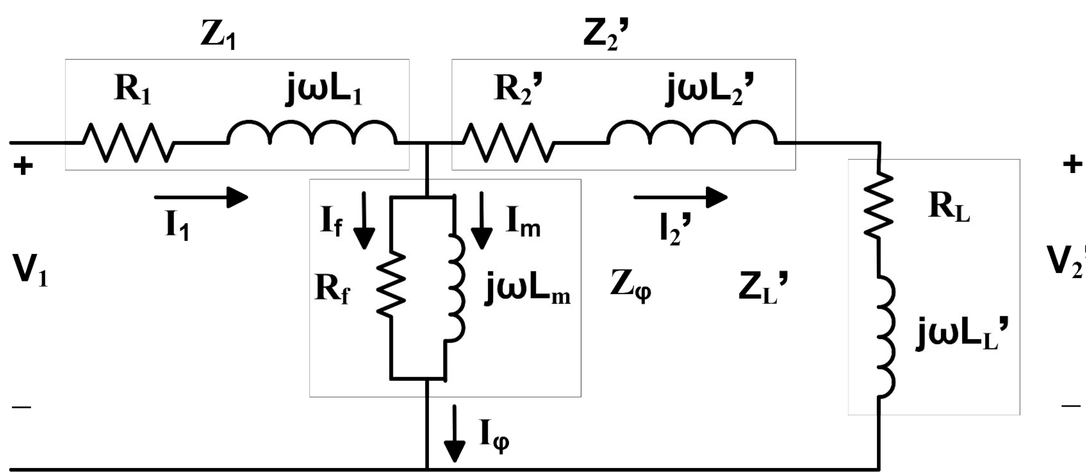

Figure 1 Equivalent Circuit for Problem 1.

Assume the frequency is 60 Hz. The circuit elements are given in table 1 below.

Table 1: Data for problem 1

Case	R_1	L_1	R_f	L_m	R_2'	L_2'	R_L	L_L	V_1	V_2	I_1	I_2'	I_f
1	1	0.01	1000	8	1	0.01	Open		480	?	?	?	?
2	1	0.01	1000	8	1	0.01	200	0	480	?	?	?	?
3	0.0	0.0026	Open		0	0	Open		1	?	?	?	?

	2	5											
4	0.02	0.00265	Open		0	0	1	0	1	?	?	?	?
5	0.02	0.00265	Open		0	0	0.707	1.875 ¿10^{-3}	?	1	?	?	?
6	0	0	100	0.1	0.01	106 ¿10^{-6}	1	0	1	?	?	?	?
7	0	0	100	0.01	0.01	106 ¿10^{-6}	1.414	3.75 ¿10^{-3}	1	?	?	?	?
8	0.3	1.33 ¿10^{-3}	Open	3.45 ¿10^{-2}	0.15	0.56 ¿10^{-3}	7.35	0	127	?	?	?	?
9	10	5.2 ¿10^{-2}	Open	0	0	200	0.4	0	500	?	?	?	?
10	0.15	2.54 ¿10^{-3}	Open	1.57	6.24 ¿10^{-3}	98.5	0.178	0	240	?	?	?	?
11	0.3	0.003	1	4.25 ¿10^{-2}	0.2	0.003	10	0	440	?	?	?	?
12	0.3	0.003	0	4.25 ¿10^{-2}	0.2	0.003	1	0	380	?	?	?	?

Use the polar form for all complex numbers and solve set 1 through set 12.

Hint: Use Z = R + jX. When an element is shorted, set that element to zero. When an element is open, set the value to a high value

Solutions

Case 1:

$$Z_L = R_L + j\ X_L = open$$

$$Z_1 = R_1 + j\ X_1 = 1 + j\ 0.01 \times 2\pi \times 60 = 1 + j\ 3.77\ \Omega$$

$$Z_{\phi}=R_f || j\ X_m=\frac{R_f \times j\ X_m}{R_f+j\ X_m}=900.95\text{+j } 298.73\ \Omega$$

$$I_1=I_{\phi}=\frac{V_1}{Z_1+Z_{\phi}}=0.504\angle\text{-}18.5407°\ A$$

$$V_2=Z\phi I_{\phi}=(900.95+j\ 298.73)0.504\angle\text{-}18.5407°= 478.91\angle\text{-}0.19°\ \text{V}$$

$$I_2=0$$

Case 2:

$$\frac{V_{\phi}-V_1}{Z_1}+\frac{V_{\phi}-V_2}{Z_2'}+\frac{V_{\phi}}{Z_{\phi}}=0$$

$$\frac{V_2-V_{\phi}}{Z_2'}+\frac{V_2}{Z_L'}=0$$

$$(V_{\phi}-V_1)Y_1+(V_{\phi}-V_2)Y_2'+V_{\phi}Y_{\phi}=0$$

$$(V_2-V_{\phi})Y_2'+V_2Y_L'=0$$

Where $Y_1=\frac{1}{Z_1},\ Y_2'=\frac{1}{Z_2'},\ Y_{\phi}=\frac{1}{Z_{\phi}}$

Rearranging,

$$\begin{bmatrix} Y_1+Y_2'+Y_{\phi} & -Y_2' \\ -Y_2' & Y_2'+Y_L' \end{bmatrix}\begin{bmatrix} V_{\phi} \\ V_2 \end{bmatrix}=\begin{bmatrix} V_1Y_1 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} V_{\phi} \\ V_2 \end{bmatrix}=\begin{bmatrix} Y_1+Y_2'+Y_{\phi} & -Y_2' \\ -Y_2' & Y_2'+Y_L' \end{bmatrix}^{-1}\begin{bmatrix} V_1Y_1 \\ 0 \end{bmatrix}$$

The MATLAB program for solving the above (Case 2) is given below.

```
clc;
V1 = 480;
f = 60;
w = 2*pi*f;
R1 = 1;
L1 = 0.01;
X1 = L1*w;
Z1 = R1+X1*1j;
```

```
Y1 = 1/Z1;
Rf = 1000;
Lm = 8;
Xm = Lm*w;
Zf = Rf*Xm*1j/(Rf+Xm*1j);
Yf = 1/Zf;
R2 = 1;
L2 = 0.01;
X2 = L2*w;
Z2 = R2+X2*1j;
Y2 = 1/Z2;
Rload = 200;
Lload = 0;
Xload = Lload*w;
Zload = Rload + Xload*1j;
Yload = 1/Zload;
Ybus = [Y1+Y2+Yf    -Y2; -Y2   Y2+Yload];
VfV2 = inv(Ybus)*[V1*Y1; 0];
Vf = VfV2(1);
V2 = VfV2(2);
abs_V2 = abs(V2)
angle_V2 = angle(V2)*180/pi
Iphi = Vf*Yf;
abs_Iphi = abs(Iphi)
angle_Iphi = angle(Iphi)*180/pi
Irf = Iphi*Xm*1j/(Rf+Xm*1j);
abs_Irf = abs(Irf)
angle_Irf = angle(Irf)*180/pi
I2 = V2*Yload;
abs_I2 = abs(I2)
angle_I2 = angle(I2)*180/pi
I1 = (V1-Vf)*Y1;
abs_I1 = abs(I1)
angle_I1 = angle(I1)*180/pi
```

The above program can be used to solve other cases by using the data from the problem by substituting the values of impedances and voltages. When a part of circuit is specified as open, its value can be substituted with a large number so that branch acts as open and when as a short with zero impedance. The results are tabulated in table below:

The results for all cases.

Case	V_1	V_2	I_1	I_2’	I_f
1	480	478.91 $\angle$-0.19°	0.505 $\angle$-18.5°	0	0.48 $\angle$-0.2°
2	480	473.82 $\angle$-2.33°	2.85 $\angle$-5.32°	2.37 $\angle$-2.33°	0.48 $\angle$-1.26°
3	1	1	0	0	0

		∠0º			
4	1	0.7 ∠-44.4º	0.7 ∠-44.4º	0.7 ∠-44.4º	0
5	1.85 ∠21.9º	1	1 ∠-45º	1 ∠-45º	0
6	1	0.989 ∠-2.27º	1 ∠-3.76º	0.989 ∠-2.27º	0.01 ∠0º
7	1	0.983 ∠-0.6º	0.71 ∠-60º	0.491 ∠-45.6º	0.01 ∠0º
8	127	115.1 ∠-3.87º	18.29 ∠-33.4º	15.65 ∠-3.87º	0
9	500	0	22.71 ∠-62.97	0	0
10	240	0.0011 ∠-89.86	0.411 ∠-89.98	0.0065 ∠-89.86	0
11	440	229.90 ∠-47.12	259 ∠-44.61	22.99 ∠-47.13	235.93 ∠-40.80
12	380	0	324.76 ∠-75.14	0	324.76 ∠-75.14