CHAPTER 8 PROBLEMS

8.1. A sinusoidal voltage given by $v(t) = 390\sin(315t + \alpha)$ is suddenly applied to a series RL circuit. $R = 32\ \Omega$ and $L = 0.4$ H.
(a) The switch is closed at such a time as to permit no transient current. What value of α corresponds to this instant of closing the switch? Obtain the instantaneous expression for $i(t)$. Use *MATLAB* to plot $i(t)$ up to 80 ms in steps of 0.01 ms.
(b) The switch is closed at such a time as to permit maximum transient current. What value of α corresponds to this instant of closing the switch? Obtain the instantaneous expression for $i(t)$. Use *MATLAB* to plot $i(t)$ up to 80 ms in steps of 0.01 ms.
(c) What is the maximum value of current in part (b) and at what time does this occur after the switch is closed?

$$v(t) = 390\sin(315t + \alpha)$$
$$i(t) = I_m \sin(315t + \alpha - \gamma) - I_m e^{-t/\tau}\sin(\alpha - \gamma)$$

(a) For no transient $\alpha = \gamma$

$$\gamma = \tan^{-1}\frac{(315)(0.4)}{32} = 75.75^\circ \quad \Rightarrow \quad \alpha = 75.75^\circ$$
$$Z = 32 + j(315)(0.4) = 32 + j126 = 130\angle 75.75^\circ\ \ \Omega$$
$$I = \frac{390}{130} = 3\ \text{ A} \quad \Rightarrow \quad i(t) = 3\sin 315t$$

(b) For maximum transient current $\alpha - \gamma = -90^\circ$. Therefore, $\alpha = 75.75 - 90 = -14.25^\circ$, and $\tau = \frac{L}{R} = 0.0125$ sec, and the current is

$$i(t) = 3\sin(315t - \frac{\pi}{2}) + 3e^{-80t}$$

(c)

$$\frac{di(t)}{dt} = (3)(315)\cos(315t - \frac{\pi}{2}) - 240e^{-80t} = 0$$

Use the command `[Imax, k] = max(i), tmax = t(k)` to find the maximum value of current, and the corresponding time.

$$i_{max} = 4.371 \text{ A}$$
$$t_{max} = 0.0096 \text{ sec}$$

Save the following statements in a file named **ch8p1.m**, and run to obtain the plots.

```
disp('Problem 8.1')
R = 32; L = 0.4; tau= L/R;w=315; X=w*L;
Z=R+j*X; Vm = 390;
gama=angle(Z);
gamad=gama*180/pi;
Im=Vm/130;
disp('(a)')
alpha1= gama; alpha = alpha1*180/pi
t=0:.0001:.08;
i1=Im*sin(315*t+alpha1 -gama);
subplot(211), plot(t, i1), grid
xlabel('t, sec'), ylabel('i(t)')
[I1max,k] = max(i1)
tmax= t(k)
disp('(b), (c)')
alpha2=gama - pi/2;  alpha = alpha2*180/pi
i2=Im*sin(315*t+alpha2 -gama)-Im*exp(-t/tau).*sin(alpha2-gama);
subplot(212), plot(t, i2), grid
xlabel('t, sec'), ylabel('i(t)')
[I2max,k] = max(i2)
tmax= t(k)
```

8.2. Consider the synchronous generator in Example 8.2. A three-phase short circuit is applied at the instant when the rotor direct axis position is at $\delta = 30°$. Use **ode45** to simulate (8.36), and obtain and plot the transient waveforms for the current in each phase and the field current.

In Example 8.2, set $\delta = 30°$, rename the file and run the program.

8.3. Consider the synchronous generator in Example 8.2. A line-to-line short circuit occurs between phases b and c at the instant when the rotor direct axis position is at $\delta = 30°$. Use **ode45** to simulate (8.46), and obtain the transient waveforms for the current in phase b and the field current.

In Example 8.3, set $\delta = 30°$, rename the file and run the program.

8.4. Consider a line-to-ground short circuit between phase a and ground in a synchronous generator. Apply the short circuit conditions

$$v_a = 0$$

When the fault is applied by closing switch S, the generator short circuit transient current is

$$I'_g = \frac{E'}{j(X'_d + X_t)} = \frac{1.24 + j0.32}{j(0.25 + 0.25)} = 0.64 - j2.4 = 2.56\angle{-75.53^\circ} \text{ pu}$$
$$= 7,393.69\angle{-75.53^\circ} \text{ A}$$

8.12. A 100-MVA, 20-kV synchronous generator is connected through a transmission line to a 100-MVA, 20-kV synchronous motor. The per unit transient reactances of the generator and motor are 0.25 and 0.20, respectively. The line reactance on the base of 100 MVA is 0.1 per unit. The motor is taking 50 MW at 0.8 power factor leading at a terminal voltage of 20 kV. A three-phase short circuit occurs at the generator terminals. Determine the transient currents in each of the two machines and in the short circuit.

$$S_m = \frac{50}{0.8}\angle{-36.87^\circ} \text{ MVA} = 0.625\angle{-36.87^\circ} \text{ pu}$$
$$V_m = \frac{20\angle 0^\circ}{20} = 1.0\angle 0^\circ \text{ pu}$$
$$I = \frac{S_m^*}{V_m^*} = 0.625\angle 36.87^\circ \text{ pu}$$

The generator emf behind transient reactance is

$$E'_g = V_m + j(X'_{dg} + X_L)I = 1.0\angle 0^\circ + j(0.25 + 0.10)(0.5 + j0.375)$$
$$= 0.8688 + j0.1750 = 0.8862\angle 11.389^\circ \text{ pu}$$

The motor emf behind transient reactance is

$$E'_m = V_m - j(X'_{dm})I = 1.0\angle 0^\circ - j(0.20)(0.5 + j0.375)$$
$$= 1.075 - j0.10 = 1.0796\angle{-5.3145^\circ} \text{ pu}$$

$$I'_g = \frac{E'_g}{j(X'_{dg})} = \frac{0.8862\angle 11.389^\circ}{j0.25} = 0.7 - j3.475 = 3.545\angle{-78.61^\circ} \text{ pu}$$

$$I'_m = \frac{E'_m}{j(X'_{dm} + X_L)} = \frac{1.0796\angle{-5.3145^\circ}}{j0.30} = -0.3333 - j3.5833$$
$$= 3.5988\angle{-95.3145^\circ} \text{ pu}$$

The short-circuit current is

$$I_f = I'_g + I'_m = (0.70 - j3.475) + (-0.3333 - j3.58333)$$
$$= 7.0679\angle{-87.026^\circ} \text{ pu}$$