ECE 576

Exam #1
Thursday, March 31, 2016
80 Minutes

Closed book, closed notes
One 8.5 by 11 inch note sheet allowed
Simple calculators allowed

1. ________ / 20

2. ________ / 20

3. ________ / 20

4. ________ / 20

5. ________ / 20

Total ________ / 100
1. (20 points total)

For the IEEET2 exciter model shown below, assume that the initial conditions are $E_{FD} = 1.867$, and the exciter’s input is the terminal voltage of 0.9742 pu.

For parameters assume $K_A = 50$, $T_A = 0.1$, $T_E = 0.5$, $K_e = 1$, $T_F = 0.1$, $T_F = 0.05$, $T_R = 0.15$, $T_R = 0.05$, $V_{RMAX} = 3$, $V_{RMIN} = -3$. The saturation values are $S_E(2.0) = 0.0216$, and $S_E(2.5) = 0.0726$. Hence for a saturation function assume

$$S_E = 0.06 \times (E_{FD} - 1.4)^2.$$ 

Determine the initial values for $V_R$ and $V_{REF}$ (you may assume $V_s = 0$).

$$V_R = 1.891$$
$$V_{REF} = 0.9742 + 1.891/50 = 1.012$$
2.  (20 points total) (True/false)

Two points each.  Circle T if statement is true, F if statement is False.

T    F  1.  When represented in the power flow as a PV bus, a generator’s terminal voltage magnitude setpoint is modeled with an algebraic equation.

T    F  2.  The backward Euler integration method is numerically stable if the system itself is stable.

T    F  3.  When using Carson’s method to calculate the inductance matrix for untransposed lines, the results depend on the assumed frequency.

T    F  4.  In the convention used in the ECE 576 book the q-axis is assumed to lead the d-axis.

T    F  5.  Because the rise times for lighting strikes is on the order of several 60 Hz cycles, the overvoltages caused by lightning strikes are usually modeled with transient stability software.

T    F  6.  With a subtransient machine model the subtransient reactances are always larger than the transient reactances.

T    F  7.  With round rotor electric machines model saturation is often ignored on the direct axis because of its relatively large air gap compared to that of the quadrature axis.

T    F  8.  Even in a large interconnection, such as the WECC, in the first few seconds following a generator loss contingency the frequency at all the buses in the system is essentially the same since electricity travels at nearly the speed of light.

T    F  9.  Regardless of the number of generators in a system, one generator must always contain an isochronous governor in order to insure that the system frequency returns to its desired value (e.g., 60 Hz here in North America).

T    F  10.  When using the Ziegler-Nichols approach for tuning a PI controller the $K_I$ value must always be larger than the $K_P$ value.
3. **(20 points total)**

Assume a 60 Hz, 100 MVA base synchronous generator is represented with a classical model with $H = 5.0$, $D = 0$, and $X_d' = 0.25$, with the generator supplying 100 MW and 0 Mvar to a $1.0 \angle 0^\circ$ infinite bus (measured at the infinite bus) through a transmission line with per unit (100 MVA base) impedance of $j0.25$. If at $t=0$ a solid three phase fault is applied to the generator’s terminal, use the implicit trapezoidal method with a time step of 0.01 seconds to determine the generator’s speed and angle at time $= 0.01$ seconds.

Let $x = \begin{bmatrix} \delta \\ \Delta \omega \end{bmatrix}$, then with $\delta(0) = 26.57^\circ \rightarrow x(0) = \begin{bmatrix} 0.464 \\ 0 \end{bmatrix}$

$P_{\text{mech}} = 1$ and during fault $P_{\text{elec}} = 0$, so the equations are

$\dot{x}_1 = x_2$

$\dot{x}_2 = \frac{\omega_1}{2H} (1-0) = 37.7$

With the Trapezoidal method with $\Delta t=0.01$,

$x(0.01) = x(0) + \frac{0.01}{2} (f(x(0)) + f(x(0.01)))$

$x(0.01) = \begin{bmatrix} 0.464 \\ 0 \end{bmatrix} + 0.005 \times \begin{bmatrix} 0 \\ 37.7 \end{bmatrix} + \begin{bmatrix} 0.464 \\ 0.377 \end{bmatrix} = \begin{bmatrix} 0.4659 \\ 0.377 \end{bmatrix}$

So $\delta(0.01) = 26.69^\circ$
4. (20 points total)

The below table lists the governor per unit R values for a five generator system, with each R specified on the unit’s MVA base. Assume the system is initially operating at 60 Hz. What would be the expected final frequency for a loss of 100 MW of load with just the governor response? Also, sketch the expected system frequency response. You may assume the system is lossless, that none of the governors reach a limit, and that the frequency response at each bus is similar.

<table>
<thead>
<tr>
<th>Generator Number</th>
<th>Generator MVA Base</th>
<th>Per Unit R Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>200</td>
<td>0.04</td>
</tr>
<tr>
<td>3</td>
<td>400</td>
<td>0.05</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>0.05</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Convert all the R's to a common 100 MVA base. Then

\[
\Delta f_{pu} = \frac{\Delta P_L}{\sum \frac{1}{R_i}} = \frac{1}{215} = 0.00465 \rightarrow 0.279 \text{ Hz}
\]
5. (20 points total)

The Lotka-Volterra equations given below (also known as the predator-prey equations) provide a simple description of how two species interact. Let $x_1$ represent the number of prey (say rabbits) in arbitrary units (say thousands) and $x_2$ the number of predators (say foxes). Let $\alpha = 0.5$, $\beta = 1.5$, $\delta = \gamma = 1$.

\begin{align*}
\dot{x}_1 &= \alpha x_1 - \beta x_1 x_2 \\
\dot{x}_2 &= \delta x_1 x_2 - \gamma x_2
\end{align*}

5pts (a) Determine an equilibrium point

15pts (b) Assume a time step size of $\Delta t = 0.1$, and initial values of $x_1(0) = 1$ and $x_2(0) = 1$. Use the second order Runge-Kutta method to calculate $x_1(0.1)$ and $x_2(0.1)$.

\begin{align*}
\dot{x}_1 &= x_1 \left( 0.5 - 1.5 x_2 \right) \\
\dot{x}_2 &= x_2 \left( x_1 - 1 \right)
\end{align*}

(a) A simple equilibrium is $x_1 = x_2 = 0$. Another is $x_1 = 1$, $x_2 = 1/3$.

(b) $x_1(0.1) = 0.905$, $x_2(0.01) = 0.995$