Name: __Answers_______________

ECEN 667

Exam #1
Thursday, October 17, 2017
75 Minutes

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

1. _________ / 24

2. _________ / 24

3. _________ / 28

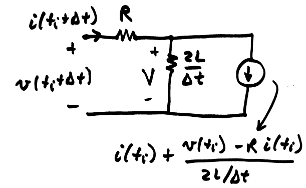
4. _________ / 24

Total _________ / 100

1. (20 points total)

Assume a 200 Ω resistor is connected in series with a 0.1 H inductor and an open switch, and the series combination is connected to a voltage source of v(t) = 1000cos(2π60t). If the switch is closed at time t=0, using the trapezoidal integration method with a time step of 0.0001 seconds, determine the current flowing in this series circuit at t=0.0002 seconds.

$$\frac{2L}{\Delta t} = \frac{0.2}{0.0001} = 2000, \text{ At } t = 0,\ i(0) = 0$$



At each time step we can get the current by superposition: the current just due to the terminal voltage plus the portion of the current source flowing into R (with terminal shorted), Which is 2000/2200*current source = 0.909

$$\text{Current Source}(0.0001) = i(0) + \frac{v(0) - 200 \times i(0)}{2000} = 0.5A$$

$$i(0.0001) = \frac{v(0.0001)}{2200} + 0.909 \times \text{Current Source}(0.0001) = 999.3/2200 + 0.4545 = 0.909A$$

$$\text{Current Source}(0.0002) = i(0.0001) + \frac{v(0.0001) - 200 \times i(0.0001)}{2000} = 1.318A$$

$$i(0.0002) = \frac{v(0.0002)}{2200} + 0.909 \times \text{Current Source}(0.0002) = 997.2/2200 + 1.199 = 1.652A$$

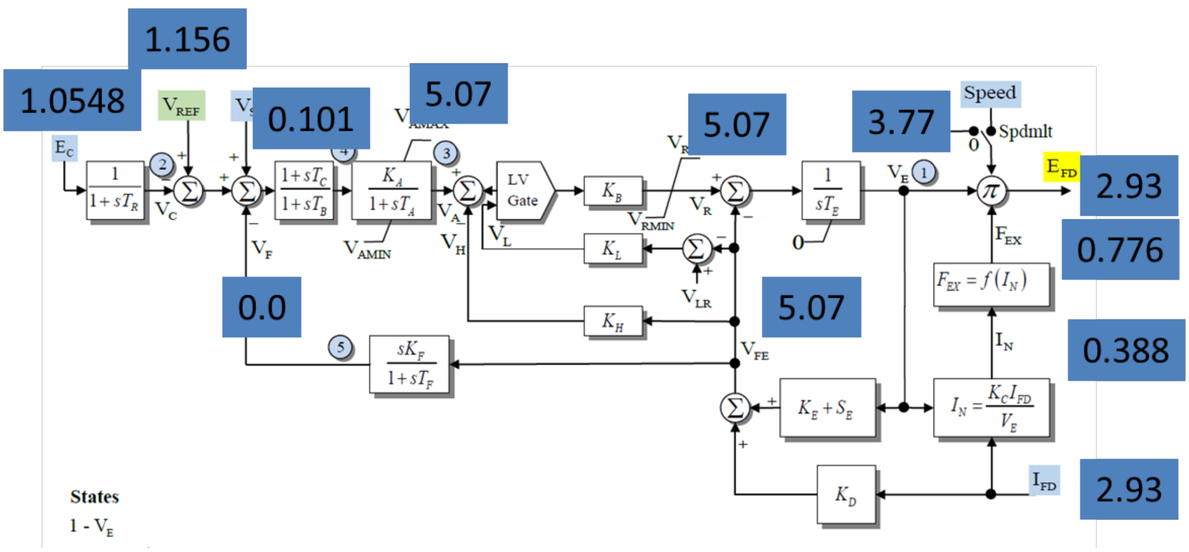
2. (24 points total)

For the EXAC2 exciter model shown below, assume that the initial conditions are E_{FD}=2.93, I_{FD} = 2.93., and the exciter's input is the terminal voltage of 1.0548 pu.
For parameters assume is T_R= 0.05, T_C=1, T_B=2, K_A=50, T_A=0.1, K_B=1, K_L=1, V_{LR}=10, T_E=0.1, K_H=0, K_E=1, K_D=0, T_F=1.2, K_F=0.02, K_C=0.5. The saturation values are $S_E(2.5)$ = 0.02, and $S_E(3.0)$ = 0.1. Hence for a saturation function assume

$$S_E(V_E) = 0.1222 \times (V_E - 2.095)^2 .$$

Determine the initial value for V_{REF} where $V_{ERR} = V_{REF} - V_T$; (you may assume V_s=0)

To simplify the problem you may assume that for the initial I_N value $f(I_N)$ can be approximated as being on the segment with $F_{EX} = 1 - 0.577*K_C*I_{FD}/V_E$.



3. (28 points total) (True/false)

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

T	F	1.	With the GENROU model we always have $X_d'' = X_q''$.
T	**F**	2.	Explicit numerical integration methods have the advantage of always being numerically stable.
T	F	3.	In EMTP analysis much of the system can be treated as decoupled because of the transmission line propagation delays.
T	F	4.	In transient stability the stator transients are typically ignored.
T	F	5.	When converting synchronous machine models to per unit the time constants are independent of the assumed MVA base.
T	**F**	6.	In contrast to EMTP applications, transient stability applications require a slack bus to insure total generation is always equal to total load plus losses
T	**F**	7.	With salient pole machines saturation is often ignored on the direct axis because of its relatively large air gap compared to the quadrature axis.
T	**F**	8.	When using Carson's method to determine the inductance of untransposed multi-phase transmission lines, the inductance is independent of the ground resistivity.
T	**F**	9.	While perhaps interesting from a theoretical perspective, machine magnetic saturation is seldom encountered in practice.
T	F	10.	There is not a unique way to implement non-windup limits for a lead-lag block.
T	F	11.	Compensation can be used to allow an exciter to regulate a voltage other than its terminal voltage.
T	**F**	12	Per unit values are always dimensionless.
T	F	13	In a large interconnection, such as the Eastern Interconnect, in the first few seconds following a generator loss contingency the frequencies at the buses in the system can vary from each other.
T	**F**	14	While one of the oldest synchronous machine models, the classical model is still widely used in commercial transient stability studies in North America.

4. (24 points total)

A 60 Hz generator is supplying 400 MW and 0 Mvar to an infinite bus (measured at the infinite bus) with 1.0 per unit voltage at the infinite bus through two parallel transmission lines. Each transmission line has a per unit impedance (100 MVA base) of 0.09j. The per unit transient reactance for the generator is 0.0375j (on a 100 MVA base), the per unit inertia constant for the generator (H) is 10 seconds, and damping is 0 per unit.

At time = 0 one of the transmission lines experiences a balanced three phase short to ground one third (1/3) of the way down the line from the generator to the infinite bus (i.e., model the line with 1/3 its original impedance on the generator side and 2/3 on the infinite bus side).

a. Using the classical generator model discussed in class (constant voltage behind transient reactance), determine the prefault internal voltage magnitude and angle of the generator.

b. Express the system dynamics during the fault as a set of first order differential equations.

c. Using a second order Runge-Kutta method, determine the generator internal angle at the end of the second time step. Use a time step of 0.02 seconds.

Solution

$a)$ $\bar{E} = 1.0 + (j0.045 + j0.0375)(4.0) = 1 + j0.33 = 1.053\angle 18.26°$

$b)$ During the fault V_{th} =0.25, Z_{th} =j0.0225

$$\frac{d\delta}{dt} = \Delta\omega_{pu}\omega_s = \Delta\omega_{pu}(377)$$

$$\frac{d\Delta\omega_{pu}}{dt} = \frac{1}{2H}(P_M - P_E) = \frac{1}{20}\left(4 - \frac{1.053 \times 0.25}{0.0225 + 0.0375}\sin\delta\right) = 0.2 - 0.22\sin\delta \quad \text{(during the fault)}$$

$c)$ $\mathbf{x} = \begin{bmatrix} \delta \\ \Delta\omega_{pu} \end{bmatrix}, \quad \mathbf{x}(0) = \begin{bmatrix} 0.3187 \\ 0 \end{bmatrix}, \quad \Delta t = 0.01$

$$\mathbf{x}(t+\Delta t) = \mathbf{x}(t) + \frac{1}{2}(\mathbf{k}_1 + \mathbf{k}_2) \text{ with } \mathbf{k}_1 = \Delta t\mathbf{f}(\mathbf{x}(t)), \mathbf{k}_2 = \Delta t\mathbf{f}(\mathbf{x}(t) + \mathbf{k}_1),$$

$$\mathbf{k}_1(0.0) = \begin{bmatrix} 0 \\ 0.0026 \end{bmatrix}, \mathbf{k}_2(0.0) = \begin{bmatrix} 0.0198 \\ 0.0026 \end{bmatrix} \rightarrow \mathbf{x}(0.02) = \begin{bmatrix} 0.3286 \\ 0.0026 \end{bmatrix} \rightarrow 18.82°$$

$$\mathbf{k}_1(0.02) = \begin{bmatrix} 0.0196 \\ 0.0026 \end{bmatrix}, \mathbf{k}_2(0.02) = \begin{bmatrix} 0.0392 \\ 0.0025 \end{bmatrix} \rightarrow \mathbf{x}(0.04) = \begin{bmatrix} 0.3580 \\ 0.0052 \end{bmatrix} \rightarrow 20.51°$$