ECEN 460 SPRING 2023 (Birchfield) Quiz 19 25 Apr 2024

Name: ______________________ UIN: __________ Section: _______ Score: _________

A 60 Hz generator is supplying 150 MW and 0 Mvar to an infinite bus (with 1.0 per-unit) through two parallel transmission lines. Each transmission line has a per-unit impedance (with 100 MVA base) of j0.05. The per-unit transient reactance for the machine is j0.02, and its inertia constant is 8 seconds. At time = 0, one of the lines opens and is removed from the system (no fault, just a line opening). There is no damping.

$$\dot{\delta} = \omega$$
$$\frac{2H}{\omega_s}\dot{\omega} = T_M - \frac{E'V_s}{X_d' + X_{ep}}\sin(\delta - \theta_{vs}) - D\cdot\omega$$

Using the classical generator model with equations given above, determine the pre-event internal voltage magnitude and angle of the generator $E'\angle\delta$, and find the pre-event initial values of ω and the mechanical torque T_M. Then write the dynamics of the system after the event as two differential equations with two variables δ and ω, and use Euler's method to solve for these variables for two time steps, with $\Delta t = 0.01$.

Euler's method
$$x(t+\Delta t) = x(t) + \Delta t\cdot f(x)$$
Where $f(x) = \dot{x}$

Before the event

The generator connects to a Thev. equiv. with $V_s\angle\theta_{vs} = 1.0\angle 0$ and $X_{ep} = j0.05||j0.05 = j0.025$

Solve the circuit for the generator internal voltage, which will give you E' and initial value of δ:

$I = \left(\frac{S}{V}\right)^* = \left(\frac{1.5}{1.0}\right)^* = 1.5$

$E'\angle\delta = 1.0 + (1.5)(j0.02 + j0.025) = 1.00228\angle 0.0674\ (rad)$

Now consider steady-state, to get $\omega = 0$

And $T_M = \frac{E'V_s}{X_d' + X_{ep}}\sin(\delta - \theta_{vs}) = \frac{1.00228\cdot 1}{0.02+0.025}\sin(0.0674) = 1.5$

After the event

The Thevenin equivalent changes. Since there is only one line, $X_{ep} = 0.05$, $V_s = 1.0$

Now rewrite the swing equation: $\frac{2\cdot 8}{2\pi 60}\dot{\omega} = 1.5 - \frac{1.00228}{0.07}\sin\delta$

So, using Euler's method starting with $\delta(0) = 0.0674$ and $\omega(0) = 0$

$\delta(0.01) = \delta(0) + \Delta t\left(\dot{\delta}(0)\right) = 0.0674 + 0.01\cdot(0) = 0.0674$

$\omega(0.01) = \omega(0) + \Delta t\left(\dot{\omega}(0)\right) = 0 + 0.01\cdot\left(\frac{2\pi 60}{16}\left(1.5 - \frac{1.00228}{0.07}\sin 0.0674\right)\right) = 0.1262$

$\delta(0.02) = \delta(0.01) + \Delta t\left(\dot{\delta}(0.01)\right) = 0.0674 + 0.01\cdot 0.1262 = 0.0687$

$\omega(0.02) = \omega(0.01) + \Delta t\left(\dot{\omega}(0.01)\right) = 0.1262 + 0.01\cdot\left(\dot{\omega}(0.01)\right) = 0.2524$