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ECE 520 Spring 2008

HW 06

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HW 06 Part 1

Using Analytical Methods (not simulation) calculate the following:

1. ***critical clearing angle, δ_cr:***
2. ***critical clearing time, t_cr:***
3. ***the maximum swing angle, δ_maxswing (with t_c = 0.8*t_cr)***
4. ***the minimum swing angle, δ_maxswing (with t_c = 0.8*t_cr)***

Given Parameters:

$H := 3.5 \qquad \omega_{eB} := 377.0 \qquad T_{max} := 2.8 \qquad T_m := 0.8$

$$T_e = \begin{cases} T_{max}\cdot\sin(\delta) & \text{if } t < 0 \\ 0 & \text{if } 0 \le t < t_c \\ T_{max}\cdot\sin(\delta) & \text{if } t_c \le t \end{cases}$$

Calculate the critical clearing angle (δ_{cr}):

For t < 0 Te = Tm $\qquad \delta := 0, 0.01 .. \pi$

$T_m - T_e = 0$

$0.8 - 2.8\cdot\sin(\delta_0) = 0$

$\delta_0 := \operatorname{asin}\left(\frac{0.8}{2.8}\right)$ $\qquad \delta_0 = 0.28975$ $\qquad \delta_0 = 16.602\,\text{deg}$ initial rotor angle

$\pi - \delta_0 = 2.852$ $\qquad \pi - \delta_0 = 163.398\,\text{deg}$

$A_a + A_c = A_{dmax} + A_c$

$A_a = T_m\cdot(\delta_{cr} - \delta_0) \qquad A_c = T_m\cdot[(\pi - \delta_0) - \delta_{cr}] \qquad A_{dmax} = \int_{\delta_{cr}}^{\pi-\delta_0} T_{max}\cdot\sin(\delta)\,d\delta$

$\delta_{cr} := 1.0$

Given

$T_m\cdot(\pi - 2\cdot\delta_0) = \int_{\delta_{cr}}^{\pi-\delta_0} T_{max}\cdot\sin(\delta)\,d\delta$

$\delta_{cr} := \text{Find}(\delta_{cr})$

$\delta_{cr} = 1.799$ $\qquad \delta_{cr} = 103.079\,\text{deg}$ this is the critical clearing angle required to satisfy the Equal Area Criteria

Calculate the critical clearing time (t_{cr}):

$$t_{cr} := \sqrt{\frac{4 \cdot H \cdot (\delta_{cr} - \delta_0)}{\omega_{eB} \cdot T_m}}$$

$t_{cr} = 0.26469$

this is the critical clearing time required to satisfy the Equal Area Criteria

maximum swing angle, $\delta_{maxswing}$ (with $t_c = 0.8 * t_{cr}$):

$t_c := 0.8 \cdot t_{cr}$ $t_c = 0.212$

$$\delta_{Tc} := \delta_0 + \frac{\omega_{eB} \cdot T_m}{2 \cdot H} \cdot \frac{t_c^2}{2}$$

$\delta_{Tc} = 1.256$ $\delta_{Tc} = 71.947 deg$

$\delta_{maxswing} := 1.0$

Given

$$T_m \cdot (\delta_{Tc} - \delta_0) = \int_{\delta_{Tc}}^{\delta_{maxswing}} (T_{max} \cdot \sin(\delta) - T_m)\, d\delta$$

$\delta_{maxswing} := \text{Find}(\delta_{maxswing})$

$\delta_{maxswing} = 1.649$ $\delta_{maxswing} = 94.508 deg$

this is the maximum swing angle at $\delta\_Tc = 0.8 * \delta\_cr$

minimum swing angle, $\delta_{minswing}$ (with $t_c = 0.8 * t_{cr}$):

$\delta_{minswing} := 0.2$

Given

$$0 = \int_{\delta_{minswing}}^{\delta_{maxswing}} (T_{max} \cdot \sin(\delta) - T_m)\, d\delta$$

$\delta_{minswing} := \text{Find}(\delta_{minswing})$

$\delta_{minswing} = -0.873$ $\delta_{minswing} = -50.042 deg$

this is the minimum swing angle at $\delta\_Tc = 0.8 * \delta\_cr$

$\delta := \frac{-\pi}{2}, \frac{-\pi}{2} + 0.01.. \pi$ $a := -3, -2.99.. 3$

$\delta\_0 := 0, 0.01.. T_{max} \cdot \sin(\delta_0)$ $\delta\_cr := 0, 0.01.. T_{max} \cdot \sin(\delta_{cr})$ $\delta\_\pi\_\delta\_0 := 0, 0.01.. T_{max} \cdot \sin(\pi - \delta_0)$

$\delta\_maxswing := 0, 0.01.. T_{max} \cdot \sin(\delta_{maxswing})$

$\delta\_minswing := T_{max} \cdot \sin(\delta_{minswing}), T_{max} \cdot \sin(\delta_{minswing}) + 0.01.. 0$

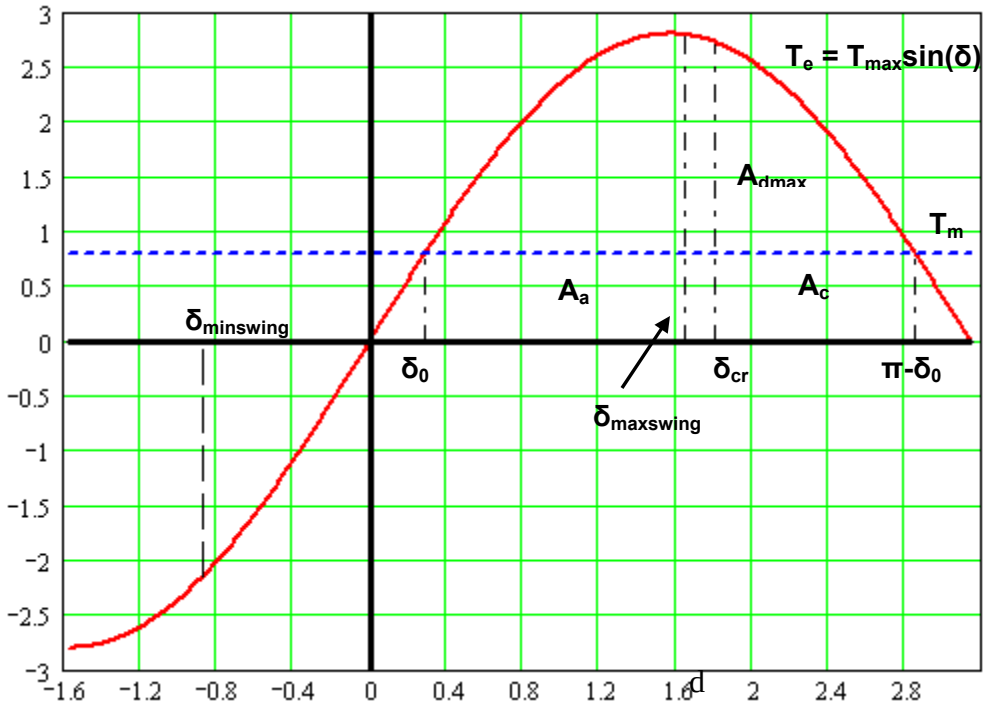
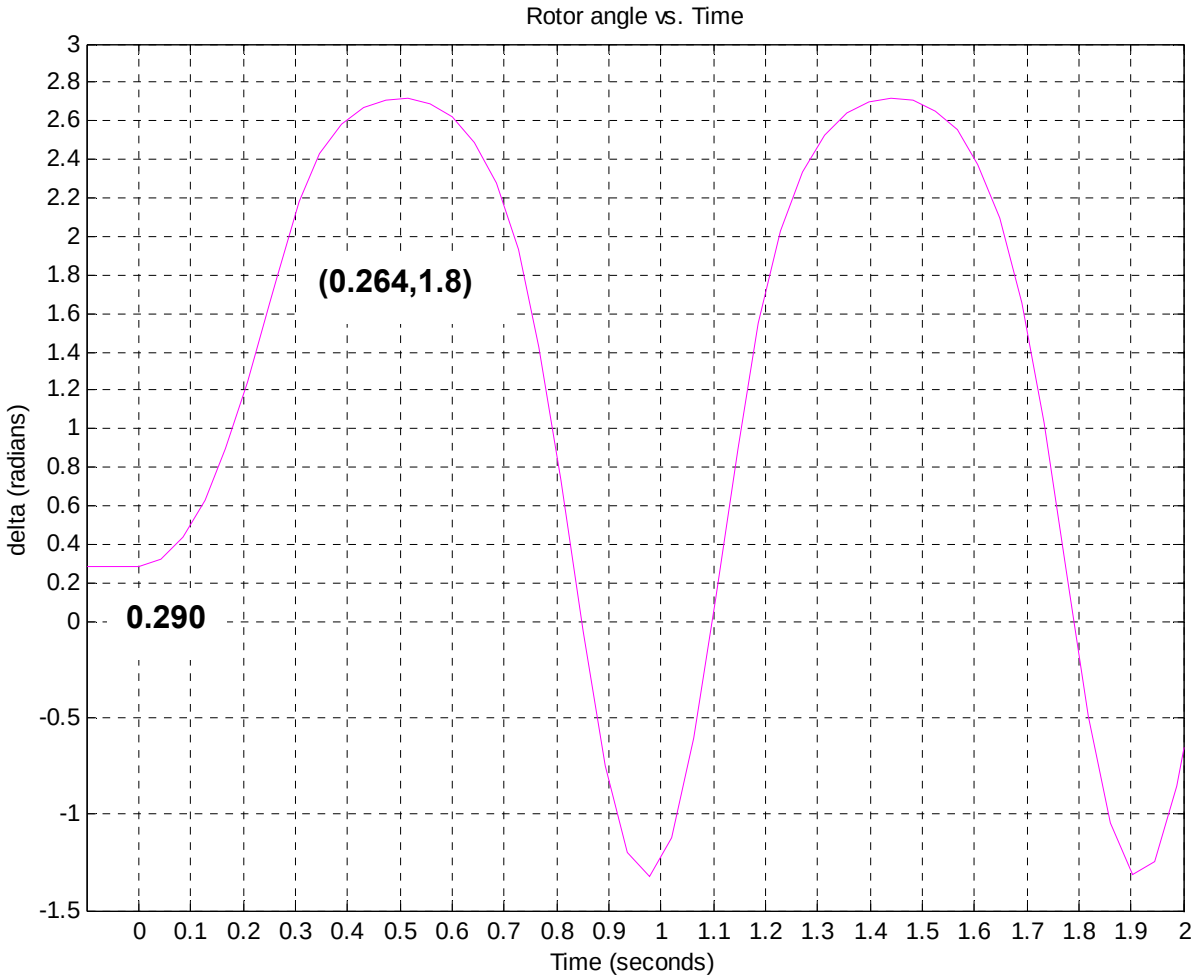


Figure 1: Equal Area Criteria

Summary

$\delta_0 = 0.28975$	$\delta_0 = 16.602\text{deg}$	$t_{cr} = 0.26469$
$\delta_{cr} = 1.79906$	$\delta_{cr} = 103.079\text{deg}$	$t_c = 0.21175$
$\delta_{Tc} = 1.25571$	$\delta_{Tc} = 71.947\text{deg}$	
$\delta_{maxswing} = 1.64947$	$\delta_{maxswing} = 94.508\text{deg}$	
$\delta_{minswing} = -0.8734$	$\delta_{minswing} = -50.042\text{deg}$	

HW 06 Part 2



Note: This is just at the edge of stability.

Figure 2: Delta vs Time ($t_c = t_{cr}$ (0.264))

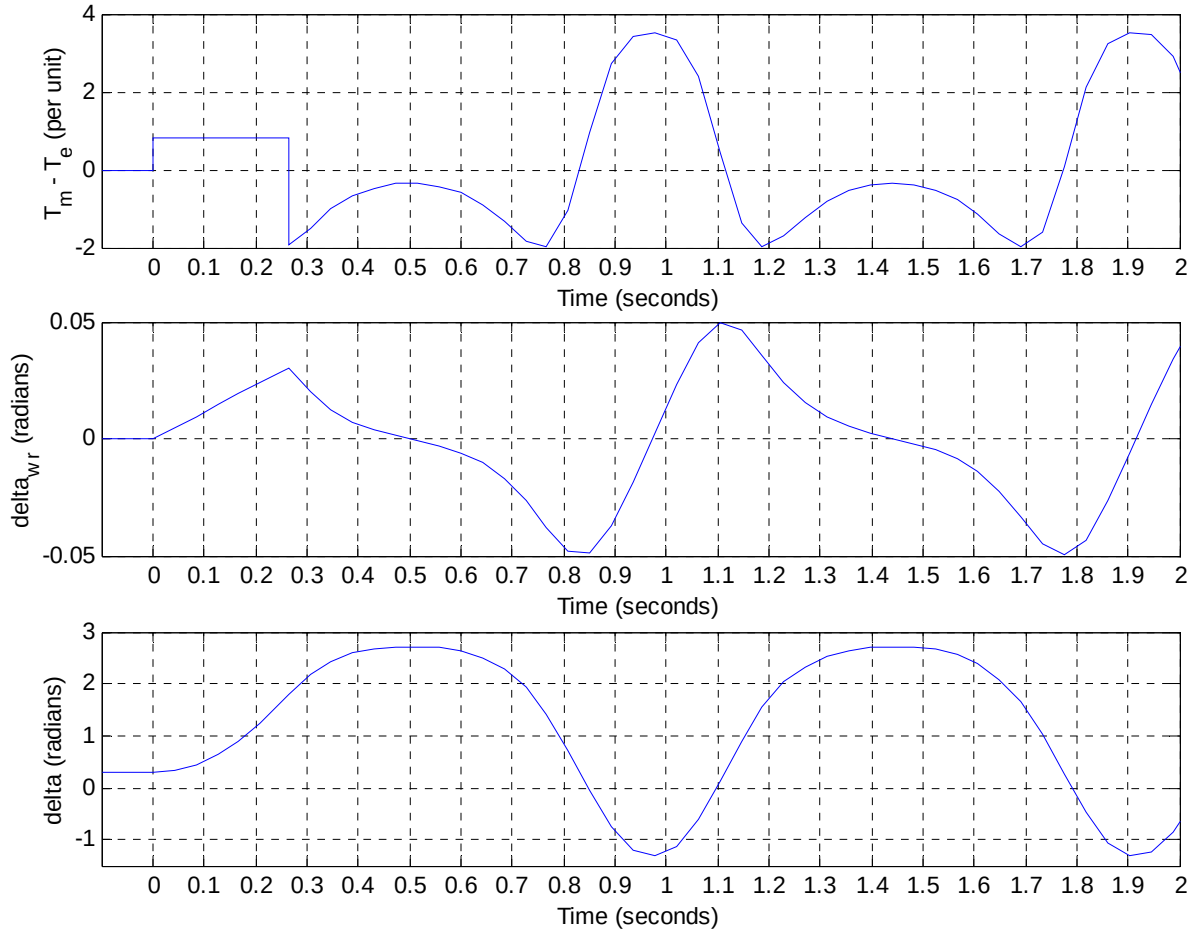
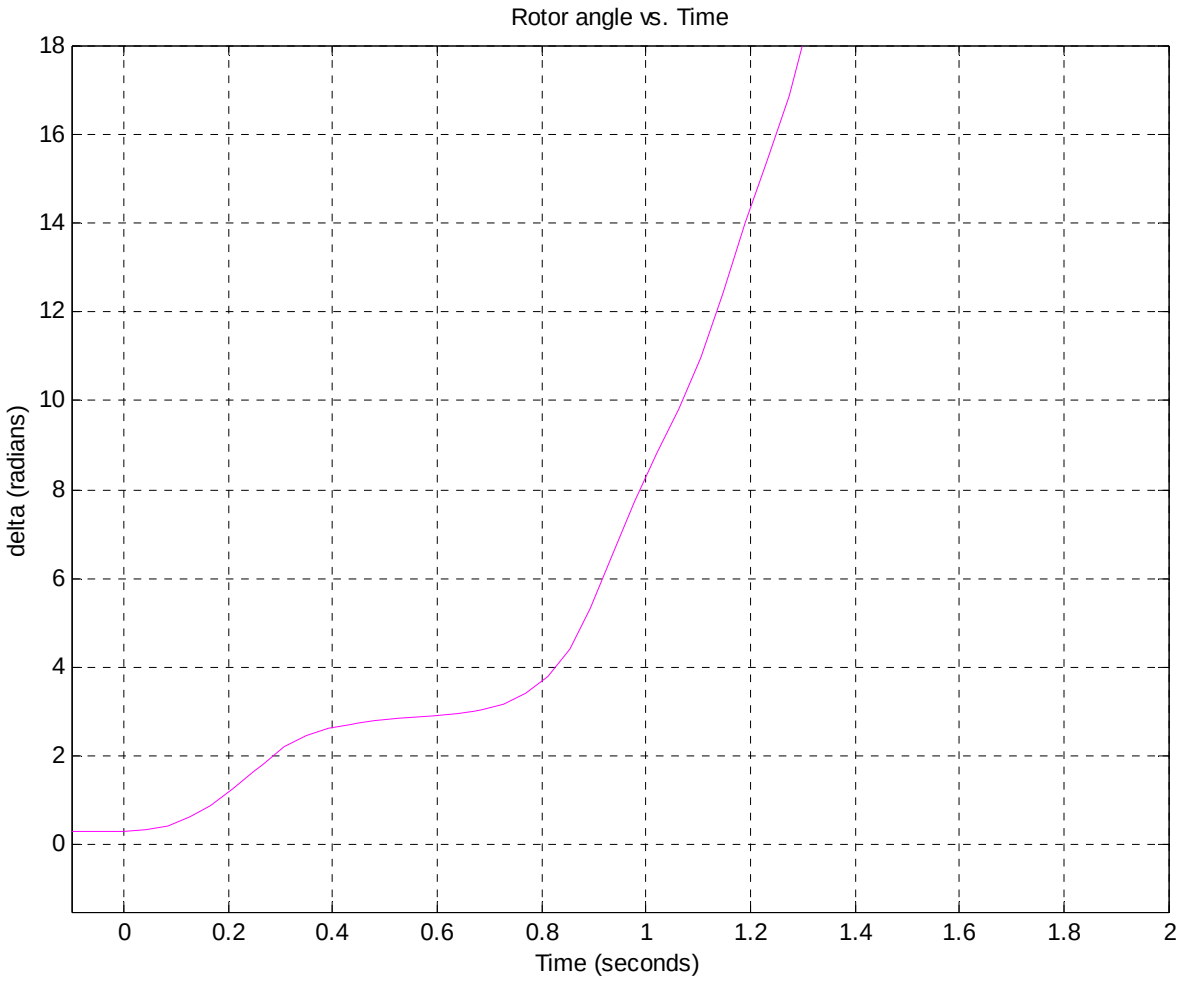


Figure 3: Delta, delta_w_r, T_m - T_e vs Time ($t_c = t_{cr}$ (0.264))



Note: System is now unstable

Figure 4: Delta vs Time ($t_c = t_{cr} + 0.001\ (0.265)$)

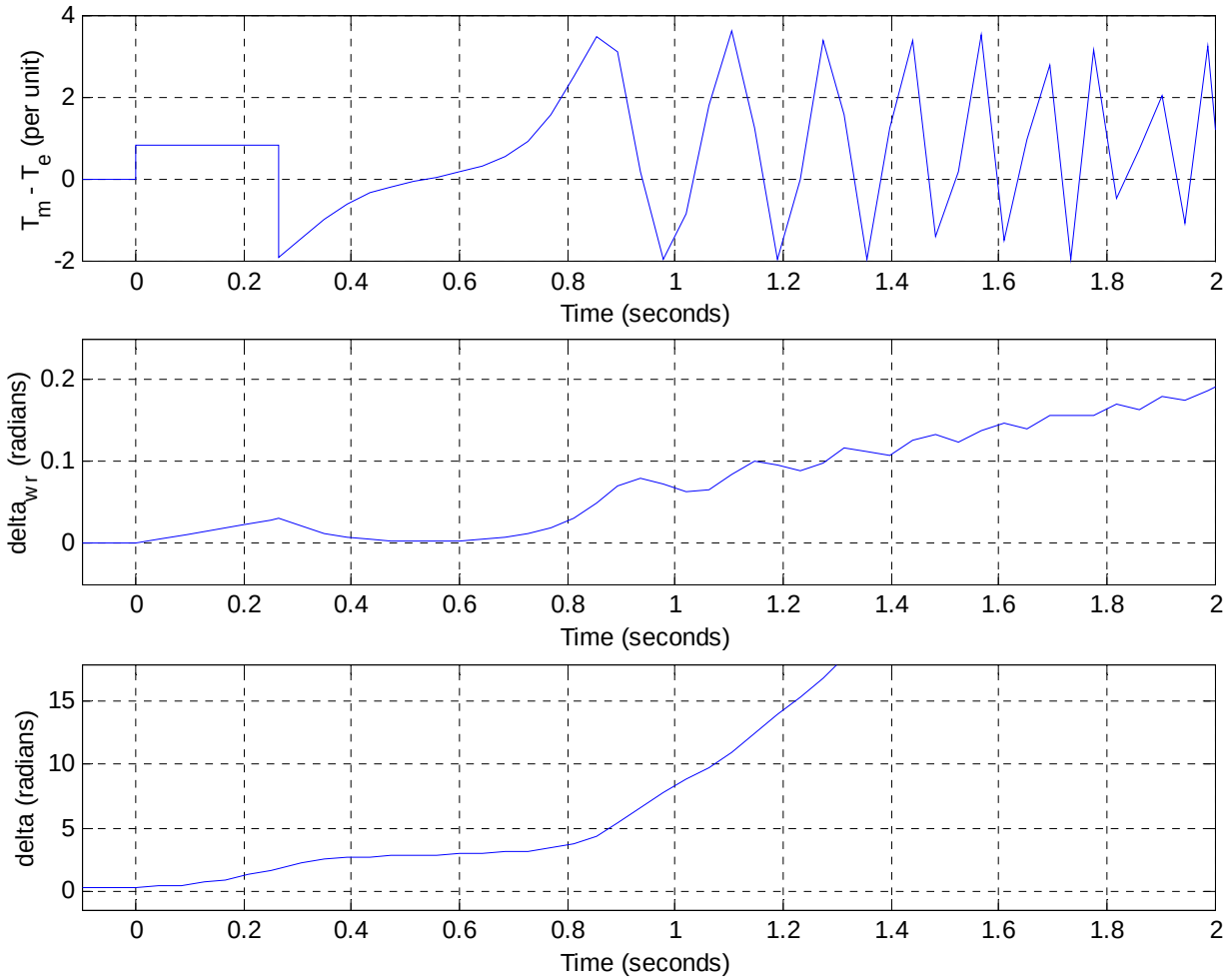
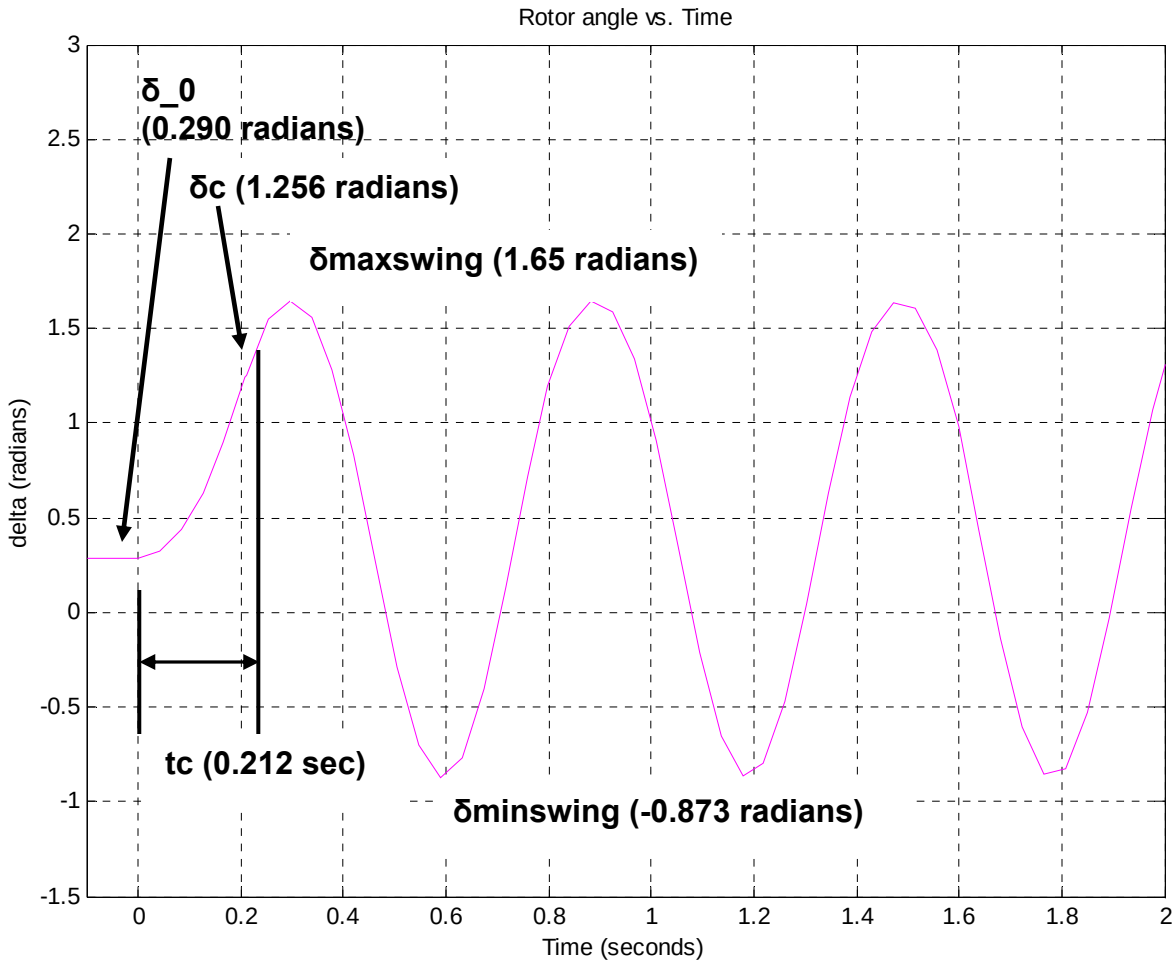


Figure 5: Delta, delta_w_r, T_m - T_e vs Time ($t_c = t_{cr} + 0.001$ (0.265))



Note: This system does not have damping, thus the rotor will continue to oscillate.

Figure 6: Delta vs Time ($t_c = 0.8t_{cr}$ (0.21175))

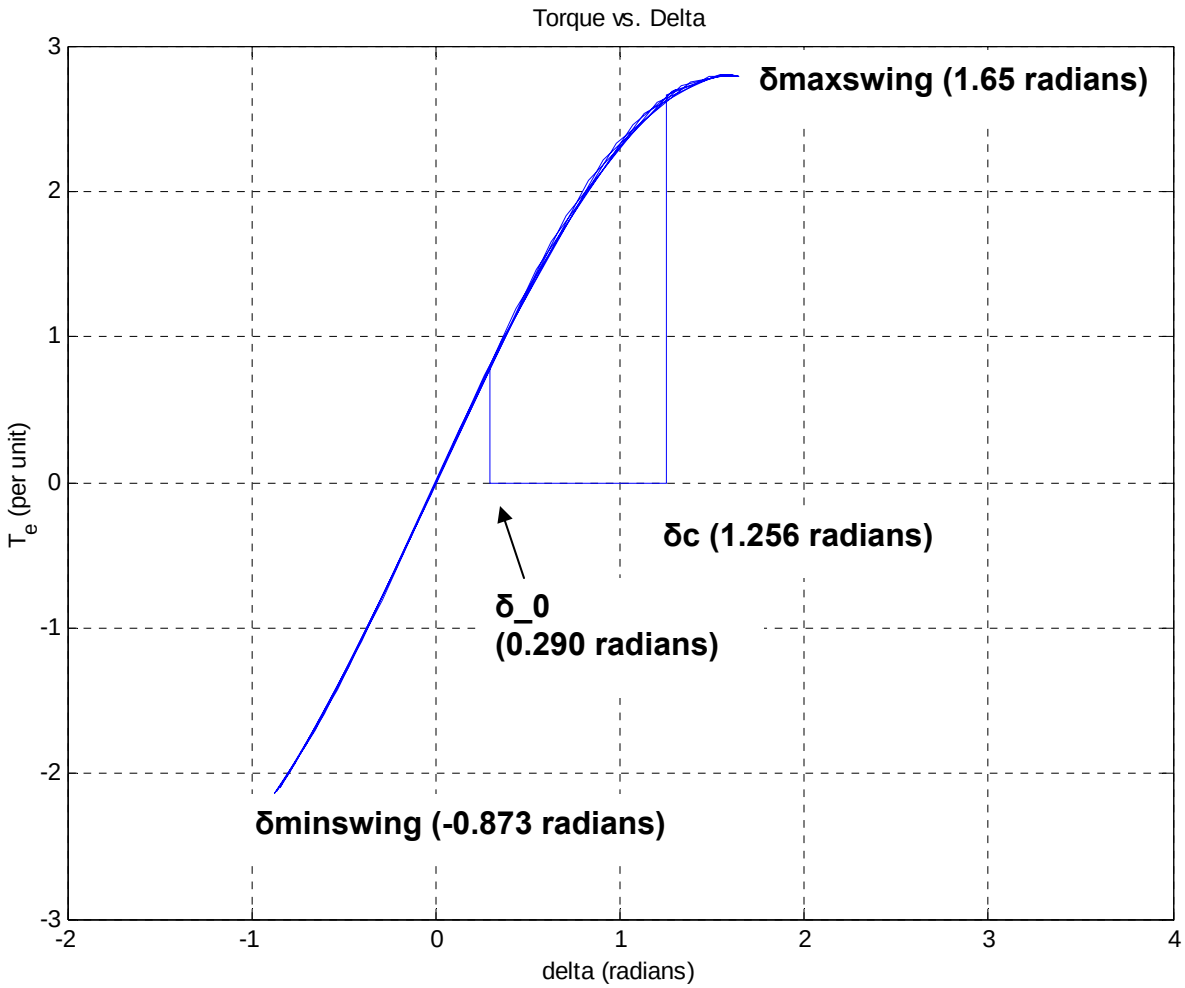


Figure 7: T_e vs Delta (t_c =0.8 t_{cr} (0.212))

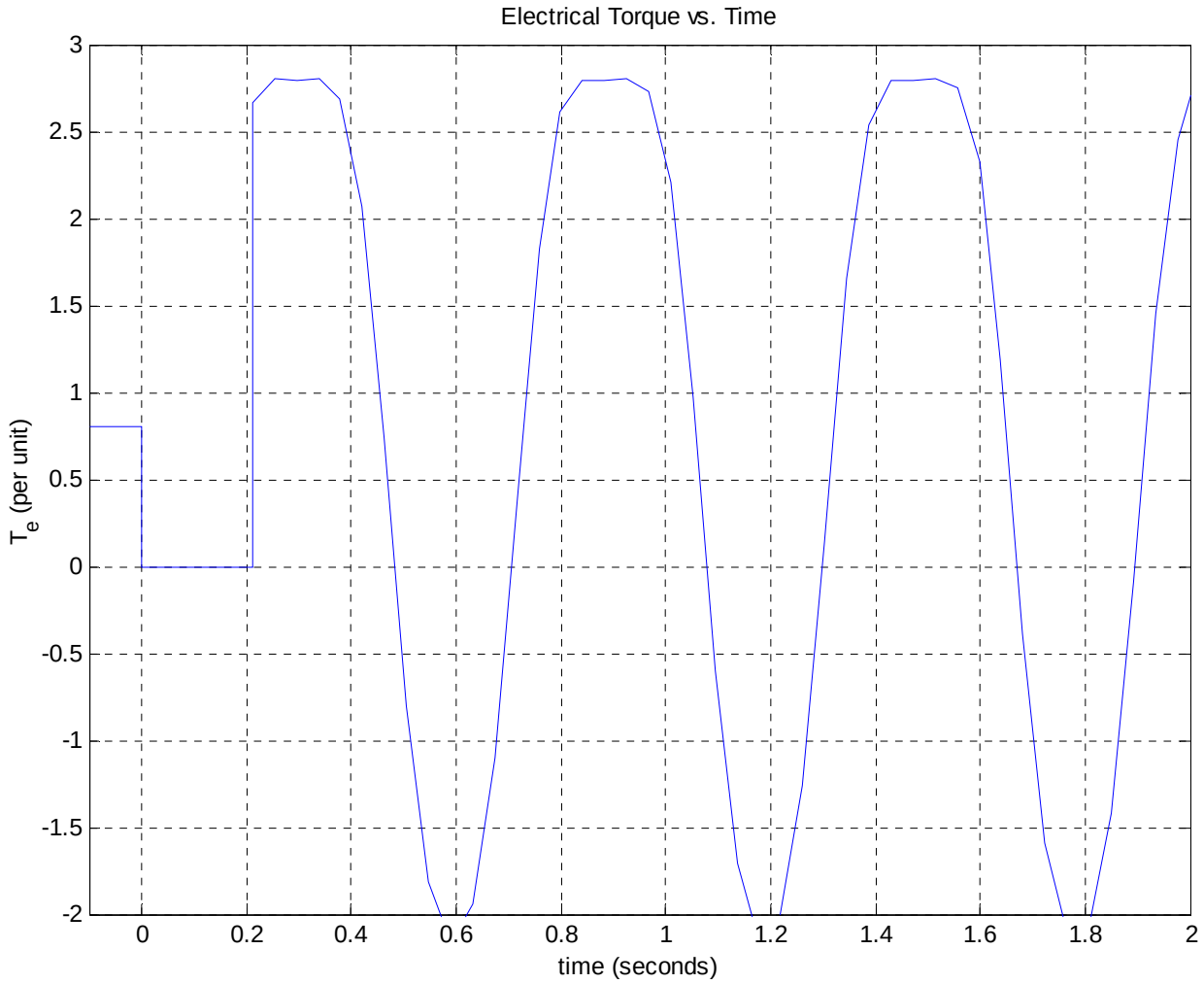
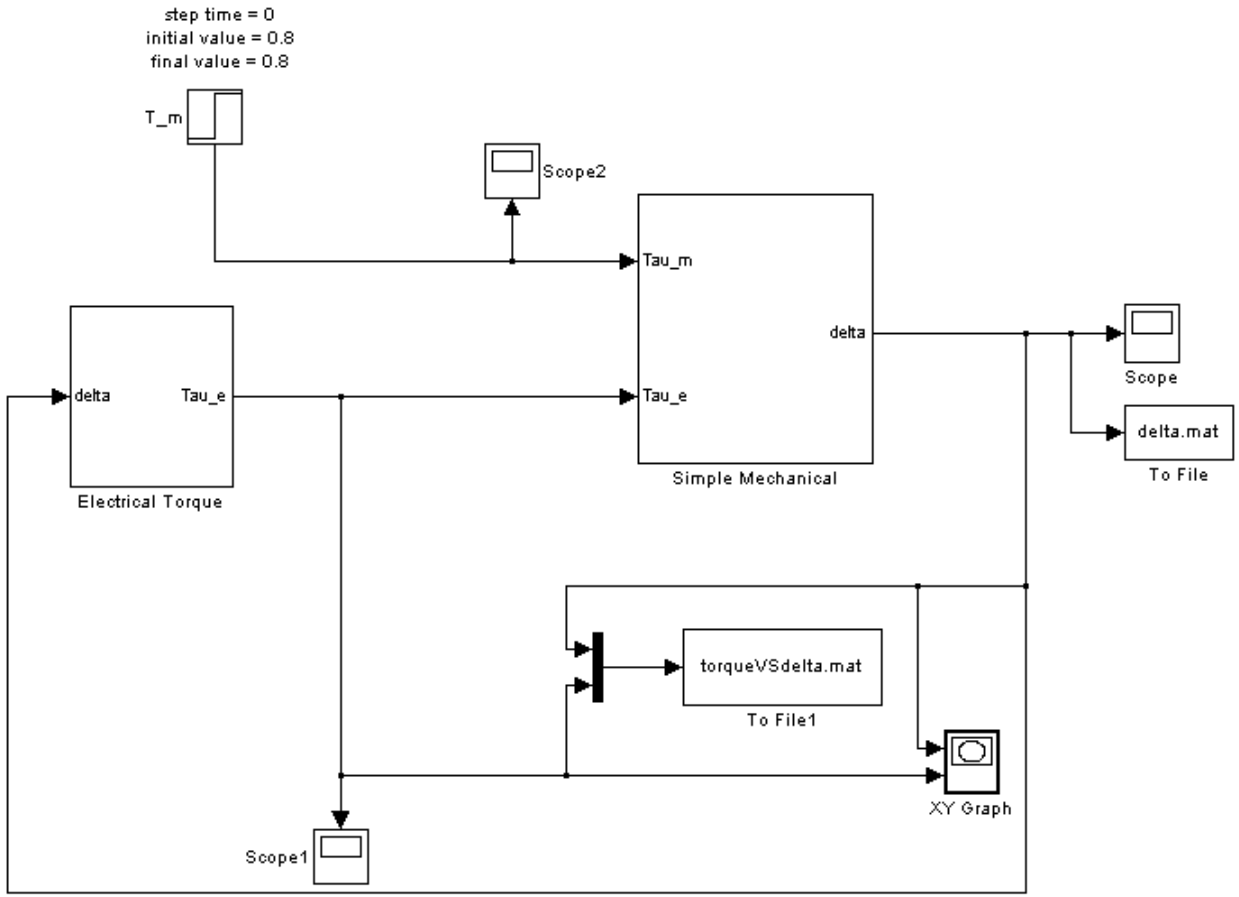


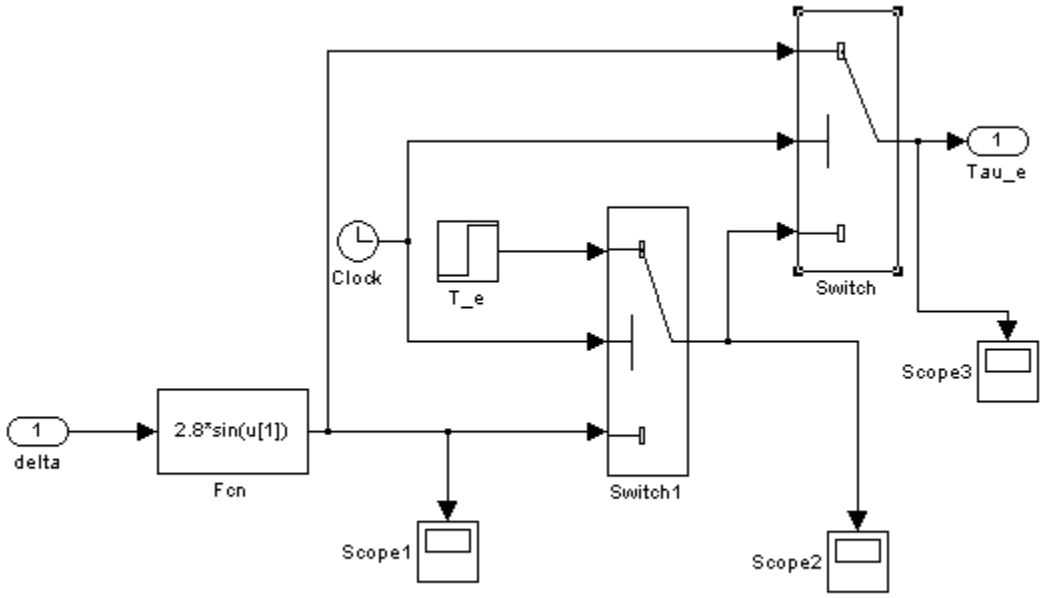
Figure 8: T_e vs Time (t_c =0.8 t_{cr} (0.212))

HW 06 Part 2

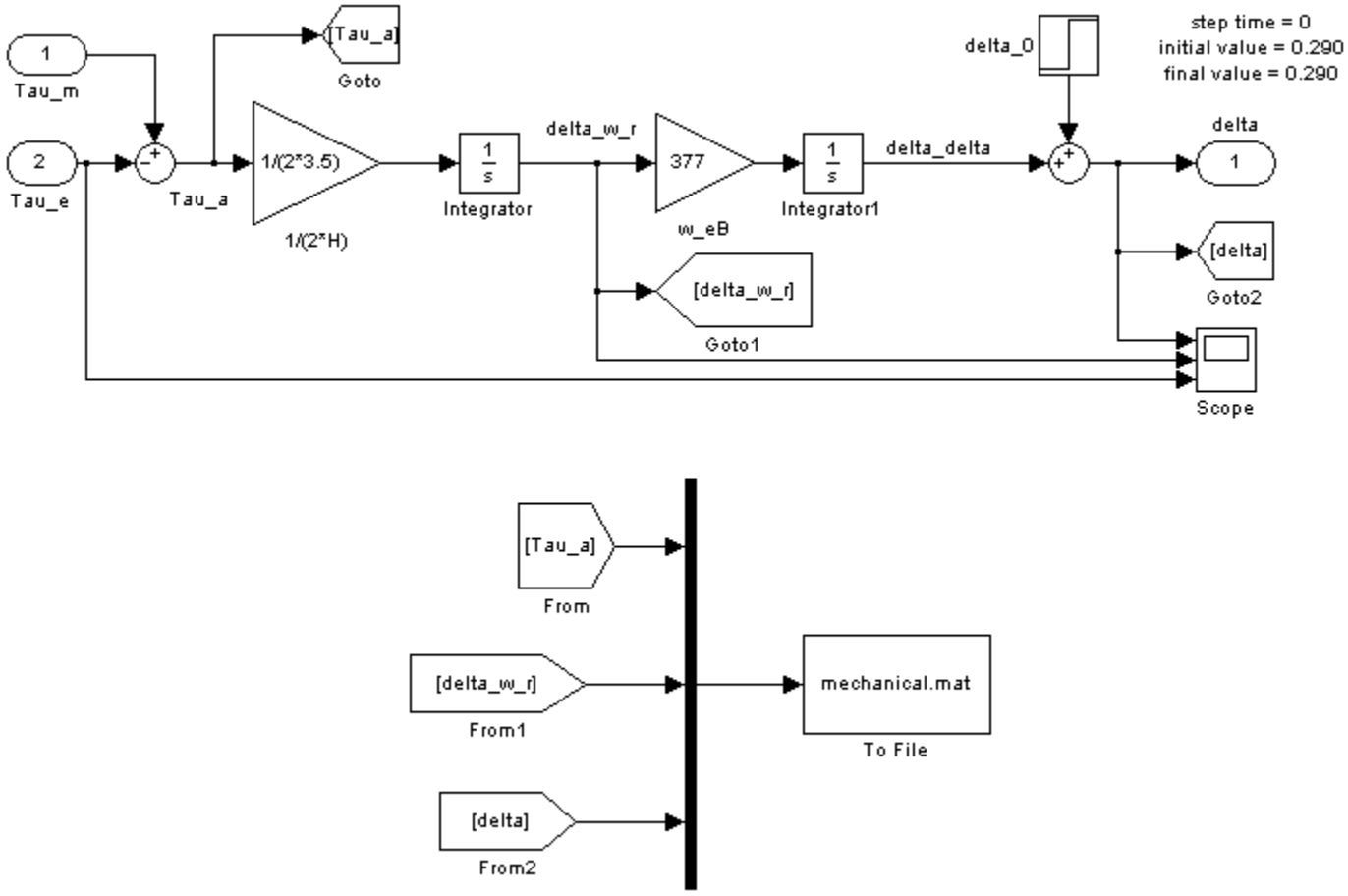
Simulink Diagram



_Overall System Diagram



Terminal Fault Subsystem



Simple Mechanical Subsystem