14.7 Refer to the figure and assume that

\[ M := 1.0 \]
\[ P_M := 0.5 \]
\[ E_a := 1.5 \quad V_\infty := 1 \]
\[ X_d := 1.0 \quad X_L := 0.5 \]
\[ X_q := 1.0 \]

(a) At \( t=0 \) the circuit breakers open and reclose \( T \) seconds later. Find \( T_{\text{critical}} \).
(b) Assume that \( T = 0.7 * T_{\text{critical}} \). Find the bounds on the swing of \( \delta \) (i.e., find \( \delta_{\text{max}} \) and \( \delta_{\text{min}} \)).

Given

\[ P_{G\delta} := 0.5 \]
\[ \delta_0 := .1 \]
Initial Guess

\[ P_{G\delta} = P_{\text{max}} \sin(\delta_0) \]

\[ \delta_0 := \text{Find}(\delta_0) \]
\[ \delta_0 = 0.524 \text{ rad} \quad \delta_0 = 30 \text{ deg} \]

\[ \delta_{\text{max}} := \pi - \delta_0 \]
\[ \delta_{\text{max}} = 2.618 \text{ rad} \quad \delta_{\text{max}} = 150 \text{ deg} \]

\[ \delta_{T_c} := \arccos \left[ \frac{P_M}{P_{\text{max}}} \left( \pi - 2\delta_0 \right) \cos(\pi - \delta_0) \right] \]
\[ \delta_{T_c} = 1.389 \text{ rad} \quad \delta_{T_c} = 79.562 \text{ deg} \]

\[ T_{\text{critical}} := 0.1 \]
Initial Guess
\begin{align*}
\delta_{\text{c}} &= \frac{P_M}{2M} T_{\text{critical}}^2 + \delta_0 \\
\delta_{\text{c}} &= \text{Find}(T_{\text{critical}}) \\
T_{\text{c}} &= 0.7 T_{\text{critical}} \\
\delta_T &= \frac{P_M}{2M} T^2 + \delta_0 \\
\delta_T = 0.947 \text{ rad} & \quad \delta_T = 54.285 \text{ deg} \\
A_a &= P_M (\delta_T - \delta_0) \\
A_a &= 0.212 \\
A_d &= A_a \\
\delta_{\max} &= 2.618 \\
\text{Initinal Guess} \\
\delta_{\max} &= \text{Find}(\delta_{\max}) \\
\delta_{\max} &= 1.45 \text{ rad} & \quad \delta_{\max} &= 83.074 \text{ deg} \\
\delta_{\min} &= \delta_0 - \delta_{\max} \\
\text{Initinal Guess} \\
\int_{\delta_{\min}}^{\delta_{\max}} (P_{\max} \sin(\delta) - P_M) \, d\delta &= 0 \\
\delta_{\min} &= \text{Find}(\delta_{\min}) \\
\delta_{\min} &= -0.248 \text{ rad} & \quad \delta_{\min} &= -14.198 \text{ deg}
\end{align*}
14.8 Refer to the figure and assume that

\[ P_M := 1.0 \]
\[ E_a := 1.5 \quad V_{\infty} := 1 \]
\[ X_d := 0.9 \]
\[ X_q := 0.9 \]
\[ X_{L1} := 0.5 \]
\[ X_{L2} := 0.125 \]

(a) At \( t=0 \) the circuit breakers open and remain open. Determine if the transient is stable.
(b) Repeat if \( X_d = 1.0 \) and \( X_q = 0.6 \).

![Diagram](image)

(a)

Pre-event

\[ P_{Gd} := P_M \]

\[ P_{\text{max}0} := \frac{|E_a| \cdot |V_{\infty}|}{X_d + \frac{X_{L1} \cdot X_{L2}}{X_{L1} + X_{L2}}} \quad P_{\text{max}0} = 1.5 \]

\[ \delta_{\text{prefault}} := 0.4 \quad \text{Initial Guess} \]

Given

\[ P_{Gd} = P_{\text{max}0} \sin(\delta_{\text{prefault}}) \]

\[ \delta_{\text{prefault}} := \text{Find}(\delta_{\text{prefault}}) \quad \delta_{\text{prefault}} = 0.73 \text{ rad} \quad \delta_{\text{prefault}} = 41.81 \text{ deg} \]
The system is not transient stable for this event as the accelerating area (0.06) enclosed while moving from the prefault $\delta (41.81\text{deg})$ to the postfault $\delta (68.96\text{deg})$ is larger than the available deaccelerating area (0.035) between the $P_{max1}$ curve and $P_M$, between the postfault $\delta$ and the maximum postfault $\delta (111.04\text{deg})$, so the system overshoots and pulls out of step.
(b)

Pre-event

\[ X_q := 1 \quad X_{q_1} := 0.6 \]

\[ P_{G\delta} := P_M \]

\[ P_{\text{max0a}} := \frac{|E_a| |V_\infty|}{X_d + X_q + X_{L1} + X_{L2}} \quad P_{\text{max0a}} = 1.364 \]

\[ P_{\text{max0b}} := \left( \frac{|V_\infty|}{2} \right)^2 \left( \frac{1}{X_q + X_{L1} + X_{L2}} - \frac{1}{X_{L1} + X_{L2}} \right)^2 \quad P_{\text{max0b}} = 0.26 \]

\[ \delta_{\text{prefault}} := 0.4 \quad \text{Initial Guess} \]

Given

\[ P_{G\delta} = P_{\text{max0a}} \sin(\delta_{\text{prefault}}) + P_{\text{max0b}} \sin(2\delta_{\text{prefault}}) \]

\[ \delta_{\text{prefault}} := \text{Find}(\delta_{\text{prefault}}) \quad \delta_{\text{prefault}} = 0.591 \text{ rad} \quad \delta_{\text{prefault}} = 33.855 \text{ deg} \]
The situation here is even worse, there is essentially no area for deacceleration, while the saliency factors have increased the acceleration area.

\[ A_d := \int_{\delta_{\text{postfault}}}^{\delta_{\text{maxpostfault}}} \left[ (P_{\text{max1a}} \sin(\delta) + P_{\text{max1b}} \sin(2\delta)) - P_M \right] d\delta \quad A_d = 7.937 \times 10^{-3} \]

\[ A_a := \int_{\delta_{\text{prefault}}}^{\delta_{\text{postfault}}} \left[ P_M - (P_{\text{max1a}} \sin(\delta) + P_{\text{max1b}} \sin(2\delta)) \right] d\delta \quad A_a = 0.074 \]
$P_M = P_{\text{max0a}} \sin(\delta) + P_{\text{max0b}} \sin(2\delta) + P_{\text{max1a}} \sin(\delta) + P_{\text{max1b}} \sin(2\delta)$
14.9 Refer to the figure and assume that

\[ P_M := 1.0 \]
\[ E_a := 1.8 \]
\[ V_\infty := 1 \]
\[ X_d := 0.9 \]
\[ X_q := 0.9 \]
\[ M := 1 \]

The system is operating in the steady state. At \( t=0 \) a solid 3φ symmetric fault occurs as shown, and the fault is not cleared until \( t_1 \), when \( \delta(t_1) = \pi/2 \). At \( t_1 \) the breakers open and remain open until a time \( t_2 \) when \( \delta(t_2) = 2\pi/3 \). By \( t_2 \) the fault has deenergized, and at \( t_2 \) the breakers close and remain closed. Is the system transient stable with respect to the fault sequence describe previously?

(a) Prefault

\[ P_{G0} := P_M \]
\[ P_{Max0} := \frac{|E_a| |V_\infty|}{X_d + 0.2} \quad P_{Max0} = 1.636 \quad \text{Two good lines.} \]
\[ \delta_0 := .1 \quad \text{Initial Guess} \]

Given

\[ P_{G0} = P_{Max0} \sin(\delta_0) \]
\[ \delta_0 := \text{Find}(\delta_0) \quad \delta_0 = 0.657 \text{ rad} \quad \delta_0 = 37.67 \text{ deg} \]
\[
\delta_{\text{max}} := \pi - \delta_0 \quad \delta_{\text{max}} = 2.484 \text{ rad} \quad \delta_{\text{max}} = 142.33 \text{ deg}
\]

(b) Fault \(0 < t < t_1\)

\[
\delta_{t1} := \frac{\pi}{2} \quad \delta_{t1} = 90 \text{ deg}
\]

\[
P_{\text{Max}1} := \frac{|E_a| \cdot |V_{\infty}|}{X_d + 0.4 + \left(\frac{X_d \cdot 0.4}{0.5 \cdot 0.4}\right)} \quad P_{\text{Max}1} = 0.581
\]

\[
t_1 := 0.1 \quad \text{Initial Guess}
\]

Given

\[
\delta_{t1} = \frac{P_M}{2M} t_1^2 + \delta_0
\]

\[
t_1 := \text{Find}(t_1) \quad t_1 = 1.352
\]

\[
A_a := \int_{\delta_0}^{\delta_{t1}} \left(P_M - P_{\text{Max}1} \cdot \sin(\delta)\right) d\delta \quad A_a = 0.454
\]

(c) Breakers Open \(t_1 < t < t_2\)

\[
P_{\text{Max}2} := \frac{|E_a| \cdot |V_{\infty}|}{X_d + 0.4} \quad P_{\text{Max}2} = 1.385 \quad \text{One good line, one open line.}
\]

\[
\delta_{t2} := \frac{2\pi}{3} \quad \delta_{t2} = 120 \text{ deg}
\]

\[
A_{d1} := \int_{\delta_{t1}}^{\delta_{t2}} \left(P_{\text{Max}2} \cdot \sin(\delta) - P_M\right) d\delta \quad A_{d1} = 0.169
\]

This is not sufficient deacceleration area, so deacceleration must continue past \(t = t_2\).

(d) Breakers Close \(t > t_2\)

\[
P_{\text{Max}3} := P_{\text{Max}0}
\]

\[
A_{d2} := \int_{\delta_{t2}}^{\delta_{\text{max}}} \left(P_{\text{Max}3} \cdot \sin(\delta) - P_M\right) d\delta \quad A_{d2} = 0.087
\]

\[
A_d := A_{d1} + A_{d2} \quad A_d = 0.256
\]
The total deacceleration area (0.256) usable for stable operation is less than the total acceleration area (0.454) used in this event. The system is not stable for this event.