The kinetic energy stored in the rotor is

\[ W_{ke\_rotor} := H \cdot S_B^3 \]

\[ W_{ke\_rotor} = 500 \text{ MJ} \]

Comparing this to the kinetic energy of the 10 ton truck traveling 60mph

\[ W_{ke\_truck} := \frac{1}{2} m_{truck} v_{truck}^2 \]

\[ W_{ke\_truck} = 3.263 \text{ MJ} \]

The ratio of the energy in the rotor to that in the truck is

\[ \frac{W_{ke\_rotor}}{W_{ke\_truck}} = 153.218 \]

For the given mechanical power the shaft acceleration \( \alpha \) would be

\[ P_{mech\_pu} := \frac{P_{mech}}{S_B} \]

\[ \alpha := \frac{P_{mech\_pu} \cdot \omega_s}{2 \cdot H} \]

\[ \alpha = 37.699 \frac{\text{rad}}{s^2} \]

At this rate the time that it would take \( \delta \) to accelerate from \( \delta_0 \) to \( \delta_0 + 2\pi \) would be

\[ t := 2 \cdot \sqrt{\frac{\pi}{\alpha}} \]

\[ t = 0.577 \text{ s} \]
Which is for \( k = 0 \) (or constant mechanical power) the same as eq 14.20 in the text. The significance of this \( k \) term is that it will increase the effective friction of the system such that the system will be slightly more damped and less oscillatory when the steady state is disturbed. If \( k \) is negative such that the steam governor action increases the mechanical input power to the generator as the rotor speed increases this would decrease the effective friction of the system such that the system would be slightly less damped and more oscillatory when the steady state is disturbed. \( k \) could be viewed as a stabilizing factor.

\[
M \frac{d^2 \delta}{dt^2} + D \frac{d \delta}{dt} + P_G(\delta) = 0
\]

Realizing that

\[
P_{\max} \sin(\delta_0) = P_{m0} \quad \frac{d^2 \delta_0}{dt^2} = 0 \quad \frac{d \delta_0}{dt} = 0 \quad \Delta \omega = \frac{d \Delta \delta}{dt}
\]

This equation simplifies to

\[
M \frac{d^2 \Delta \delta}{dt^2} + (D + k) \frac{d \Delta \delta}{dt} + P_{\max} \Delta \delta \cos(\delta_0) = 0
\]

Which is for \( k \) equal to zero (or constant mechanical power) the same as eq 14.20 in the text. The significance of this \( k \) term is that it will increase the effective friction of the system such that the system will be slightly more damped and less oscillatory when the steady state is disturbed. If \( k \) is negative such that the steam governor action increases the mechanical input power to the generator as the rotor speed increases this would decrease the effective friction of the system such that the system would be slightly less damped and more oscillatory when the steady state is disturbed. \( k \) could be viewed as a stabilizing factor.
14.4a

\[ P_{g0} := 0.5 \quad X_L := 0.4 \quad E_a := 1.8 \quad V_{bus} := 1 \]

\[ H := 5 \cdot s \quad X_d := 1.0 \]

The maximum voltage can then be calculated as

\[ P_{max} := \frac{V_{bus} \cdot E_a}{X_d + X_L} \quad P_{max} = 1.286 \]

\[ P_g(\delta_{\Delta}) := P_{max} \cdot \sin(\delta_{\Delta}) \]

The two operating points are where the two curves above cross they are

\[ \delta_1 := \sin\left(\frac{P_{g0}}{P_{max}}\right) \quad \delta_1 = 22.885 \text{ deg} \quad \delta_2 := \pi - \delta_1 \quad \delta_2 = 157.115 \text{ deg} \]

\[ \delta_1 = 0.399 \text{ rad} \quad \delta_2 = 2.742 \text{ rad} \]
14.6

\[ P_{g0} := 0.4 \quad X_L := 0.3 \quad E_a := 2.0 \quad V_{bus} := 1 \]

\[ H := 0.4 \cdot s \quad X_d := 1.2 \quad f_0 := 60 \cdot Hz \]

The maximum power is

\[ P_{\text{max}} := \frac{E_a \cdot V_{bus}}{X_d + X_L} \quad P_{\text{max}} = 1.333 \]

\[ P_{g(\delta)} := P_{\text{max}} \cdot \sin(\delta) \]

Pre Transient Operating Condition \( \delta_0 \) is

\[ \delta_0 := \arcsin \left( \frac{P_{g0}}{P_{\text{max}}} \right) \quad \delta_0 = 17.458 \text{deg} \quad \delta_0 = 0.305 \text{rad} \]

The critical angle can then be found by guess value \( \delta_{tc} := \frac{\pi}{2} \)

\[ \text{Given} \]

\[ P_{g0} \left( \pi - \delta_0 - \delta_0 \right) = P_{\text{max}} \left( \cos(\delta_{tc}) - \cos(\pi - \delta_0) \right) \]

\[ \delta_{tc} := \text{Find}(\delta_{tc}) \quad \delta_{tc} = 101.202 \text{deg} \quad \delta_{tc} = 1.766 \text{rad} \]

The time associated with this critical angle is

\[ T_{\text{critical}} := \sqrt{\frac{(\delta_{tc} - \delta_0) \cdot 2 \cdot H}{\pi \cdot f_0 \cdot P_{g0}}} \quad T_{\text{critical}} = 0.125 \text{s} \]

Assuming that \( T = 90\% \) \( T_{\text{critical}} \) this produces a \( \Delta \) of

\[ \delta_T := \frac{\pi \cdot f_0 \cdot P_{g0} \cdot T^2}{2 \cdot H} + \delta_0 \quad \delta_T = 85.291 \text{deg} \quad \delta_T = 1.489 \text{rad} \]
\[ \delta_{\text{max}} \text{ is then found to be} \quad \text{guess value} \quad \delta_{\text{max}} := \frac{\pi}{2} \]

Given

\[ P_{g0} (\delta_T - \delta_0) = P_{\text{max}} (\cos(\delta_T) - \cos(\delta_{\text{max}})) - P_{g0} (\delta_{\text{max}} - \delta_T) \]

\[ \delta_{\text{max}} := \text{Find}(\delta_{\text{max}}) \quad \delta_{\text{max}} = 115.571 \text{ deg} \quad \delta_{\text{max}} = 2.017 \text{ rad} \]

The minimum delta can then be found as

\[ \text{guess value} \quad \delta_{\text{min}} := 0 \]

Given

\[ 0 = P_{\text{max}} (\cos(\delta_{\text{min}}) - \cos(\delta_{\text{max}})) - P_{g0} (\delta_{\text{max}} - \delta_{\text{min}}) \]

\[ \delta_{\text{min}} := \text{Find}(\delta_{\text{min}}) \quad \delta_{\text{min}} = -60.605 \text{ deg} \quad \delta_{\text{min}} = -1.058 \text{ rad} \]