HW #1, EE 554, Spring 2023, Dr. McCalley, Due: Thursday, Feb 2, 2023

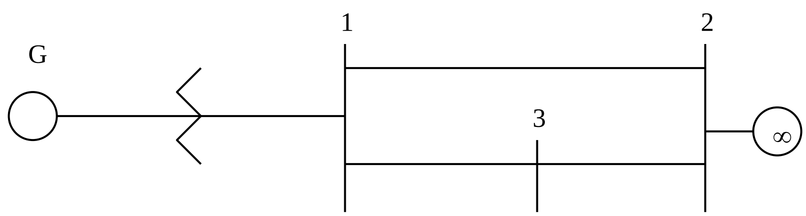
1. Show that the kinetic energy in MW-sec (or Mjoules) is related to the WR^2 according to $W_K=2.31\times10^{-10}(WR^2)n_R^2$, where n_R is the rated mechanical speed of rotation of the machine in rpm and WR^2 is given in lb(mass)*ft^2.
2. A manufacturer provides the following data for a proposed steam turbo-generator unit:

Rated output:	85 MW at 0.85 power factor
Rated voltage:	13.2 kV
Moment of inertia:	859,000 lb-ft^2
Number of poles:	4
Rated frequency:	60 Hz

   Compute the following quantities:
   a. Kinetic energy in MW-sec at rated speed
   b. Inertia constant H on the machine base
   c. Angular momentum M in MW-sec^2 (or Joule
3. A power plant has two three-phase, 60 Hz generating units with the following ratings:
   Unit 1: 500 MVA, 15kV, 0.85 pf, 32 poles, H_1=2.0 sec.
   Unit 2: 300 MVA, 15kV, 0.90 pf, 16 poles, H_2=2.5 sec.
   a. Give the per-unit swing equation of each unit on a 100 MVA system base.
   b. If the units are assumed to "swing together," that is, $\delta_1(t)=\delta_2(t)$, combine the two swing equations into a single, equivalent swing equation.
4. A 3-phase, 60Hz, 500 MVA, 15 kV, 32 pole hydroelectric generating unit has an H constant of 2.0 sec.
   a. Determine ω_R.
   b. Give the per-unit swing equation for this unit.
   c. The unit is initially operating at $P_{mu}=P_{eu}=1.0$pu, $\omega_e=\omega_{Re}=377$rad/sec when a 3phase fault at the generator terminals causes P_{eu} to drop to 0 for $t\geq0$. Determine the power angle 3 cycles after the fault commences. Assume P_{mu} remains constant at 1.0pu, and the initial angle is δ_0.
5. The figure below shows a single line diagram of a three-phase 60 Hz synchronous generator, connected through a transformer and parallel transmission lines to an infinite bus. Data for this system are given in per-unit on a common system base, as follows:

Generator:	$X'_d=0.3$, H=3.0 sec, $P_{mu}=1.0$.
Infinite bus:	$\lvert V_\infty\rvert=1.0$
Transformer:	$X_T=0.1$
Lines:	$X_{12}=0.2$, $X_{13}=0.1$, $X_{23}=0.2$

   If the infinite bus receives 1.0 pu real power at 0.95 pf lagging, determine:
   a. The internal voltage of the generator and
   b. The equation for the electrical power delivered by the generator versus its power angle δ.



6. For the system in problem 5, the generator is initially operating in the steady-state condition specified in problem 5 when a three-phase fault occurs on line 1-3 at bus 3. The fault is cleared by opening the circuit breakers at the ends of lines 1-3 and 2-3. These circuit breakers then remain open. Calculate the critical clearing angle.
7. Consider the pre-fault (1), fault-on (2), and post-fault (3) expressions used in class:
   $P_{e1}=P_{M1}\sin\delta$; $P_{e2}=P_{M2}\sin\delta$; $P_{e3}=P_{M3}\sin\delta$
   with $P_{Mi}=E\,V_\infty/X_i$. Define $r_1=X_1/X_2$ and $r_2=X_1/X_3$. Use the equal area criterion to derive that the critical clearing angle is given by $\delta_c=\cos^{-1}\{[(\delta_m-\delta_1)\sin\delta_1-r_1\cos\delta_1+r_2\cos\delta_m]/(r_2-r_1)\}$ where $(\delta_m-\delta_1)$ is expressed in radians. (Note that this is eq. 2.51 in the text, except that the text refers to δ_1 as δ_0.)
8. Work problem 2.14 in your textbook.

9. Given a 2pole turbine-generator unit rated 100 MVA with a per unit inertia constant H=5 sec.
    a. Calculate the kinetic energy stored at synchronous speed (3600 rpm).
    b. Compare the part (a) calculation with the kinetic energy of a 10-ton trick moving at 60 mph.
    c. Suppose that the generator is delivering 100 MW and then, at t=0, the line circuit breakers open. Calculate the shaft acceleration in rad/sec^2.
    d. At the acceleration rate of part (c), how long does it take for the rotor angle δ to increase by 2π radians?