Course:
ELEC ENG 3110 Electric Power Systems
ELEC ENG 7074 Electric Power Systems PG

(Semester 2, 2021)

Tutorial 2

(Due by 16:10 18 August 2021:
Onshore students: submit in person;
Offshore students: submit via myUni)

Lecturer & Coordinator: David Vowles
david.vowles@adelaide.edu.au

T2.1 What are the primary objectives when operating a power system?

T2.2 Refer to Figure 1. During a windy day, Area 1 is generating 2,000 MW from grid scale wind farms and the area's operational demand is 1,800 MW. Area 1 is exporting 300 MW to Area 2. There are two synchronous generators online in Area 1 with a total synchronous inertia of 3000 MW.s.

(a) Neglecting losses what is the output of the synchronous generators in Area 1?

(b) In the event that both transmission lines between Area 1 & 2 are disconnected due to a fault at what rate will the frequency in Area 1 change? Does the frequency in Area 1 increase or decrease?

(c) At this rate of change how long will it take for the frequency in Area 1 to change by 2 Hz from its initial value of 50 Hz?

(d) What action(s) could be taken to prevent frequency instability within Area 1 in this situation?

(e) Area 2 is a large system with online synchronous inertia of 90,000 MW.s. What is the rate of change of frequency in Area 2 following the outage of the interconnector?

(f) How will the frequency in Area 2 be restored following the interconnector outage? Comment on the difference in how the frequency is restored in Area's 1 & 2.

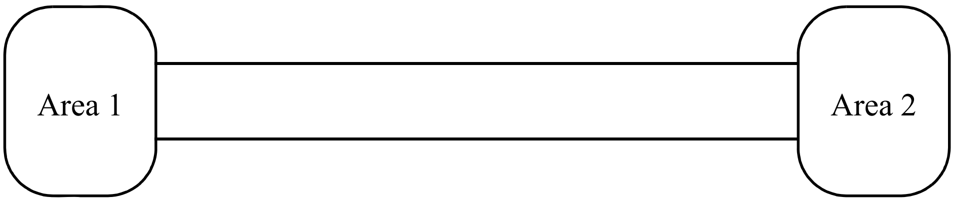

Figure 1: Problem 2.2 – Interconnection between Area 1 and 2.

T2.3 Prove that $\cos(x) = \dfrac{e^{jx}+e^{-jx}}{2}$ and $\sin(x) = \dfrac{e^{jx}-e^{-jx}}{j2}$.

T2.4 Explain how a sinusoidal signal can be represented in terms of complex exponentials.

T2.5 Represent each of the following sinusoidal signals as RMS cosine referenced phasors. Express the phasors in rectangular, polar and exponential form. In each case state the frequency in Hz.

(a) $i(t) = 11.48\cos\left(100\pi t - \dfrac{\pi}{12}\right)$ (kA)

(b) $v(t) = 13.06\sin\left(100\pi t + \dfrac{\pi}{4}\right)$ (kV)

(c) $i(t) = \sqrt{2}\times 50\sin\left(120\pi t - \dfrac{\pi}{3}\right) + 150\cos\left(120\pi t + \dfrac{5\pi}{12}\right)$ (A)

T2.6 Referring to your answers to Problem 2.5 (a) and (b) and assuming that $v(t)$ is the generator voltage and $i(t)$ is the current delivered by the generator what is:

(a) the average real power (in MW); and

(b) the reactive power (in MVAr)

delivered by the generator?

T2.7 For each of the following RMS cosine referenced phasors write the corresponding signal as a function of time. In each case what is the value of the signal at time $t = T_p$ where T_p is the period of the sinusoid.

(a) $\hat{V} = 240\angle{-30°}$, $f = 133\ \text{Hz}$

(b) $\hat{I} = 1500e^{j(\pi/4)}$, period $T_p = 20\ \text{ms}$

(c) $\hat{V} = 6134 + j1644$, $f = 50\ \text{Hz}$

T2.8 The RMS voltage and current phasors of a load are respectively $\hat{V} = 6.35\angle{-30°}\ \text{kV}$ and $\hat{I} = 1969\angle{-66.87°}\ \text{A}$.

(a) Calculate the average power and reactive power consumed by the load. State whether the reactive power is leading or lagging.

(b) The supply frequency is 50 Hz. Derive an equation, p(t), for the instantaneous power consumed by the load. Produce a plot of the instantaneous power for a period of 0.04s.

(c) What is the (i) maximum and (ii) minimum value of instantaneous power?

(d) What is the duration of one complete instantaneous power cycle?

(e) It is required to improve the power factor of the load to 0.95 (lagging). Calculate the capacitance required to achieve this reduction. (In this analysis the source impedance is neglected, which, as we will see later in the course should only be done if the source has very low impedance).

T2.9 Figure 2 shows a loss-less transmission system.

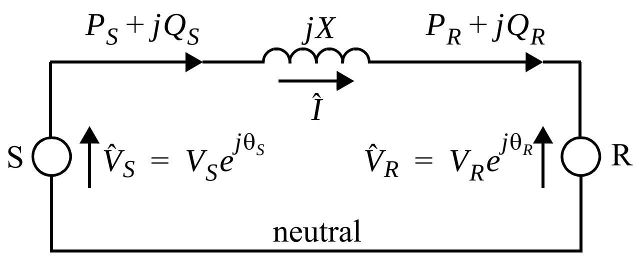

Figure 2: Loss-less transmission system.

Derive the transmission equations (1) taking care to show all of your working.

$$
\begin{aligned}
P_S &= P_R = \frac{V_S V_R}{X}\sin\delta \\
Q_S &= \frac{V_S^2 - V_S V_R \cos\delta}{X} \qquad \text{where } \delta = \theta_S - \theta_R \\
Q_R &= \frac{V_S V_R \cos\delta - V_R^2}{X}
\end{aligned}
\tag{1}
$$

T2.10 The reactive power loss in the transmission line in Figure 2 is:

$$
Q_{loss} = Q_S - Q_R = \frac{V_S^2 - 2V_S V_R \cos\delta + V_R^2}{X} \tag{2}
$$

(a) Suppose the power flow and source voltage are given. Derive an equation for the receiving end voltage that will minimize the reactive power losses of the system. [Hint: eliminate $\cos\delta$ from (2) using the expression for power in (1) resulting in an expression for Q_{loss} in terms of the one unknown V_R. Then you can derive an expression for V_R that minimizes the reactive power losses.]

(b) If the power transmission angle is small, estimate from (2) the value of V_R that minimizes the reactive power losses. How closely does this estimate agree with result from (a) above.

(c) For PS = 1.0 pu, VS = 1.05 pu, X = 0.3 pu plot Qloss as a function of VR over the range from 0.9 to 1.1 pu. At what value of VR is Qloss least. Does the value determined from your plot agree with the value obtained from the equation you derived in (a) above. How accurate the approximation in (b) in this case?