S. KARAKI AMERICAN UNIVERSITY OF BEIRUT FALL 2005/2006

FACULTY OF ENGINEERING AND ARCHITECTURE

MIDTERM

FUNDAMENTALS OF POWER SYSTEMS ANALYSIS
(EECE 471)

CLOSED BOOK (2 HOURS) **NOVEMBER 14, 2005**

PROGRAMMABLE CALCULATORS ARE NOT ALLOWED

THIS QUESTION SHEET MUST BE RETURNED WITH THE ANSWER BOOKLET.

NAME: _________________________ **ID#:** _________________________

1. Answer the following questions in the space provided for each on this question sheet:

a) Label the various components of the power station schematic shown in Fig.1 below and give it a specific caption next to the figure number.

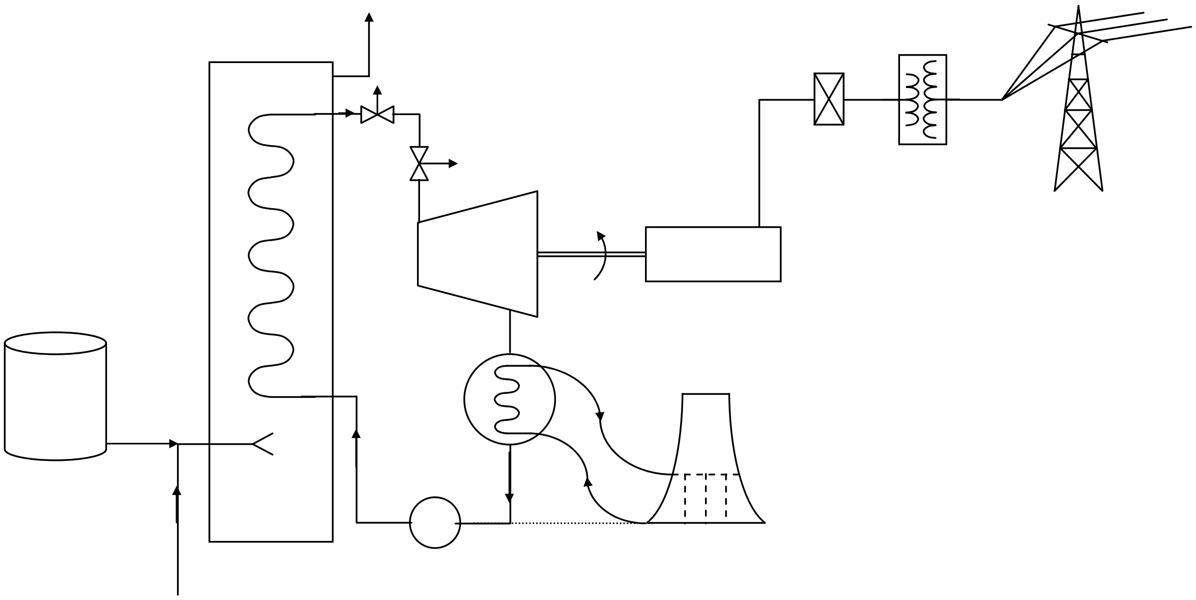


Fig.1: ____

b) What is the most efficient thermal power generation technology used throughout the world nowadays and what is its approximate efficiency?

____

c) Name two environmental problems associated with fossil-fuel power plants and indicate ways of mitigating them?

____

d) Name a renewable energy technology that you believe is most likely to be used and explain the reasons?

____

e) Why do we raise the voltage to transmit a given amount of power over a long distance?

____

2. It is required to design a transmission line of 200 mile length to supply a demand of 300 MW at 0.9 PF lagging considering one of two voltages 220 and 400 kV at a frequency of 50Hz with typical phase-to-phase spacing of 8 m and 12 m, respectively. Note that 1 kcmil= 0.507mm^2 and 1 ft= 0.305 m.

a) Considering that characteristic impedances of lines vary within a narrow range around 300Ω, calculate the surge impedance loading (P/P_{SIL}) at both voltage levels. Refer to Fig. 2 below and deduce the more economic voltage that would maintain a stability margin such that the phase angle from sending to receiving is smaller than or equal to 45°.

b) From Table 1 shown below select the most appropriate conductor size at the selected voltage if the current density is not to exceed 2.5 A/mm^2 at the given load conditions and the prevailing 35°C ambient temperature. Consider using bundled conductors in your design and select the appropriate number of bundles in your conductor.

c) Calculate the resistance, inductance and capacitance for the line design and determine its actual characteristic impedance and its surge impedance loading at the selected voltage level.

d) If at minimum load conditions, the demand drops to about 40% of its peak value, estimate the voltage at the sending end under such conditions. Having reached so far in your design, are you still confident that you have made the correct voltage choice? Explain.

Table 1: Main Properties of Selected ACSR Bare Wires

Name	Size (kcmil)	Resistance at 60Hz (Ω/mile)	GMR (ft)
Partridge	266.8	0.411	0.0217
Linnet	336.4	0.327	0.0244
Ibis	397.5	0.277	0.0265
Hawk	477.0	0.231	0.0290
Dove	556.5	0.198	0.0313
Grosbeak	636.0	0.173	0.0335
Drake	795.0	0.139	0.0375

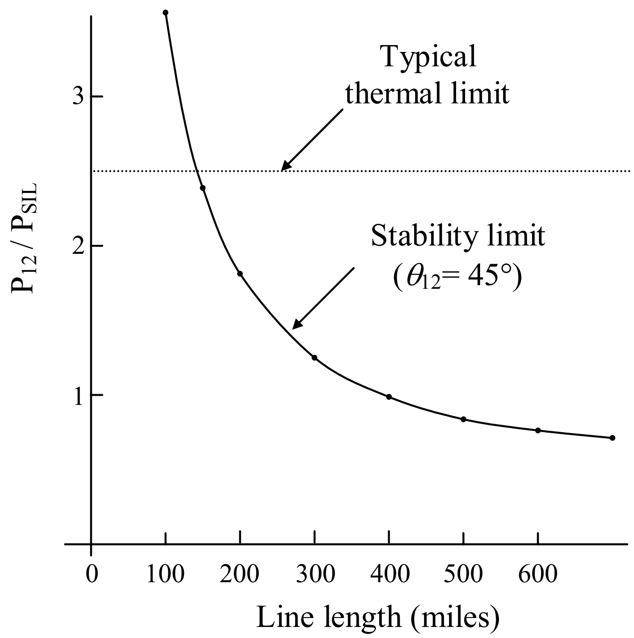


Fig. 2: Stability limit of lines

3. Consider a generation system supplying a load through a Δ-Y connected transformer and a transmission line, shown in Fig. 3 below. The nominal line-to-line voltages on the transformer are 13.8-66 kV. The transformer rating is 80 MVA with leakage and magnetizing reactance of one set of low-high turns are x_l= 0.8Ω and x_m= 25Ω, referred to the low voltage side. The load is consumes 50 MW at 0.85 PF lagging when the voltage at the receiving end is nominal. The line length is 100km, its series reactance is 0.4Ω/ km, its resistance is 0.08Ω/ km, and its susceptance is y_c= 4 μS/ km.

   a) Divide the system into regions and select an appropriate base system and indicate the base MVA, base voltage, and base impedance in each region.

   b) Calculate the per-unit impedances of the load, transmission line and transformer. Draw the per-unit equivalent circuit of the system and show the values of all impedances.

   c) If power to the load is delivered at nominal voltage, determine the voltage and current at the generator terminal and deduce the active and reactive power supplied by the generator.

   d) Is this system well designed? If yes, explain in what way it is good, other wise explain what is not good about this design and the possible ways of improving it.

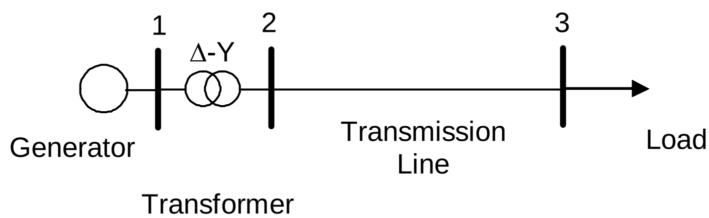


Fig. 3: Small power system for Problem 4

Fundamentals of Power Systems Analysis
(EECE 471)
FORMULAE

- Ch.2: **Basic Principles**

  $$Z_Y = \frac{Z_\Delta}{3}$$

- Ch.3: **Transmission-Line Parameters**

  $$l = 2*10^{-7} \ln \frac{D}{R_b} \qquad H/m$$

  D: geometric mean distance between phases
  R_b: geometric mean radius of bundle

  $$D = \sqrt[3]{D_{ab} D_{ac} D_{bc}} \qquad R_b = \sqrt[4]{r' d_{12} d_{13} d_{14}}$$

  $$c = \frac{2\pi\varepsilon}{\ln \frac{D}{R_b^c}} \qquad \varepsilon = 8.854*10^{-12} \qquad F/m$$

  $$R_b^c = \sqrt[4]{r \quad d_{12} d_{13} d_{14}}$$

- Ch.4: **Transmission Line Modeling**

  - $z = r + j\omega l \qquad \Omega/m \qquad y = j\omega c \qquad S/m$
  - $\gamma = \sqrt{yz} \qquad Z_c = \sqrt{\frac{z}{y}}$
  - $V_1 = V_2 \quad \cosh \gamma l + Z_c I_2 \quad \sinh \gamma l = AV_2 + BI_2$

    $$I_1 = I_2 \quad \cosh \gamma l + \frac{V_2}{Z_c} \quad \sinh \gamma l = CV_2 + DI_2$$

    $$\mathrm{T}=\begin{bmatrix} A & B \\ C & D \end{bmatrix} \quad \text{and} \quad T^{-1} = \begin{bmatrix} D & -B \\ -C & A \end{bmatrix}$$

  - Complex Power Flow on Medium Line:

    $$S_{12} = \frac{Y^*}{2} \quad |V_1|^2 + \frac{|V_1|^2}{Z^*} - \frac{|V_1||V_2|}{Z^*} e^{j\theta_{12}}$$

    For S_{21} exchange indices 1 and 2 in above equation

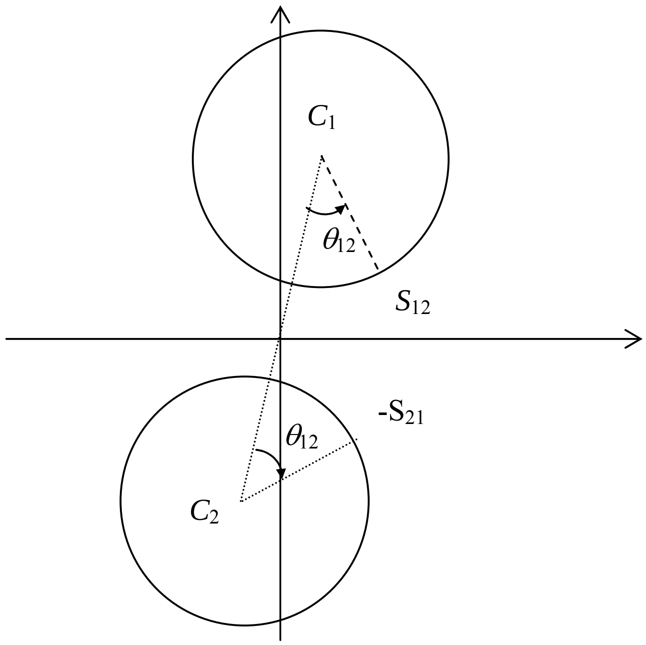
  - Power Flow on a short loss-less line:

    $$P_{12} = -P_{21} = \frac{|V_1||V_2|}{X} \sin \theta_{12} \qquad Z = z \times l = R + jX$$

$$Q_{12} = \frac{|V_1|^2}{X} - \frac{|V_1||V_2|}{X}\cos\theta_{12} \qquad Y = y \times l$$

$$Q_{21} = \frac{|V_2|^2}{X} - \frac{|V_1||V_2|}{X}\cos\theta_{12} \qquad l\text{: length of line}$$

- Power Circle Diagram



Both circles have a radius: $B = \frac{|V_1||V_2|}{|Z|}$

$$C_1 = \frac{|V_1|^2}{|Z|}\angle Z \qquad C_2 = -\frac{|V_2|^2}{|Z|}\angle Z$$

- Power transmission capability:

$$P_{12} = \frac{|V_1|^2}{Z_c}\frac{\sin\theta_{12}}{\sin\beta l} = P_{SIL}\frac{\sin\theta_{12}}{\sin\beta l}$$

$$\beta = \text{Im}(\gamma)$$

- ∗Ch.5: **Transformers and the Per-Unit System**

$$V_{a'n'} = K \; V_{an} \qquad \text{and} \qquad I_{a'n'} = \frac{1}{K^*} \; I_{an}$$

$$\Delta - Y : K = \sqrt{3} \; n \; e^{j\frac{\pi}{6}} \qquad Y - \Delta : K = \frac{n}{\sqrt{3}} \; e^{j\frac{\pi}{6}} \qquad n = \frac{N2}{N_1}$$

$$Z_B = \frac{{V_B^{ll}}^2}{S_B^{3\Phi}} = \frac{{V_B}^2}{S_B} \qquad Z_{actual} = Z_{pu} Z_B \qquad Z_{pu}^n = \frac{Z_{actual}}{Z_B^n} = Z_{pu}^o \frac{Z_B^o}{Z_B^n}$$