ER66 MIDTERM EXAM

5 novembre 2024 de 10h15 à 12h15 en salle A201 et A202 à Belfort

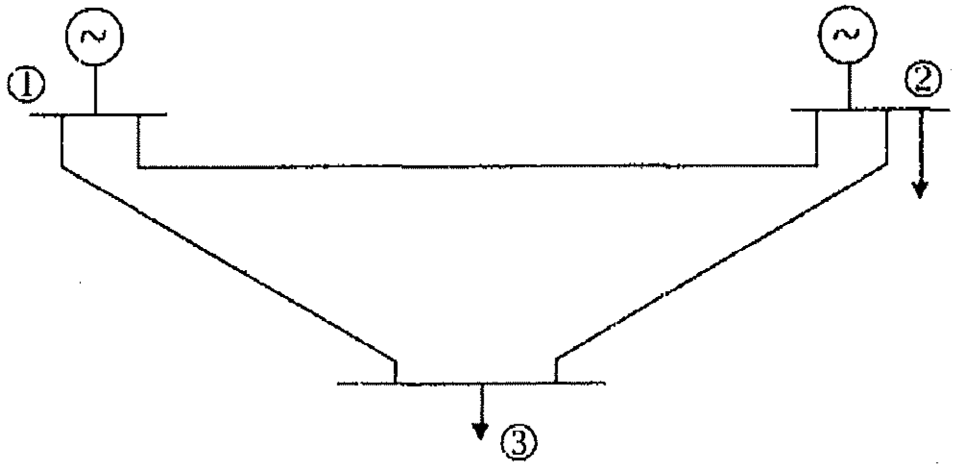
The use of lecture notes is not allowed.
You can reply either in English or in French.
Use of programmable calculators is not allowed.

The exam consists of two sections: A and B. Section A contains only one question worth 10 marks, which you must answer. Section B contains three questions, each worth 5 marks, and you are required to answer two of them. The maximum score is 20 marks.

Section A: COMPULSORY QUESTION

QUESTION A1 (10 MARKS)

For the simple three bus system below, write the load flow equations.



Choose Bus 1 as the reference bus, and, for simplicity, assume that the lines have all the same series impedance Z_s and the admittance $Y_p/2$ in the π- model of the line.

- **(a)** Construct the admittance matrix. *(2 mark)*
- **(b)** For each bus, define the net complex power, noting that Bus 2 is connected to both a generator and a load, while Bus 3 is connected only to a load. *(1 mark)*

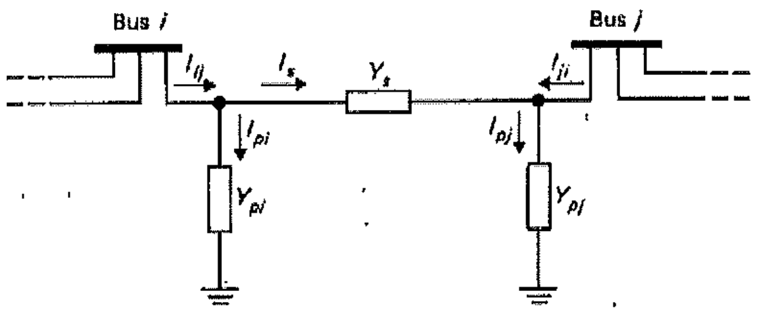
- **(c)** Determine which buses can be PV or PQ and justify your choice. Specify also the known and unknown variables for each bus. *(1 mark)*
- **(d)** Prove, in general, that the load flow equations in real form for each bus are given by:

$$P_i = \sum_{k=1}^{3} |y_{ik}||V_i||V_k|\cos(\delta_k - \delta_i + \gamma_{ik})$$

$$Q_i = -\sum_{k=1}^{3} |y_{ik}||V_i||V_k|\sin(\delta_k - \delta_i + \gamma_{ik}) \text{ for } i = 1,2,3$$

Remark: Consider each element of the admittance matrix in the polar form: $y_{ij} = |y_{ij}|e^{j\gamma_{ij}}$
(4 mark).

- **(e)** Assuming the equations above are solved, yielding the voltage magnitudes and phases at each node, explain how to calculate the power flows between bus 1 and bus 2 and viceversa . Use the figure below, taken from the course slides.

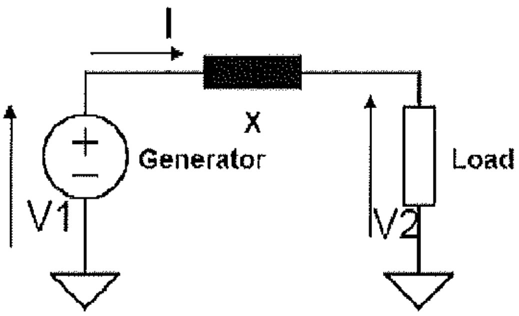


(2 mark)

Section B: solve 2 out of the following 3 exercises

QUESTION B1 (5 MARKS)

Consider the following figure:



This figure shows a generator connected to a load through a reactance, which includes both the generator and line reactances. The real power transmitted by the generator and the reactive power supplied to the load, assuming a constant voltage V_2, are given by the following formulas:

$$P = \frac{|V_1||V_2|}{X}\sin\delta \qquad \text{MW/phase}$$

$$Q_2 = \frac{|V_1||V_2|\cos\,\delta - |V_2|^2}{X} \qquad \text{Mvar/phase}$$

a) Prove the first formula *(2 marks)*
b) Prove the second formula *(2 marks)*
c) When is the real flow positive, that is when does it enter the load 2? In other words when is δ positive and how is it defined? *(1 mark)*

QUESTION B2 (5 MARKS)

An area of an interconnected power system has two fossil-fuel units operating under economic dispatch. The variable operating costs of these units are given by:

$$C_1 = 10P_1 + 8 \times 10^{-3}P_1^2 \text{ \$/h}$$
$$C_2 = 8P_2 + 9 \times 10^{-3}P_2^2 \text{ \$/h}$$

where P_1 and P_2 are in megawatts.

Determine, when the total load demand P_T is 1500 MW,

1. The power output of each unit under economic dispatch. *(3 marks)*
2. The incremental operating cost. *(1 mark)*
3. The total operating cost C_T that minimizes C_T *(1 mark)*

Assume that generating unit inequality constraints and transmission losses are neglected.

QUESTION B3 (5 MARKS)

The block-diagram representation of a closed-loop automatic regulating system, in which generator voltage control is accomplished by controlling the exciter voltage, is shown in the figure below. T_a, T_e, and T_f are the time constants associated with the amplifier, exciter, and generator field circuit, respectively.

(a) Find the open-loop transfer function G(s) and deduce the type of the system, by giving proper explanation. *(1 mark)*

(b) Evaluate the minimum open-loop gain such that, for a unit step input, the steady-state error Δe_{ss} does not exceed 1%. *(2 marks)*

(c) Draw a qualitative root locus of the system as the amplifier gain k_a varies and determine its stability limit. Given parameters are $T_f = 1, T_e = 0.4, T_a = 0.1$, and $k_e = k_f = 1$.

Calculate only the real root locus, the angles of the asymptotes, their intercept on the real axis, and the intercept on the imaginary axis using the Routh-Hurwitz Criterion. *(2 marks)*