Exercise 1: Load flow (3pts)

1- Define how many types of bus exist in the power flow system, for each of them give the known parameters and the unknown parameters
2- How many slack (swing) bus, can we have on power system? Explain the particularity of this bus.
3- Give the general expression of active and reactive power
   P,Q = f(V_k, V_n, Y_{kn}, Θ_{kn}, δ_n, δ_k)
4- To solve power flow equations two methods are generally used, list and explain their particularities.

Exercise 2: Unbalanced system analysis (5pts)

An unbalanced set of three phase system voltage or current can be represented by a set of symmetrical components:

1- Named the set of symmetrical components

A generator supplying an unbalanced load measures the following for each phase-to-ground voltage:
Va = 18 / 0° kV , Vb= 10/ -132° kV and Vc = 15/ +90°

2- Find the symmetrical components of the set of phase voltages.

We have measured the following set of phase current on each phase:
Ia = 180 / -10° A, Ib= 250/ -100° A and Ic=200/ +50°

3- Find the active and reactive power supplied by the generator to unbalanced load.

The neutral point of our generator is grounded via a 10 Ohm:

4- Compute the voltage of the neutral relative to ground in the current load.

Remind

[Phase set of volt or Amps]= $\begin{bmatrix} 1 & 1 & 1 \\ a^2 & a & 1 \\ a & a^2 & 1 \end{bmatrix}$[symmetrical set components]

and [symmetrical set components]= $\frac{1}{3}\begin{bmatrix} 1 & a & a^2 \\ 1 & a^2 & a \\ 1 & 1 & 1 \end{bmatrix}$[Phase set of volt or Amps]

Exercise 3: Per unit and power system modelling (5pts)

A 50Hz synchronous generator (G1) is connected to an HV infinite bus. The armature of a generator is connected to the LV of the step up transformer with HV phase winding of the transformer connected to the grid through a line bus represented as two Xl1 and Xl2 impedances in parallel. All resistances are assumed to be negligible.

Generator (G1): Xd=1.5pu, X'd = 0.3pu, H= 4 MW.s/MVA, Sngen= 300MVA, Ungen = 18kV
Step-up transformer: Str=330MVA, Ztr = 11%, Utr: 18/220kV
Line impedances Xl1 = 0.3pu and Xl2 = 0.6pu. Line reactance's are given on the generator base (Sngen, Ungen ie LV side of the step-up transformer).

1- Give the definition of the Xd and X'd.
2- Propose a single line diagram an above power system of SMIB (Single Machine to infinite bus), with all parameters in pu expressed in generator base.
3- In case of three-phases fault takes place at the **sending end (entrance) of line Xl2** (at point noted A), compute the transfer reactance "Xfn" of our system (between the generator and the infinite bus):
    a. Before the fault noted **Xf1**,
    b. During the fault noted **Xf2**,
    c. After clearing the fault noted **Xf3**, with Xl2 completely isolated,
    d. Represent curves of the synchronous generator electrical power sending function of rotor angle P_e = f(rotor angle) of above case a, b and c.
4- Repeat 3a, b, c and d, now with a three-phase fault takes place in the **middle of line Xl2** (at point noted B). Compute the transfer reactance's noted **Xe1**(before), **Xe2** (during), **Xe3** (after).

Exercise 4: Stability (7pts)

At steady state, generator (G1) is delivering Pe=0.8pu power and Q=0.1pu (lagging) to the infinite bus (grid) represented by a voltage V = 1pu / 0° with Xgrid = 0.015 pu (associated reactance of grid).
It is recommended to represent the new form of single diagram of this network power system.

1- Give the definition of the *Stability of the power system*
2- Give the swing equation of a power system

The power system is subjected to disturbance as describe in Exercise 3- Question 3)

3- Determine the critical fault clearing angle and plot the power angle curves.
4- Determine the critical clearing time.
5- Plot the swing curves tendencies both under sustained fault and when Xl2 is completely removed at the end of 10 cycles, i.e. 0.2 s, with step by step (or point by point) method with a minimum of 3 iterations. Use a step time of 0.05Sec

With

$$\cos\delta_{cl} = \frac{(\delta_m - \delta_0)\sin\delta_0 - r_1\cos\delta_0 + r_2\cos\delta_m}{r_2 - r_1} \qquad r_1 = \frac{P_{max_1}}{P_{max}} \qquad r_2 = \frac{P_{max_2}}{P_{max}}$$

- before the fault : P_{max}
- during the fault : P_{max_1}
- after the fault : P_{max_2}

$$P_a(n-1) = P_m - P_e(n-1),\ P_e(n-1) = \frac{|E||V|}{X}\operatorname{Sin}\delta(n-1),\ \Delta\delta(n) = \Delta\delta(n-1) + \frac{P_a(n-1)}{M}(\Delta t)^2$$

$\delta(n) = \delta(n-1) + \Delta\delta(n)$, $\Delta\delta 0 = 0$, n=number of iteration (General formula for step by step method)