EXPERIMENT 6
Per Unit calculations, Impedance Diagrams

Objectives:
Construct per-phase equivalent circuits and impedance diagrams with all values in per unit.

Statement of the Problem:
An orderly procedure is followed to assist in the construction. It is illustrated in the steps below:

1. Draw the power system One-Line diagram and put all the values on it. Include base values for all data given in per unit.
2. Specify the new Power base – MVA
3. Specify the new voltage base in the region where calculations should begin.
4. Calculate all per phase circuit values in per unit with respect to the new bases just specified. This required calculating new base values, then changing to per unit, or calculating change-of-base in per unit to get the new per phase equivalent circuit with per unit values with respect to the new base values.
5. Perform the next set of calculations requested in per unit. The result is usually simpler and easier to check than calculating circuit values in volts, amps, and watts, etc.

Follow the above procedure and solve the following problems.

Problem 1 – *Per unit computation and change of base*
A four-bus power system is shown below. The 3-phase power and line-line voltage ratings are given below: By selecting a common system base of 100 MVA and 33 kV on the generator side, draw an impedance diagram showing all impedances including the load impedance in per unit on the same system base.
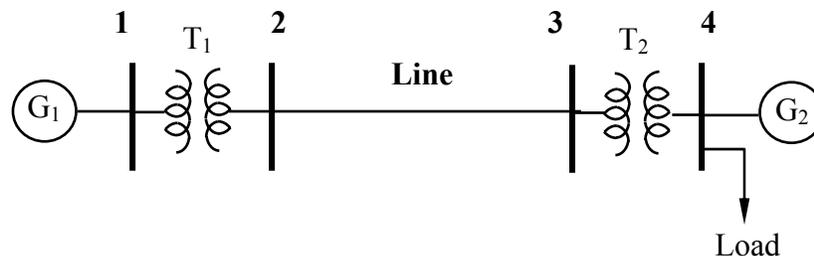
Generator:	75 MVA, 33 kV, X = 0.2 pu
Transformer T_1:	50 MVA, 33 kV Y/115 kV, X = 0.08 per unit
Transformer T_2:	60 MVA, 11.5 kV /115 kV, X = 0.10 per unit
Transmission line:	Series reactance X = 55 Ω.
Motor:	45 MVA, 10.45 kV, X = 0.22 pu
Load:	Draws 10 MVA at 10.45 kV 0.6 power factor leading

Problem 2 - *Per unit computation in balanced systems with 3-phase, 2-winding transf.*
Consider the single line diagram of the power system shown below.
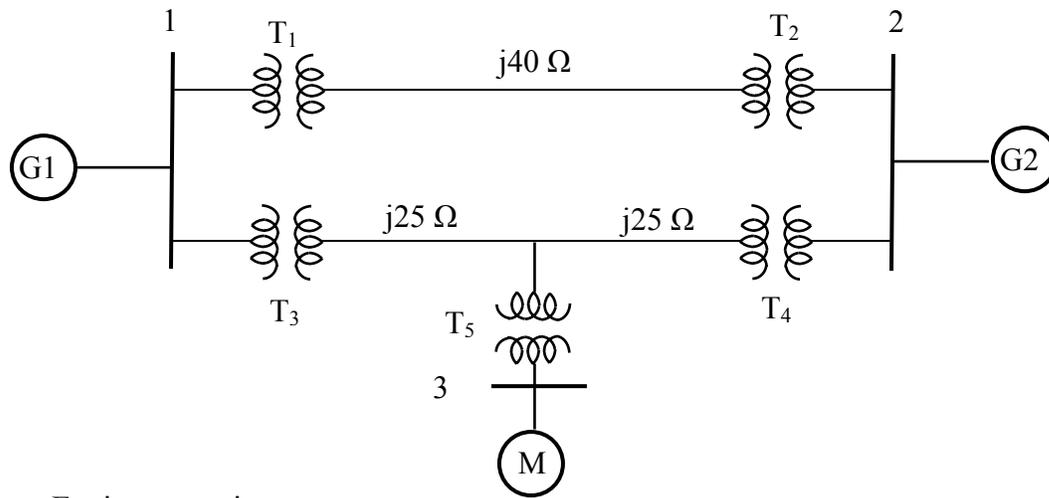
Equipment ratings are:

Generator 1:	750 MVA, 18 kV, X = 0.2 pu
Generator 2:	750 MVA, 18 kV, X = 0.2 pu
Motor:	1500 MVA, 20 kV, X = 0.2 pu
Transformer:	750 MVA, 500 kV/20 kV, X = 0.1 per unit
T_1, T_2, T_3, T_4	
Transformer T_5:	1500 MVA, 500 kV /20 kV, X = 0.10 per unit

By selecting a common system base of 100 MVA and 500 kV for the 40 Ω line, draw a reactance diagram with reactances in per unit on the same system base.

Problem 3 - *Working with a three-winding transf. Read Section 3.6 of Glover/Sarma text.*
Do the following problem This illustrates working with a three-winding transformer.

The ratings of a three-phase, three-winding transformer are

Primary (1):	Y connected, 66 kV, 20 MVA
Secondary (2):	Y connected, 13.2 kV, 15 MVA
Tertiary (3):	Δ connected, 2.3 kV, 5 MVA

Neglecting winding resistances and exciting current, the per-unit leakage reactances are:

$X_{12} = 0.08$ on a 20-MVA, 66-kV base

$X_{13} = 0.10$ on a 20-MVA, 66-kV base

$X_{23} = 0.09$ on a 15-MVA, 13.2-kV base

(a) Determine the per-unit reactances X_1, X_2, X_3 of the equivalent circuit on a 20-MVA, 66-kV base at the primary terminals. (b) Purely resistive loads of 12 MW at

13.2 kV and 5 MW at 2.3 kV are connected to the secondary and tertiary sides of the transformer, respectively. Draw the per-unit impedance diagram, showing the per-unit impedances on a 20-MVA, 66-kV base at the primary terminals.

Include, in your report, the items listed below.

Results Obtained: For each problem, draw the per phase equivalent circuit (impedance diagram) and put all the values on it, including base voltages and power.

Discussion of Results: Compare the ease/difficulty in getting answers to the problems in per unit vs. conventional units (volts, watts, amps). Be open-minded. It's your grade!!