SCHULICH
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UNIVERSITY OF CALGARY

DEPARTMENT OF ELECTRICAL
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ENEL 487
ELECTRICAL ENGINEERING ENERGY SYSTEMS

Lab Instructions

Lab 2: PU, Transformers and Transmission Lines

SYSTEM DESCRIPTION

The system to be studied in this lab consists of 4 buses and is representative of a small-sized power system. The plant (load) is fed from two main generators operating at 2.5 kV and the load operates at 4.6 kV. The single line diagram of the network is shown in Figure 1

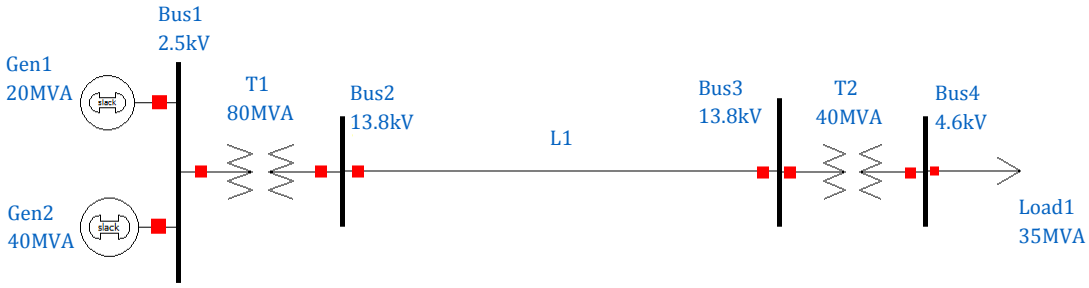

Figure 1-Network Single Line Diagram

The parameters of this network are provided in the following sections. Use Lab 1 Instructions as a guide to define the parameters of the system, to define the fields required to measure different variables, and to adjust the animated flow during the simulation.

Note: All per unit impedances provided below are calculated based on the equipment's rating. **These pu impedances must be changed to the system base before being entered into PowerWorld** (i.e. you need to perform some calculations for the impedance values!). 100MVA and 2.5kV are chosen as the base power and the base voltage on the generator side, respectively.

Bus 1:

- '*Nominal Voltage*' box: 2.5kV
- Fields Required on the SLD:
  - Bus Number
  - Bus Voltage (kV)

Bus 2:

- '*Nominal Voltage*' box: 13.8kV
- Fields Required on the SLD :
  - Bus Number
  - Bus Voltage (kV)

Bus 3:

- '*Nominal Voltage*' box: 13.8kV
- Fields Required on the SLD :
  - Bus Number
  - Bus Voltage (kV)

Bus 4:

- '*Nominal Voltage*' box: 4.6kV
- Fields Required on the SLD :
  - Bus Number
  - Bus Voltage (kV)
  - Bus Voltage (p.u.)

Generator 1:

- Under '*Power and Voltage Control*' tab:
  MW Setpoint: 20 Max. MW Output: 20 Mvar Output: 4 Max Mvar: 9900
  Regulated Bus Number: 1 Setpoint Voltage: 1 (pu)[1]
- Under '*Fault Parameters*' tab:
  Internal Sequence impedance-Positive: j0.3pu (Change this to System Base first)
- Fields Required on the SLD:
  - Gen MW Output
  - Gen Mvar Output

Generator 2:

- Under '*Power and Voltage Control*' tab:
  MW Setpoint: 40 Max. MW Output: 40 Mvar Output: 4 Max Mvar: 9900
  Regulated Bus Number: 1 Setpoint Voltage:: 1 (pu)
- Under '*Fault Parameters*' tab:
  Internal Sequence impedance-Positive: j0.25pu (Change this to System Base first)
- Fields Required on the SLD:
  - Gen MW Output
  - Gen Mvar Output

Note: Create 4 extra fields for the generators using the **Transmission Line field**. Create the following fields: one for **MW Flow**, one for **MVAR Flow**, one for **MVA Flow** and one for **Amp Flow**. These fields are used to measure the combined output of the generators, therefore the 'transmission line' used in the fields is actually transformer T1! For more details on fields, please refer to Step 13 of Lab 1 Instructions.

Transformer 1:

- Under '*Parameters*' tab:
  Series Reactance(X): 0.1pu (Change this to System Base first)

Transformer 2:

- Under '*Parameters*' tab:
  Series Reactance(X): 0.1pu (Change this to System Base first)
- Fields Required on the SLD:
  - Using the '*Transformer Field Options*', generate the field according to Figure 2. This will allow you to use transformer taps (i.e. change the transformer ratio).

[1] With a typical generator, we control the real power output (by controlling the prime mover) and the magnitude of the voltage at the terminals (by controlling the exciter/magnetic field strength)

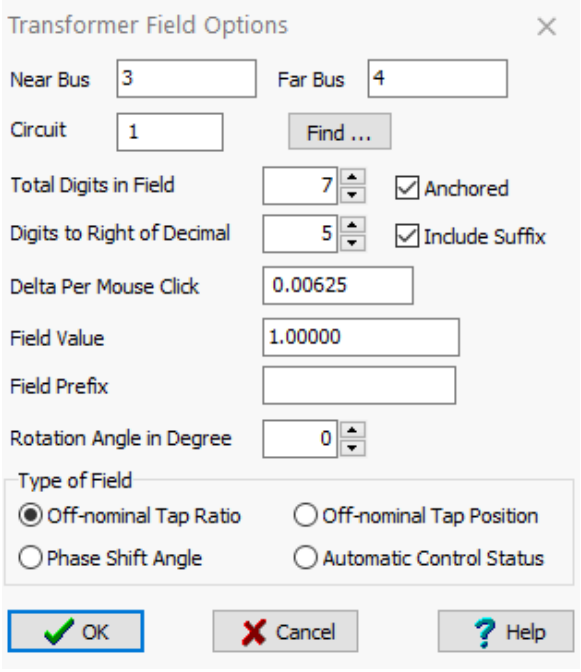

Figure 2-Transformer *Field Options*

Transmission Line L1:

- The transmission line has the following specifications:
  R=0.005 Ω/km X=0.038 Ω/km Line Length: 20 km
  Under '*Parameters*' tab:
  Series Resistance (R): Provide the Per Unit value of R under the System Base
  Series Reactance (X): Provide the Per Unit value of X under the System Base
- Fields Required on the SLD:
  - Amp Flow

Load 1:

- Under '*Load Information*' tab:
  Constant Power – MW Value: 35
- Fields Required on the SLD:
  - Load MW
  - Load Mvar

Note: Create an extra field for the load using the **Transmission Line field**. Create the following field: **Amp Flow**.
This field is used to measure the current drawn by the load, therefore the 'transmission line' used in this field is actually transformer T2!

After creating the network, defining all the required fields, and performing a Power Flow (using the '*Run Mode*' and '*Solve*'), the system should look similar to Figure 3.

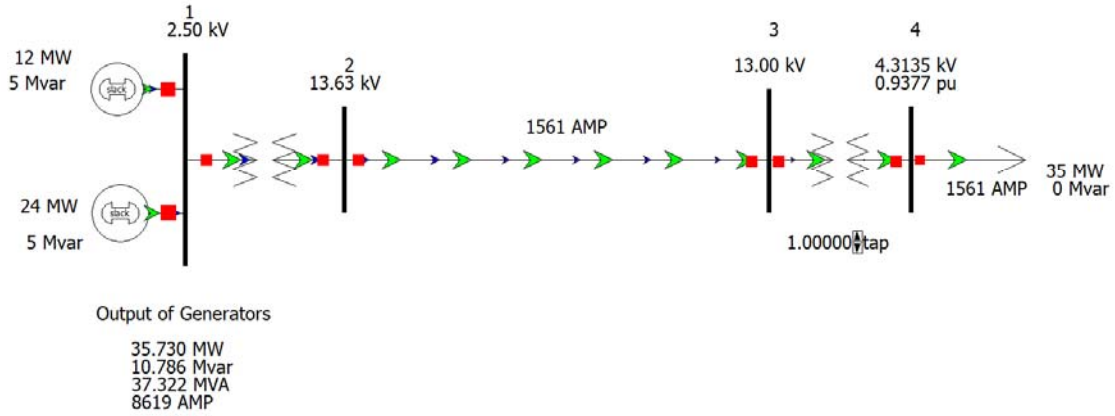

Figure 3-Network One Line Diagram

Questions:

In your lab report, please respond to the following questions. Use snapshots from the PowerWorld environment in your responses when applicable.

Q1) Show the calculations of new pu impedances (on system base) for all the required elements.

Q2) Draw the impedance diagram for this system showing the new pu impedances as calculated in Question 1.

Q3) The System Operator has requested that the voltage at Bus 4 is increased so that it is as close to 4.6kV (1pu) as possible. With the current system configuration, what can be changed in order to increase the voltage of bus 4?

Recommendation: Change the tap value of Transformer T2. What is the tap value that gets the voltage at Bus 4 closest to 1pu?
Aside: Without a functioning tap changing scheme, regulation of system voltages is not possible. This can result in inconvenience for the customer (load not operating at unacceptably low voltage levels) or dangerous (high) voltage levels that can damage equipment.

Q4) The System Operator has requested that the current in Transmission Line L1 does not exceed 800 Amp per phase, in order to avoid thermal damages to the line. Does L1 meet this criteria? Explain. If it does not, what solution can be implemented to meet this requirement?

Recommendation: The existing transmission line structures have the spare space to allow stringing of a second, identical circuit between bus 2 and 3. Similar to the following transmission line near the Calgary Zoo:

Q5) Implement your proposed solution in PowerWorld and take a snapshot of the system. What is the new value of current flowing through the line?
Note: Please check to see if your solution has affected the Voltage level at Bus 4. If so, please adjust the Tap changer again and record this new value.

Q6) The current drawn by the load is greater than the current entering Bus 3 from the lines. Can you explain why this happens?