# EXPERIMENT PX: ENGINEERING DRAWING 1 (OPEN-ENDED)

Related course: KIE4004 (Power System)

**OBJECTIVES:**

1. To draw a single line diagram of a power system using PowerWorld Simulator software to better understand of how to use the simulator for power system analysis and visualization.
2. To learn techniques for building good power system models and show how these techniques can be used to analyze power system issues.

**EQUIPMENT:**
PC with PowerWorld Simulator software

**INSTRUCTIONS:**

1. Save all your results in a folder on the PC you are using.
2. Follow the written and video's instructions throughout the experiment.
3. Handle the PC with care.
4. Use only PowerWorld Simulator for this experiment.

**REFERENCE(S):**

1. http://www.powerworld.com
2. References for KIE 4004 course

**INTRODUCTION:**

In power engineering, a power-flow study is a critical numerical analysis used to examine the flow of electrical power in an interconnected system. The analysis typically employs simplified notation, such as a one-line diagram and per-unit system, to focus on essential AC power parameters—voltages, voltage angles, real power, and reactive power—while assuming a steady-state operation. The accuracy and reliability of power system analysis depend heavily on the development of a robust model that reflects actual system characteristics.

A well-constructed power-flow model is essential for systems with multiple load centers, such as industrial complexes and refineries, as it ensures that the system can reliably meet load demands under normal operating conditions. This study not only provides critical insights into the system's voltage profile but also calculates total system losses, individual line losses, and transformer tap settings to ensure optimal performance at critical load points like motor control centers. Additionally, it offers recommendations for optimizing control settings to achieve maximum capacity utilization while minimizing operational costs.

The primary goal of a power-flow study is to determine complete voltage angle and magnitude data for each bus in the system under specific load and generator conditions. With this information, real and reactive power flows on each branch and the reactive power output of generators can be accurately calculated. Given the nonlinear nature of power systems, numerical methods are employed to reach solutions within acceptable tolerances.

Accurate system modeling is indispensable for identifying known and unknown variables in power-flow studies, which vary depending on bus type. These variables are crucial for understanding the performance of load buses, generator buses, and the system's slack bus, which provides a reference point for system balancing. The Newton-Raphson and Fast-Decoupled Load Flow methods are commonly used to solve the nonlinear equations associated with these studies, offering efficient solutions for complex power systems.

**PROCEDURES:**

Figure 1 shows a single-line diagram of a five-bus power system. Input data are given in Tables 1, 2, and 3. As shown in Table 1, bus 1, to which a generator is connected, is the swing bus. Bus 3, to which a generator and a load are connected, is a voltage-controlled bus. Buses 2, 4 and 5 are load buses. Note that the loads at buses 2 and 3 are inductive since $Q_2 = -Q_{L2} = -2.8$ and $Q_{L3} = -0.4$ are negative.

1. Use the given data as input data to model this system in the PowerWorld Simulator.

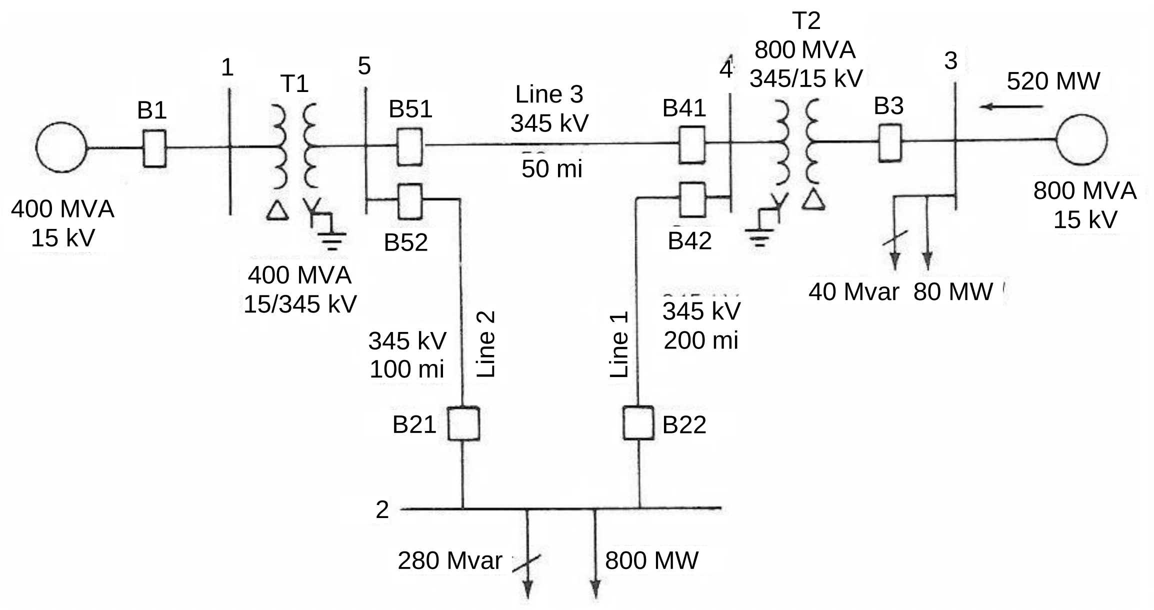


Figure 1. Single Line diagram five-bus system

Table 1. Bus input data

| BUS | TYPE | V (per unit) | δ (degrees) | $P_G$ (per unit) | $Q_G$ (per unit) | $P_L$ (per unit) | $Q_L$ (per unit) | $Q_{Gmax}$ (per unit) | $Q_{Gmin}$ (per unit) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Swing | 1.0 | 0 | — | — | 0 | 0 | — | — |
| 2 | Load | — | — | 0 | 0 | 8.0 | 2.8 | — | — |
| 3 | Generator | 1.05 | — | 5.2 | — | 0.8 | 0.4 | 4.0 | -2.8 |
| 4 | Load | — | — | 0 | 0 | 0 | 0 | — | — |
| 5 | Load | — | — | 0 | 0 | 0 | 0 | — | — |

*$S_{base}$ = 100 MVA, $V_{base}$ = 15 kV at buses 1, 3, and 345kV at buses 2, 4, 5

Table 2. Line input data

| Bus-to-Bus | R' (per unit) | X' (per unit) | G' (per unit) | B' (per unit) | Maximum MVA (per unit) |
|---|---|---|---|---|---|
| 2 – 4 | 0.0095 | 0.105 | 0 | 1.70 | 12.0 |
| 2 – 5 | 0.0040 | 0.055 | 0 | 0.90 | 12.0 |
| 4 – 5 | 0.00338 | 0.022 | 0 | 0.45 | 12.0 |

Table 3. Transformer input data

| Bus-to-Bus | R (per unit) | X (per unit) | $G_C$ (per unit) | $B_M$ (per unit) | Maximum MVA (per unit) | Maximum TAP Setting (per unit) |
|---|---|---|---|---|---|---|
| 1 – 5 | 0.00160 | 0.018 | 0 | 0 | 6.0 | — |
| 3 – 4 | 0.00080 | 0.012 | 0 | 0 | 10.0 | — |

Table 4. Input data and unknowns

| BUS | INPUT DATA | UNKNOWNS |
|---|---|---|
| 1 | $V_1 = 1.0$, $\delta_1 = 0$ | $P_1$, $Q_1$ |
| 2 | $P_2 = P_{G2} - P_{L2} = -8$<br>$Q_2 = Q_{G2} - Q_{L2} = -2.8$ | $V_2$, $\delta_2$ |
| 3 | $V_3 = 1.05$, $P_3 = P_{G3} - P_{L3} = 4.4$ | $Q_3$, $\delta_3$ |
| 4 | $P_4 = 0$, $Q_4 = 0$ | $V_4$, $\delta_4$ |
| 5 | $P_5 = 0$, $Q_5 = 0$ | $V_5$, $\delta_5$ |

2. Draw and simulate the above circuit in PowerWorld Simulator for power flow analysis using Newton Raphson method for one iteration.
3. From your simulation, determine the Y-bus matrix of the test system.
4. From your simulation, determine the dimension of the Jacobian matrix for the power system in Figure 1.
5. From procedure no. 1, modify your circuit by inserting a second line between bus 2 and bus 5. Give the new line circuit identifier of "2" to distinguish it from the existing line. The line parameters of the added line should be identical to those of the existing line 2 -5. Determine the effect of this new line on $V_2$, the line loading and on the total real power losses. In your report, discuss your observation.

**OPEN-ENDED TASKS (complete these tasks during lab session):**

Continued from your simulation in step 1 (from PROCEDURES),

1. Explain the effect of adding a 200 MVar shunt capacitor bank at bus 2 on this power system.
2. Determine the MVar rating of the shunt capacitor bank that can increase $V_2$ by 2%. Also, explain the effect of this capacitor bank on line loading and the total real power losses.
3. Add any type of renewable power plant (e.g., generator) of appropriate capacity at suitable bus in your modelled circuit to reduce the power losses. Explain your choice of bus and describe your observation on the change of power flows in the circuit and the effect the RE plant has on the power losses.

**END OF EXPERIMENT**