Analysis of electrical power and energy systems

Practical session 7

25 November 2021

1 Transient stability and primary frequency control

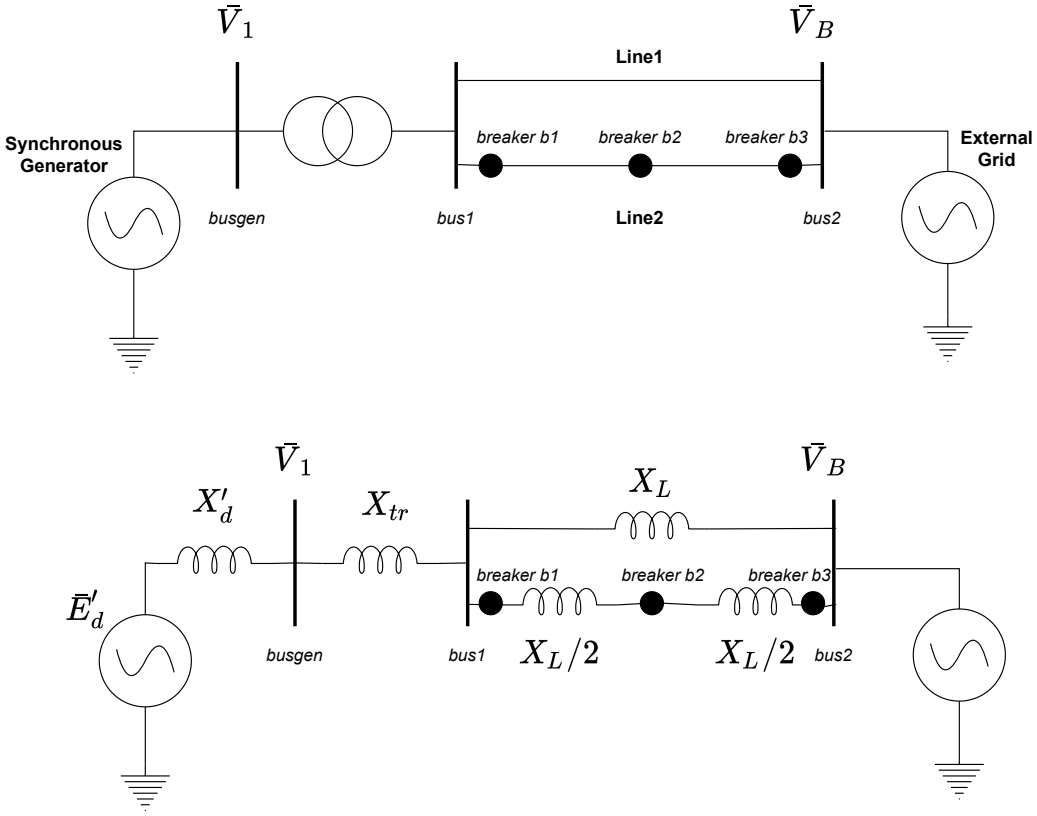

Figure 1: One-Machine-Infinite-Bus system.

1. Consider the one-machine-infinite-bus system shown in Figure 1. A synchronous generator converts a mechanical power P_m into an electrical power P_e (without conversion losses) which is transferred to the network through a step-up transformer and two parallel lines with same impedances. The electrical losses are not considered in this system therefore, the step-up transformer can be represented by an equivalent reactance X_{tr}. The following data are given :
   $X_L = 1pu$, $X'_d = 0.3pu$, $X_{tr} = 0.5pu$, $\bar{V}_B = 1\angle 0°$.
   Initial values : $\bar{E}'_d = E'_d\angle\delta$, $\bar{V}_1 = 1\angle 30°$

   (a) What is the initial active power transferred P_e? Calculate the maximal power transmissible $\hat{P}_e$.

   (b) Consider a three-phase short-circuit close to breaker b_2 cleared by the tripping of line 2. Plot the $P - \delta$ curves for the three situations: before short-circuit, during

short-circuit and after short-circuit. Assume that the voltage magnitude E' is kept constant as well as voltage phasor $\bar{V}_B$.

(c) Calculate the critical fault clearing angle δ_{cr} using the equal area criterion.

(d) What is the impact on the critical fault clearing angle if the short-circuit occurs close to breaker b_1?

2. A power system has a total load of 1260MW at 60Hz. The load varies 1.5% for every 1% change in frequency (D = 1.5). The system has 240MW of spinning reserve evenly spread among 500MW of generation capacity with 5% regulation based on this capacity. All other generators are operating with their valves wide open and are capable of down regulation only, also with R = 5%. Find the steady-state frequency deviation when a 60MW load is suddenly tripped.[1]

2 Solutions

Link to the Python notebook shown during the session: Python Notebook TP7

1. (a) $P_e = 0.5$ pu, $\hat{P}_e = 1.051$ pu

   (b) See python notebook

   (c) $\delta_{cr} = 49.37°$

   (d) $\delta_{cr} = 43.74°$

2. $f_{ss} = 60.1132$ Hz

[1] This exercise has been adapted from the course *31750 Stability and control in electric power systems* given at Technical University of Denmark.