

Power Systems Analysis, Mock-up Exam, Part II

0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9

Questions:
3 points for this section

Remember to write down the calculations and eventual considerations that allowed you to derive the result. For part II, you can get a maximum of $\Rightarrow +3$ points and a minimum of $\Rightarrow 0$ point.

← Insert your SCIPER number on the left and write your full name below. ↓

Surname and Name:

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Exercise

In the event of a massive blackout, the Transmission System Operator (TSO) is responsible for restoring (black-start) a power station to operation without relying on the external electric power transmission network. You are asked to study the black-start process of a small generator G_1 supplying auxiliary power to a larger power station (represented with the load U_1) located 100 km from the generator. The circuit is visible in Figure 1.

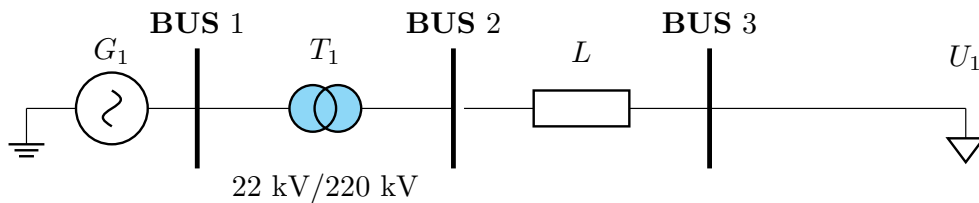


Figure 1: Single phase equivalent circuit of the power grid used during the black-start process.

Questions:

1. **Case 1:** The generator supplies the transformer T_1 and the line L , but the load is disconnected. The voltage at the end of the line (BUS 3) is 220 kV.
 - (i) Compute the ABCD parameters of the line, with no approximation.
 - (ii) Calculate voltage, active and reactive power at the start of the line (BUS 2).
 - (iii) Determine the voltage at the generator terminal (BUS 1) and its internal EMF.
2. **Case 2:** Consider the load U_1 to be supplied, with a voltage of 220 kV. The load is consuming 150 MVA at a power factor of 0.95 lagging.
 - (i) Calculate voltage, active and reactive power at the start of the line (BUS 2).
 - (ii) Calculate the voltage at the generator terminal (BUS 1) and its internal EMF.
3. **Step 3:** For both the loading conditions of Case 1 and Case 2, draw the phasor diagram of the generator and elaborate on the requirements of the synchronous generator excitation system to withstand both no load and supply conditions.

Little help: The TSO is advising to perform all the calculations in p.u., with the bases:

$$V_{1b} = 22 \text{ kV}, \quad V_{2b} = V_{3b} = 220 \text{ kV}, \quad S_b = 300 \text{ MW}.$$

and reminding you that to obtain the per-unit power, knowing the per-unit voltage $\bar{v}$ and the per-unit current $\bar{i}$, you simply have to do: $\bar{s} = \bar{v}\bar{i}^*$.

Data:

The characteristics of L , T_1 and G_1 are contained in Table 1, 2 and 3, respectively.

Parameter	Value
Resistance (r)	$0.020 \cdot 10^{-3} \text{ [Ohm/m]}$
Reactance (x)	$0.268 \cdot 10^{-3} \text{ [Ohm/m]}$
Susceptance (b)	$4.300 \cdot 10^{-9} \text{ [S/m]}$
Conductance (g)	$0.007 \cdot 10^{-9} \text{ [S/m]}$
Length (l)	$100.0 \cdot 10^3 \text{ [m]}$

Table 1: Nominal Parameters of Transmission Line

Parameter	Value
Nominal Voltage Primary (V_1)	22 kV
Nominal Voltage Secondary (V_2)	220 kV
Nominal Power (S_n)	300 MVA
Short Circuit Voltage (v_{cc})	10%
Short Circuit Resistance (r_{cc})	0

Table 2: Nominal Parameters of Transformer T_1

Parameter	Value
Nominal Power (S_n)	250 MVA
Nominal Voltage (V_n)	20 kV
Synchronous Reactance (x_s)	1.7241 pu

Table 3: Nominal Parameters of Generator G_1