

## Exercise 5.1 The Load Flow calculus in electrical power transmission networks

The power network of Fig. 1 is characterised by the following parameters

Rated voltage: 220 kV

Line lengths reported in Table 1.

Load on node #2:  $P_{2,load}=20$  MW,  $Q_{2,load} = 10$  MVar;

Load on node #3:  $P_{3,load} =45$  MW,  $Q_{3,load} =15$  MVar

Load on node #4:  $P_{4,load} =40$  MW,  $Q_{4,load} =5$  MVar,

Load on node #5:  $P_{5,load} =60$  MW,  $Q_{5,load} =10$  MVar.

Node #1 is the slack bus with a voltage of 220 kV (assumed with a zero phase); on node #2 there is also generation of  $P_{4,gen}=40$  MW and we impose there a voltage of 220 kV.

The overhead lines are characterised by the following per-unit-length parameters

$r = 0.0717 \Omega/\text{km}$

$x_l = 0.424 \Omega/\text{km}$ ,

$b = 2.64 \cdot 10^{-6} \text{ S/km}$ ,

$g \cong 0$ .

The line lengths are given in the table below.

| Line | Length (km) |
|------|-------------|
| 1-2  | 70          |
| 1-3  | 280         |
| 2-3  | 210         |
| 2-4  | 210         |
| 2-5  | 140         |
| 3-4  | 35          |
| 4-5  | 280         |

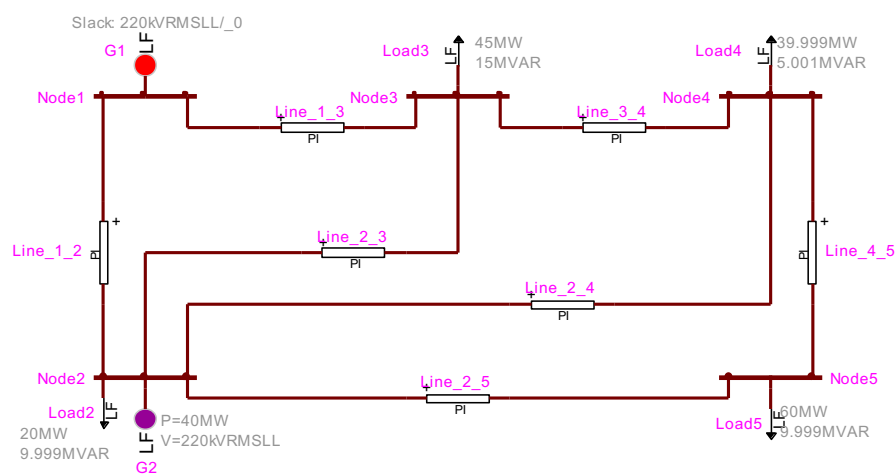


Fig. 1. The power grid under study.

It is requested to address the following points.

1. Verify that both generators connected to the grid absorb reactive power and say why. Repeat the same computation by switching the generator on node #2 as a  $PQ$  one in which the reactive power is  $Q_{2,gen} = -20$  MVar. Observe the largest voltage variations and understand why.
2. Increase the reactive power requested at load 5,  $Q_{5,load} = 60$  MVar. With respect to the previous case, compare the node voltages and the network losses and try to understand which is the reason of the differences. It is also requested to modify the reactive power at node 5 in order to bring the voltage value at this node to the rated one (i.e., 220 kV).
3. Increase the network loading by increasing the active powers as follows:  $P_{5,load} = 130$  MW,  $P_{3,load} = P_{4,load} = 150$  MW, with the node 2 in the same conditions of question #1 (i.e.,  $P_{1,load} = 40$  MW and voltage equal to 220 kV. Identify the lines with the largest angle separations of the voltage phasors and correlate them with the respective line power flows.