### 3.1 Linear Feeder

Consider the linear feeder shown in Fig. 4, which consists of a synchronous machine (SM), two transformers (TF1, TF2), a transmission line (TL), and a load (L). The electrical parameters of these components are listed in Tab. 1.

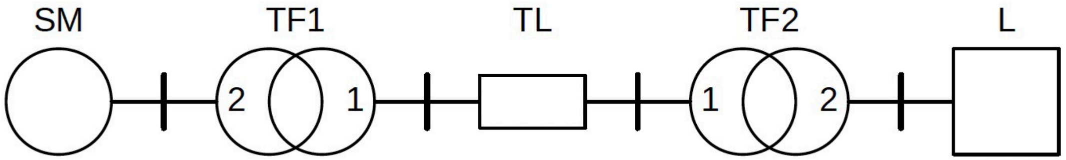
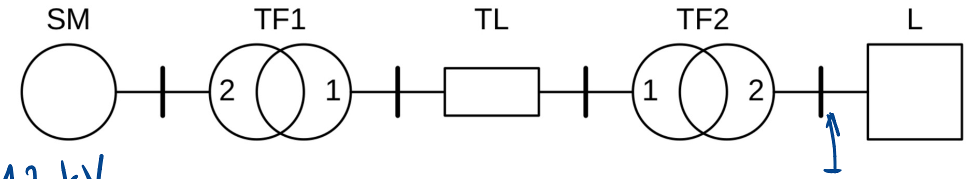



Figure 4: Schematic of the linear feeder.

Table 1: Electrical parameters of the components forming the linear feeder.

| Component | Parameters |
|---|---|
| SM | $A_n$=50 MVA, $V_n$=12 kV, $x_{\text{SM}}$=1.1 pu ($\bar{Z}_{\text{SM}} = jX_{\text{SM}}$) |
| TF1 | $A_n$=60 MVA, $V_{n,1}$=220 kV, $V_{n,2}$=10 kV, $V_{sc,\%}$=10% |
| TL | $X_{\text{TL}}$= 65 Ω ($\bar{Z}_{\text{TL}} = jX_{\text{TL}}$) |
| TF2 | $A_n$=30 MVA, $V_{n,1}$=220 kV, $V_{n,2}$=20 kV, $V_{sc,\%}$=10% |
| L | $P_L$=24 MW, $Q_L$=15 MVar, $V_L$=19 kV |

**Q1/** Compute the voltage magnitudes on the primary sides of the two transformers and at the internal bus of the synchronous machine.




| Component | Parameters |
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| SM | $A_n$=50 MVA, $V_n$=12 kV, $x_{\text{SM}}$=1.1 pu ($\bar{Z}_{\text{SM}} = jX_{\text{SM}}$) |
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| TF2 | $A_n$=30 MVA, $V_{n,1}$=220 kV, $V_{n,2}$=20 kV, $V_{sc,\%}$=10% |
| L | $P_L$=24 MW, $Q_L$=15 MVar, $V_L$=19 kV |

12 kV

$n_1 = 10\text{ kV} / 220\text{ kV}$

$n_2 = 220\text{ kV} / 20\text{ kV}$

19 kV

$V_{b,1}$ $V_{b,2}$ $V_{b,3}$

$A_b = ?$

$A_b = 60\text{ MVA}$

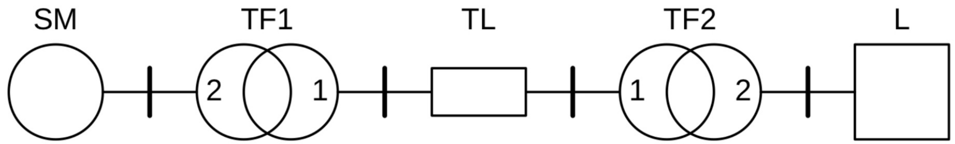
$$\frac{V_{b,1}}{V_{b,2}} = n_1 \qquad \frac{V_{b,2}}{V_{b,3}} = n_2$$

$V_{b,1} = 10\text{ kV}$

$V_{b,2} = 220\text{ kV}$

$V_{b,2} = 220\text{ kV}$

$V_{b,3} = 20\text{ kV}$




| Component | Parameters |
|---|---|
| SM | $A_n$=50 MVA, $V_n$=12 kV, $x_{\mathrm{SM}}$=1.1 pu ($\bar{Z}_{\mathrm{SM}} = jX_{\mathrm{SM}}$) |
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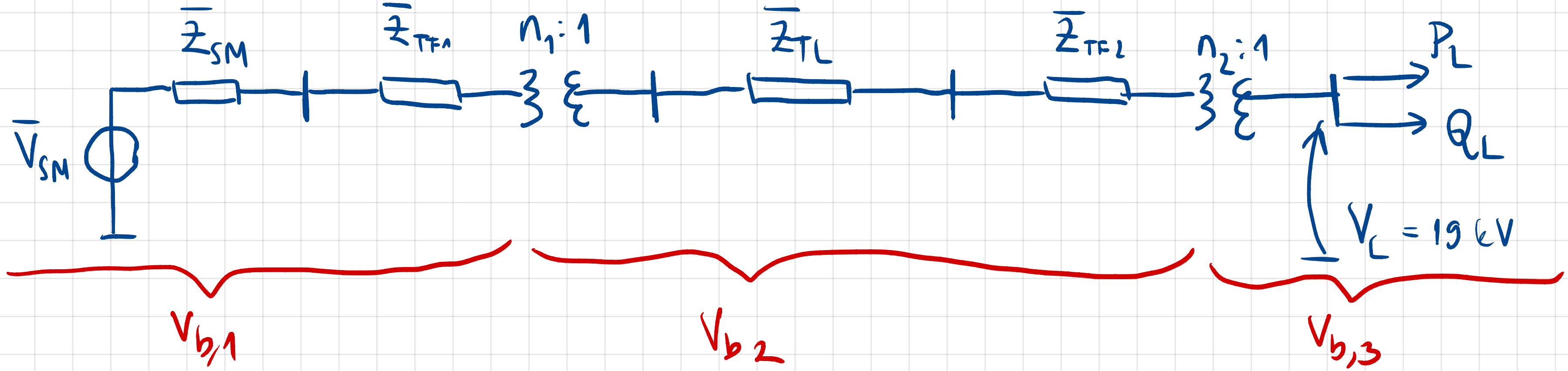
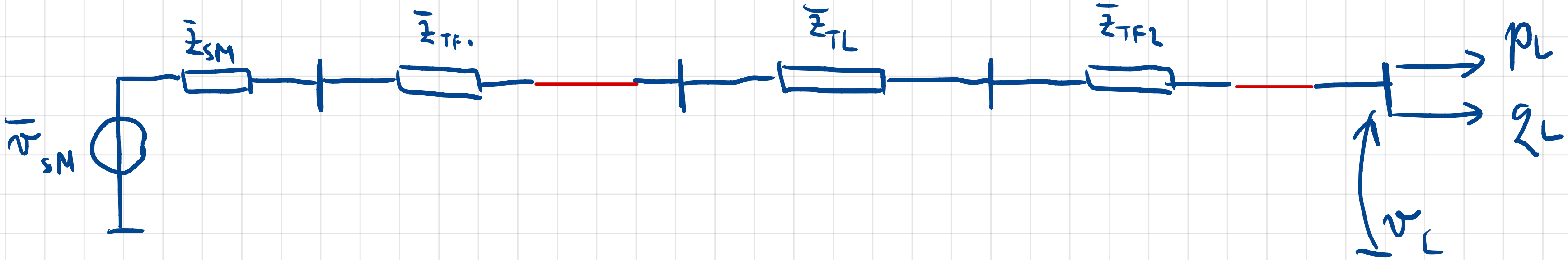
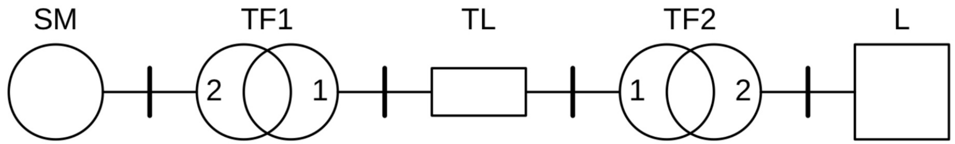
| TF2 | $A_n$=30 MVA, $V_{n,1}$=220 kV, $V_{n,2}$=20 kV, $V_{sc,\%}$=10% |
| L | $P_L$=24 MW, $Q_L$=15 MVar, $V_L$=19 kV |




in abs. units




in per-unit




| Component | Parameters |
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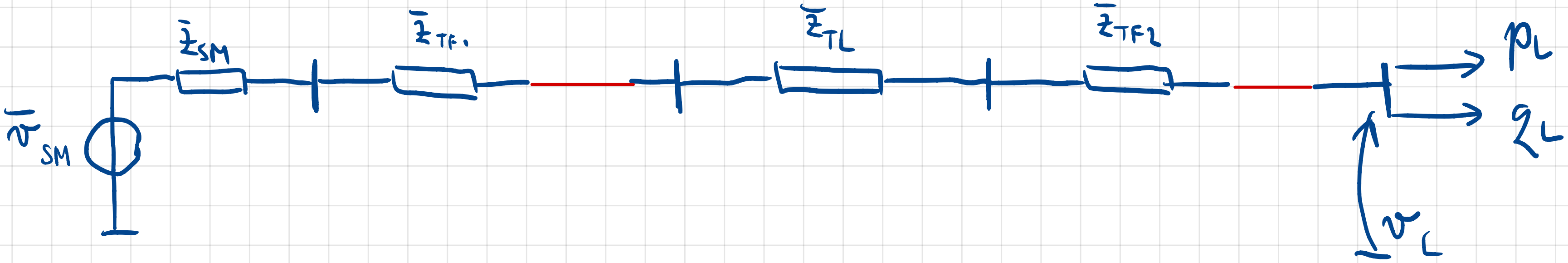
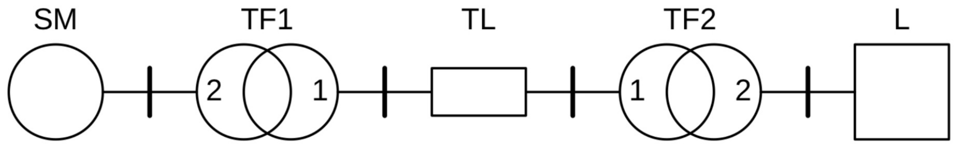



$$x_{SM}^{ds} = 1.1 \text{ p.u} \longrightarrow X_{SM} = x_{SM}^{ds} \cdot \frac{V_n^2}{A_n}$$

$$\downarrow$$

$$x_{SM} = \frac{X_{SM}}{\frac{V_{b,1}^2}{A_b}} = x_{SM}^{ds} \cdot \frac{V_n^2}{A_n} \cdot \frac{A_b}{V_{b,1}^2} = 1.901 \text{ p.u}$$

$$\bar{Z}_{SM} = j x_{SM} = j1.901 \text{ p.u}$$




| Component | Parameters |
| --- | --- |
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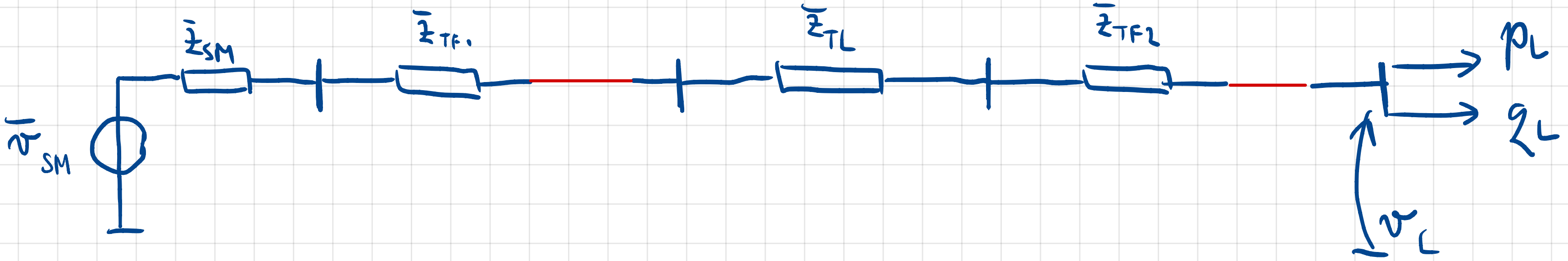
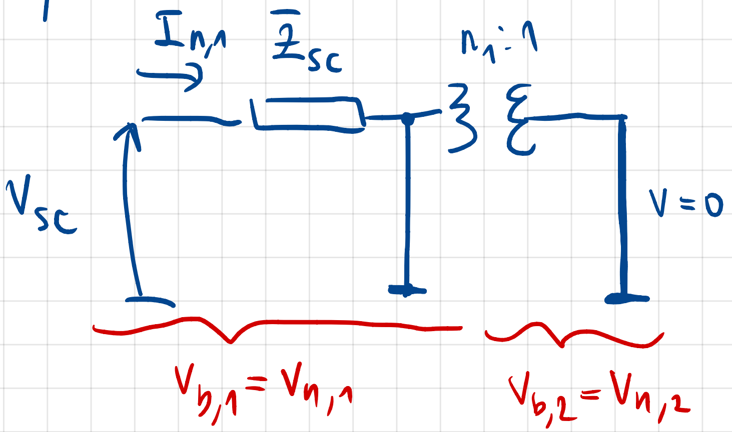
| TL | $X_{\mathrm{TL}}$= 65 Ω ($\bar{Z}_{\mathrm{TL}} = jX_{\mathrm{TL}}$) |
| TF2 | $A_n$=30 MVA, $V_{n,1}$=220 kV, $V_{n,2}$=20 kV, $V_{sc,\%}$=10% |
| L | $P_L$=24 MW, $Q_L$=15 MVar, $V_L$=19 kV |




$V_{sc,\%} = 10\%$

short-circuit test:




$$V_{sc} = Z_{sc} \cdot I_{n,1}$$

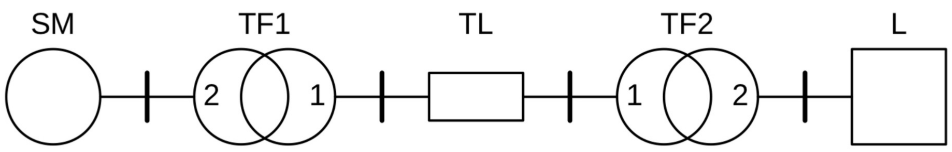
$$\downarrow$$

$$\frac{V_{sc}}{V_{n,1}} = \frac{Z_{sc} \cdot I_{n,1}}{V_{n,1}} = \frac{Z_{sc}}{Z_b} = z_{sc}$$

$$\| $$

$$V_{sc,\%}$$

$z_{TF1} = V_{sc\%} = 0.1$, $\boxed{\bar{z}_{TF1} = j\,0.1 \text{ p.u}}$




| Component | Parameters |
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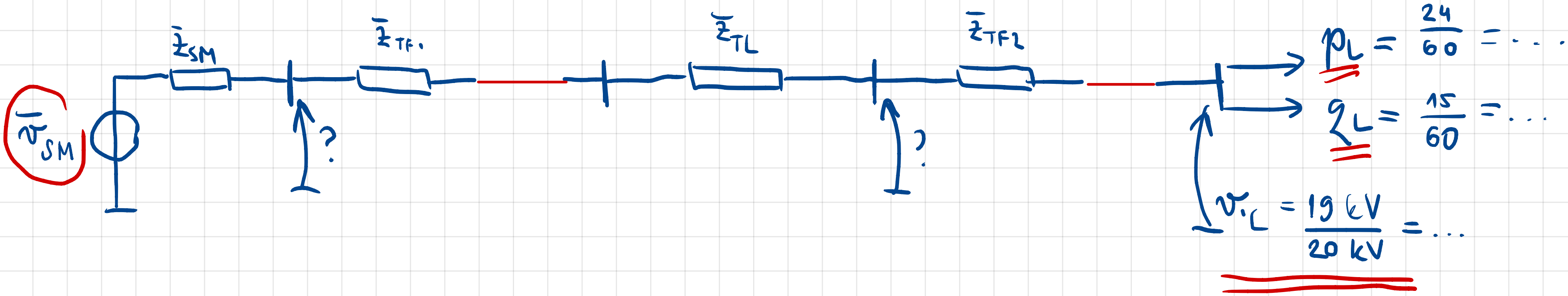
| TF1 | $A_n$=60 MVA, $V_{n,1}$=220 kV, $V_{n,2}$=10 kV, $V_{sc,\%}$=10% |
| TL | $X_{TL}$= 65 Ω ($\bar{Z}_{TL} = jX_{TL}$) |
| TF2 | $A_n$=30 MVA, $V_{n,1}$=220 kV, $V_{n,2}$=20 kV, $V_{sc,\%}$=10% |
| L | $P_L$=24 MW, $Q_L$=15 MVar, $V_L$=19 kV |




TL

$$x_{TL} = \frac{X_{TL}}{Z_{b,2}} = \frac{X_{TL}}{\frac{V_{b,2}^2}{A_b}} = 0.081 \Rightarrow \boxed{\bar{z}_{TL} = j0.081 \text{ p.u}}$$

TF2

$$V_{sc,\%} = 10\%$$

$$z_{sc} = 10\% \cdot \frac{\cancel{V_{n,1}^2}}{A_n} : \frac{\cancel{V_{n,1}^2}}{A_b} = 10\% \cdot \frac{A_b}{A_n} = 0.2$$

$$\boxed{\bar{z}_{TF2} = j0.2 \text{ p.u}}$$