Example 1

Three phase MV power line has nominal voltage $U = 22$ kV, resistance $R_1 = 0{,}334$ Ω/km, inductive reactance $X_1 = 0{,}42$ Ω/km and length $l = 20$ km - see Fig. 1. At the end of power line there is load $S = 8$ MVA with $\cos\varphi = 0{,}9$ of inductive character. Calculate the voltage drop.

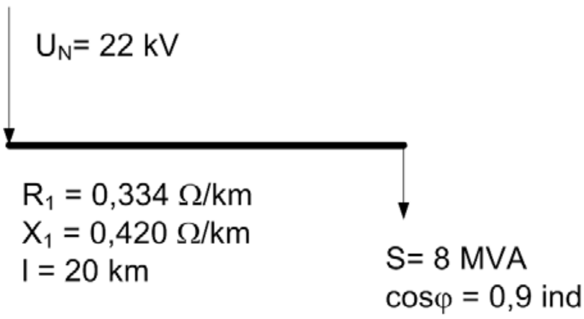

Fig. 1

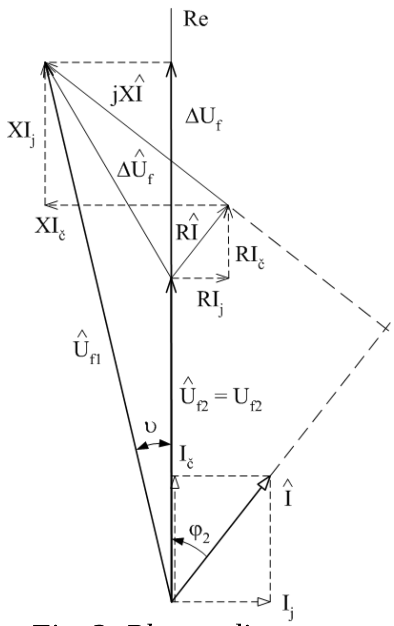

Fig. 2: Phasor diagram

$$R = R_1.l = 6{,}68\ \Omega$$
$$X = X_1.l = 8{,}4\ \Omega$$
$$P = S.\cos\varphi = 7{,}2\ \text{MW}$$
$$Q = S.\sin\varphi = 3{,}487\ \text{MVAr}$$
$$\hat{U}_{f2} = U_{f2} = \frac{U}{\sqrt{3}} = 12{,}7\ \text{kV}$$

The complex voltage drop (for reactive power – inductive load):

$$\Delta\hat{U}_f = \hat{Z}_1.\hat{I} = (R + j.X)\cdot(I\check{c} - jI_j) = (R.I_{\check{c}} + X.I_j) + j(X.I_{\check{c}} - R.I_j)$$

longitudinal component transverse component

If we know powers:

$$\Delta\hat{U}_f = [(R.I_{\check{c}} + X.I_j) + j(X.I_{\check{c}} - R.I_j)]\frac{3.U_f}{3.U_f} = \frac{R.P + X.Q}{3.U_f} + j\frac{X.P - R.Q}{3.U_f} = 2{,}03 + j0{,}98\ \text{kV}$$

$$\left|\Delta\hat{U}_f\right| = 2{,}25\ \text{kV}$$

BUT!

$$\hat{U}_{f1} = \hat{U}_{f2} + \Delta\hat{U}_f = 14{,}73 + j0{,}98\ \text{kV}$$
$$U_{f1} = \left|\hat{U}_{f1}\right| = 14{,}76\ \text{kV}$$
$$\underline{\Delta U_f = \left|\hat{U}_{f1}\right| - \left|\hat{U}_{f2}\right| = 2{,}06\ \text{kV}}$$

If the transverse component is neglected, the voltage drop is calculated as:

$$\Delta\hat{U}_f \cong \left(R.I_{č} + X.I_j\right)\cdot\frac{3.U_f}{3.U_f} = \frac{R.3.U_f.I_{č} + X.3.U_f.I_j}{3.U_f} = \frac{R.P + X.Q}{3.U_f} = 2{,}03\ \text{kV}$$

Percentage voltage drop:

$$\varepsilon_{\%} = \frac{\Delta U_f}{U_f}\cdot 100 = \frac{R.P + X.Q}{3.U_f^2}\cdot 100 = \frac{R.P + X.Q}{U^2}\cdot 100 = 16\ \%$$

The power on both sides of power line:

$$\hat{S}_2 = P_2 + jQ_2 = 7{,}2\ \text{MW} + j\,3{,}5\ \text{MVAr}$$

$$\hat{I}_1 = \hat{I}_2 = \left(\frac{\hat{S}_2}{3\hat{U}_{f2}}\right)^* = (189 - j92)\ \text{A}$$

$$\hat{S}_1 = 3\hat{U}_{f1}\hat{I}_1^* = 8{,}1\ \text{MW} + j\,4{,}6\ \text{MVAr}$$

$$\Delta\hat{S} \cong 0{,}9\ \text{MW} + j\,1{,}1\ \text{MVAr}$$

Example 2

Three phase ring MV power line with given longitudinal impedance $\hat{Z}_{lk}$ is shown in Fig. 3.

In the Fig. 4 there is the same power line after splitting in the feeder. Calculate the feeders load, current distribution along the power line and the place with the biggest voltage drop.

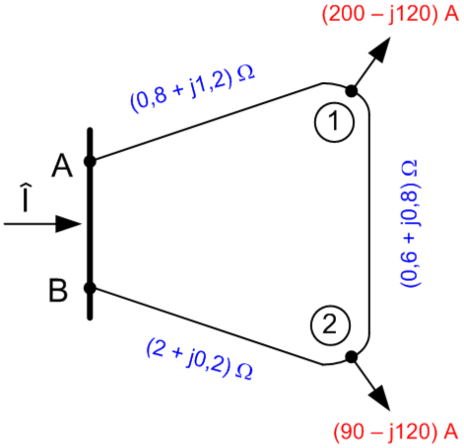

Fig. 3

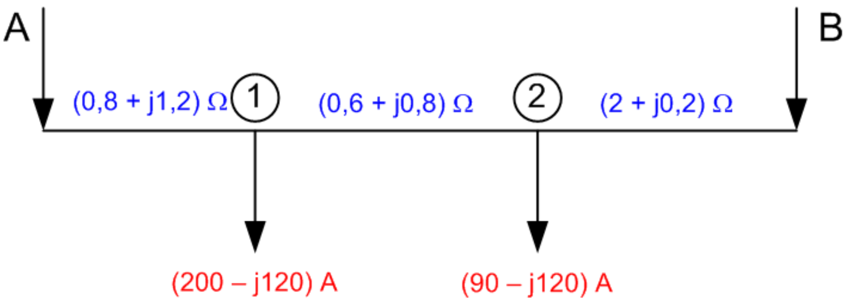

Fig. 4

Partial feeder currents ($\hat{U}_A = \hat{U}_B$):

$$\hat{I}_B = \frac{\sum_{k=1}^{2} \hat{I}_k . \hat{Z}_{lk}}{\hat{Z}_{lAB}} = \frac{(200 - j120)(0,8 + j1,2) + (90 - j120)(1,4 + j2)}{3,4 + j2,2} = (159,8 - j57,6) \text{ A}$$

$$\hat{I}_A = \frac{\sum_{k=1}^{2} \hat{I}_k . (\hat{Z}_{lAB} - \hat{Z}_{lk})}{\hat{Z}_{lAB}} = \frac{(90 - j120)(2 + j0,2) + (200 - j120)(2,6 + j1)}{3,4 + j2,2} = (130,2 - j182,4) \text{ A}$$

The current distribution is in the Fig. 5. The active current dividing is in the point 1, reactive current dividing in the point 2.

For the biggest voltage drop:

$$\Delta U_f = R.I_č \pm X.I_j \quad \begin{matrix} + & \text{inductive} \\ - & \text{capacitive} \end{matrix}$$

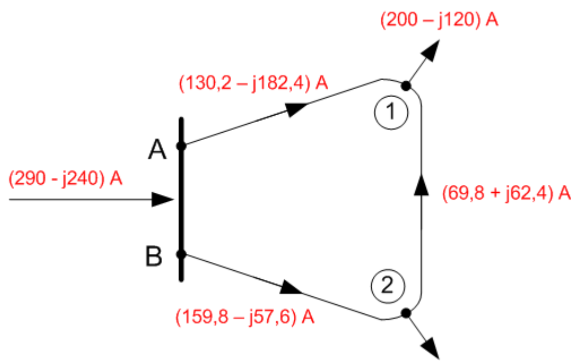

Fig. 5.

The voltage drop between the point A and 1: (attention to the current sign, apart from the sign for $I_{j\ inductive}$ or $I_{j\ capacity}$ the sign corresponds to the specified direction from the point A to the point 1):

$$\Delta U_{fA1} = 0,8.130,2 + 1,2.182,4 = 323 \text{ V}$$

$$\Delta U_{f12} = -0,6.69,8 - (-0,8.62,4) = 8,04 \text{ V}$$

$$\Delta U_{fA2} = \Delta U_{fA1} + \Delta U_{f12} = 323 + 8,04 = 331 \text{ V}$$

The place with biggest voltage drop is the point 2.

$$\Delta U_{fB2} = 2.159,8 + 0,2.57,6 = \Delta U_{fA2} = 331 \text{ V}$$