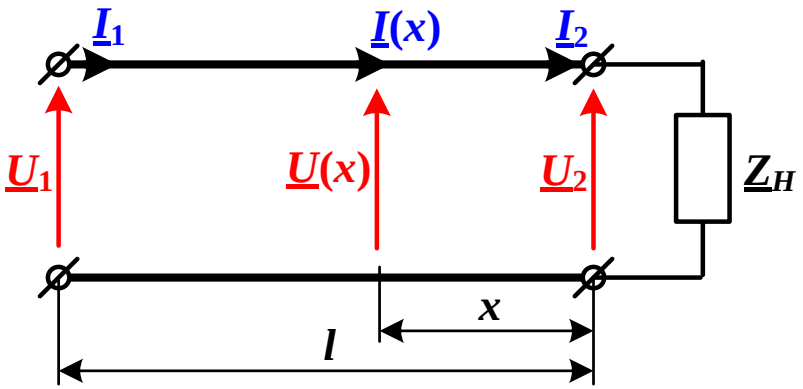
ТОЭ – часть 2
практическое занятие 13

Расчет установившегося режима длинных линий

Уравнения длинной линии для комплексов действующих значений напряжений и токов при отсчете x от конца линии:



$$\underline{U}(x) = \underline{A}_1 \cdot e^{\underline{\gamma} \cdot x} + \underline{A}_2 \cdot e^{-\underline{\gamma} \cdot x} = \underline{U}_2 \cdot \mathrm{ch}\underline{\gamma} x + \underline{Z}_B \cdot \underline{I}_2 \cdot \mathrm{sh}\underline{\gamma} x ;$$

$$\underline{I}(x) = \frac{\underline{A}_1}{\underline{Z}_B} \cdot e^{\underline{\gamma} \cdot x} - \frac{\underline{A}_2}{\underline{Z}_B} \cdot e^{-\underline{\gamma} \cdot x} = \frac{\underline{U}_2}{\underline{Z}_B} \cdot \mathrm{sh}\underline{\gamma} x + \underline{I}_2 \cdot \mathrm{ch}\underline{\gamma} x ;$$

$$\underline{A}_1 = \frac{\underline{U}_2 + \underline{Z}_B \cdot \underline{I}_2}{2}; \quad \underline{A}_2 = \frac{\underline{U}_2 - \underline{Z}_B \cdot \underline{I}_2}{2};$$

$$\underline{K}_U = -\underline{K}_I = \frac{\underline{Z}_H - \underline{Z}_B}{\underline{Z}_H + \underline{Z}_B}; \quad \underline{Z}_H = \frac{\underline{U}_2}{\underline{I}_2}; \quad \underline{Z}_{BX} = \frac{\underline{U}_1}{\underline{I}_1}.$$

Задача 1

Дано:

$\underline{U}_1 = 1000e^{j0^o}$ (В); $l = 100$ (км);

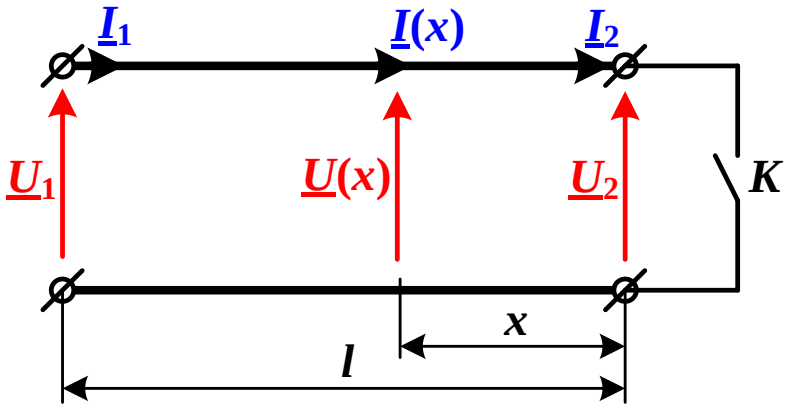
$\underline{Z}_B = 400e^{-j30^o}$ (Ом);

$\gamma = 0{,}001 + j\pi/600$, (1/км).

Определить:

$\underline{U}_2 = ?$ $\underline{I}_1 = ?$ $\underline{I}_2 = ?$ $\underline{Z}_{BX} = ?$

1. Режим **холостого хода**:
   ключ *K* **разомкнут**, $\underline{I}_2 = 0$.
2. Режим **короткого замыкания**:
   ключ *K* **замкнут**, $\underline{U}_2 = 0$.



Решение:

$$\underline{\gamma} l = \left(0{,}001 + j\frac{\pi}{600}\right)\cdot 100 = 0{,}1 + j\frac{\pi}{6};$$

$$e^{\underline{\gamma} l} = e^{0{,}1 + j\frac{\pi}{6}} = e^{0{,}1} e^{j\frac{\pi}{6}} = 1{,}105 e^{j30^\circ} = 0{,}957 + j0{,}553;$$

$$e^{-\underline{\gamma} l} = \frac{1}{e^{\underline{\gamma} l}} = \frac{1}{1{,}105 e^{j30^\circ}} = 0{,}905 e^{-j30^\circ} = 0{,}784 - j0{,}452;$$

$$\mathrm{sh}\underline{\gamma} l = \frac{e^{\underline{\gamma} l} - e^{-\underline{\gamma} l}}{2} = 0{,}087 + j0{,}503 = 0{,}51 e^{j80{,}21^\circ};$$

$$\mathrm{ch}\underline{\gamma} l = \frac{e^{\underline{\gamma} l} + e^{-\underline{\gamma} l}}{2} = 0{,}87 + j0{,}05 = 0{,}872 e^{j3{,}29^\circ}.$$

1. Режим **холостого хода**: ключ K **разомкнут**, $\underline{I}_2=0$, $x=l$.

$$\underline{U}_1 = \underline{U}_2 \cdot \mathrm{ch}\underline{\gamma} l \; ; \; \underline{I}_1 = \frac{\underline{U}_2}{\underline{Z}_B} \cdot \mathrm{sh}\underline{\gamma} l \; .$$

$$\underline{U}_2 = \frac{\underline{U}_1}{\mathrm{ch}\underline{\gamma} l} = \frac{1000 e^{j0^\circ}}{0,872 e^{j3,29^\circ}} \approx 1147 e^{-j3,29^\circ} \; (\text{В});$$

$$\underline{I}_1 = \frac{\underline{U}_2}{\underline{Z}_B} \cdot \mathrm{sh}\underline{\gamma} l = \frac{1147 e^{-j3,29^\circ}}{400 e^{-j30^\circ}} 0,51 e^{j80,21^\circ} \approx 1,46 e^{j106,9^\circ} \; (\text{А});$$

$$\underline{Z}_{BX} = \frac{\underline{U}_1}{\underline{I}_1} = \frac{1000 e^{j0^\circ}}{1,46 e^{j106,9^\circ}} \approx 684,9 e^{-j106,9^\circ} \; (\text{Ом}).$$

2. Режим **короткого замыкания**: ключ ***K*** **замкнут**, $\underline{U}_2=0$, $x=l$.

$$\underline{U}_1 = \underline{Z}_B \cdot \underline{I}_2 \cdot \mathrm{sh}\underline{\gamma} l \; ; \;\; \underline{I}_1 = \underline{I}_2 \cdot \mathrm{ch}\underline{\gamma} l \; .$$

$$\underline{I}_2 = \frac{\underline{U}_1}{\underline{Z}_B \mathrm{sh}\underline{\gamma} l} = \frac{1000 e^{j0^\circ}}{400 e^{-j30^\circ} \cdot 0,51 e^{j80,21^\circ}} \approx 4,9 e^{-j50,2^\circ} \; (\mathrm{A});$$

$$\underline{I}_1 = \underline{I}_2 \cdot \mathrm{ch}\underline{\gamma} l = 4,9 e^{-j50,2^\circ} \cdot 0,872 e^{j3,29^\circ} \approx 4,27 e^{-j46,9^\circ} \; (\mathrm{A});$$

$$\underline{Z}_{BX} = \frac{\underline{U}_1}{\underline{I}_1} = \frac{1000 e^{j0^\circ}}{4,27 e^{-j46,9^\circ}} \approx 234,2 e^{j46,9^\circ} \; (\mathrm{Ом}).$$

Задача 2

Дано:

$\underline{I}_2 = -j10$ (А); $\underline{U}_1 = 8000$ (В);

$\underline{Z}_B = 400e^{j0^\circ}$ (Ом); $l = 100$ (км);

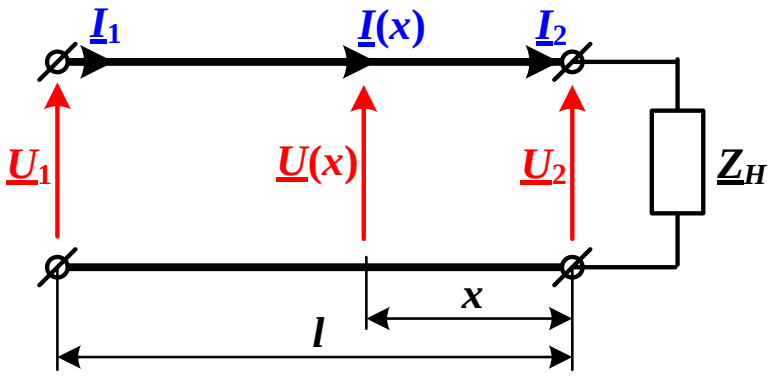
$\underline{Z}_H = \underline{Z}_B$.

Определить:

$\gamma = ?$

Режим **согласованной нагрузки**:

$\underline{Z}_H = \underline{Z}_B$, $\underline{U}(x)/\underline{I}(x) = \underline{Z}_B$.



Решение:

$$\underline{U}(x)=\underline{U}_2 e^{\underline{\gamma} x};\ \underline{I}(x)=\underline{I}_2 e^{\underline{\gamma} x};\ \frac{\underline{U}(x)}{\underline{I}(x)}=\frac{\underline{U}_2}{\underline{I}_2}=\frac{\underline{U}_1}{\underline{I}_1}=\underline{Z}_B.$$

$$\underline{U}_1=\underline{U}_2 e^{\underline{\gamma} l}=\left(\underline{Z}_B \underline{I}_2\right) e^{\underline{\gamma} l}\rightarrow$$

$$\rightarrow e^{\underline{\gamma} l}=\frac{\underline{U}_1}{\underline{Z}_B \underline{I}_2}=\frac{8000}{400 e^{j0^\circ}\left(-j10\right)}=2e^{j90^\circ};$$

$$\underline{\gamma}=\frac{1}{l}\ln\left(2e^{j90^\circ}\right)=\frac{1}{100}\ln\left(2e^{j\frac{\pi}{2}}\right)=$$

$$=\frac{\ln 2}{100}+\frac{j0,5\pi}{100}=6,971\cdot 10^{-3}+j1,57\cdot 10^{-2}\approx$$

$$\approx 1,7\cdot 10^{-2} e^{j66,6^\circ}\left(1/\text{км}\right).$$