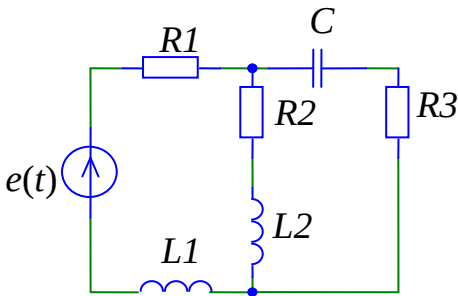


МЕТОДИЧЕСКИЕ УКАЗАНИЯ ПО ВЫПОЛНЕНИЮ



$$e(t) = 28,3 \cos(\omega t + 10^\circ) \text{ В}$$

$$R1 = 30 \text{ Ом}$$

$$R2 = 10 \text{ Ом}$$

$$R3 = 5 \text{ Ом}$$

$$L1 = 5 \text{ мГн}$$

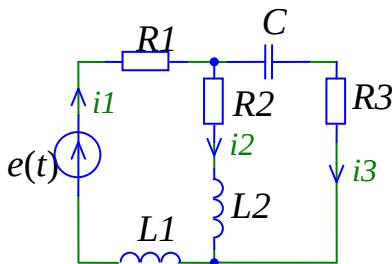
$$L2 = 10 \text{ мГн}$$

$$C = 10 \text{ мкФ}$$

$$\omega = 4000 \text{ рад/с}$$

1. Найти комплексные токи во всех ветвях схемы. Записать выражения для мгновенных значений токов.
2. Построить потенциальную диаграмму и векторную для токов.

1. Символический метод расчета



1. Переход к комплексам.

$$X_{L1} = \omega L_1 = 4000 \cdot 5 \cdot 10^{-3} = 20 \text{ Ом}$$

$$\underline{Z}_{L1} = j \cdot X_{L1} = j20 \text{ Ом},$$

$$X_{L2} = \omega L_2 = 4000 \cdot 10 \cdot 10^{-3} = 40 \text{ Ом}$$

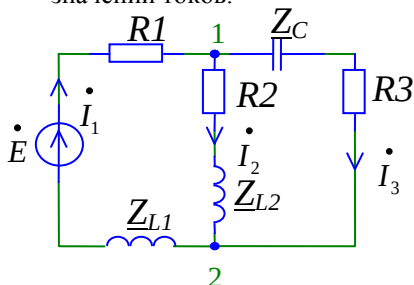
$$\underline{Z}_{L2} = j \cdot X_{L2} = j40 \text{ Ом},$$

$$\dot{E} = \frac{28,3}{\sqrt{2}} e^{j10^\circ} = 20 e^{j10^\circ} \text{ В},$$

$$X_C = \frac{1}{\omega C} = \frac{1}{4000 \cdot 10 \cdot 10^{-6}} = 25 \text{ Ом},$$

$$\underline{Z}_C = -j \cdot X_C = -j25 \text{ Ом}.$$

2. Переход к схеме для комплексов. Расчет комплексов действующих значений токов.



$$\begin{aligned} \underline{Z}_{\text{BX}} &= R_1 + \underline{Z}_{L1} + \frac{(R_2 + \underline{Z}_{L2})(R_3 + \underline{Z}_C)}{R_2 + \underline{Z}_{L2} + R_3 + \underline{Z}_C} \\ &= 30 + j20 + \frac{(10 + j40)(5 - j25)}{10 + j40 + 5 - j25} = \\ &= 30 + j20 + \frac{(1050 - 50j)(15 - 15j)}{(15 + 15j)(15 - 15j)} = \end{aligned}$$

$$= 30 + j20 + \frac{15700 - 16500j}{450} = 30 + 20j + 35 - 37j = 65 - 17j = 67,2 e^{-j15^\circ} \text{ Ом}.$$

$$\dot{I}_1 = \frac{\dot{E}}{\underline{Z}_{\text{BX}}} = \frac{20 e^{j10^\circ}}{67,2 e^{-j15^\circ}} = 0,297 e^{j25^\circ} \text{ А}.$$

$$\dot{U}_{12} = \dot{I}_1 \underline{Z}_{12} = 0,297 e^{j25^\circ} \cdot (35 - 37j) = 0,297 e^{j25^\circ} \cdot 50,9 e^{-j46,6^\circ} = 15,1 e^{-j21,6^\circ} \text{ В}$$

$$\dot{I}_2 = \frac{\dot{U}_{12}}{R_2 + \underline{Z}_{L2}} = \frac{15,1 e^{-j21,6^\circ}}{10 + j40} = \frac{15,1 e^{-j21,6^\circ}}{41,2 e^{j76^\circ}} = 0,366 e^{-j97,6^\circ} \text{ А},$$

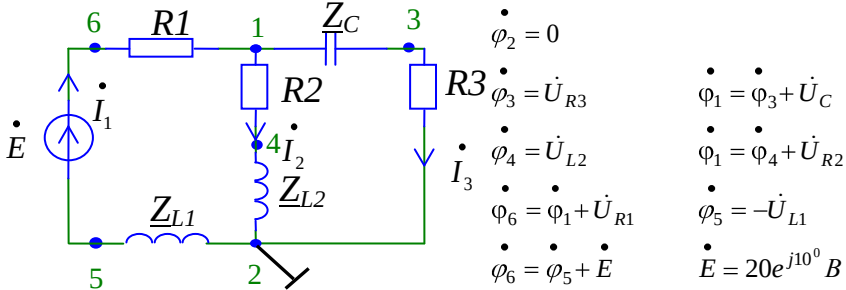
$$\dot{I}_3 = \frac{\dot{U}_{12}}{R_3 + \underline{Z}_C} = \frac{15,1 e^{-j21,6^\circ}}{5 - j25} = \frac{15,1 e^{-j21,6^\circ}}{25,5 e^{-j78,7^\circ}} = 0,592 e^{j57,1^\circ} \text{ А}.$$

3. Мгновенные значения токов:

$$i_1(t) = 0,297 \sqrt{2} \cos(4000t + 25^\circ) \text{ А},$$

$$i_2(t) = 0,366 \sqrt{2} \cos(4000t - 97,6^\circ) \text{ А}, \quad i_3(t) = 0,592 \sqrt{2} \cos(4000t + 57,1^\circ) \text{ А}.$$

2. Диаграммы



$$\dot{I}_1 = 0,297e^{j25^\circ} A \quad \dot{U}_{R1} = \dot{I}_1 \cdot R1 = 0,297e^{j25^\circ} \cdot 30 = 8,91e^{j25^\circ} B$$

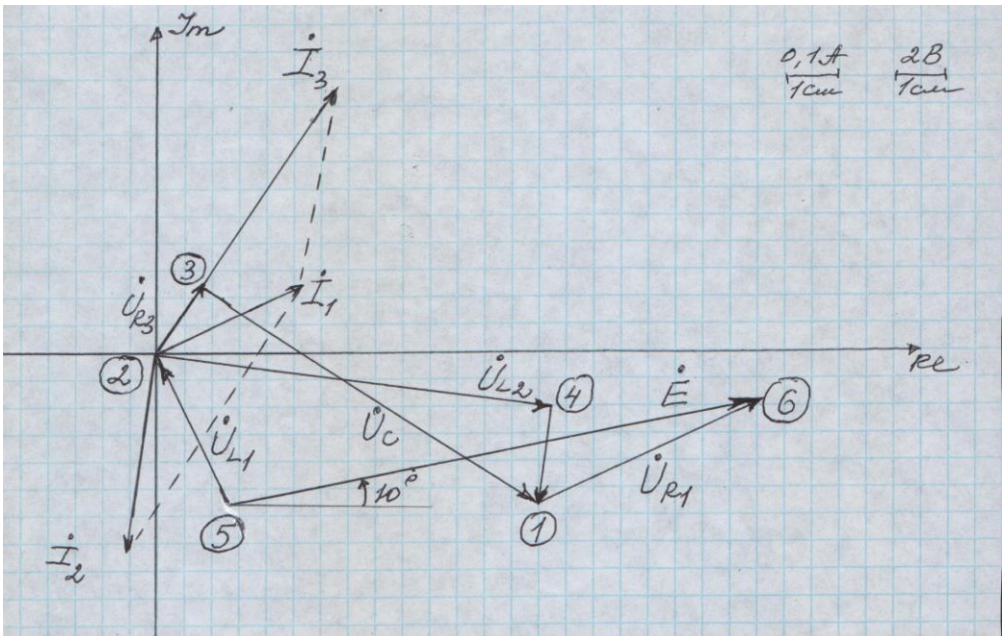
$$\dot{U}_{L1} = \dot{I}_1 \cdot \underline{Z}_{L1} = 0,297e^{j25^\circ} \cdot 20e^{j90^\circ} = 5,94e^{j115^\circ} B$$

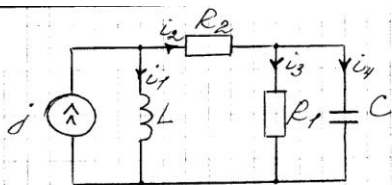
$$\dot{I}_2 = 0,366e^{-j97,6^\circ} A \quad \dot{U}_{R2} = \dot{I}_2 \cdot R2 = 0,366e^{-j97,6^\circ} \cdot 10 = 3,66e^{-j97,6^\circ} B$$

$$\dot{U}_{L2} = \dot{I}_2 \cdot \underline{Z}_{L2} = 0,366e^{-j97,6^\circ} \cdot 40e^{j90^\circ} = 14,6e^{-j7,6^\circ} B$$

$$\dot{I}_3 = 0,592e^{j57,1^\circ} A \quad \dot{U}_{R3} = \dot{I}_3 \cdot R3 = 0,592e^{j57,1^\circ} \cdot 5 = 2,96e^{j57,1^\circ} B$$

$$\dot{U}_C = \dot{I}_3 \cdot \underline{Z}_C = 0,592e^{j57,1^\circ} \cdot 25e^{-j90^\circ} = 14,8e^{-j32,9^\circ} B$$





$$j = 0,1 \cos(\omega t - 60^\circ) \text{ A}$$

$$\omega = 2000 \text{ rad/s}$$

$$R_1 = 150 \text{ Ohm} \quad R_2 = 50 \text{ Ohm}$$

$$L = 25 \text{ mH} = 25 \cdot 10^{-3} \text{ H}$$

$$C = 5 \text{ nF} = 5 \cdot 10^{-6} \text{ F}$$

1. Преобразование к комплексам.

$$\dot{y} = \sqrt{2} e^{j\varphi_1} = \frac{\gamma_m}{\sqrt{2}} e^{j\varphi_1} = \frac{0,1}{\sqrt{2}} e^{j60^\circ} = 0,07 e^{j60^\circ} \text{ A}$$

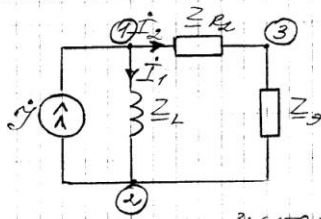
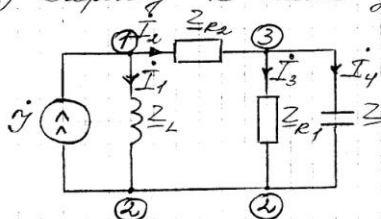
$$X_L = \omega L = 2 \cdot 10^3 \cdot 25 \cdot 10^{-3} = 50 \text{ Ohm} \rightarrow Z_L = jX_L = j50 \text{ Ohm}$$

$$X_C = \frac{1}{\omega C} = \frac{1}{2 \cdot 10^3 \cdot 5 \cdot 10^{-6}} = 100 \text{ Ohm} \rightarrow Z_C = -jX_C = -j100 \text{ Ohm}$$

$$Z_{R1} = R_1 = 150 \text{ Ohm}$$

$$Z_{R2} = R_2 = 50 \text{ Ohm}$$

2. Преобразование к схеме двух комплексов. Перенос токов.



$$Z_{R1} \parallel Z_C \rightarrow Z_3 = \frac{Z_{R1} \cdot Z_C}{Z_{R1} + Z_C} = \frac{150 \cdot (-j100)}{150 - j100} = \frac{-15 \cdot 10^3 \cdot j(150 + j100)}{150^2 + 100^2} = \frac{-225 \cdot 10^4 j + 15 \cdot 10^5}{32500} = 46,15 - 69,2j = 83,2 e^{j56,3^\circ} \text{ (Ohm)}$$

$$Z_{R212} = \frac{Z_L \cdot (Z_{R2} + Z_3)}{Z_L + (Z_{R2} + Z_3)} = \frac{j50(50 + 46,15 - 69,2j)}{j50(50 + 46,15 - 69,2j)} = \frac{j50(96,15 - 69,2j)}{86,15 - 19,2j} = \frac{50 e^{j90^\circ} \cdot 118,5 e^{-j35,7^\circ}}{98 e^{-j11,3^\circ}} = 60,4 e^{j65,6^\circ} \text{ (Ohm)}$$

$$\dot{U}_{12} = \dot{y} \cdot Z_{R212} = 0,07 e^{j60^\circ} \cdot 60,4 e^{j65,6^\circ} = 4,23 e^{j5,6^\circ} \text{ (V)}$$

$$\dot{I}_1 = \frac{\dot{U}_{12}}{Z_L} = \frac{4,23 e^{j5,6^\circ}}{50 e^{j90^\circ}} = 0,085 e^{j84,4^\circ} \text{ (A)}$$

$$\dot{I}_2 = \frac{\dot{U}_{12}}{Z_{R2} + Z_3} = \frac{4,23 e^{j5,6^\circ}}{50 + 46,15 - 69,2j} = \frac{4,23 e^{j5,6^\circ}}{118,5 e^{-j35,2^\circ}} = 0,036 e^{j41,3^\circ} \text{ (A)}$$

$$\dot{U}_{32} = \dot{I}_2 \cdot Z_3 = 0,036 e^{j41,3^\circ} \cdot 83,2 e^{j56,3^\circ} = 3 e^{j97,6^\circ} \text{ (V)}$$

$$\dot{I}_3 = \frac{\dot{U}_{32}}{Z_{R1}} = \frac{3 e^{j97,6^\circ}}{150} = 0,02 e^{j97,6^\circ} \text{ (A)}$$

$$\dot{U}_{12} = \dot{U}_L$$

$$\dot{I}_4 = \frac{\dot{U}_{32}}{Z_C} = \frac{3 e^{j97,6^\circ}}{100 e^{-j90^\circ}} = 0,03 e^{j8,6^\circ} \text{ (A)}$$

$$\dot{U}_{32} = \dot{U}_{R1} = \dot{U}_C$$

$$\dot{U}_{R2} = \dot{I}_2 \cdot R_2 = 0,036 e^{j41,3^\circ} \cdot 50 = 1,8 e^{j41,3^\circ} \text{ (V)}$$

$$\begin{aligned} \dot{I}_1 &= 0,085 e^{-j84,4^\circ} \text{ A}, \quad \dot{I}_2 = 0,036 e^{j41,3^\circ} \text{ A}, \quad \dot{I}_3 = 0,02 e^{-j75^\circ} \text{ A}, \quad \dot{I}_4 = 0,03 e^{j45^\circ} \text{ A} \\ \dot{I}_k &\rightarrow i_k(t) \quad \dot{I}_k = I_k e^{j\varphi_k} \quad i_k(t) = I_k \sqrt{2} \cos(\omega t + \varphi_k) \\ i_1(t) &= 0,085 \sqrt{2} \cos(2 \cdot 10^3 t - 84,4^\circ) = 0,12 \cos(2 \cdot 10^3 t - 84,4^\circ) \text{ A} \\ i_2(t) &= 0,051 \cos(2000 t + 41,3^\circ) \text{ A} \quad i_3(t) = 0,028 \cos(2000 t - 75^\circ) \text{ A} \\ i_4(t) &= 0,042 \cos(2000 t + 45^\circ) \text{ A} \end{aligned}$$

③ Расчет мощности, отдаваемой источником тока

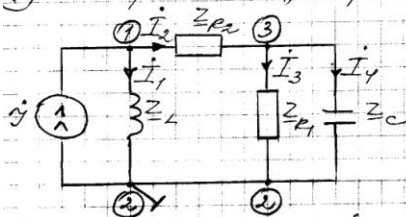
$$P = U_{12} \cdot I \cdot \cos \varphi = 4,23 \cdot 0,07 \cos(5,6^\circ - (-60^\circ)) = 0,122 \text{ (Вт)}$$

$$Q = U_{12} \cdot I \cdot \sin \varphi = 4,23 \cdot 0,07 \sin(5,6^\circ - (-60^\circ)) = 0,27 \text{ (Вар)}$$

$$S = U_{12} \cdot I = 4,23 \cdot 0,07 = 0,296 \text{ (В·А)}$$

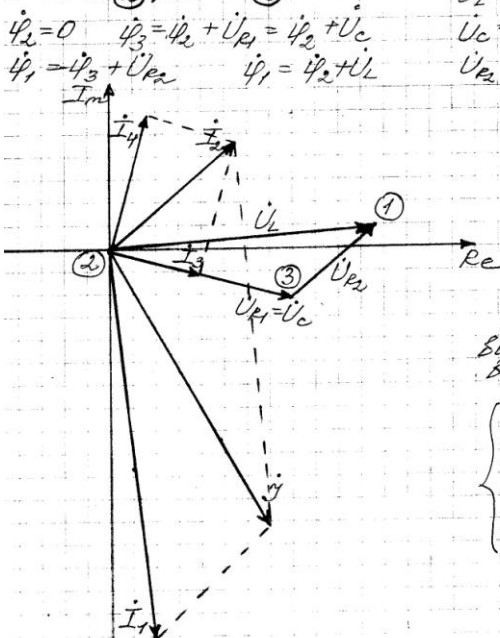
Проверка $S = |S| = \sqrt{P^2 + Q^2} = \sqrt{0,122^2 + 0,27^2} = 0,296 \text{ (В·А)}$

④ Построение диаграмм токов и ВПХ напряжений.



$$\begin{aligned} \dot{I}_1 &= 0,085 e^{-j84,4^\circ} & (8,5 \text{ см}) \\ \dot{I}_2 &= 0,036 e^{j41,3^\circ} & (3,6 \text{ см}) \\ \dot{I}_3 &= 0,02 e^{-j75^\circ} & (2 \text{ см}) \\ \dot{I}_4 &= 0,03 e^{j45^\circ} & (3 \text{ см}) \end{aligned}$$

$$\begin{aligned} \dot{U}_L &= 4,23 e^{j5,6^\circ} & (5,65 \text{ см}) \\ \dot{U}_C = \dot{U}_R &= 3 e^{-j75^\circ} & (4 \text{ см}) \\ \dot{U}_R &= 1,8 e^{j41,3^\circ} & (2,4 \text{ см}) \end{aligned}$$



$$\begin{aligned} 0,01 \text{ A} & \quad 1 \text{ см} \\ 0,25 \text{ В} & \quad 1 \text{ см} \end{aligned}$$

На диаграмме должны выполняться следующие выражения:

$$\begin{cases} \dot{I} = \dot{I}_1 + \dot{I}_2 \\ \dot{I}_2 = \dot{I}_3 + \dot{I}_4 \\ \dot{U}_L = \dot{U}_R + \dot{U}_C \\ \dot{U}_C = \dot{U}_R \end{cases}$$

