• PREHODNI POJAVI

- Da prehod mine ter se vzpostavi stalno stanje je potrebnih 5 časovnih konstant (5τ)
- Prehodni pojav je prehod iz enega stacionarnega stanja v drugo stacionarno stanje.

• Sistem enačb SLDE:

$$u = i \cdot R$$

$$u = L \cdot \frac{di}{dt}$$

$$i = \frac{1}{L}\int u_{(t)}\,dt + k$$

$$u = \frac{1}{C}\int i_{(t)}\,dt + k$$

$$i = C\frac{du_C}{dt}$$

• KOMUTACIJSKI POGOJI

energija se lahko spremeni le zvezno in ne hipoma.

L (pred spremembo → (-0), po spremembi → (+0))

$$W_m(-0) = W_m(+0)$$

$$\Psi(-0) = \Psi(+0)$$

$$i_L(-0) = i_L(+0)$$

C

$$W_e(-0) = W_e(+0)$$

$$Q(-0) = Q(+0)$$

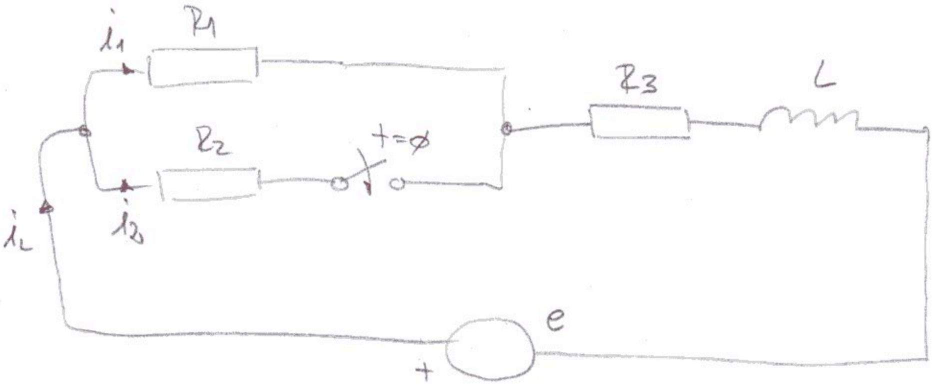
$$U_C(-0) = U_C(+0)$$

veličine z odkrito začetno vrednostjo → najprej računamo U_C, i_L.

• POSTOPKI:

- klasičen (DE)
- polklasičen
- LAPLACE (LT)

Primer predavanja:



$\omega = 5000\ s^{-1}$

$R_1 = 8\Omega$

$R_2 = 12\Omega$

$R_3 = 5{,}2\Omega$

$L = 2\ mH$

a) $e = 100V$

b) $e = 100\sqrt{2}\cdot\cos(\omega t + 60°)$

1) SLDE

$$i_1R_1 + i_LR_3 + L\frac{di}{dt} = e$$

$$i_1R_1 - i_2R_2 = 0$$

$$i_L = i_1 + i_2$$

2) $(-0)(+0)$ (i_L!)

(enosmerne razmere!)

(L = kratek stik)

$$i_L(-0) = \frac{e}{R_1+R_3} = \frac{100}{13{,}2} = \boxed{7{,}5758\ A}$$

$$i_{Ls}(+0) = \frac{e}{R_3 + \frac{R_1R_2}{R_1+R_2}} = \frac{100}{10} = \boxed{10\ A}$$

3) KE: $t=0$

$$Z(j\omega) = R' + j\omega L$$

$$Z(j\omega) = \underbrace{R_3 + \frac{R_1R_2}{R_1+R_2}}_{10\Omega} + j\omega L$$

$$p = -\frac{R'}{L} = \frac{-10}{2\cdot 10^{-3}} = \boxed{-5000\ s^{-1}}$$

nastavek: $i_{Lp} = A\cdot e^{pt} = \boxed{A\cdot e^{-5000t}}$

4) Zapis nastavka za skupno rešitev

$$i_L = i_{Lp} + i_{Ls}$$

$$i_L = 10 + A\cdot e^{-5000t}$$

Pomni KOMUTACIJSKI pogoj

$$i_L(-0) = i_L(+0) \qquad \boxed{t=0}$$

$$7{,}5758 = 10 + A\cdot e^{-5000t}$$

$$A = -2{,}4242$$

$$\Rightarrow \boxed{i_L = 10 - 2{,}4242\cdot e^{-5000t}}$$

• POLKLASIČNI POSTOPEK

1.) Zapis sistema enačb (SLDE)

2.) Izračun začetnih (-0) in končnih (+0) vrednosti spremenljivk z začetno vrednostjo (u_c, i_L).

3.) Določitev karakteristične enačbe (KE) sistema.
- Izračun ničelnih korenov (ničle)
- Izbor nastavka za rešitev prehodne komponente

4.) Zapis nastavka za skupno rešitev (polno vrednost) spremenljivk z odvisno začetno vrednostjo ($i_L = i_{Lp} + i_{Ls}$)
($u_c = u_{cp} + u_{cs}$)

3.1. – KE;
- napetostne ali kratko sklenemo
- prežimo tuljavo
- na sponkah izračunamo nadomestno impedanco notalga vezja $Z(jw)$
- zamenjamo $jw \to p$
- Izračunamo ničle enačbe $KE = 0$.
  ± dobimo rešitve $p_1, p_2, \dots$

• NASTAVKI ZA PREHODNE KOMPONENTE

$p = jw$

- 1 energ. posoda;

$$i_{Lp} = A \cdot e^{pt}$$

- 2 energ. posodi

• $D = 0$ $\quad p_1 = p_2 = -\frac{b}{2a}$ $\quad i_{Lp} = (A_1 + A_2 t) \cdot e^{pt}$

• $D > 0$ $\quad -a_1 = p_1$, $-a_2 = p_2$ $\quad i_{Lp} = A_1 e^{p_1 t} + A_2 e^{p_2 t}$

• $D < 0$ $\quad p_{1,2} = -\alpha \pm j w_0$

prehodnega pojava

$e^{ax} = a \cdot e^{ax}$

$$u_L = L\frac{di}{dt} = L\frac{d}{dt}\left(10 - 2{,}4242 \cdot e^{-5000t}\right)$$

$$= L \cdot (-2{,}4242) \cdot (-5000) \cdot e^{-5000t}$$

$$= \boxed{24{,}242 \cdot e^{-5000t}\ V}$$

b) $e = 100\sqrt{2} \cdot \cos(\omega t + 60^\circ)$

1.) SLDE - enake - se ne spremeni nič

2.) (-0) in (+0)

$$Z(-0) = R_1 + R_3 + j\omega L$$

$$i(-0) = \frac{E}{Z}$$

$$= 8 + 5{,}2 + j(5000 \cdot 2 \cdot 10^{-3})$$

$$I_L = \frac{100 \cdot e^{j60^\circ}}{13{,}2 + j10} = \boxed{6{,}0386 \cdot e^{j22{,}85^\circ}} = \boxed{13{,}2 + j\,10\ \Omega}$$

$$i_L(t) = 6{,}0386 \cdot \sqrt{2} \cdot \cos(\omega t + 22{,}85^\circ) \quad v\ t = \emptyset \Rightarrow i_L(-0) = \boxed{7{,}8695\ A}$$

(pred spremembo)

$$Z(+0) = \frac{R_1 R_2}{R_1 + R_2} + R_3 + j\omega L = \boxed{10 + j\,10\ \Omega}$$

$$I_L = \frac{E}{Z(+0)} = \frac{100 \cdot e^{j60^\circ}}{10 + j10\ \Omega} = \frac{100 \cdot e^{j60^\circ}}{10\sqrt{2} \cdot e^{j45^\circ}} = \boxed{5\sqrt{2} \cdot e^{j15^\circ}\ A}$$

$/ \cdot \sqrt{2}$

$\sqrt{10^2 + 10^2} = 10\sqrt{2}$

$tg\varphi = \frac{10}{10} = 1 \Rightarrow \varphi = 45^\circ$

$$i_{LS} = \boxed{10 \cdot e^{j15^\circ}\ A}$$

3.) KE: = enaka $p = -\frac{R'}{L} = -5000\ s^{-1}$

$i_{Lp} = A \cdot e^{pt}$

4.) $i_L = i_{Lp} + i_{Ls}$

$$i_L = 10 \cdot \cos(\omega t + 15^\circ) + A \cdot e^{pt}\ A$$

v $t = \emptyset$

$$i_L(-0) = i_{Ls} + i_{Lp}$$

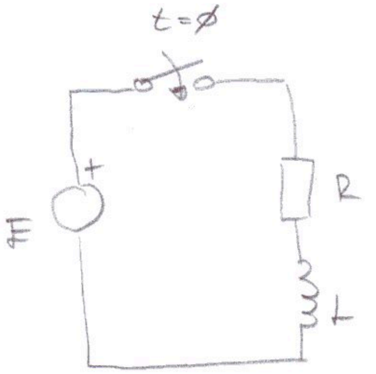
$$\Rightarrow 7{,}8695 = 10 \cdot \cos(15^\circ) + A \cdot e^{p \cdot 0}$$

$$\Rightarrow A = \boxed{-1{,}78981}$$

ZAPIS

$$\Rightarrow \boxed{i_L = 10 \cdot \cos(5000t + 15^\circ) - 1{,}78981 \cdot e^{-5000t}\ A}$$

• VAJE – 01.06.2012 – primer



$E = 200\,V$

$R = 20\,\Omega$

$L = 4\,mH$

$i, u_R, u_L = ?$

1.) SLDE:

$$iR + L\frac{di}{dt} = E$$

2.) (−0) (+0) (i_L)

$$i_L(-0) = 0$$

↓ ko stikalo ni sklenjeno tok ne teče!

$$I_L = \frac{E}{Z} = \frac{200}{20} = \boxed{10\,A} \quad (=,\ L = \text{kratek stik})$$

$$= i_{LS}(+0)$$

3.) KE:

$$\tau = \frac{1}{|p|}$$

$$Z(j\omega) = R + j\omega L \quad (j\omega \to p)$$

$$R + pL = 0$$

$$p = -\frac{R}{L} = -\frac{20}{4\cdot 10^{-3}} = \boxed{-5000\,s^{-1}}$$

4.) nastavek:

$$i_{Lp} = A \cdot e^{pt}$$

$$i_L = i_{LS} + i_{Lp}$$

$$i_L = 10 + A \cdot e^{-5000t}\,A$$

$t = 0$: $\quad 0 = 10 + A \cdot e^{-5000\cdot 0}$ (= 1)

$$\Rightarrow \boxed{A = -10}$$

$$\boxed{i_L = 10 - 10 \cdot e^{-5000t}\,A} = 10\left(1 - e^{-5000t}\right)$$

5.) ostali neznanki

$$u_L = L\frac{di}{dt}$$

$$= L\frac{d}{dt}\left(10 - 10 \cdot e^{-5000t}\right)$$

$$= L \cdot (-10) \cdot (-5000) \cdot e^{-5000t}$$

$$= \boxed{200 \cdot e^{-5000t}\,V}$$

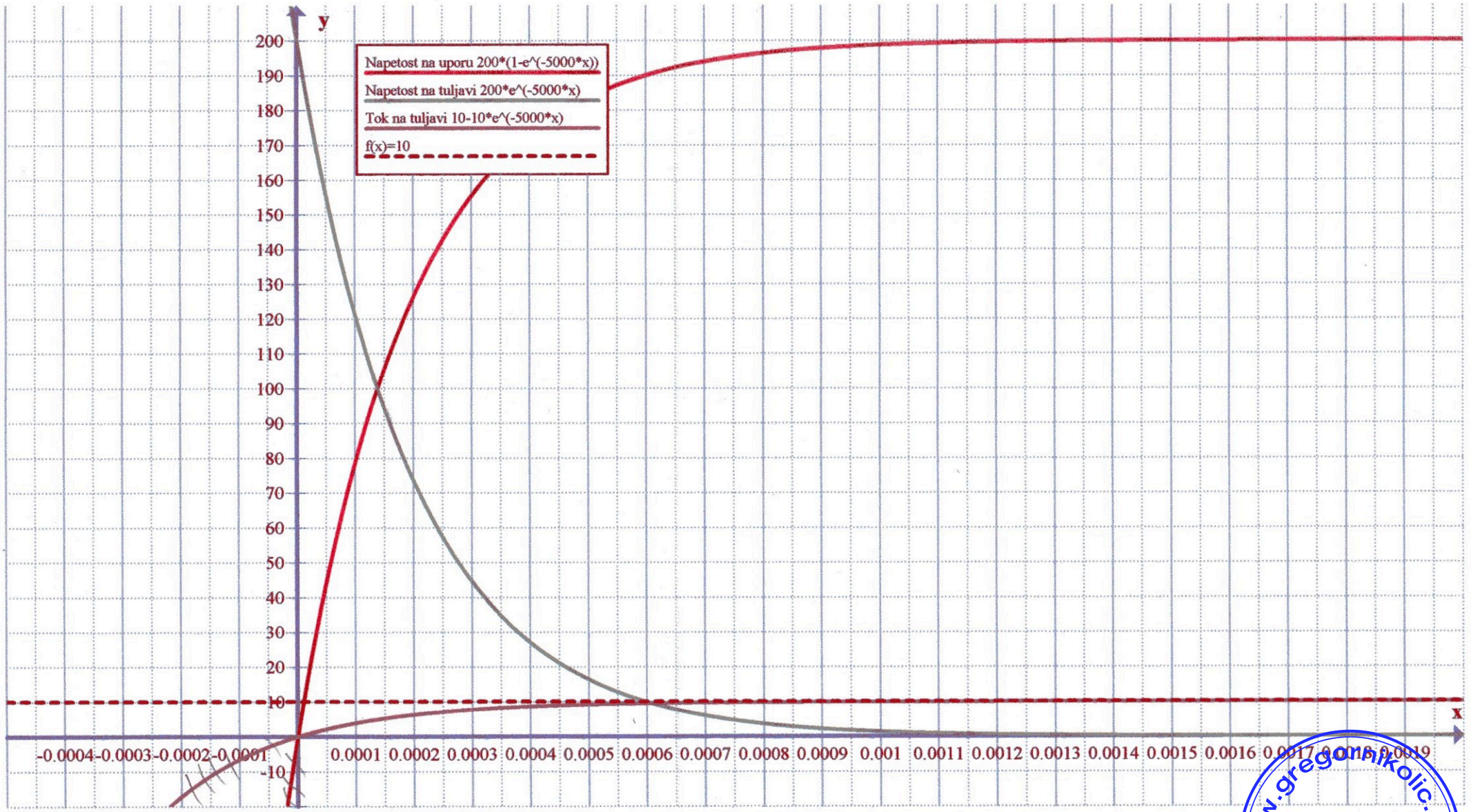
↓ (e^{-5000t}) vrste proti vrednosti 1.

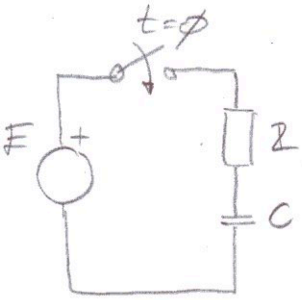
$$u_R = i \cdot R = 20 \cdot \left(10 - 10 \cdot e^{-5000t}\right)$$

$$= 200 - 200 \cdot e^{-5000t}$$

$$= \boxed{200\left(1 - e^{-5000t}\right)\,V}$$

pada proti vrednosti 0





$E = 10\,V$
$R = 0{,}1\,\Omega$
$C = 10\,\mu F$

$i, u_R, u_C = ?$

1.) SLDE

$$iR + \frac{1}{C}\int i_{(t)}\,dt = E$$

2.) (−0), (+0)

$t = \emptyset \quad u_C(-0) = \emptyset$

$u_C(+0) = E$ (C = prekinitev toliko dugo u =, kozi R ne teče tok tako U_R ne obstoja – celotna napetost je na C)

3.) KE:

$$\underline{Z}(j\omega) = R + \frac{1}{j\omega C}$$

$$R + \frac{1}{pC} = \emptyset$$

$$RpC + 1 = 0$$

$$p = -\frac{1}{RC} = -\frac{1}{1\cdot 10^{-1}\cdot 10\cdot 10^{-6}} = \boxed{-1\cdot 10^{6}\,s^{-1}}$$

$$u_{Cp} = A\cdot e^{pt} = A\cdot e^{-10^6 t}\,V$$

4.) Sk. Ri

$$u_C = u_{Cp} + u_{Cs}$$

$$u_C = A\cdot e^{-10^6 t} + E = 10 + A\cdot e^{-10^6 t}$$

$t = \emptyset$

$u_C = \emptyset$

$10 + A\cdot e^{-10^6\cdot 0} = \emptyset$ (where $e^{-10^6\cdot 0} = 1$)

$\Rightarrow \boxed{A = -10}$

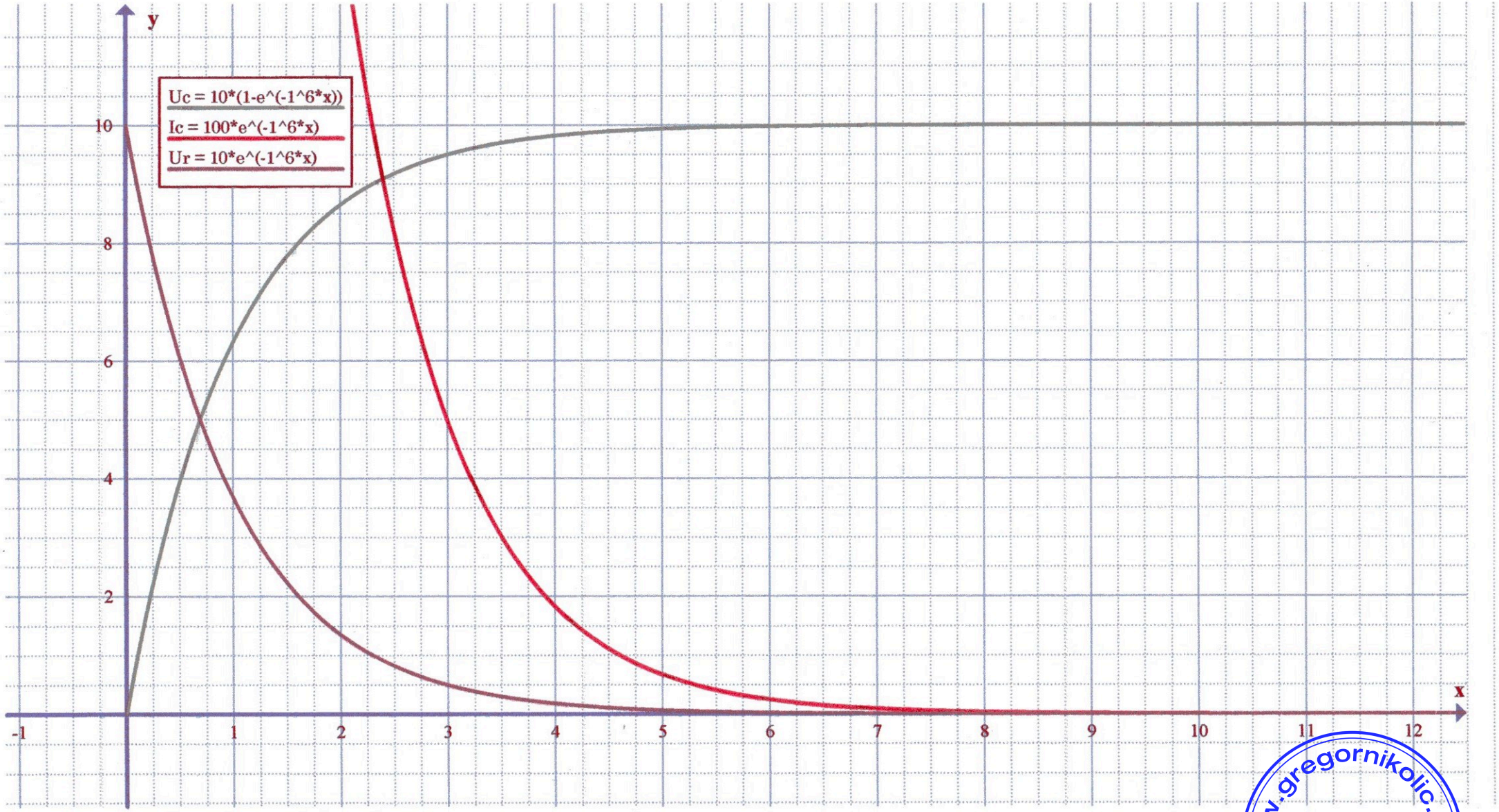
$$u_C = \boxed{10 - 10\cdot e^{-10^6 t}\,V} = 10(1 - e^{-10^6 t})\,V$$

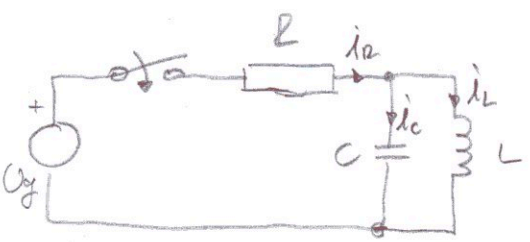
5.) Ostale veličine:

$$i_R = i_C = C\frac{du_C}{dt} = C\frac{d}{dt}\left(10 - 10\cdot e^{-10^6 t}\right) = C\cdot(-10)\cdot(-1\cdot 10^{+6})\cdot e^{-10^6 t}$$

$$= \boxed{+100\cdot e^{-10^6 t}\,A}$$

$$U_R = i_R\cdot R = \boxed{+10\cdot e^{-10^6 t}\,A}$$





$U_g = 100V$

$R = 100\Omega$

$L = 40mH$

$C = 5\mu F$

$u_C, i_L = ?$

1) SLDF

$$i_R = i_C + i_L$$

$$i_R R + \frac{1}{C}\int i_{(t)}\,dt = U_g$$

$$\frac{1}{C}\int i_{(t)}\,dt = L\frac{di}{dt}$$

2) $(-0), (+0)$

$i_L(-0) = 0$ $\quad t = \infty$ (ustaljeno stanje! C = prekidač! L = kratki spoj!)

$u_C(-0) = 0$

$$I_L = I_C = \frac{U_g}{R} = \frac{100V}{100\Omega} = \boxed{1A} = i_{LS}$$

$$U_C = U_g - U_R = 100 - 100 = \boxed{0}$$

3) KE:

$$Z(j\omega) = R + \frac{j\omega L \cdot \frac{1}{j\omega C}}{j\omega L + \frac{1}{j\omega C}}$$

$j\omega \to p$

$$R + \frac{pL \cdot \frac{1}{pC}}{pL + \frac{1}{pC}} = 0$$

$$R + \frac{\frac{pL}{pC}}{\frac{p^2LC+1}{pC}} = 0$$

$$R + \frac{p^2LC}{p^3LC^2 + pC} = 0$$

$$R + \frac{p^2LC}{RC(p^2LC+1)} = 0$$

$$p^2RLC + R + pL = 0$$

$$p_{1,2} = \frac{-L \pm \sqrt{L^2 - 4R^2LC}}{2RLC}$$

$p_1 = -1000 + j2000\ s^{-1}$

$p_2 = -1000 - j2000\ s^{-1}$

4) rastući za prelazne:

$$\boxed{i_L = A \cdot e^{-pt} \cdot \cos(\omega t + \beta)}$$

$$i_L = A \cdot e^{-1000t} \cdot \cos(2000t + \beta)$$

$$u_C = u_L = L\frac{di}{dt}$$

$$i_L = i_{LS} + i_{LP}$$

$$i_L = 1 + A e^{-1000t} \cdot \cos(2000t + \beta)$$

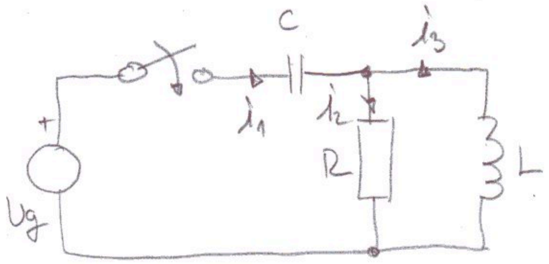
$$u_L = L\frac{di}{dt}$$

$$= L\frac{d}{dt}\left(1 + A e^{-1000t} \cdot \cos(2000t + \beta)\right)$$

$$= L\left(-1000A e^{-1000t} \cdot \cos(2000t + \beta) + A e^{-1000t} \cdot \left(-\sin(2000t + \beta) \cdot 2000\right)\right)$$

$$= -40A \cdot e^{-1000t} \cdot \cos(2000t + \beta) - 80A \cdot e^{-1000t} \cdot \sin(2000t + \beta)$$

$$= -40A \cdot e^{-1000t}\left(\cos(2000t + \beta) + 2\sin(2000t + \beta)\right)$$



$U_g = 200\,V$

$R = 25\,\Omega$

$L = \frac{1}{6}\,H$

$C = 50\,\mu F$

$U_C,\ i_3 = ?$

1.) SLDE

$$\frac{1}{C}\int i_{(t)}\,dt + iR = U_g$$

$$\frac{1}{C}\int i_{(t)} + L\frac{di}{dt} = U_g$$

$$i_1 = i_2 + i_3$$

2.) (-0), (+0)

$u_C(-0) = \emptyset$

$i_3(-0) = \emptyset$

$t = \infty$ (ениже мегене!)

$u_C(+0) = U_g = 200V$

$i_3(+0) = \emptyset$ (емнича кер. = L = ... x)

3.) KE:

$$Z(j\omega) = \frac{1}{j\omega C} + \frac{Rj\omega L}{R + j\omega L}$$

$$j\omega \rightarrow p$$

$$\frac{1}{pC} + \frac{RpL}{R + pL} = \emptyset$$

$$\frac{R + pL + Rp^2LC}{pC(R + pL)} = \emptyset$$

$$R + pL + p^2RLC = \emptyset$$

$$p^2\underbrace{RLC}_{a} + p\underbrace{L}_{b} + \underbrace{R}_{c} = \emptyset$$

$$p_{12} = \frac{-L \pm \sqrt{L^2 - 4R^2LC}}{2RLC}$$

$$p_{12} = \frac{-\frac{1}{6} \pm \sqrt{\frac{1}{36} - 4\cdot 25^2\cdot\frac{1}{6}\cdot 50\cdot 10^{-6}}}{2\cdot 25\cdot\frac{1}{6}\cdot 50\cdot 10^{-6}}$$

$p_1 = -200\,s^{-1}$

$p_2 = -600\,s^{-1}$

4.) мсталши, эплебнии мешите

$$i_{3p} = A\cdot e^{p_1 t} + A\cdot e^{p_2 t}$$

$$i_{3p} = A_1\cdot e^{-200t} + A_2\, e^{-600t}$$

$$U_L = L\frac{di}{dt}$$

$$= L\frac{d}{dt}\left(A_1 e^{-200t} + A_2 e^{-600t}\right)$$

$$= \frac{1}{6}\cdot\left(-200A_1 e^{-200t} - 600A_2 e^{-600t}\right)$$

Решимо $t = \emptyset$.

$$u_L = \frac{1}{6}\left(-200A_1 e^{-200t} - 600A_2 e^{-600t}\right)$$

$$u_C = U_g - U_L = 200 - \frac{1}{6}\left(-200A_1 e^{-200} - 600A_2 e^{-600t}\right)$$

$$i_{3p} = A_1\cdot e^{-200t} + A_2\cdot e^{-600t}$$

$0 = A_1 + A_2 \Rightarrow A_1 = -A_2$

$0 = 200 + \frac{100}{3}A_1 + 100A_2$

$0 = 200 + A_2\left(\frac{100}{3} - 100\right)$

$A_1 = \frac{-200\cdot 3}{-200} = \boxed{-3}$ $\quad A_1 = \boxed{+3}$