



IEL – protokol k projektu

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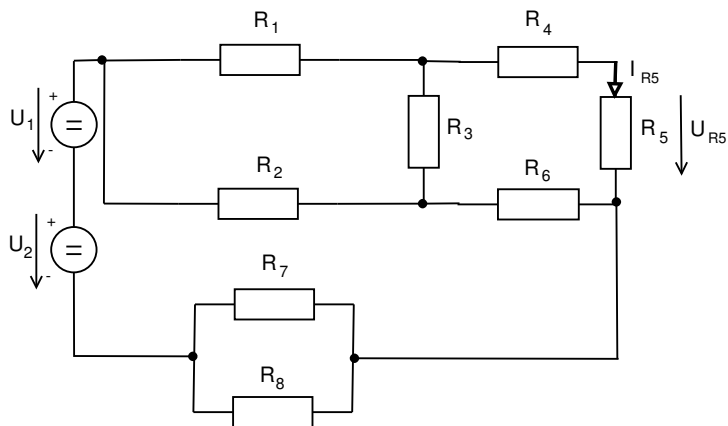
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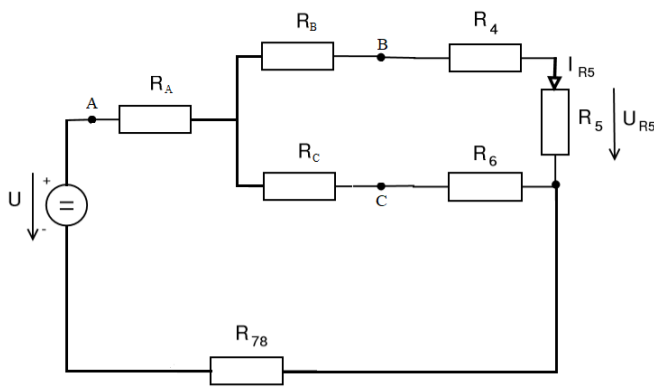
Příklad 1

Stanovte napětí U_{R5} a proud I_{R5} . Použijte metodu postupného zjednodušování obvodu.

sk.	U_1 [V]	U_2 [V]	R_1 [Ω]	R_2 [Ω]	R_3 [Ω]	R_4 [Ω]	R_5 [Ω]	R_6 [Ω]	R_7 [Ω]	R_8 [Ω]
F	125	65	510	500	550	250	300	800	330	250



Postupně zjednodušíme obvod



$$U = U_1 + U_2 \quad (1)$$

$$U = 125 + 65 = 190 \text{ V}$$

$$R_{78} = \frac{R_7 * R_8}{R_7 + R_8} \quad (2)$$

$$R_{78} = \frac{330 * 250}{330 + 250} = 291.5194 \Omega$$

$$R_A = \frac{R_1 * R_2}{R_1 + R_2 + R_3} \quad (3)$$

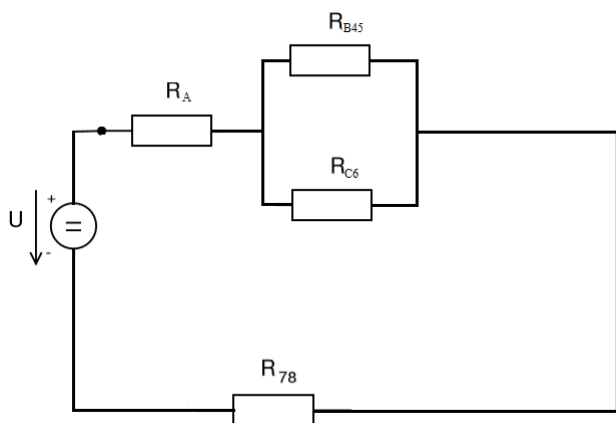
$$R_A = \frac{510 * 500}{510 + 500 + 550} = 163.4615 \Omega$$

$$R_B = \frac{R_1 * R_3}{R_1 + R_2 + R_3} \quad (4)$$

$$R_B = \frac{510 * 550}{510 + 500 + 550} = 179.8077 \Omega$$

$$R_C = \frac{R_2 * R_3}{R_1 + R_2 + R_3} \quad (5)$$

$$R_C = \frac{500 * 550}{510 + 500 + 550} = 176.2820 \Omega$$

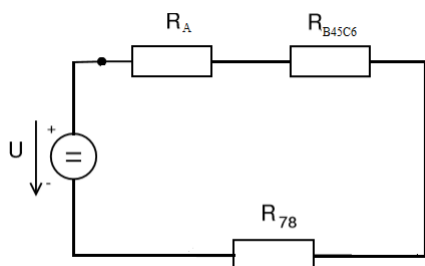


$$R_{B45} = R_B + R_4 + R_5 \quad (6)$$

$$R_{B45} = R_B + R_4 + R_5 = 179,8077 + 250 + 300 = 729.8077 \Omega$$

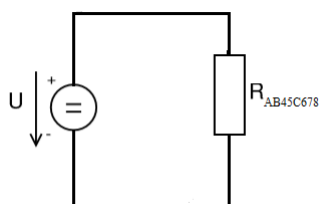
$$R_{C6} = R_C + R_6 \quad (7)$$

$$R_{C6} = R_C + R_6 = 176,2820 + 800 = 976.2820 \Omega$$



$$R_{B45C6} = \frac{R_{B45} * R_{C6}}{R_{B45} + R_{C6}} \quad (8)$$

$$R_{B45C6} = \frac{729,8077 * 976,2820}{729,8077 + 976,2820} = 417.6205 \Omega$$



$$R_{ekv} = R_{AB45C678} = R_A + R_{B45C6} + R_{78} \quad (9)$$

$$R_{ekv} = 163,4615 + 417,6205 + 291,5194 = 872.6015 \Omega$$

Podle Ohmova zákona:

$$I = \frac{U}{R_{kv}} \quad (10)$$

$$I = \frac{190}{872,601} = 0,2177 A$$

Podle II K.z.:

$$U_{RA} + U_{RB45C6} + U_{R78} = U \quad (11)$$

$$U_{RB45C6} = I * R_{B45C6} \quad (12)$$

$$U_{RB45C6} = 0,2177 * 417,6205 = 90,916V$$

Podle I K.z.:

$$I = I_{RB45} + I_{RC6} \quad (13)$$

$$I_{RB45} = I_{R5} = \frac{U_{RB45C6}}{R_{B45}} \quad (14)$$

$$I_{R5} = \frac{90,916}{729,8077} = 0,1246A$$

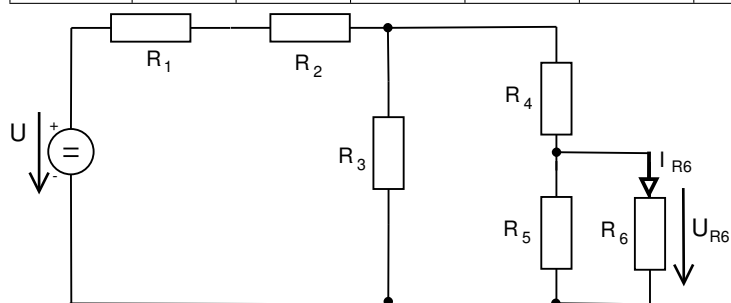
$$U_{R5} = I_{R5} * R_5 \quad (15)$$

$$U_{R5} = 0,1246 * 300 = 37,38V$$

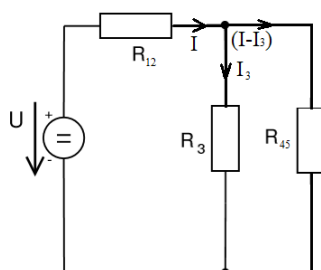
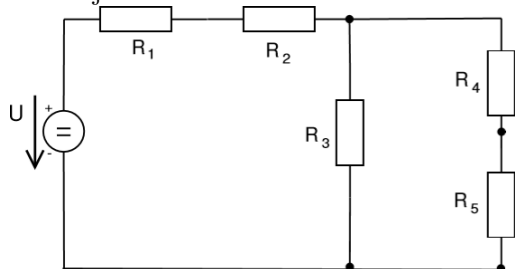
Příklad 2

Stanovte napětí U_{R_6} a proud I_{R_6} . Použijte metodu Théveninovy věty.

sk.	U [V]	R_1 [Ω]	R_2 [Ω]	R_3 [Ω]	R_4 [Ω]	R_5 [Ω]	R_6 [Ω]
H	220	190	360	580	205	560	180



Najdeme U Thevenina

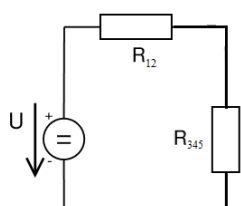


$$R_{12} = R_1 + R_2 \quad (16)$$

$$R_{12} = 190 + 360 = 550 \, \Omega$$

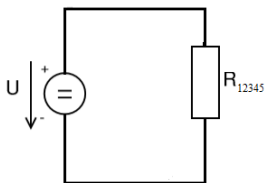
$$R_{45} = R_4 + R_5 \quad (17)$$

$$R_{45} = 205 + 560 = 765 \, \Omega$$



$$R_{345} = \frac{R_3 * R_{45}}{R_3 + R_{45}} \quad (18)$$

$$R_{345} = \frac{580 \cdot 765}{580 + 765} = 329.8885 \Omega$$



$$R_{ekv} = R_{12345} = R_{12} + R_{345} \quad (19)$$

$$R_{ekv} = 550 + 329.8885 = 879.8885 \Omega$$

Najdeme proud:

$$I = \frac{U}{R_{ekv}} = \frac{220}{879.8885} = 0.25 A \quad (20)$$

Podle II K.z.:

$$(I - I_{R3}) * R_{45} - I_{R3} * R_3 = 0 \quad (21)$$

$$I_{R3} = \frac{I * R_{45}}{R_{45} + R_3} \quad (22)$$

$$I_{R3} = \frac{0.25 \cdot 765}{765 + 580} = 0.1422 A$$

Podle I K.z.:

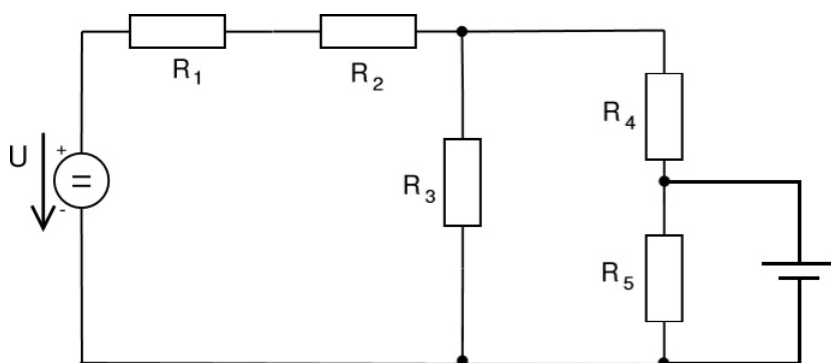
$$I_{R45} = I - I_{R3} \quad (23)$$

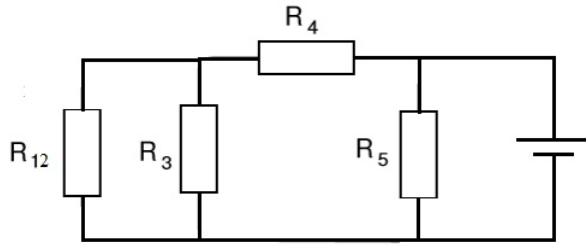
$$I_{R45} = 0.25 - 0.1422 = 0.1078 A$$

$$U_i = I_{R45} * R_5 \quad (24)$$

$$U_i = 0.1078 * 560 = 60.368 V$$

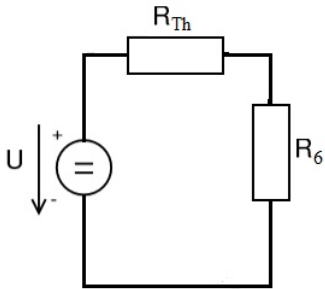
Najdeme R Thevenina





$$R_{12} = R_1 + R_2 \quad (25)$$

$$R_{12} = 190 + 360 = 550 \, \Omega$$



$$R_{123} = \frac{R_{12} * R_3}{R_{12} + R_3} \quad (26)$$

$$R_{123} = \frac{550 * 580}{550 + 580} = 282.3009 \, \Omega$$

$$R_{1234} = R_{123} + R_4 \quad (27)$$

$$R_{1234} = 282,3009 + 205 = 487.3009 \, \Omega$$

$$R_i = \frac{R_{1234} * R_5}{R_{1234} + R_5} \quad (28)$$

$$R_i = \frac{487,3009 * 560}{487,3009 + 560} = 260.5636 \, \Omega$$

$$I_{R6} = \frac{U_i}{R_i + R_6} \quad (29)$$

$$I_{R6} = \frac{60,368}{260,5636 + 180} = 0,137 A$$

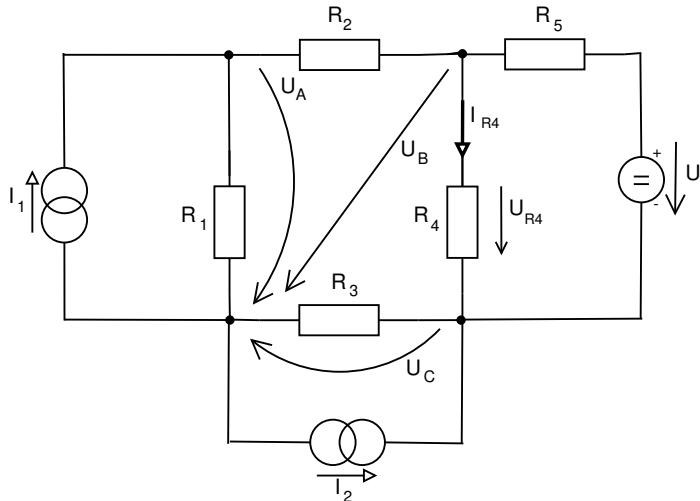
$$U_{R6} = I_{R6} * R_6 \quad (30)$$

$$U_{R6} = 0,137 * 180 = 24,66 V$$

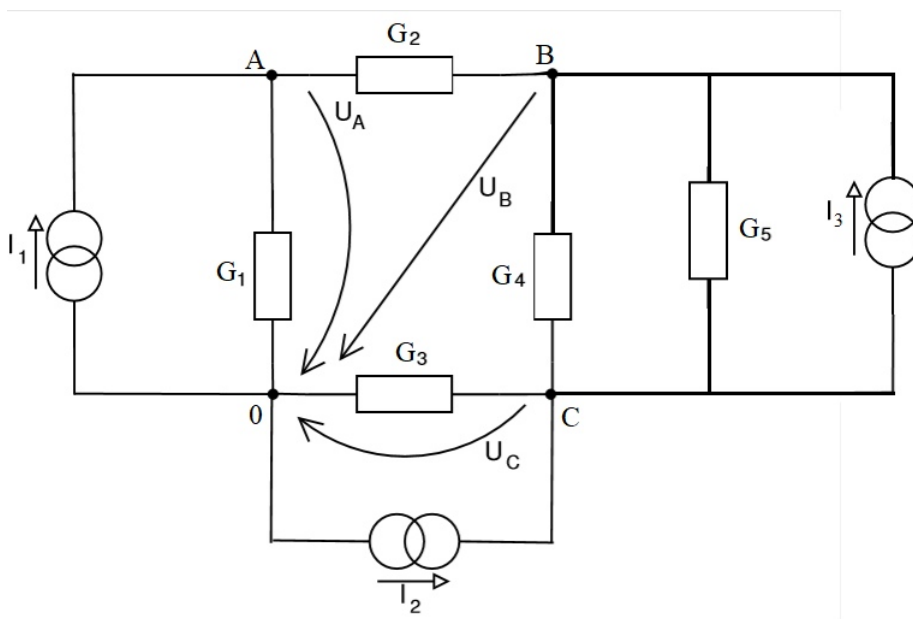
Příklad 3

Stanovte napětí U_{R4} a proud I_{R4} . Použijte metodu uzlových napětí (U_A, U_B, U_C).

sk.	U [V]	I_1 [A]	I_2 [A]	R_1 [Ω]	R_2 [Ω]	R_3 [Ω]	R_4 [Ω]	R_5 [Ω]
A	120	0.9	0.7	53	49	65	39	32



Změníme odpory na vodivosti a napěťový zdroj na proudový:



$$G = \frac{1}{R} \quad (31)$$

$$G_1 = \frac{1}{R_1} = \frac{1}{53} = 0,0189S$$

$$G_2 = \frac{1}{R_2} = \frac{1}{49} = 0,0204S$$

$$G_3 = \frac{1}{R_3} = \frac{1}{65} = 0,0154S$$

$$G_4 = \frac{1}{R_4} = \frac{1}{39} = 0,0256S$$

$$G_5 = \frac{1}{R_5} = \frac{1}{32} = 0,0313S$$

$$I_3 = \frac{U}{R_5} \quad (32)$$

$$I_3 = \frac{120}{32} = 3.75A$$

podle I K.z.:

$$\begin{cases} G_1 U_A + G_2 (U_A - U_B) - I_1 = 0 \\ G_2 (U_B - U_A) + G_{45} (U_B - U_C) - I_3 = 0 \\ G_{45} (U_C - U_B) + G_3 U_3 - I_2 + I_3 = 0 \end{cases}$$

$$\begin{pmatrix} G_1 + G_2 & -G_2 & 0 \\ -G_2 & G_2 + G_{45} & -G_{45} \\ 0 & -G_{45} & G_3 + G_{45} \end{pmatrix} * \begin{pmatrix} U_A \\ U_B \\ U_C \end{pmatrix} = \begin{pmatrix} I_1 \\ I_3 \\ I_2 - I_3 \end{pmatrix}$$

$$\begin{pmatrix} (G_1 + G_2)U_A & (-G_2)U_B & 0 \\ (-G_2)U_A & (G_2 + G_{45})U_B & (-G_{45})U_C \\ 0 & (-G_{45})U_B & (G_3 + G_{45})U_C \end{pmatrix} = \begin{pmatrix} I_1 \\ I_3 \\ I_2 - I_3 \end{pmatrix}$$

$$\begin{pmatrix} (0,0393)U_A & (-0,0204)U_B & 0 \\ (-0,0204)U_A & (0,0773)U_B & (-0,0569)U_C \\ 0 & (-0,0569)U_B & (0,0723)U_C \end{pmatrix} = \begin{pmatrix} 0,9 \\ 3,75 \\ -3,05 \end{pmatrix}$$

$$\begin{aligned} D &= 0,0393 * 0,0773 * 0,0723 - 0,0569 * 0,0569 * 0,0393 - 0,0204 * 0,0204 * 0,0723 = 6.2313 * 10^{-5} \\ D_B &= 0,0393 * 3,75 * 0,0723 - 3,05 * 0,0569 * 0,0393 + 0,0204 * 0,9 * 0,0723 = 0.0052 \\ D_C &= -0,0393 * 0,0773 * 3,05 + 0,0204 * 0,0569 * 0,9 + 0,0569 * 3,75 * 0,0393 + 0,0204 * 0,0204 * 3,05 = 0,0014 \end{aligned}$$

$$U_B = \frac{D_B}{D} \quad (33)$$

$$U_B = \frac{-0.0035}{6.2313 * 10^{-5}} = 82,845V$$

$$U_C = \frac{D_C}{D} \quad (34)$$

$$U_C = \frac{-0.0054}{6.2313 * 10^{-5}} = 23,0136V$$

$$U_{R4} = U_B - U_C \quad (35)$$

$$U_{R4} = 82.845 - 23.0136 = 59,8314V$$

$$I_{R4} = \frac{U_{R4}}{R_4} \quad (36)$$

$$I_{R4} = \frac{30.208}{39} = 1,5341A$$

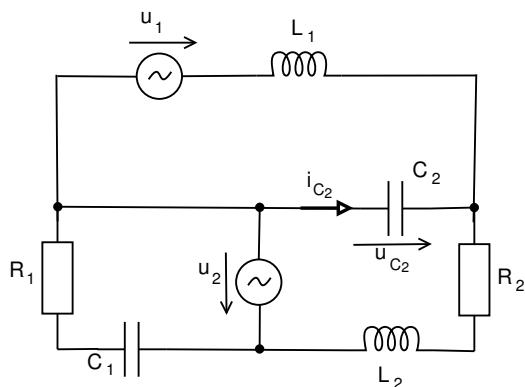
Příklad 4

Pro napájecí napětí platí: $u_1 = U_1 \cdot \sin(2\pi ft)$, $u_2 = U_2 \cdot \sin(2\pi ft)$.

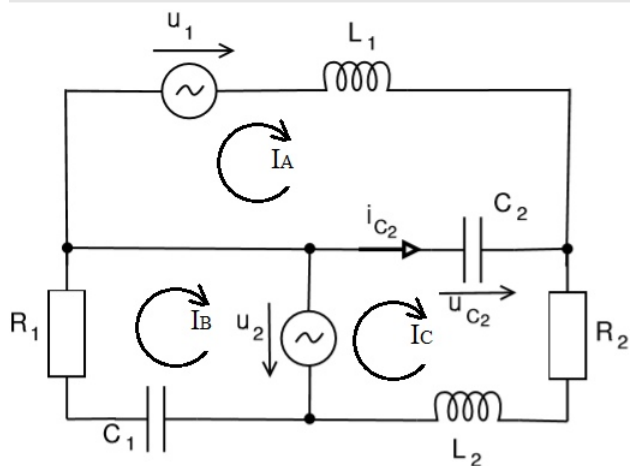
Ve vztahu pro napětí $u_{C_2} = U_{C_2} \cdot \sin(2\pi ft + \varphi_{C_2})$ určete $|U_{C_2}|$ a φ_{C_2} . Použijte metodu smyčkových proudů.

Pozn: Pomocné směry šipek napájecích zdrojů platí pro speciální časový okamžik ($t = \frac{\pi}{2\omega}$).

sk.	U_1 [V]	U_2 [V]	R_1 [Ω]	R_2 [Ω]	L_1 [mH]	L_2 [mH]	C_1 [μ F]	C_2 [μ F]	f [Hz]
F	20	35	12	10	170	80	150	90	65



Po upravě:

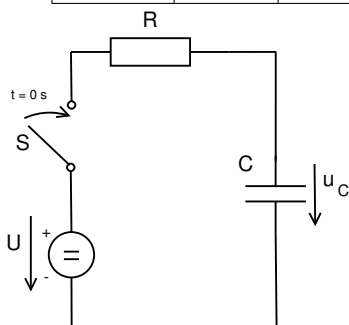


Příklad 5

V obvodu na obrázku níže v čase $t = 0[\text{s}]$ sepne spínač S . Sestavte diferenciální rovnici popisující chování obvodu na obrázku, dále ji upravte dosazením hodnot parametrů. Vypočítejte analytické řešení $u_C = f(t)$. Proveďte kontrolu výpočtu dosazením do sestavené diferenciální rovnice.

Pozn: Pomocné směry šipek napájecích zdrojů platí pro speciální časový okamžik ($t = \frac{\pi}{2\omega}$).

sk.	U [V]	C [F]	R [Ω]	$u_C(0)$ [V]
H	18	50	40	5



$$i = \frac{U}{R} \quad (37)$$

$$U = U_R + U_C \Rightarrow U = iR + U_C \quad (38)$$

$$U'_C = \frac{i}{C} \quad (39)$$

$$U'_C = \frac{U_R}{R * C} \Rightarrow U'_C = \frac{U - U_C}{R * C} \quad (40)$$

$$U'_C = \frac{U - U_C}{R * C} \Rightarrow U'_C + \frac{U_C}{R * C} = \frac{U}{R * C} \quad (41)$$

Charakteristická rovnice:

$$U'_C + \frac{U_C}{R * C} = 0 \quad (42)$$

$$U'_C = \lambda \Rightarrow U_C = 1$$

$$\lambda + \frac{1}{R * C} = 0 \Rightarrow \lambda = -\frac{1}{R * C} \quad (43)$$

Obecný tvar:

$$U_C(t) = k(t) * e^{t\lambda} \quad (44)$$

$$U'_C(t) = k'(t) * e^{t\lambda} + k(t) * (e^{t\lambda})' \quad (45)$$

$$U'_C(t) = k'(t) * e^{t\lambda} + \lambda * k(t) * e^{t\lambda}$$

$$U'_C + \frac{U_C}{R * C} = \frac{U}{R * C} \quad (46)$$

$$k'(t)e^{t\lambda} + \lambda k(t)e^{t\lambda} - \lambda \quad (47)$$

$$k(t)e^{t\lambda} = \frac{U}{R * C} \Rightarrow k'(t) = \frac{e^{-t\lambda} * U}{R * C} \quad (48)$$

$$\int k'(t)dx = \int \frac{e^{-t\lambda} * U}{R * C} dx = \frac{U}{R * C} \int e^{-t\lambda} = U * e^{\frac{t}{R * C}} + k \quad (49)$$

$$k(t) = U * e^{\frac{t}{R * C}} + k \quad (50)$$

$$U_C(t) = k(t) * e^{t\lambda} = (U * e^{\frac{t}{R * C}} + k) * e^{t\lambda} \quad (51)$$

$$U_C(0) = U + k \Rightarrow k = U_C(0) - U \quad (52)$$

$$k = 5 - 18 = -13$$

$$U_C(t) = U + e^{t\lambda} * k \quad (53)$$

$$U_C(t) = 18 - 13 * e^{-t \frac{1}{2000}} \quad (54)$$

Zkontrolujeme výpočtu dosazením do sestavené rovnice

Shrnutí výsledků

Příklad	Skupina	Výsledky	
1	F	$U_{R5} = 37,38V$	$I_{R5} = 0,1246A$
2	H	$U_{R6} = 24,66V$	$I_{R6} = 0,137A$
3	A	$U_{R4} = 59,8314V$	$I_{R4} = 1,5341A$
4	F	$ U_{C2} =$	$\varphi_{C2} =$
5	H	$u_C = 18 - 13 * e^{-t \frac{1}{2000}}$	