04.03.2021

WYBRANE ZAG. TO
ĆWICZENIA 1

INFO WSTĘPNE

- Kontakt przez pocztę studencką
- Obecność nie będzie sprawdzana, jak ktoś chce to niech chodzi, nie to nie
- Komunikacja bez czatu, tylko głosowo
- Zalogować się na portalu eny → tam będą zadania do zrobienia, etc.
- * - Kolokwium - podstawa zaliczenia; termin do ustalenia

- Trzeba umieć równania różniczkowe
- przejrzeć literaturę do przedmiotu
  - Lipiński - Obliczenia Numeryczne → przykłady z rozwiązaniami
- powtórka z równań różniczkowych na kolejne zajęcia;
  - będzie do zrobienia lista zadań
  - zadania na kartce do zrobienia - uzupełnić programem, np. Matlab/ATP-EMTP
    - Multisim - do obliczeń: wirtualne przyrządy do wyk. w trakcie obliczeń numerycznych; można wirtualnie wykonać badania układu i sprawdzić wyniki swoich obliczeń
- * - Stosować oznaczenia zgodnie z jego tabelą z e-portalu

- Jeżeli ktoś chce, może chodzić na obie grupy

- Nie ograniczać się do ~~x-y~~ obliczeń, sprawdzać też x-y i inne wykresy

- Ocena końcowa na podst. kolosa; 3 zadania na kolosie

- Zadania będą dodawane sukcesywnie; będą się powtarzać

- Laplace / Równania różniczkowe → um. porównania zastosowań

~~03.03.2021~~
18.03.2021

WYBRANE ZAG. T. O. - ĆWICZENIA 2
~~ZAKŁ. W UKŁADACH ELEKTROENERGETYCZNYCH~~
~~WYKŁAD 1~~

Et_W21

- Niektóre zadania będą sprawdzane i punktacja może być zero-jedynkowa lub w innej skali. To nie jest ocena kompletności zadania, może być też brak oceny
  - Najczęściej
- Podstawowy problem: nie mieszać liczb rzeczywistych i zespolonych i ich oznaczeń, "nie jest to tolerowalne" XD
- Brak oceny ~~że~~ nie znaczy, że nie sprawdzał XD
- Zadanie z 3-fazówką: aby to np. punkt przyłączenia domu
- * - Rozwiązując zadania trzeba rozpisać np. układ 3-fazowy na układ równań
  - Zapisać też równania w funkcji czasu (np. $i(t) = 23\sin(\omega t + 33°)$)
  - Straty mocy: tylko na rezystancji !
  - Policzenie
  - Moc bierna: związana z magazynowaniem energii w cewkach i kondensatorach
- * - Moc czynna: moc średnia mocy chwilowej
- Moc pozorna:

$$\boxed{S_A = |\underline{S}_a| + |\underline{S}_b| + |\underline{S}_c|}$$

$S_V \neq S_A$

$$S_V = |\underline{S}_a + \underline{S}_b + \underline{S}_c|$$

- Doczytać o sposobach liczenia mocy pozornej, trzymamy się tego
- Zbudować układ do ćwiczeń
- ATP EMTP / Matlab + Simulink

* • na kolejne zajęcia: korzystając z obwodu z war. początkowymi rozwiązać równania różniczkowe cewki
  - ograniczyć się do znalezienia wartości zanikającej składowej

• obliczyć stan przejściowy: metoda klasyczna i Laplace'a

A-10C CZUJNIK

ACS-758

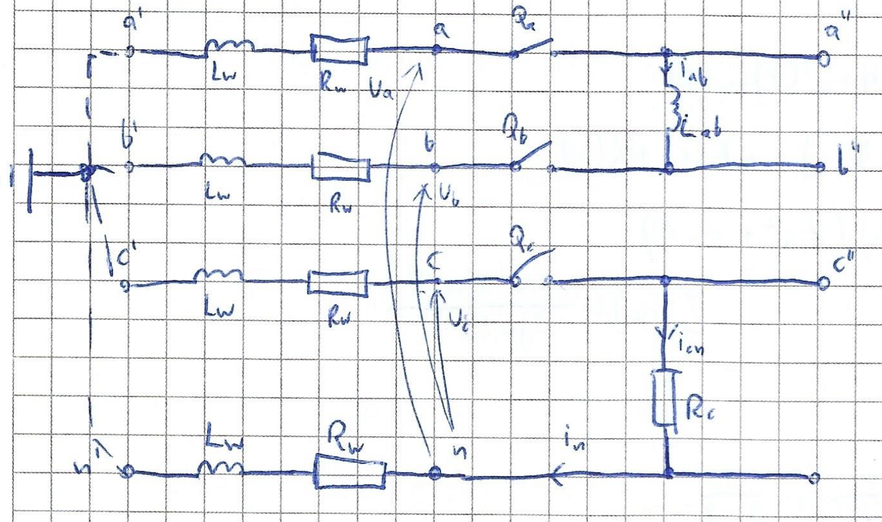
15.04.2021

WZTO – ćwiczenia 3

Dla obwodu RL, $tg\,\varphi = \frac{\omega L}{R}$, z kąd stała czasowa $= \frac{R}{L}$

Jeżeli dł. fali jest 10-kr. mniejsza od rozmiarów układu, trzeba mówić o linii długiej.

W linii długiej v jest mniejsze od 300 tys. $\frac{km}{s}$. Wynika to z przenikalności elektrycznej.



$f = 50\,Hz$

$U = 230\,V$

$R_w = 0{,}02\,\Omega$

$L_w = 0{,}318\,mH$

$L_{ab} = 41{,}38\,mH$

$R_c = 12\,\Omega$

$u_a(t) = 230 \sin(\omega t) = 230 \sin(314\,t)$

$u_b(t) = 230 \sin(\omega t - 120°) = 230 \sin(314t - 120°)$

$u_c(t) = 230 \sin(314t - 240°)$

$L_{ab} = 41{,}38\,mH \rightarrow X_{ab} = j\omega X = 314 \cdot 41{,}38 \cdot 0{,}001 = 13\,\Omega$

$Z_w = R_w + j\omega L_w = 0{,}02\,\Omega + j \cdot 314 \cdot 0{,}000318\,mH = 0{,}02\,\Omega + j0{,}1\,\Omega$

ZADANIE 1 c:

$$2y'(t)+3y(t)=2x''(t)+x'(t)+x(t)$$

$$2sY(s)+3Y(s)=2s^2X(s)+sX(s)+X(s)$$

$$Y(s)(2s+3)=X(s)(2s^2+s+1)$$

$$G(s)=\frac{2s^2+s+1}{2s+3} \qquad G(j\omega)=\frac{-2\omega^2+j\omega+1}{2j\omega+3}$$

$$g(t)=\mathcal{L}^{-1}\{G(s)\}=$$

$$G(s)=\frac{2s^2}{2s+3}+\frac{s}{2s+3}+\frac{1}{2s+3}$$

1B:

$$y'(t)+y(t-1)=x'(t-1)+x(t)$$

$$sY(s)+Y(s)e^{-s}=sX(s)e^{-s}+X(s)$$

$$Y(s)(s+e^{-s})=X(s)(se^{-s}+1)$$

$$G(s)=\frac{se^{-s}+1}{s+e^{-s}} \qquad G(j\omega)=\frac{j\omega e^{-j\omega}+1}{j\omega+e^{-j\omega}}$$

$$G(s)=\frac{se^{-s}+1}{s+e^{-s}}=\frac{\frac{s}{e^s}+1}{s+\frac{1}{e^s}}=\frac{\frac{s+e^s}{e^s}}{\frac{se^s+1}{e^s}}=\frac{s+e^s}{se^s+1}$$

ZAD. 3:

$$K(s) = \mathcal{L}\{h(t)\} = \frac{s+1}{s(s+3)}$$

a) $\lambda(t) = \mathcal{L}^{-1}\{ \frac{1}{s} K(s) \}$

$$\frac{1}{s} K(s) = \frac{s+1}{s^2(s+3)}$$

$$\lambda(t) = \mathcal{L}^{-1}\{ \frac{1}{s} K(s) \} =$$

$$= \left[\frac{d}{ds}\left[\frac{s+1}{s+3} e^{st} \right]\Big|_{s=0} + \frac{s+1}{s^2} e^{st}\Big|_{s=-3} \right] 1(t) =$$

$$= \dots = \left(\frac{t}{3} - \frac{2e^{-3t}}{9} + \frac{2}{9} \right) 1(t)$$

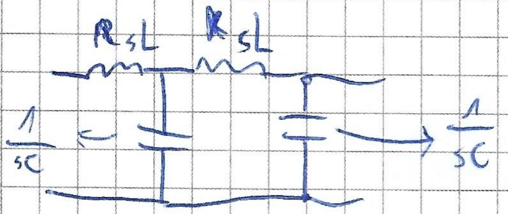
b) $x(t)$ $\quad t \in \langle -2; 2)$ $\quad x(t) = 1$

$t \in \langle 2; 4)$ $\quad x(t) = 2$

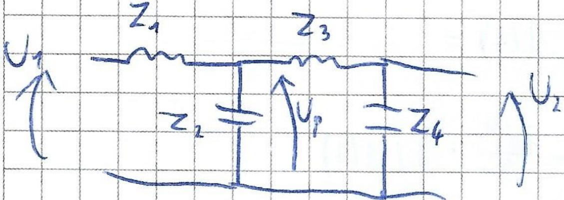
$t \in \langle 4; 6)$ $\quad x(t) = 3$

$$k(t) = \left(\frac{2}{3} e^{-3t} + \frac{1}{3} \right) 1(t)$$

ZAD. 4A:



1. Wstawić napięcie U_p za pierwszym czwórnikiem
2. Z równania dzielnika: $H_1 = \frac{U_p}{U_1} = \frac{Z_2}{Z_1+Z_2}$ obliczyć H_1
3. Policzyć $H_2 = \frac{U_2}{U_p} = \frac{Z_4}{Z_3+Z_4}$.
4. Pomnożyć $H_1 H_2$ $\left(\frac{U_p}{U_1} \cdot \frac{U_2}{U_p} = \frac{U_2}{U_1}\right)$



$$H_1 = \frac{U_p}{U_1} = \frac{Z_2}{Z_1+Z_2}$$

$$H_2 = \frac{U_2}{U_p} = \frac{Z_4}{Z_3+Z_4}$$

$$H = H_1 H_2 = \frac{U_p}{U_1} \cdot \frac{U_2}{U_p} = \frac{U_2}{U_1} = \frac{Z_2 Z_4}{(Z_1+Z_2)(Z_3+Z_4)} = \frac{Z_2 Z_4}{Z_1Z_3 + Z_1Z_4 + Z_2Z_3 + Z_2Z_4} =$$

$$\begin{matrix} Z_1 = Z_3 \\ Z_2 = Z_4 \end{matrix} \Longrightarrow \frac{\frac{1}{sC} \cdot \frac{1}{sC}}{sL \cdot sL + \frac{1}{sC} sL + \frac{1}{sC} sL + \frac{1}{sC} \cdot \frac{1}{sC}} =$$

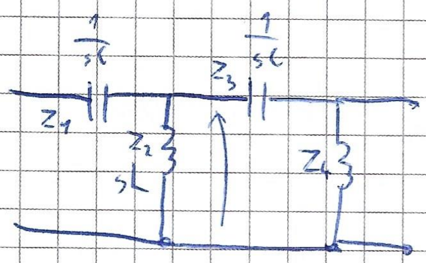
$$= \frac{1}{(s^2C^2)\left(s^2L^2 + 2\frac{L}{C} + \frac{1}{s^2C^2}\right)} =$$

$$= \frac{1}{s^2C^2\left(\frac{s^3L^2C^2}{sC^2} + \frac{s2LC}{sC^2} + \frac{1}{sC^2}\right)} = \left[\frac{1}{s^4L^2C^2 + 2s^2LC + s}\right]$$

$$\frac{Z_2^2}{(Z_1+Z_2)^2} = \frac{\frac{1}{s^2C^2}}{\left(\frac{1}{sC} + sL\right)^2} = \frac{\frac{1}{s^2C^2}}{\left(\frac{1+s^2LC}{sC}\right)^2} = \cancel{\frac{1}{s^2C^2} \cdot \frac{sC}{1+s^2LC}} =$$

$$= \cancel{\frac{1}{sC + s^3LC^2}} = \frac{1}{s^2C^2} \cdot \frac{(sC)^2}{(1+s^2LC)^2} = \frac{1}{(s^2LC+1)^2}$$

4B:



$$\frac{s^2LC+1}{s^2LC+1} - \frac{1}{s^2LC+1}$$

$$H_1(s) = \frac{Z_2}{Z_1+Z_2} = \frac{sL}{\frac{1}{sC}+sL} = \frac{sL}{\frac{1}{sC}+\frac{sLsC}{sC}} = \frac{sL}{\frac{s^2LC+1}{sC}} = \frac{s^2\cancel{LC}}{s^2LC+1} =$$

$$H_2 = \frac{Z_4}{Z_3+Z_4} = \frac{Z_2}{Z_1+Z_2}$$

$$H = \frac{Z_2^2}{(Z_1+Z_2)^2} = \frac{s^2L^2}{\left(\frac{1}{sC}+sL\right)^2} = \frac{s^2L^2}{\left(\frac{s^2LC+1}{sC}\right)^2} = \frac{s^4L^2C^2}{(s^2LC+1)^2}$$

$$= \frac{s^4L^2C^2}{s^4L^2C^2+2s^2LC+1}$$

$$\frac{1}{s^2LC+1} = \frac{(s^2LC-1)}{(s^2LC+1)(s^2LC-1)} = \frac{s^2LC-1}{s^4L^2C^2-1}$$

1C:

$$2y'(t)+3y(t)=2x''(t)+x'(t)+x(t)$$

$$2sY(s)+3Y(s)=2s^2X(s)+sX(s)+X(s)$$

$$Y(s)(2s+3)=X(s)(2s^2+s+1)$$

$$G(s)=\frac{Y(s)}{X(s)}=\frac{2s^2+s+1}{2s+3}$$

$$G(j\omega)=\frac{-2\omega^2+j\omega+1}{2j\omega+3}=\frac{(-2\omega^2+j\omega+1)(2j\omega-3)}{-4\omega^2-9}=$$

$$=\frac{-4j\omega^3+6\omega^2-2\omega^2-3j\omega+2j\omega-3}{-4\omega^2-9}=\frac{-4j\omega^3+4\omega^2+j\omega-3}{-4\omega^2-9}=\frac{4j\omega^3-4\omega^2-j\omega+3}{4\omega^2+9}$$

$$G(s)=\frac{2s^2+s+1}{2s+3}$$

s^2+s+1

$$=\frac{2s^2+3s}{2s+3}-\frac{2s+3}{2s+3}+\frac{4}{2s+3}=s-1-\frac{1}{s+1,5}$$

$$\mathcal{L}^{-1}\{G(s)\}=\delta'(t)-\delta(t)-2e^{-1,5t}$$

sk. JEDN:

$$\mathcal{L}^{-1}\{\tfrac{1}{s}G(s)\}=\mathcal{L}^{-1}\{1-\tfrac{1}{s}+2\tfrac{1}{s(s+\frac{3}{2})}\}=\delta(t)-1(t)+\tfrac{4}{3}(1-e^{-\frac{3}{2}t}$$

W. Z. T. O.

ZADANIE 12 → MET. UZMIENNIANIA STAŁEJ

a) $x'(t) + x(t) = [1+\cos(2t)]e^{-t}$ (1)

$x' - x = 0 \to \frac{dx}{dt} = x \to \cancel{dx = x\,dt \to \int dx = \int x\,dt}$

↳ $\frac{1}{x}dx = dt \to \int \frac{1}{x}dx = \int dt \to \ln|x| = t + c$

$x = e^{t+c} = e^t \cdot c(t) \to \frac{d}{dt} \to \cancel{e^t \cdot 0 + e^t \cdot e^c =}$ (3)

$\cancel{x' = e^{t+c} = ce^t}$ $x' = (c(t)e^t)' = c'(t)e^t + c(t)e^t$ (2)

(2) i (3) wstawiam do (1)

$\cancel{ce^t + ce^t = (1+\cos(2t))e^{-t}}$

$c'(t)e^t + c(t)e^t - c(t)e^t = (1+\cos(2t))e^{-t}$

$c'(t)e^t = (1+\cos 2t)e^{-t}$

$c'(t) = (1+\cos 2t)e^{-2t} = e^{-2t} + (\cos 2t)(e^{-2t})$

$c(t) = \int e^{-2t}dt + \int (\cos 2t)(e^{-2t})dt$

$c(t) = -\frac{1}{2}e^{-2t} + \frac{1}{4}e^{-2t}(\sin(2t) - \cos(2t)) + c_1 =$

$x(t) = c(t)\cdot e^t = e^t\left(-\frac{1}{2}e^{-2t} + \frac{1}{4}e^{-2t}(\sin 2t - \cos 2t) + c_1\right) =$

$= -\frac{1}{2}e^{-t} + \frac{1}{4}e^{-t}(\sin 2t - \cos 2t) + c_1e^t =$ ŹLE

$= \frac{1}{4}e^{-t}(-2 + \sin 2t - \cos 2t + c_2e^{2t})$

---

a) $x'(t) + x(t) = (1+\cos 2t)e^{-t}$

$x' + x = 0 \to \frac{dx}{dt} = -x \to \int -\frac{1}{x}dx = \int dt \to -\ln x = t$ (1)

Stąd: $\ln x = -t + c \to x = e^{-t}\cdot c(t)$ (2)

Więc: $x' = (e^{-t}c(t))' \to x' = -e^{-t}c(t) + e^{-t}c'(t)$ (3)

(2) i (3) do (1): $-e^{-t}c(t) + e^{-t}c'(t) + e^{-t}c(t) = (1+\cos 2t)e^{-t}$

↳ $e^{-t}c'(t) = e^{-t} + e^{-t}\cos 2t \to c'(t) = 1 + \cos 2t$

Całka: $c(t) = \int 1 + \cos 2t\,dt = t + \sin t\cos t + c_1$

Stąd: $x = e^{-t}c(t) = e^{-t}(t + \sin t\cos t + c_1) = c_1e^{-t} + te^{-t} + e^{-t}\sin t\cos t$

↑ wzór ogólny, trzeba całkę szczególną ; stąd ↑ odjąć t_0

b) $x''(t) - 4x'(t) + x(t) = \sin(t)$

$\lambda^2 - 4\lambda + 1 = 0 \rightarrow \Delta = 16 - 4 = 12$ $\qquad \sqrt{\Delta} = 2\sqrt{3}$

$\lambda_1 = \frac{4-2\sqrt{3}}{2} = 2-\sqrt{3} \approx 0,268$ $\qquad \lambda_2 = \frac{4+2\sqrt{3}}{2} = 2+\sqrt{3} = 3,732$

$y_1(t) = e^{0,268t}$ $\qquad y_2(t) = e^{3,732t}$

$y(t) = c_1 e^{0,268t} + c_2 e^{3,732t}$

$y_1'(t) = 0,268 e^{0,268t}$ $\qquad y_2'(t) = 3,732 e^{3,732t}$

$$\begin{bmatrix} e^{0,268t} & e^{3,732t} \\ 0,268 e^{0,268t} & 3,732 e^{3,732} \end{bmatrix} \cdot \begin{bmatrix} c_1'(t) \\ c_2'(t) \end{bmatrix} = \begin{bmatrix} 0 \\ \sin t \end{bmatrix}$$

Wyznacznik: $3,372 e^{3,372t} e^{0,268t} - e^{3,732t} 0,268 e^{0,268t} = 3,372 e^{3,64t} - 0,268 e^{3,64t} =$
$= 3,104 e^{3,64t}$

Metoda Cramera: $W_{c_1'(t)} = \begin{vmatrix} 0 & e^{3,732t} \\ \sin t & 3,732 e^{3,732t} \end{vmatrix} = -e^{3,732t} \sin t$

$$c_1'(t) = \frac{W_{c_1'(t)}}{W} = \frac{-e^{3,732t}\sin t}{3,104 e^{3,64t}} = -0,322 e^{0,092} \sin t$$

$$W_{c_2'(t)} = \begin{vmatrix} e^{0,268t} & 0 \\ 0,268 e^{0,268t} & \sin t \end{vmatrix} = e^{0,268t} \sin t$$

$$c_2'(t) = \frac{e^{0,268t}\sin t}{3,104 e^{3,64t}} = 0,322 e^{-3,372t} \sin t$$

$c_1 = \int c_1'(t)dt = \int -0,322 e^{0,092t} \sin t \, dt = 0,319 e^{0,092t} (\cos(t) - 0,092 \sin(t)) + c_1$

$c_2 = \int c_2'(t)dt = \int 0,322 e^{-3,372t} \sin t \, dt = e^{-3,372t} (-0,088 \sin t - 0,026 \cos t + c_2)$

przyblizenia rozsypane

Stąd:

$y(t) = c_1 e^{0,268t} + c_2 e^{3,732t} = e^{0,268t}($

b) $x''(t) - 4x'(t) + x(t) = \sin t$

$\lambda^2 - 4\lambda + 1 = 0 \rightarrow \Delta = 12 \rightarrow \sqrt{\Delta} = 2\sqrt{3}$

$\lambda_1 = 2-\sqrt{3}$ $\qquad$ $\lambda_2 = 2+\sqrt{3}$

$y_1(t) = e^{(2-\sqrt{3})t}$ $\qquad$ $y_2(t) = e^{(2+\sqrt{3})t}$

1 $\quad y(t) = c_1 e^{(2-\sqrt{3})t} + c_2 e^{(2+\sqrt{3})t}$

$y_1'(t) = (2-\sqrt{3})e^{(2-\sqrt{3})t}$ $\qquad$ $y_2'(t) = (2+\sqrt{3})e^{(2+\sqrt{3})t}$

St. ukł.:
$$\begin{bmatrix} e^{(2-\sqrt{3})t} & e^{(2+\sqrt{3})t} \\ (2-\sqrt{3})e^{(2-\sqrt{3})t} & (2+\sqrt{3})e^{(2+\sqrt{3})t} \end{bmatrix}\begin{bmatrix} c_1'(t) \\ c_2'(t)\end{bmatrix} = \begin{bmatrix} 0 \\ \sin t\end{bmatrix}$$

Wyznacznik: $e^{(2-\sqrt{3})t}(2+\sqrt{3})e^{(2+\sqrt{3})t} - e^{(2+\sqrt{3})t}(2-\sqrt{3})e^{(2-\sqrt{3})t} =$

$= e^{4t}(2+\sqrt{3}) + (\sqrt{3}-2)e^{4t} = 2\sqrt{3}e^{4t}$

Metoda Cramera:

$$W_{c_1'(t)} = \begin{vmatrix} 0 & e^{(2+\sqrt{3})t} \\ \sin t & (2+\sqrt{3})e^{(2+\sqrt{3})t}\end{vmatrix} = -e^{(2+\sqrt{3})t}\sin t$$

$$C_1'(t) = \frac{W_{c_1'(t)}}{W} = \frac{-e^{(2+\sqrt{3})t}\sin t}{2\sqrt{3}e^{4t}} = \frac{-1}{2\sqrt{3}}e^{(\sqrt{3}-2)t}\sin t$$

$$W_{c_2'(t)} = \begin{vmatrix} e^{(2-\sqrt{3})t} & 0 \\ (2-\sqrt{3})e^{(2-\sqrt{3})t} & \sin t\end{vmatrix} = e^{(2-\sqrt{3})t}\sin t$$

$$C_2'(t) = \frac{W_{c_2'(t)}}{W} = \frac{e^{(2-\sqrt{3})t}\sin t}{2\sqrt{3}e^{4t}} = \frac{1}{2\sqrt{3}}e^{(-2-\sqrt{3})t}\sin t$$

$$c_1(t) = \int \frac{-1}{2\sqrt{3}}e^{(\sqrt{3}-2)t}\sin t\,dt = -\frac{1}{2\sqrt{3}}\int e^{(\sqrt{3}-2)t}\sin t = -\frac{e^{(\sqrt{3}-2)t}((\sqrt{3}-2)\sin(t) - \cos(t))}{2\sqrt{3}(8-4\sqrt{3})}$$

$$c_2(t) = \int \frac{1}{2\sqrt{3}}e^{(-2-\sqrt{3})t}\sin t\,dt = -\frac{e^{-(2+\sqrt{3})t}((2+\sqrt{3})\sin(t) + \cos(t))}{8\sqrt{3}(2+\sqrt{3})}$$

Wstawiam do 1:

$$y = e^{(2-\sqrt{3})t}\cdot\left(-\frac{e^{(\sqrt{3}-2)t}\cdot((\sqrt{3}-2)\sin(t)-\cos(t))}{(2\sqrt{3})(8-4\sqrt{3})}\right) + e^{(2+\sqrt{3})t}\cdot\left(-\frac{e^{(-2-\sqrt{3})t}((2+\sqrt{3})\sin(t)+\cos(t))}{8\sqrt{3}(2+\sqrt{3})}\right) =$$

$-24+16\sqrt{3}$

$26+16\sqrt{3}$

$$= \frac{-((\sqrt{3}-2)(\sin t - \cos t))}{(2\sqrt{3})(8-4\sqrt{3})} - \frac{((2+\sqrt{3})\sin t + \cos t)}{8\sqrt{3}(2+\sqrt{3})} =$$

$8\sqrt{3}(2-\sqrt{3})$

$$= \frac{(2-\sqrt{3})\sin t + \cos t}{8\sqrt{3}(2-\sqrt{3})} - \frac{(2+\sqrt{3})\sin t + \cos t}{8\sqrt{3}(2+\sqrt{3})} = \frac{(2+\sqrt{3})(2-\sqrt{3})\sin t + (2+\sqrt{3})\cos t - (2+\sqrt{3})(2-\sqrt{3})\sin t - (2-\sqrt{3})\cos t}{8\sqrt{3}(4-3)} =$$

$$= \frac{\sin t + (2+\sqrt{3})\cos t - \sin t - (2-\sqrt{3})\cos t}{8\sqrt{3}} = \frac{2\sqrt{3}\cos t}{8\sqrt{3}} = \frac{1}{4}\cos t + c_1$$

c) $x''(t)+2x'(t)+5x(t) = 1+\cos(t)$

$\lambda^2+2\lambda+5=0$ $\quad \Delta = 4-20=-16 \quad \sqrt{\Delta} = j4$

$\lambda_1 = \frac{-2-j4}{2} = -1-j2 \quad \lambda_2 = -1+j2$

$y_1(t) = e^{(-1-j2)t} \quad y_2(t) = e^{(-1+j2)t}$

$y = c_1(t)y_1(t) + c_2(t)y_2(t)$

$\int_0^\infty 3e^{(2-s)t}dt =$

$=$

ZADANIE 5.1:

a) $f_1(t) = 3e^{2t}u(t)$

$F_1(s) = \int_{-\infty}^{0} 0e^{-st}dt + \int_0^\infty 3e^{2t}e^{-st}dt = \int_0^\infty 3e^{(2-s)t}dt = \int_0^\infty 3e^{-t(s-2)}dt =$

$= 3\cdot\frac{1}{2-s}e^{+t(2-s)}\Big|_{t\to\infty} - 3\cdot\frac{1}{2-s}e^{+t(2-s)}\Big|_{t\to 0} =$

a) $f_1(t) = 3e^{2t}u(t)$

$F_1(s) = \int_{-\infty}^{0} 0e^{-st}dt + \int_0^\infty 3e^{2t}e^{-st}dt = \int_0^\infty 3e^{t(2-s)}dt =$

$= 3\cdot\left[\frac{1}{2-s}e^{t(2-s)}\right]_0^\infty = 3\cdot\left(\frac{1}{2-s}e^{t(2-s)}\Big|_{t\to\infty} - \frac{1}{2-s}e^{t(2-s)}\Big|_{t\to 0}\right) =$

$= 3\cdot\left(-\frac{1}{2-s}\right) = \frac{3}{s-2}$ przy $Re\{s\}>2$

b) $f_2(t) = 3e^{2t}u(-t)$

$F_1(s) = \int_{-\infty}^{0} 3e^{2t}e^{-st}dt = \int_{-\infty}^{0} 3e^{(2-s)t}dt = 3\left[\frac{1}{2-s}e^{(2-s)t}\right]_{-\infty}^{0} =$

$= 3\cdot\left(\underbrace{\frac{1}{2-s}e^{(2-s)t}\Big|_{t=0}}_{1} - \underbrace{\frac{1}{2-s}e^{(2-s)t}\Big|_{t=-\infty}}_{0}\right) = \frac{3}{2-s} = \frac{-3}{s-2}$ dla $Re\{s\} \cancel{>} < 2$

e) $f_5(t) = -3e^{-2t}u(-t) + 4e^{t}u(-t)$

$$F_5(s) = \int_{-\infty}^{0} -3e^{-2t}e^{-st}\,dt + \int_{-\infty}^{0} 4e^{t}e^{-st}\,dt =$$

$$= -3\left[\frac{1}{-2-s}e^{(-2-s)t}\right]_{-\infty}^{0} + 4\left[\frac{1}{1-s}e^{(1-s)t}\right]_{-\infty}^{0} =$$

$$= -3\left[\frac{1}{-2-s}e^{(-2-s)t}\Big|_{t=0} - \frac{1}{-2-s}e^{(-2-s)t}\Big|_{t=-\infty}\right] + 4\left[\frac{1}{1-s}e^{(1-s)t}\Big|_{t=0} - \frac{1}{1-s}e^{(1-s)t}\Big|_{t=-\infty}\right] =$$

$$= -3\left[\frac{1}{-s-2} - 0\right]_{Re\{s\}<-2} + 4\left[\frac{1}{1-s} - 0\right]_{Re\{s\}<1} =$$

$$= \frac{3}{s+2} - \frac{4}{s-1} \qquad \text{f\"ur} \quad Re\{s\} < -2$$

TO

LISTA 2, ZAD. 4:

$$f(\infty),\ f'(\infty),\ f''(\infty)$$

Jeżeli $\mathcal{L}\{f(t)\} = \frac{-2s^4-3}{s(s^2+1)^2}$

LISTA 2, ZAD. 9:

$$F(s) = \frac{2s+1}{s^3(s+1)}$$

$$\mathcal{L}^{-1}\left\{\frac{2s+1}{s^3(s+1)}\right\} = \left(\frac{2s+1}{s^3} e^{st}\Big|_{s=-1} + \frac{1}{2} \cdot \frac{d^2}{ds^2}(2s+1)e^{st}\Big|_{s=0}\right) 1(t) =$$

$$= \left(\frac{-1}{-1} e^{-t} + \frac{1}{2}\left(\frac{d}{ds}\left(\frac{d}{ds}\frac{(2s+1)}{s+1} e^{st}\Big|_{s=0}\right) 1(t) =\right.\right.$$

$$= \left(e^{-t} + \left(\frac{1}{2}\left(\frac{d}{ds}\left(2e^{st} + (2s+1)te^{st}\right)\right)\Big|_{s=0}\right) 1(t) =\right.$$

$$= \left(e^{-t} + \frac{1}{2}\left(2te^{st} + 2te^{st} + (2s+1)t^2e^{st}\Big|_{s=0}\right) 1(t) =\right.$$

$$= \left(e^{-t} + \frac{1}{2}\left(4te^{st} + 2s\,t^2e^{st} + t^2e^{st}\Big|_{s=0}\right)\right) 1(t) =$$

$$= \left(e^{-t} + 2t + t^2\right) 1(t)$$

WZiO – ĆWICZENIA 29.04.2021

Analiza – wyznaczenie napięć i prądów obwodów

Synteza – dobór elementów i układów połączeń tych elementów na podstawie zadanej, pożądanej transmitancji

SYNTEZA OBWODÓW

Dla elementów ~~zespo~~ liniowych i stacjonarnych:

1. Wsp. wielomianów licznika (a_k) i mianownika (b_k) są stałe i rzeczywiste, bo elementy są elem. pasywnymi, liniowymi
2. Różnica stopni licznika i mianownika : max. 1 stopień
3. Bieguny (pierw. mianownika) i zera (pierw. licznika) muszą być parami sprzężone

...

Przystępując do syntezy trzeba pamiętać, że kaskadowo poł. elementy stanowią iloczyn.

* Zadane będą : linia kablowa i transformator – synteza na podstawie

Najważniejsza rzecz : sprawdzenie jak częstotliwość ma się do wymiarów geometrycznych układu → jeden czwórnik czy kilka?

→ dł. fali odniesiona do wymiarów linii ; $\frac{1}{10}$ wystarcza żeby wykluczyć parametry rozłożone, nie skupione

---

LINIA KABLOWA – ZADANIE

- Wykresy można sporządzić w Excelu albo czymkolwiek
- Zrobić obliczenia w arkuszu ; może się przydać potem.
- Korzystając z tabl. zn. trafo – stworzyć model trafo ; najczęściej obrazowuje się jedną fazę ; model typu T lub Π – zależnie od wartości R, C, L przyjętych dla modelu.
- M_{bc} zn. w MW, ΔP_{fe} w kW

ZADANIA LUB ICH CZĘŚCI MOGĄ SIĘ POJAWIAĆ NA KOLOKWIUM !

ZAD. LINIA KABLOWA

STAN POCZĄTKOWY:

$$u_e(t) = e_s(t) - i(t)(R_k + R_a) - (L_k + L_a)\frac{di(t)}{dt} - \frac{1}{C_k}\int i(t)\,dt$$

$P = UI\cos\varphi$ $\cos\varphi$

$Z = \frac{U}{I}$

$S = UI$ $S = \frac{U^2}{Z} \Rightarrow |Z| = \frac{U^2}{S}$

KOLOS ZAK.-OCENIA: 16.06 → można przełożyć

$U = 36V$ $f_i = 8kHz$

$$\Delta I = \frac{U}{4L_A f_i} = \frac{36}{4 \cdot 0{,}9 \cdot 10^{-3} \cdot 8000} = 1{,}25 A$$

$$\Delta \Omega = \frac{UKT_i^2}{16 L_A J} = \frac{36 \cdot 0{,}105 \cdot \frac{1}{8000}}{16 \cdot 0{,}9 \cdot 10^{-3} \cdot 1{,}45 \cdot 10^{-4}} = 226{,}293 \frac{obr}{min}$$

$$I_{Ac} = \frac{U}{R_A}\left(\varepsilon - \frac{e^{\varepsilon\gamma}-1}{e^{\gamma}-1}\right) = \frac{36}{0{,}56}\left(0{,}50325 - \frac{e^{0{,}50325 \cdot 0{,}078}-1}{e^{0{,}078}-1}\right) = 0{,}6267 \; A$$

$$\gamma = \frac{T_i}{T_A} = \frac{1}{8000} \cdot \frac{5600}{9} = \frac{7}{90} = 0{,}078 \qquad T_i = 0{,}125 \cdot 10^{-3}$$

$$T_A = \frac{L_A}{R_A} = \frac{0{,}9 \cdot 10^{-3}}{0{,}56} = \frac{9}{5600} \approx 1{,}607 \cdot 10^{-3} \; s$$

$$\varepsilon = \frac{1}{\gamma} \ln \frac{e^{\gamma}-1}{\gamma} = \frac{1}{0{,}078} \ln \frac{e^{0{,}078}-1}{0{,}078} = 0{,}50325$$

UKŁAD:

- pr. obcowzbudna $I_f = 0{,}134 A$
- ω w układzie: TP i mierzy napięcie, $6V \rightarrow 1000 \frac{obr}{min}$
- $f = 1500 Hz$
- obroty w prawo: 2 ch-ki

Praca magisterska:

SPRAWKO:

- kątowa ω [obr/min]
- prędkość wzg. znamionowo;

1. ω max na potencjometrze = 1500 obr/min.

[– strona tytułowa: druk wypełnić / lub zrobić tabelkę w Wordzie z info. Dane grupy, bez maszyn.

A. Wstęp: może być z instrukcji – silnik z PM impulsowy; + literatura, można z instrukcji 1 str.

2. Układ pomiarowy – rys. 14.9:

3. Tab. pomiarowe – z excela identyczne. Prędkości $\frac{obr}{min}$.

4. Wykresy: $\omega = f(I_A)$, 1 wykres kopatkowy, 2 prędkości.

5. Wnioski: czy ch-ka zgadza się z teoretyczną? Co rosło? Co malało?

Deadline: Pn, 16:00

WZTO – TRANSFORMATA LAPLACE'A
KACPER BORUCKI 245365

OCZKO 1:

$\underline{E}_a = 232{,}81\sqrt{2}e^{j0{,}3114°}$

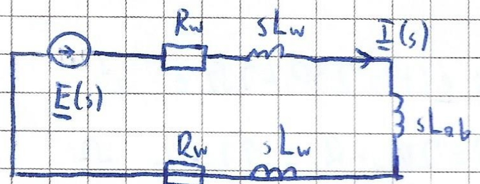
$\underline{E}_b = 232{,}51\sqrt{2}e^{-j120{,}44°}$

$L_w = 0{,}318\ mH \qquad R_w = 0{,}02\ \Omega$

$L_{ab} = 41{,}38\ mH$

$\underline{E} = \underline{E}_a - \underline{E}_b = 404{,}5\sqrt{2}e^{j29{,}91°}$

OBWÓD OPERATOROWY:



$\underline{E}(s) = \mathcal{L}\{404{,}5\sqrt{2}e^{j29{,}91°}e^{j\omega t}\} = \dfrac{404{,}5\sqrt{2}e^{j29{,}91°}}{s-j\omega} = \dfrac{\underline{E}_m}{s-j\omega}$

$\underline{E}_m = 404{,}5\sqrt{2}e^{j29{,}91°}$

WAR. POCZĄTKOWE: $i_L(0^+) = i_L(0^-) = i_L(0) = 0$

$\underline{I}_L(s) = \dfrac{\underline{E}(s)}{\underline{Z}(s)} = \dfrac{\underline{E}(s)}{(2R_w + 2L_w s + L_{ab}s)\cancel{(s-j\omega)}} = \dfrac{\underline{E}(s)}{(2L_w+L_{ab})(s+\frac{2R_w}{2L_w+L_{ab}})} = \dfrac{\underline{E}(s)}{L(s+X)}$

gdzie: $X = \dfrac{2R_w}{2L_w+L_{ab}} = 0{,}476 \qquad L = 2L_w + L_{ab} = 0{,}042$

$\underline{I}_L(s) = \dfrac{\underline{E}(s)}{L(s+X)} = \dfrac{\underline{E}_M}{s-j\omega}\dfrac{1}{L(s+X)} = \dfrac{\underline{E}_M}{L}\cdot\dfrac{1}{s-j\omega}\cdot\dfrac{1}{s+X} = \dfrac{\underline{A}_1}{s-j\omega} + \dfrac{\underline{A}_2}{s+X}$

$\underline{A}_1 = \dfrac{\underline{E}_M}{L}\cdot\dfrac{1}{(s+X)(s-j\omega)}\cdot(s+X)\Big|_{s\to X} = \dfrac{\underline{E}_M}{L}\cdot\dfrac{1}{-X-j\omega} = \dfrac{\underline{E}_M}{-L(X+j\omega)}$

$\underline{A}_2 = \dfrac{\underline{E}_M}{L}\cdot\dfrac{1}{(s+X)(s-j\omega)}\cdot(s-j\omega)\Big|_{s\to j\omega} = \dfrac{\underline{E}_M}{L}\cdot\dfrac{1}{X+j\omega} = \dfrac{\underline{E}_M}{L(X+j\omega)}$

$\underline{I}_L(s) = \dfrac{\underline{E}_M}{-L(X+j\omega)}\cdot\dfrac{1}{s+X} + \dfrac{\underline{E}_M}{L(X+j\omega)}\cdot\dfrac{1}{s-j\omega} = \dfrac{\underline{A}_1}{s+X} + \dfrac{\underline{A}_2}{s-j\omega}$

$\underline{A}_2 = -\underline{A}_1$

TRANSFORMATA ODWROTNA:

$i_L(t) = \mathcal{L}^{-1}\{\underline{I}_L(s)\} = \mathcal{L}^{-1}\left\{\dfrac{\underline{A}_1}{s+X} + \dfrac{\underline{A}_2}{s-j\omega}\right\} = \underline{A}_1 e^{-Xt} + \underline{A}_2 e^{j\omega t}$

$\underline{A}_1 = \dfrac{404{,}5\sqrt{2}e^{j29{,}9°}}{-0{,}042(0{,}476+j\,27{,}50)} = -21{,}669 + j37{,}531 = 43{,}337e^{j120°}$

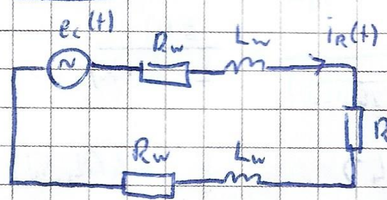
$\underline{A}_2 = -\underline{A}_1 = 21{,}669 - j37{,}531 = 43{,}337e^{-j60°}$

$i_L(t) = 43{,}337e^{j120°}e^{-0{,}476t} + 43{,}337e^{j\omega t}e^{-j60°}$

$i_L(t) = \mathrm{Im}\{\underline{i}_L(t)\} = 43{,}337\sin(120°)e^{-0{,}476t} + 43{,}337\sin(\omega t - 60°) =$

$= 37{,}531e^{-0{,}476t} + 43{,}337\sin(\omega t - 60°)$

OCZKO 2:



$\underline{E}_c = 230{,}42\sqrt{2}\,e^{j120{,}47°}$

$R_w = 0{,}02\,\Omega$ $\quad L_w = 0{,}318\,mH$ $\quad R_c = 12\,\Omega$

OBWÓD OPERATOROWY:

$$E(s) = \mathcal{L}\{230{,}42\sqrt{2}\,e^{j120{,}47°}\} = \frac{230{,}42\sqrt{2}\,e^{j120{,}47°}}{s-j\omega} = \frac{\underline{E}_M}{s-j\omega}$$

gdzie $\underline{E}_M = 230{,}42\sqrt{2}\,e^{j120{,}47°}$

$R = 2R_w + R_c = 12{,}04\,\Omega$ $\qquad L = 2L_w = 0{,}636\,mH$

Dla warunków początkowych $i_R(0^-) = i_R(0^+) = i_R(0) = 0$:

$$\underline{I}_R(s) = \frac{\underline{E}(s)}{Z(s)} = \frac{\underline{E}_M}{s-j\omega}\cdot\frac{1}{sL+R} = \frac{\underline{E}_M}{s-j\omega}\cdot\frac{1}{L(s+\frac{R}{L})} = \frac{\underline{E}_M}{L}\cdot\frac{1}{(s-j\omega)(s+X)}$$

gdzie: $X = \frac{R}{L} = 18931$

$$\underline{I}_R(s) = \frac{\underline{A}_1}{s-j\omega} + \frac{\underline{A}_2}{s+X}$$

$$\underline{A}_2 = \frac{\underline{E}_M}{L}\cdot\frac{1}{(s-j\omega)(s+X)}(s+X)\Big|_{s\Rightarrow -X} = \frac{\underline{E}_M}{L}\cdot\frac{1}{-X-j\omega} = \frac{\underline{E}_M}{-L}\,\frac{1}{X+j\omega}$$

$$\underline{A}_1 = \frac{\underline{E}_M}{L}\cdot\frac{1}{(s-j\omega)(s+X)}(s-j\omega)\Big|_{s\to j\omega} = \frac{\underline{E}_M}{L}\cdot\frac{1}{X+j\omega}$$

TRANSFORMATA ODWROTNA:

$$\underline{i}_R(t) = \mathcal{L}^{-1}\{\underline{I}_R(s)\} = \mathcal{L}^{-1}\left\{\frac{\underline{A}_2}{s-j\omega} + \frac{\underline{A}_1}{s+X}\right\} = \underline{A}_2 e^{j\omega t} + \underline{A}_1 e^{-Xt}$$

$$\underline{A}_1 = \frac{\underline{E}_M}{-L}\,\frac{1}{X+j\omega} = \frac{230{,}42\sqrt{2}\,e^{j120{,}47°}}{-0{,}000636}\cdot\frac{1}{18931+j\cdot 2\cdot\pi\cdot 50} = 13{,}335 - j23{,}548 = 27{,}061\,e^{-j60{,}48°}$$

$$\underline{A}_2 = \cancel{\underline{E}_M} - \underline{A}_1 = -13{,}335 + j\,23{,}548 = 27{,}061\,e^{j119{,}52°}$$

$$\underline{i}_R(t) = 27{,}061\,e^{j119{,}52°}e^{j\omega t} + 27{,}061\,e^{-j60{,}48°}e^{-18931t}$$

$$i_R(t) = \mathrm{Im}\{\underline{i}_R(t)\} = 27{,}061\sin(\omega t + 119{,}52°) + 27{,}061\cdot\sin(-60{,}48°)e^{-18931t} =$$

$$\cancel{= 27{,}061\sin(\omega t + 119{,}52°) + 2\ldots}$$

$$= 27{,}061\sin(\omega t + 119{,}52°) + 23{,}548\,e^{-18931t}$$

$$\underline{E}(s) = \mathcal{L}\{404{,}5\sqrt{2}e^{j29{,}9^\circ}\} = \frac{404{,}5\sqrt{2}e^{j29{,}9^\circ}}{s-j\omega} = \frac{\underline{E}_m}{s-j\omega}$$

$$\underline{I}_L(s) = \frac{\underline{E}(s)}{\underline{Z}(s)} = \frac{\underline{E}(s)}{2R_w+2sL_w+sL_{ab}} = \frac{\underline{E}_0(s)}{(2L_w+L_{ab})\left(s+\frac{2R_w}{2L_w+L_{ab}}\right)} = \frac{\underline{E}(s)}{L\cdot(s+X)}$$

$$X = \frac{2R_w}{2L_w+L_{ab}} = 0{,}476 \qquad L = 2L_w+L_{ab} = 0{,}042 \qquad \underline{E}_m = 404{,}5\sqrt{2}e^{j29{,}9^\circ}$$

$$\underline{I}_L(s) = \frac{\underline{E}(s)}{L\cdot(s+X)} = \frac{\underline{E}_m}{s-j\omega}\cdot\frac{1}{L\cdot(s+X)} = \frac{\underline{E}_m}{L}\cdot\frac{1}{(s+X)(s-j\omega)} = \frac{A_1}{s+X} + \frac{A_2}{s-j\omega}$$

$$\cancel{\underline{I}_L(s) = \frac{\underline{E}_m}{L}\cdot}$$

$$A_1 = \frac{\underline{E}_m}{L}\cdot\frac{1}{\cancel{(s+X)}(s-j\omega)}\cdot\cancel{(s+X)}\Big|_{s\to -X} = \frac{\underline{E}_m}{L}\cdot\frac{1}{-X-j\omega} = \frac{\underline{E}_m}{-L(X+j\omega)}$$

$$A_2 = \frac{\underline{E}_m}{L}\cdot\frac{1}{(s+X)(s-j\omega)}\cdot(s-j\omega)\Big|_{s\to j\omega} = \frac{\underline{E}_m}{L}\cdot\frac{1}{j\omega+X} = \frac{\underline{E}_m}{L(X+j\omega)}$$

$$\underline{I}_L(s) = \frac{\underline{E}_m}{-X(X+j\omega)}\cdot\frac{1}{s+X} + \frac{\underline{E}_m}{X(X+j\omega)}\cdot\frac{1}{s-j\omega}$$

$$\underline{A} = -\frac{\underline{E}_m}{L(X+j\omega)} \qquad \underline{B} = \frac{\underline{E}_m}{X(L+j\omega)} = -\underline{A}$$

$$\mathcal{L}^{-1}\{\underline{I}_L(s)\} = (\underline{A}e^{-Xt} + \underline{B}e^{+j\omega t})\,1(t)$$

$$\cancel{\underline{A} = -0{,}476(0{,}476+j\cdot 2\pi\cdot 50) = -0{,}227 - j149{,}54}$$

$$\cancel{\underline{B} = -\underline{A} = 0{,}227 + j149{,}54}$$

$$\underline{A} = \frac{404{,}5\sqrt{2}e^{j29{,}9^\circ}}{-0{,}042\cdot(0{,}476+j\cdot 2\pi\cdot 50)} = -21{,}669 + j37{,}531$$

$$\underline{B} = -\underline{A} = 21{,}669 + j37{,}531$$

$$A = 43{,}337\cdot\sin(\omega t+\psi_A) = 43{,}337\cdot\sin(\omega t+120^\circ) = 37{,}531\ \mathrm{A}$$

$$B = 43{,}337\cdot\sin(\omega t-60^\circ) = -37{,}531$$

$$\underline{A} = 43{,}337e^{j120^\circ} \qquad \underline{B} = 43{,}337e^{-j60^\circ}$$

$$\underline{i}(t) = \underline{A}e^{-Xt} + \underline{B}e^{j\omega t} = 43{,}337e^{j120^\circ}\cdot e^{-0{,}476t} + 43{,}337e^{-j60^\circ}e^{j\omega t} =$$

$$\cancel{= 43{,}337e^{j120^\circ}e^{-0{,}476} + 43}$$

$$= 43{,}337\sin(120^\circ)e^{-0{,}476} + 43{,}337\sin(j\omega t - 60^\circ)$$

WZTD

KACPER BORUCKI
245365

28.04.2021

$$F(s)=\frac{s^2+4s+3}{s^3+6s^2+8s}$$

METODA CAUERA:

$$Z(s)=\frac{s^2+4s+3}{s^3+6s^2+8s}=0+\frac{1}{\frac{s^3+6s^2+8s}{s^2+4s+3}}=\frac{1}{s+\frac{2s^2+5s}{s^2+4s+3}}$$

$$Z_1=0$$

$$Z(s)=\frac{1}{s+\frac{1}{\frac{s^2+4s+3}{2s^2+5s}}}=\frac{1}{s+\frac{1}{\frac{1}{2}+\frac{1{,}5s+3}{2s^2+5s}}}$$

$$Y_2=s \qquad Z_3=\frac{1}{2}$$

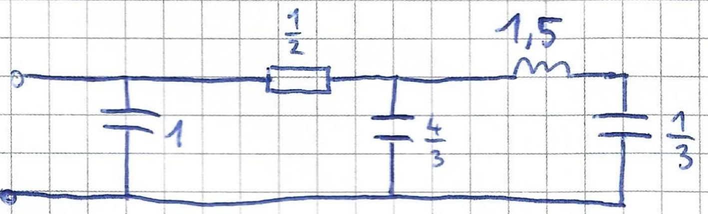
$$Z(s)=\frac{1}{s+\frac{1}{\frac{1}{2}+\frac{1}{\frac{2s^2+5s}{1{,}5s+3}}}}=\frac{1}{s+\frac{1}{\frac{1}{2}+\frac{1}{\frac{4}{3}s+\frac{s}{1{,}5s+3}}}}$$

$$Y_4=\frac{4}{3}s$$

$$\frac{s}{1{,}5s+3}=\frac{1}{\frac{1{,}5s+3}{s}}=\frac{1}{1{,}5s+\frac{3}{s}}$$

$$Z_5=1{,}5s$$

$$\frac{1}{Y_6}=\frac{3}{s} \rightarrow Y_6=\frac{s}{3}=\frac{1}{3}s$$



DZIELENIE

s

$(s^3+6s^2+8s) : (s^2+4s+3)$

$-s^3-4s^2-3s$

$0 \quad 2s^2+5s$

$\frac{1}{2}$

$s^2+4s+3 : 2s^2+5s$

$-s^2-2{,}5s$

$1{,}5s+3$

$\frac{4}{3}s$

$2s^2+5s : 1{,}5s+3$

$-2s^2-4s$

s

$1{,}5$

$1{,}5s+3 : s$

$-1{,}5s$

3

WZTO
SYNTEZA

KACPER BORUCKI
245365

28.04.2021

$$F(s) = \frac{s^2+4s+3}{s^3+6s^2+8s} = \frac{(s+3)(s+1)}{s(s+2)(s+4)} = \frac{(s+1)(s+3)}{s(s+2)(s+4)}$$

~~BIEGUNY~~ ZERA : $N(s) = s^2+4s+3$ $\quad \Delta = 16-12=4 \quad \sqrt{\Delta}=2$

$$s_1 = \frac{-4-2}{2} = -3 \qquad s_2 = \frac{-4+2}{2} = -1$$

BIEGUNY: $D(s) = (s^3+6s^2+8s) = s(s^2+6s+8) = s(s+2)(s+4)$

$$\Delta = 36-32=4 \quad \sqrt{\Delta} = 2$$

$$s_1 = \frac{-6-2}{2} = -4 \qquad s_2 = \frac{-6+2}{2} = -2$$

METODA ~~CAUERA~~ FOSTERA, LC

$$Z(s) = \frac{(s+1)(s+3)}{s(s+2)(s+4)}$$

$$Z(s) = F(s) = h_\infty s + \frac{h_0}{s} + \sum_{k=1}^{4} \frac{h_{2k} s}{s^2+\omega_{2k}^2}$$

$$h_\infty = \underset{s=\infty}{\mathrm{Res}}\, Z(s) = \lim_{s\to\infty} \frac{Z(s)}{s} = \lim_{s\to\infty} \frac{1}{s}\frac{(s+1)(s+3)}{s(s+2)(s+4)} = \lim_{s\to\infty} \frac{1}{s}\frac{s^2(1+\frac{4}{s}+\frac{3}{s^2})}{s^3(1+\frac{6}{s}+\frac{8}{s^2})} = \lim_{s\to\infty}\frac{1}{s^2} = 0$$

$$h_0 = \underset{s=0}{\mathrm{res}}\, Z(s) = \lim_{s\to 0} s Z(s) = \lim_{s\to 0} \cancel{s}\cdot\frac{(s+1)(s+3)}{\cancel{s}(s+2)(s+4)} = \frac{1\cdot 3}{2\cdot 4} = \frac{3}{8}$$

$h_2 = \lim$

$Z(s) = \frac{s^4+4s^2+3}{s^3+2s} = \frac{(s^2+1)(s^2+3)}{s(s^2+2)}$

$N(s) = (s^2+1)(s^2+3)$ $\qquad$ $D(s) = s(s^2+2)$

DLA RC: bieguny $j1,\ -j1,\ j\sqrt{3},\ -j\sqrt{3},\ -j\sqrt{2},\ j\sqrt{2}$ uniemożliwiają Fostera

ZERA: $\omega = 1$ $\qquad$ $\omega = \sqrt{3}$

BIEGUNY: $\omega = 0$ $\qquad$ $\omega = \sqrt{2}$

$$Z(s) = F(s) = h_\infty s + \frac{h_0}{s} + \sum_{k=1}^{n} \frac{h_{2k}s}{s^2+\omega_{2k}^2}$$

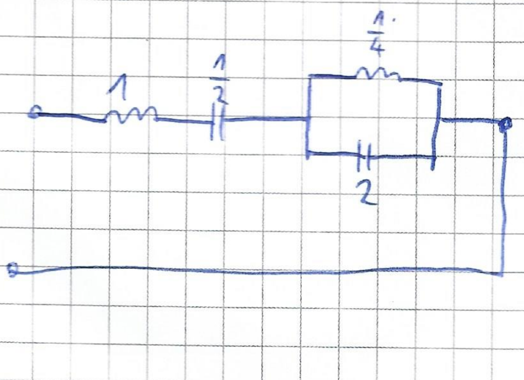
$$h_\infty = \operatorname*{res}_{s=\infty} Z(s) = \lim_{s\to\infty} \frac{Z(s)}{s} = \lim_{s\to\infty} \frac{1}{s}\frac{s^4+4s^2+3}{s^3+2s} = \lim_{s\to\infty} \frac{s^4(1+\overset{\to 0}{\frac{4}{s^2}}+\overset{\to 0}{\frac{3}{s^4}})}{s^4(1+\underset{\to 0}{\frac{2}{s^2}})} = 1 \to L_0 = 1$$

$$h_0 = \operatorname*{res}_{s=0} Z(s) = \lim_{s\to 0} s\cdot Z(s) = \lim_{s\to 0} s\cdot\frac{s^4+4s^2+3}{s^3+2s} = \lim_{s\to 0}\frac{\cancel{s}(s^2+1)(s^2+3)}{\cancel{s}(s^2+2)} = 2 \to C_0 = \frac{1}{2}$$

$$\cancel{h_2 = \lim_{s^2\to 0}\left(\frac{s^2}{s} Z(s)\right) = \lim_{s^2\to 0}\frac{s^2}{s}\cdot\frac{(s^2+1)(s^2+3)}{s(s^2+2)} =}$$

$$h_2 = \lim_{s^2\to -2}\left(\frac{s^2+2}{s} Z(s)\right) = \lim_{s^2\to -2}\frac{\cancel{s^2+2}}{s}\cdot\frac{(s^2+1)(s^2+3)}{s(\cancel{s^2+2})} = \frac{(-2+1)(-2+3)}{-2} = \frac{-1\cdot 1}{-2} = \frac{1}{2}$$

$L_1 = \frac{h_2}{\omega_2^2} = \frac{\frac{1}{2}}{2} = \frac{1}{4}$ $\qquad$ $C_1 = \frac{1}{h_2} = \frac{1}{\frac{1}{2}} = 2$



WZTO – ZADANIE STAN PRZEJŚCIOWY
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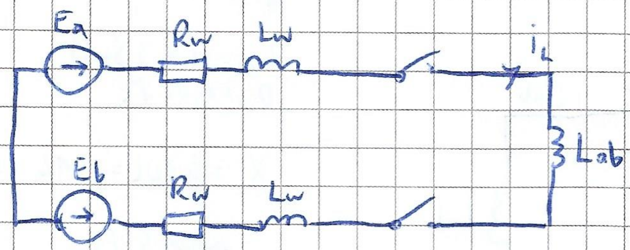
OCZKO I:



DANE:

$\underline{E}_a = 232,81\sqrt{2}\, e^{j0,314^\circ}$ $\qquad R_w = 0,02\,\Omega$

$\underline{E}_b = 232,51\sqrt{2}\, e^{j(-120,44^\circ)}$ $\qquad X_w = 0,1\,\Omega$

$L_w = 0,318\,mH \qquad L_{ab} = 41,38\,mH \qquad X_{ab} = 13\,\Omega$

$\underline{E}_{ab} = \underline{E}_a - \underline{E}_b = (232,8 + j1,3) - (-117,8 - 209,5) = 350,6 + j201,7$ [V]

$e_{ab}(t) = 404,5\sqrt{2}\sin(\omega t + 29,9^\circ)$

(1) WAR. POCZĄTKOWE: $i_{L}(t) = 0 \qquad i_{Lab}(0^-) = 0$

(2) PRAWA KOMUTACJI: $i_L(0^+) = i_L(0^-) = 0$

(3) RÓWNANIE RÓŻNICZKOWE:

$$\cancel{404}\; E_m \sin(\omega t + \psi_e) = 2L_w \frac{di_L(t)}{dt} + 2R_w\, i_L(t) + L_{ab}\frac{di_L(t)}{dt}$$

$$404,5\sqrt{2}\sin(\omega t + 29,9^\circ) = (L_{ab} + 2L_w)\frac{di_L(t)}{dt} + 2R_w\, i_L(t)$$

(4) SKŁADOWA USTALONA: $t \to +\infty$: $E_m \sin(\omega t + \psi_e) = U_{Lum}\sin(\omega t + \psi_{Lu}) + U_{Rum}\sin(\omega t + \psi_{Ru})$

$$\underline{I}_{Lu} = \frac{\underline{E}_{ab}}{\underline{Z}} = \frac{350,6 + j201,7}{0,02 + j13,2} = 15,32 - j26,54 \ [A]$$

$i_{Lu}(t) = 30,64\sqrt{2}\sin(\omega t - 60^\circ) = 30,64\sqrt{2}\sin(\omega t + 29,9^\circ - 89,9^\circ)$

(5) SKŁADOWA PRZEJŚCIOWA $i_{Lp}(t)$, $t > 0$

Równanie jednorodne: $L\frac{di_{Lp}(t)}{dt} + R\, i_{Lp}(t) = 0$

Wielomian charakt: $V(\lambda) = L\lambda + R = 0 \rightarrow \lambda = -\frac{R}{L}$

Przew. postać skł. przejściowej: $i_{Lp}(t) = Ae^{\lambda t} = Ae^{-\frac{R}{L}t}$ dla $t > 0$

$i_{Lp}(t = 0^+) = A$

$i_L(t) = i_{Lu}(t) + i_{Lp}(t) \qquad (t > 0)$

$i_L(0^+) = i_{Lu}(0^+) + i_{Lp}(0^+)$

$$0 = \frac{E_m}{Z}\sin(\psi_e - \varphi) + A \rightarrow A = \frac{-E_m}{Z}\sin(\psi_e - \varphi)$$

$$A = -\frac{404{,}5\sqrt{2}}{13{,}2}\sin(\cancel{\omega t} + 29{,}9^\circ - 89{,}91^\circ) = -30{,}64\sin(\cancel{\omega t}+29{,}9^\circ - 89{,}91^\circ) = \cancel{26{,}54}\ A$$

37,53 A

$$\begin{cases} Z = |2R_w + 2jX_w + jX_{ab}| = 13{,}2\ \Omega \\ \varphi = \arg(2R_w + 2jX_w + jX_{ab}) = 89{,}91^\circ \end{cases}$$

$$i_{Lp}(t) = -\frac{E_m}{Z}\sin(\psi_e - \varphi)e^{-\frac{R}{L}t} \quad \text{dla } t > 0$$

$$\cancel{i_{Lp}(t) = 30{,}64\sin(29{,}9}$$

$$i_{Lp}(t) = 26{,}54\, e^{-0{,}476t}$$

⑥ PRĄD PŁYNĄCY PRZEZ CEWKĘ:

$$i_L(t) = i_{Lu}(t) + i_{Lp}(t) = 30{,}64\sqrt{2}\sin(\omega t - 60^\circ) + \cancel{26{,}54}\, e^{-0{,}476t}$$

37,53 e

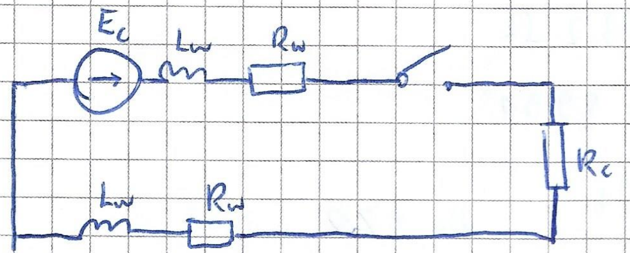
OBWÓD II:

$L_w = 0{,}318\,mH \rightarrow X_w = 0{,}1\,\Omega$

$R_w = 0{,}02\,\Omega \quad R_c = 12\,\Omega$

~~$e_c(t) = 230{,}42\sqrt{2}\sin(\omega t + 27{,}23$~~

$e_c(t) = 230{,}42\sqrt{2}\sin(\omega t + 120{,}47^\circ)$



① PRAWA KOMUTACJI : $i_R(0^+) = i_R(0^-) = 0$

② RÓWN. RÓŻNICZKOWE:

$$E_m \sin(\omega t + \psi_e) = L\frac{di_R(t)}{dt} + R i_R(t)$$

$$230{,}42\sqrt{2}\sin(\omega t + 120{,}47^\circ) = 0{,}000636 \cdot \frac{di_R(t)}{dt} + 12\, i_R(t)$$

③ SKŁADOWA USTALONA:

$$\underline{I}_{Ru} = \frac{\underline{E}_c}{\underline{Z}} = \frac{E}{Z} e^{j(\psi_e - \varphi)} = \frac{230{,}42}{12{,}042} e^{j(120{,}47 - 0{,}95^\circ)}$$

$$Z = |2R_w + R_c + 2jX_w| = 12{,}042$$

$$\varphi = \arg(Z) = \operatorname{arctg}\left(\frac{\omega L}{R}\right) = 0{,}95^\circ$$

$$i_{Ru}(t) = 19{,}1\sqrt{2}\sin(\omega t + 119{,}05^\circ)$$

④ SKŁADOWA PRZEJŚCIOWA:

$$L\frac{di_{Rp}(t)}{dt} + R i_{Rp}(t) = 0 \rightarrow V(\lambda) = L\lambda + R \rightarrow \lambda = \frac{-R}{L}$$

$$i_{Rp}(t) = Ae^{\lambda t} = Ae^{-\frac{R}{L}t} \qquad t > 0$$

$$A = -\frac{E_m}{Z}\sin(\psi_e - \varphi) = -\frac{230{,}42\sqrt{2}}{12{,}04}\sin(120{,}47 - 0{,}95) = -23{,}548$$

$$i_{Rp}(t) = -23{,}548\, e^{-\frac{R}{L}t} = -23{,}548\, e^{-18931t}$$

⑤ PRĄD REZYSTANCJI:

$$i_R(t) = i_{Ru}(t) + i_{Rp}(t) = 19{,}1\sqrt{2}\sin(\omega t + 119{,}05^\circ) - 23{,}548\, e^{-18931t}$$

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$d = 5\,km$

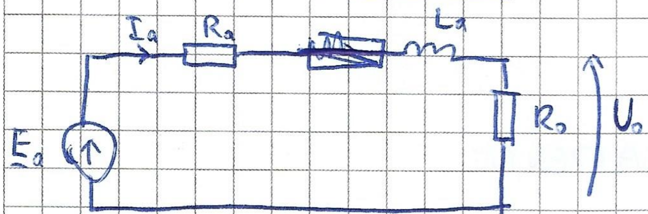
PARAMETRY ODBIORNIKA DLA JEDNEJ FAZY:

$U_o = \frac{15000}{\sqrt{3}} = 8,6603\cdot10^{3}$ V

$P = \frac{1}{3}\cdot10^{5} = 3,3333\cdot10^{4}$ W

$R_o = \frac{1}{P}\cdot U_o^2 = \frac{(8,6603\cdot10^3)^2}{3,3333\cdot10^4} = 2250\,\Omega$

LINIA NAPOWIETRZNA



$\omega = 2\pi f = 2\cdot3,14\cdot50\,Hz = 314\cdot\frac{1}{rad}$

$R_a = R_a'\cdot d = 0,434\cdot5 = 2,17\,\Omega$

$X_a = X_L'\cdot d = 0,369\cdot5 = 1,845\,\Omega$

$L_a = \frac{X_L}{\omega} = \frac{X_L'\cdot d}{314} = 6,3\,mH$

$C_a = C_a'\cdot d = 0,0045\cdot10^{-3}\cdot5 \approx 0$

$Z_n = R_a + R_o + j\omega L_a$

$\frac{E_a}{Z_n} = \frac{U_o}{R_o} \rightarrow E = \frac{U_o}{R_o}\cdot Z_n = \frac{U_o}{R_o}(R_a + R_o + j\omega L_a) =$

$= \frac{8,6603\cdot10^3}{2250}\cdot(2,17 + 2250 + j1,845) = 8,6688\cdot10^3 + j7,6210$ V

$\varphi_n = arctg\frac{7,6210}{8,6688\cdot10^3} = 8,7915\cdot10^{-4}$

$|E_a| = \sqrt{(8,6688\cdot10^3)^2 + (7,6210)^2} = 8,6686\cdot10^3$

$E_{am} = |E_a|\cdot\sqrt{2} = 8,6686\cdot10^3\cdot\sqrt{2} = 1,2259\cdot10^4$ V

$I_a = \frac{E_a}{Z_n} = \frac{U_o}{R_o} = \frac{8,6603\cdot10^3}{2250} = 3,8490$ A

$I_{am} = \sqrt{2}\,|I_a| = \sqrt{2}\cdot3,8490\,A = 5,4433$ A

STAN USTALONY:

$e_a(t) = E_{am}\sin(\omega t) = 1,2259\cdot10^4\sin(314t)$

$i_a(t) = I_{am}\sin(\omega t - \varphi_n) = 5,54433\sin(314t - 8,7915\cdot10^{-4})$

SKŁADOWA PRZEJŚCIOWA PO ZAŁĄCZENIU I WYŁĄCZENIU:

$$0 = i_p(t)(R_a + R_o) + \frac{di_p(t)}{dt} L_a$$

$$0 = R_a + R_o + \lambda L_a \rightarrow \lambda = -\frac{R_a + R_o}{L_a} = -\frac{2,17 + 2250}{0,0063} = -3,57 \cdot 10^5$$

$$i_p(t) = Ae^{\lambda t} = Ae^{-3,57 \cdot 10^5}$$

$$i(0) = 0 = i_p(0) + i_u(0) \rightarrow i_p(0) = A = -i_u(0) = -5,4433 \sin(8,7915 \cdot 10^{-4}) =$$

$$= -0,0048$$

$$i_p(t) = -0,0048 e^{-3,57 \cdot 10^5 t}$$

STAN PRZEJŚCIOWY PO ZAŁĄCZENIU:

$$\begin{cases} e_a(t) = 1,2259 \cdot 10^4 \sin(314t) \\ i_a(t) = i_p(t) + i_u(t) = -0,0048 e^{-3,57 \cdot 10^5 t} + 5,4433 \sin(314t - 8,8 \cdot 10^{-4}) \end{cases}$$

STAN PRZEJŚCIOWY PO WYŁĄCZENIU:

$$\begin{cases} e_a(t) = 1,2259 \cdot 10^4 \sin(314t) \\ i_a(t) = i_p(t) = -0,0048 e^{-3,57 \cdot 10^5 t} \end{cases}$$

LINIA KABLOWA

$R_k = R_k' d = 0,255 \cdot 5 = 1,2750\ \Omega$

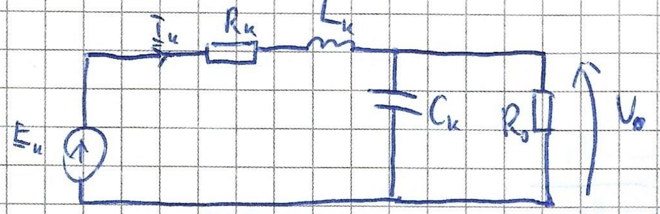
$X_k = X_k' d = 0,091 \cdot 5 = 0,455\ \Omega$

$L_k = \frac{X_k}{\omega} = \frac{0,455}{314} = 1,4 \cdot 10^{-3}\ H$

$C_k = C_k' \cdot d = 0,3962 \cdot 10^{-6} \cdot 5 = 1,981 \cdot 10^{-6}\ F$

$X_{CK} = \frac{1}{\omega C} = \frac{1}{314 \cdot 1,981 \cdot 10^{-6}} = 1,6068 \cdot 10^{3}\ \Omega$

STAN USTALONY:



$Z_{oc} = \frac{R_0 (-jX_{ck})}{R_0 - jX_{ck}} = \frac{2250 \cdot (-j1,6068 \cdot 10^3)}{2250 - j1,6068 \cdot 10^3} = 7,5993 \cdot 10^2 - j1,0641 \cdot 10^3$

$Z_k = R_k + jX_k + Z_{oc} = 7,612 \cdot 10^2 - j1,0641 \cdot 10^3 = 761,2 - j1064,1\ \Omega$

$|Z_k| = 1308\ \Omega \qquad \varphi_z = \mathrm{arctg}\frac{-1064,1}{761,2} = -0,9469\ \mathrm{rad}$

$\frac{E_k}{Z_k} = \frac{U_0}{Z_{oc}} \rightarrow E = \frac{U_0}{Z_{oc}} \cdot Z = \frac{8,6603 \cdot 10^3}{7,5993 \cdot 10^2 - j1,0641 \cdot 10^3} \cdot (761,2 - j1064,1) =$

$= 8,6627 \cdot 10^3 + j8,6232\ V$

$\psi_u = \mathrm{arctg}\frac{8,6232}{8,6627 \cdot 10^3} = 9,954 \cdot 10^{-4}\ \mathrm{rad}$

$|E_k| = \sqrt{(8662,7)^2 + (8,6232)^2} = 8,6627 \cdot 10^3\ V$

$E_m = \sqrt{2}\,|E_k| = 1,2251 \cdot 10^4\ V$

$I_k = \frac{E_k}{Z_k} = \frac{8,6627 \cdot 10^3 + j8,6232}{761,2 - j10,64} = 3,849 + j5,3897\ A$

$\psi_i = \mathrm{arctg}\frac{5,3897}{3,849} = 0,9506\ \mathrm{rad}$

$I_m = |I_k| = \sqrt{(3,849)^2 + (5,3897)^2} = 6,623\ A$

STAN USTALONY:

$$\begin{cases} e_k(t) = E_m \sin(\omega t) = 12251 \sin(314t) \\ i_k(t) = I_m \sin(\omega t + \psi_i) = 6,623 \sin(314t + 0,9506) \end{cases}$$

//BEZ STANÓW NIEUSTALONYCH — DUŻO OBLICZEŃ

TRANSMITANCJA UKŁADU Z ODBIORNIKIEM:

1. ~~Transmitancja~~ Impedancja zastępcza gałęzi poprzecznej:

$$Z_0(s) = \frac{R_{Fe} \cdot sL_N}{R_{Fe} + sL_N}$$

2. Impedancja transformatora – gałąź poprzeczna + strona wtórna

$$Z_2(s) = \frac{Z_0(s) \cdot (R_2' + sL_2' + R_{obc})}{Z_0(s) + R_2' + sL_2' + R_{obc}}$$

3. Impedancja zastępcza transformatora:

$$Z(s) = R_1 + sL_1 + Z_2(s)$$

4. Transmitancja układu (równanie dzielnika):

$$H(s) = \frac{R_{obc}'}{Z(s) + R_{obc}'}$$

$$H(s) = \frac{R_{obc}}{R_1 + sL_1 + \frac{R_{Fe} \cdot sL_N}{R_{Fe} + sL_N} \cdot (R_2}$$

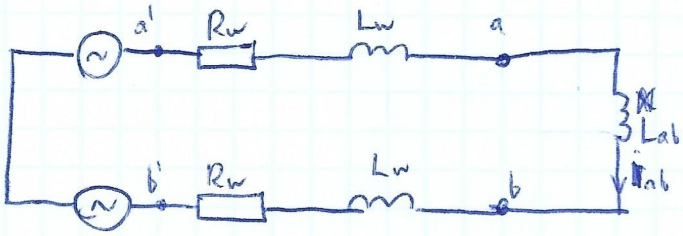
WARUNKI ABCN:

$$\underline{U}_{an} = 230\angle 0^\circ = 230V$$

$$\underline{U}_{bn} = 230\angle 240^\circ = -115-j199{,}2\ V$$

$$\underline{U}_{cn} = 230\angle 120^\circ = -115+j199{,}2V$$

OBWÓD AB:



$R_w = 0{,}02\ \Omega$

$L_w = 0{,}318\ mH$
$L_{ab} = 41{,}38\ mH$

$X_w = \omega L_w = 314 \cdot 0{,}318mH \approx 0{,}1\ \Omega$
$X_{ab} = \omega L_{ab} = 314 \cdot 41{,}38mH \approx 13\ \Omega$

PRĄD:
$$\underline{I}_{ab} = \frac{\underline{U}_{ab}}{jX_{ab}} = \frac{\underline{U}_{an} - \underline{U}_{bn}}{jX_{ab}} = \frac{230-(-115-j199{,}2)}{j13} = 26{,}54+j15{,}32\ \ A$$
$$\underline{I}_{ab} = 30{,}64\angle 30^\circ$$

SPADKI NAPIĘĆ:
$$\Delta\underline{U}_{w1} = \underline{I}_{ab}(R_w + jX_w) = (26{,}54+j15{,}32)(0{,}02+j0{,}1) = -1+j2{,}96\ V$$

NAPIĘCIA:
$$\underline{U}_{a'n'} = \underline{U}_a + \Delta\underline{U}_{w1} + \Delta\underline{U}_{w2} = 230 + (-1+j2{,}96) + (-1{,}85-j0{,}63) = 227{,}15+j2{,}33$$
$$\underline{U}_{b'n'} = \underline{U}_b - \Delta\underline{U}_{w1} + \Delta\underline{U}_{w2} = -115-j199{,}2-(-1+j2{,}96)+(-1{,}85-j0{,}63) = -115{,}85-j202{,}79$$

$$\underline{U}_{a'} = 227{,}16\angle 0^\circ\ \ V$$
$$\underline{U}_{b'} = 233{,}55\angle 240{,}26^\circ$$

STRATY MOCY LINII:

$$\Delta\underline{S}_w = 2\cdot\Delta\underline{U}_{w1}\cdot\underline{I}^*_{ab} = 2\cdot(-1+j2{,}96)(26{,}54-j15{,}32) = 37{,}61+j187{,}76\ VA$$

MOC ELEMENTU:

$$\underline{S}_{ab} = \underline{U}_{ab}\underline{I}^*_{ab} = (230-(-115-j199{,}2))(26{,}54-j15{,}32) =$$

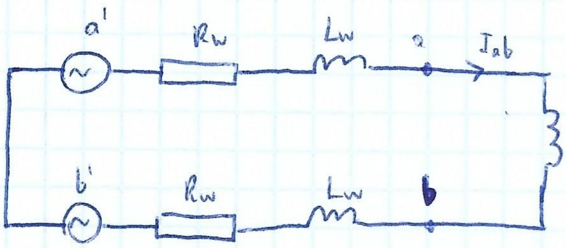
WARUNKI . abcn

$\underline{U}_{an} = 230\angle 0° = 230(\cos 0° + j\sin 0°) = 230\ V$

$\underline{U}_{bn} = 230\angle 240° = 230(\cos 240° + j\sin 240°) = -115 - j199{,}2\ V$

$\underline{U}_{cn} = 230\angle 120° = 230(\cos 120° + j\sin 120°) = -115 + j199{,}2\ V$

OCZKO AB:



$R_w = 0{,}02\ \Omega$
$L_w = 0{,}318\ mH$
$L_{ab} = 41{,}38\ mH$

$X_w = \omega L_w = 314 \cdot 0{,}318\ mH = 99{,}852\ m\Omega$

$X_{ab} = \omega L_{ab} = 314 \cdot 41{,}38\ mH = 12{,}99\ \Omega$

DO POPRAWY PRĄD

$\underline{I}_{ab} = \frac{\underline{U}_{an} - \underline{U}_{bn}}{2R_w + j2X_w + jX_{ab}} = \frac{230 - (-115 - j199{,}2)}{2\cdot 0{,}02 + j2\cdot 0{,}1 + j13} =$

$= 26{,}69 + j14{,}87\ A = 30{,}55\angle 29{,}12°$

$\underline{U}_{a'} = U_a + I_{ab}(R_w + jX_w) = 230 + (26{,}69 + j14{,}87)(0{,}02 + j0{,}1) = 229{,}05 + j2{,}97\ V$

$\underline{U}_{b'} = U_b - I_{ab}(R_w + jX_w) = (-115 - j199{,}2) - (26{,}69 + j14{,}87)(0{,}02 + j0{,}1) = -114{,}05 - j202{,}17\ V$

SPADKI NAPIĘĆ:

$U_a' = 229{,}07\angle 0{,}74°$

$U_b' = 232{,}12\angle 240{,}57°$

$\Delta\underline{U}_{a'a} = \underline{U}_{a'} - \underline{U}_a = 229{,}05 + j2{,}97 - 230 = -0{,}95 + j2{,}97\ V$

$\Delta\underline{U}_{b'b} = \underline{U}_{b'} - \underline{U}_b = -114{,}05 - j202{,}17 - (-115 - j199{,}2) = 0{,}95 - j2{,}97\ V$

$\Delta U_{a'a} = \Delta U_{b'b} = 3{,}12\ V$

PRĄD I MOC

$\boxed{\underline{S} = \underline{U}\,\underline{I}^*}$

$\underline{U}_{ab} = \underline{I}_{ab} \cdot jX_{ab} = (26{,}69 + j14{,}87)\cdot j13\ \Omega = -193{,}31 + j346{,}97\ V$

$\underline{S}_{ab} = \underline{U}_{ab}\underline{I}_{ab}^* = (-193{,}31 + j346{,}97)(26{,}69 - j14{,}87) = j12135{,}15\ VA$

COS φ:

$\underline{S}_a = \underline{U}_a \underline{I}_{ab}^* = 230\cdot(26{,}69 - j14{,}87) = 6138{,}7 - j3420{,}1\ VA$

$\underline{S}_b = \underline{U}_b \underline{I}_{ab}^* = (-115 - j199{,}2)(26{,}69 - j14{,}87) = -6031{,}454 - j3606{,}598\ VA$

$\cos\varphi_a = \cos\left(tg^{-1}\left(\frac{-3420{,}1}{6138{,}7}\right)\right) = 0{,}874$

$\cos\varphi_b = \cos\left(tg^{-1}\left(\frac{-3606{,}598}{-6031{,}454}\right)\right) = 0{,}858$

$\cos\varphi_{ab} = 0$

WAR. POCZĄTKOWE:

$\underline{U_{an}} = 230\angle 0^\circ$ $\underline{U_{bn}} = 230\angle 240^\circ$ $\underline{U_{cn}} = 230\angle 120^\circ$

$\underline{U_{an}} = 230 + j0$

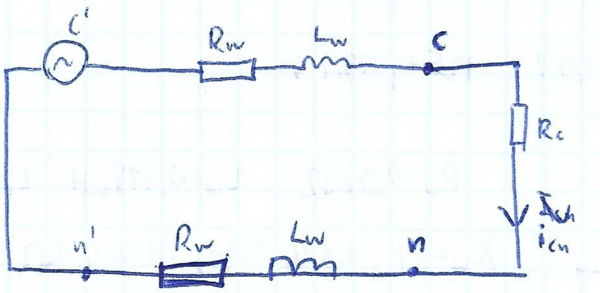
$\underline{U_{bn}} = 230e^{j240} = 230(\cos 240 + j\sin 240) = -115 - j200$

$\underline{U_{cn}} = 230e^{j120} = 230(\cos 120 + j\sin 120) = \cancel{-115}\ -115 + j199{,}2\ V$

PRĄD i_{ab}

$$i_{ab} = \frac{U_{an} - U_{bn}}{L_{ab} + 2R_w + 2L_w}$$

OCZKO CN:



$R_c = 12\,\Omega$

$\underline{U}_{cn} = -115 + j199{,}2\ V$

$\underline{I}_{cn} = \frac{\underline{U}_{cn}}{R_c} = \frac{-115+j199{,}2}{12} = -9{,}583 + j16{,}6\ A$ $\qquad$ $\underline{I}_{cn} = 19{,}17\angle 120^\circ$

$\Delta\underline{U}_{wz} = \underline{I}_{cn}(R_w + jX_w) = (-9{,}583 + j16{,}6)(0{,}02 + j0{,}1) = -1{,}85 - j0{,}63\ V$ $\qquad$ -60°

$\underline{U}_{c'n'} = \underline{U}_{cn} + 2\Delta\underline{U}_{wz} = -115 + j199{,}2 + 2\cdot(-1{,}85 - j0{,}63)\ V =$

$= -118{,}7 + j197{,}94$ $\qquad$ $-59{,}05^\circ$

$U_{c'n'} = 230{,}8\angle 120{,}95^\circ$ $\qquad$ -60

$-60+180=$

$\Delta\underline{S}_{cn} = 2\Delta\underline{U}_w\underline{I}^*_{cn} = 2\cdot(-1{,}85 - j0{,}63)\cdot(-9{,}583 - j16{,}6) = 14{,}54 + j73{,}49\ VA$ $\qquad$ 120

$\underline{S}_{Rc} = \underline{U}_{cn}\underline{I}^*_{cn} = (-115 + j199{,}2)(-9{,}583 - j16{,}6A) = 4408{,}77\ VA$ $\qquad$ -5

$\cos\varphi_c = 1$

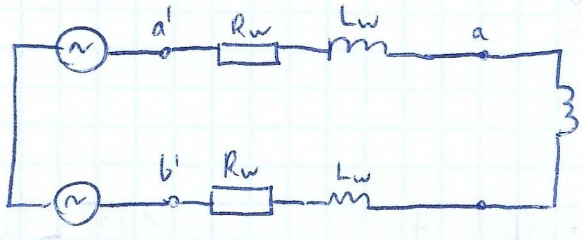
WARUNKI ABCN:

$\underline{U}_{an} = 230\angle 0^\circ = 230(\cos 0^\circ + j\sin 0^\circ) = 230 \ V$

$\underline{U}_{bn} = 230\angle 240^\circ = 230(\cos 240^\circ + j\sin 240^\circ) = -115 - j199{,}2 \ V$

$\underline{U}_{cn} = 230\angle 120^\circ = 230(\cos 120^\circ + j\sin 120^\circ) = -115 + j199{,}2 \ V$

OCZKO AB:



$R_w = 0{,}02\,\Omega \quad L_w = 0{,}318\,mH \quad L_{ab} = 41{,}38\,mH$

$X_w = \omega L_w = 314 \cdot 0{,}318\,mH \approx 0{,}1\,\Omega$

$X_{ab} = \omega L_{ab} = 314 \cdot 41{,}38\,mH \approx 13\,\Omega$

PRĄD: $\underline{I}_{ab} = \frac{\underline{U}_{ab}}{jX_{ab}} = \frac{\underline{U}_{an} - \underline{U}_{bn}}{jX_{ab}} = \frac{230-(-115-j199{,}2)}{j13} = 15{,}32 - j26{,}54 \ A$

$\underline{I}_{ab} = 30{,}64\angle -60^\circ$

SPADKI NAPIĘĆ: $\Delta \underline{U}_{w1} = \underline{I}_{ab}(R_w + jX_w) = (15{,}32 - j26{,}54)(0{,}02 + j0{,}1) = 2{,}96 + j1 \ V$

NAPIĘCIA: $\underline{U}_{a'} = \underline{U}_a + \Delta\underline{U}_{w1} + \Delta\underline{U}_{w2} = 230 + 2{,}96 + j1 + (-1{,}85 - j0{,}63) = 231{,}11 + j0{,}37$

$\underline{U}_{b'} = \underline{U}_b - \Delta\underline{U}_{w1} + \Delta\underline{U}_{w2} = -115 - j199{,}2 - (2{,}96 + j1) + (-1{,}85 - j0{,}63) = -119{,}81 - j200{,}83$

$U_{a'} = 231{,}11\angle 0{,}09^\circ$

$U_{b'} = 233{,}85\angle 239{,}18^\circ$

STRATY MOCY: LINII:

$\Delta \underline{S}_w = 2 \cdot \Delta\underline{U}_{w1} \cdot \underline{I}^*_{ab} = 2\cdot(2{,}96 + j1)(15{,}32 + j26{,}54) = 37{,}61 + j187{,}76 \ VA$

MOC ODBIORNIKA:

$\underline{S}_{ab} = \underline{U}_{ab}\underline{I}^*_{ab} = (230 - (-115 - j199{,}2)(15{,}32 + j26{,}54) \approx j12\,208 \ VA$

ŁĄCZNY POBÓR MOCY:

$\underline{S} = \underline{S}_{ab} + \underline{S}_{RC} = j12\,208 \ VA + 4409 \ VA = 4409 + j12208 \ VA$

$\cos\varphi = \cos\left(tg^{-1}\left(\frac{12208}{4409}\right)\right) = 0{,}34$

ŁĄCZNE STRATY MOCY:

$\Delta\underline{S} = \Delta\underline{S}_w + \Delta\underline{S}_{cn} = 37{,}61 + j187{,}76 + 14{,}54 + j73{,}49 \ VA$

$\Delta P = 52{,}15 \ W$

$\Delta Q = 261{,}25 \ Var$

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$P = 7$ $\quad d = 6 \cdot 10 = 60$ (km)

Linia napowietrzna: AFL 15

SILNIK: $P = 7 kW$ $\quad \cos\varphi = 0,95$ $\quad$ ~~$S = \frac{P}{\cos\varphi} = 7,3684 kVA$~~

~~$Z_0 = \frac{U_n^2}{S} = \frac{U_n}{...} = \frac{15^2}{7,3684} = 30,53 \Omega$~~

$R_0 =$

Dla 1 fazy: $P_0 = P/3 = 7/3 = 2,33 kW$ $\quad S_0 = \frac{P_0}{\cos\varphi} = \frac{2,33}{0,95} = 2,46 kVA$

$0,00246 MVA$

$U_0 = \frac{15 kV}{\sqrt{3}} = 8,66 kV$

$Z_0 = \frac{U_0^2}{S} = \frac{(8,66)^2}{2,46 kVA} = 30,53 k\Omega$

1

$R_0 = Z_0 \cos\varphi =$ $\quad X_0 = Z_0 \sin\varphi = 30,53 \cdot \sqrt{1-(0,95)^2}$

$= 30,53 \cdot 0,95 = 29 k\Omega$ $\quad = 9,53 k\Omega$

~~$L_0 = 0,0306 H$~~ $L_0 = 30,5 mH$

LINIA: $R = R' \cdot d = 0,434 \cdot 60 = 26,04 \Omega$

$X = X' \cdot d = 0,369 \cdot 60 = 22,14$ mH

TRAFO: $Z_T = \frac{12}{100} \cdot \frac{15^2}{0,025} = 1,08 \Omega$

Przy uleznanym Δp_{cu}: $X_T = Z_T =$ ~~$1,08 \Omega$~~ $0,0011 \Omega$

$L_T = \frac{X_T}{\omega} = \frac{1,08}{314} = 3,437$ mH

SYSTEM: $Z_s = \frac{U_n^2 \cdot c}{S_n} = \frac{15^2 \cdot 1,1}{800} = 0,3094 \Omega$

$\frac{R_s}{X_s} = 0,1 \rightarrow R_s = 0,1 X_s$ $\quad Z_s = \sqrt{R_s^2 + X_s^2} =$

~~$R_s = \sqrt{Z_s^2 - 0,1}$~~ $\quad Z_s = \sqrt{(0,1 X_s)^2 + X_s^2} =$

$Z_s = \sqrt{1,1 X_s^2} \rightarrow 1,1 X_s^2 = Z_s^2 \rightarrow X_s = \sqrt{\frac{Z_s}{1,1}}$

$X_s = \sqrt{\frac{0,3094}{1,1}} = 0,53 \Omega$ $\quad R_s = 0,1 X_s = 0,053 \Omega$

$L_s = \frac{X_s}{\omega} = \frac{0,573}{314} = 0,0017$ H

Punkt 1:

Zakładam, że skoro napięcie na zaciskach abcn jest znamionowe, to:

$$U_{an} = \frac{U_n}{\sqrt{3}} = 8{,}66\ kV$$

Z parametrów silnika: $R_0 = 29\,k\Omega$ $X_0 = 9{,}53\,k\Omega$

$$\underline{I}_{an} = \frac{U_{an}}{R_0 + jX_0} = \frac{8{,}66\ kV}{29 + j9{,}53} = 0{,}27 - j0{,}089\ kA$$

$$I_{an} = \frac{U_{an}}{Z_0} = \frac{8{,}66}{30{,}53} = 0{,}2837\ \cancel{k}A$$

Napięcie zespolone:

$$\underline{U}_{an} = \underline{I}_{an} \cdot \underline{Z}_0 = (0{,}27 - j0{,}089)(29 + j9{,}53) = 8{,}663 + j0{,}0005\ kV$$

$$\underline{S}_{an} = \underline{U}\underline{I}^* = \underline{U}_{an}\underline{I}_{an}^* = (8{,}663 + j0{,}0005)(0{,}27 + j0{,}089) =$$

$$= 2{,}3349 + j0{,}7674\ kVA$$

WSKAZANIA PRZYRZĄDÓW:

$A_1 = A_2 = A_3 = \cancel{283{,}7\ kA}$ $0{,}2837\ A$

$V_1 = 8{,}66\ kV$

$W = 2{,}335\ kW$

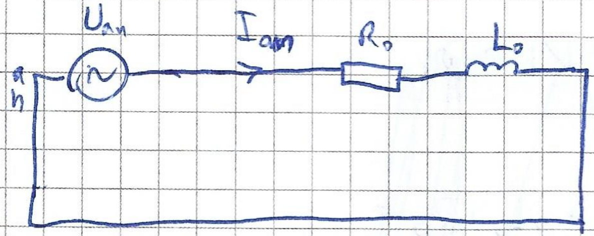
PUNKT 2: P_1, W_1 zamknięte:

STAN USTALONY 1:

$U_a = 8{,}66\sqrt{2}\,\sin(\omega t)$

$I_a = 0{,}2837\sqrt{2}\,\sin(\omega t - 18{,}19°)$

$\varphi_I = \arctan\left(\frac{-0{,}089}{0{,}27}\right) = -18{,}19°$



STAN USTALONY 2:

$U_a = 8{,}66\,\sin(\omega t)$ $\qquad I_a = 0\,\sin(\omega t)$

WARUNKI POCZĄTKOWE: $U = U_{max} \to \sin(\omega t) = 0$, $\quad t=0$, $\varphi_U = 90°$

$U_0^- = 8{,}66\sqrt{2}$ kV

$I_0^- = 0{,}2837\sqrt{2}\sin(\overset{t=0}{314t} - 18{,}19° + 90°) = 0{,}2837\sqrt{2}\,\sin(-18{,}19+90) =$

$= 0{,}3811$ A

$U_{an}(t) = i_{an}(t)R_0 + L_0\frac{di_a(t)}{dt}$

$I_0^+ = I_0^-$ $\quad i(t=0^-) = i(t=0^+) = 0{,}3811$ A

$0 = i_{an}(t)R_0 + L_0\frac{di_a(t)}{dt} \to 0 = R_0 + L_0\lambda \to \lambda = \frac{-R_0}{L_0} = -955{,}81$

$i_p(t) = Ae^{\lambda t} = Ae^{-955{,}81t}$

CZYLI PRĄD PO WYŁĄCZENIU:

$i_a(t) = 0{,}3811\,e^{-955{,}81t}$

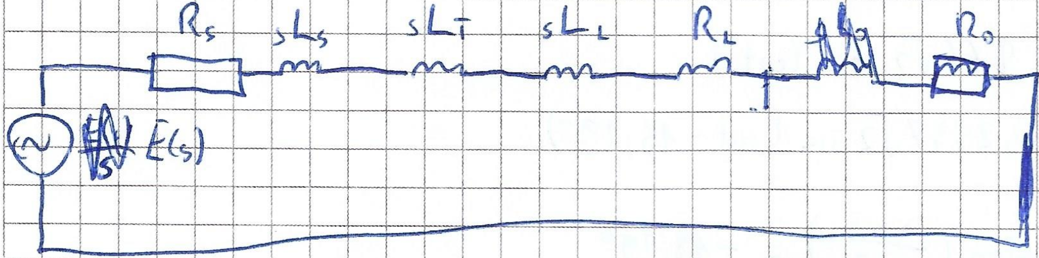
NAPIĘCIE:

$u_a(t) = 0{,}2837\sqrt{2}\,\sin(\omega t + 90°)$

$U_{max} = 8{,}66\sqrt{2}$ kV

PUNKT 3:

DLA JEDNEJ FAZY:



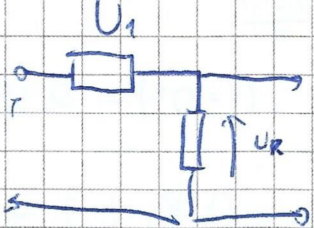
~~TRANSMITANCJA UKŁADU~~

$$\cancel{Z(s) = R_s + sL_s + sL_T + sL_L + R_L + sL_o + R_o =}$$

$$\cancel{i(t) = \frac{E(s)}{s} \cdot}$$

$$\cancel{Z(s) = R_s + R_L + R_o + s(L_s + L_T + L_L + L_o) =}$$

$$\cancel{= 29{,}035 \cdot 10^3 + s52{,}4918}$$

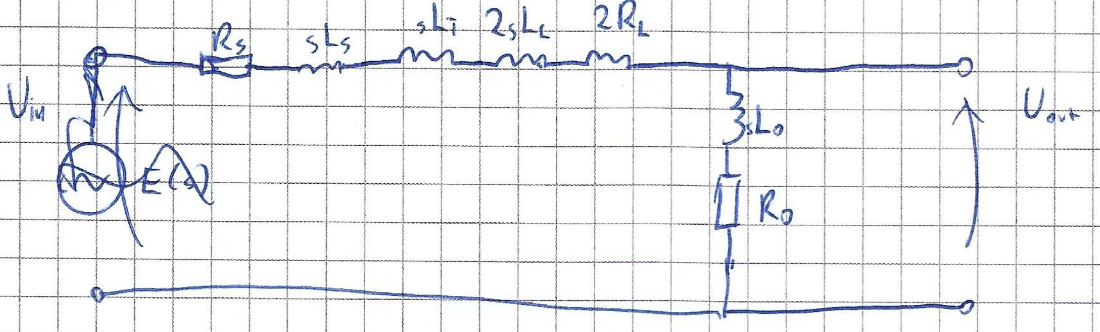


$U_0 = U_R$

$$U_R = U_{in} - U_1 \rightarrow U_{in} = U_R + U_1$$

$$\frac{U_R}{U_{in}} = \cancel{\frac{U_{in} - U_1}{U_1}} = \frac{U_R}{U_R + U_1}$$

Punkt 3:



TRANSMITANCJA:

$$H(s) = \frac{sL_0 + R_0}{sL_0 + R_0 + R_s + sL_s + sL_T + 2sL_s + 2R_L} =$$

$$= \frac{2{,}909 \cdot 10^4 + s30{,}35}{29061 + s74{,}63}$$

Zera: $30{,}35s + 2{,}909 \cdot 10^4 = 0$

$$s = \frac{-2{,}909 \cdot 10^4}{30{,}35s} = -955{,}8091$$

Bieguny: $s74{,}63 + 29061 = 0$

$$s = \frac{-29061}{74{,}63} = -387{,}84$$