TET4100 Kretsanalyse – Løsning

Institutt: Elkraftteknikk Dato: 2012.08.15

Øving 3

8) Vekselstrømanalyse 3.A

8.1) $v_s(t)=V_s\cdot\cos(\omega_f t+\phi_s)$ $\omega_f=2\pi f_f \approx 502{,}65$

$v_s(t=0)=\hat{V}_s\cdot\cos(\phi_s)$

$$\phi_s=\cos^{-1}\left(\frac{\hat{V}_s}{2\hat{V}_s}\right)=\cos^{-1}\left(\frac{1}{2}\right)=\pm\frac{\pi}{3}rad\rightarrow spenning\ stigende\rightarrow\phi_s=-\frac{\pi}{3}rad$$

$$v_s(t)=\hat{V}_s\cdot\cos(\omega_f t+\phi_s)$$

8.2) $V_{s,eff}=\frac{\hat{V}_s}{\sqrt{2}} = 63{,}64\,V$

8.3) $T_f=\frac{1}{f_f} = 12{,}5\ ms$

8.4) $\hat{V}_s\cdot\cos(\omega_f t_1+\phi_s)=\hat{V}_s$ $t_1>0$

$\rightarrow$ $\cos(\omega_f t_1+\phi_s)=1$ $\rightarrow$ $\omega_f\cdot t_1+\phi_s=0$

$t_1=\frac{-\phi_s}{\omega_f} \approx 2{,}1\ ms$

8.5) $\phi(t_2)=\omega_f\cdot t_2+\phi_s \approx 1{,}47\ rad$

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9) Vekselstrømanalyse 3.B

9.1) $v(t)=V_1\cdot\cos(\omega t+\phi_1)+V_2\cdot\sin(\omega t+\phi_2)$

$$\sin(x)=\cos\left(x-\frac{\pi}{2}rad\right)$$

$$\phi_2'=\phi_2-\frac{\pi}{2}rad$$

$$v(t)=V_1\cdot\cos(\omega t+\phi_1)+V_2\cdot\cos(\omega t+\phi_2')$$

$$\mathbf{V}=V_1\measuredangle\phi_1+V_2\measuredangle\phi_2'$$

$$\mathbf{V}=V_1(\cos(\phi_1)+j\sin(\phi_1))+V_2(\cos(\phi_2')+j\sin(\phi_2'))$$

$$\mathbf{V}=(V_1\cos(\phi_1)+V_2\cos(\phi_2'))+j(V_1\sin(\phi_1)+V_2\sin(\phi_2'))$$

$$V=\sqrt{(V_1\cos(\phi_1)+V_2\cos(\phi_2'))^2+(V_1\sin(\phi_1)+V_2\sin(\phi_2'))^2}$$

$$\phi=atan\left(\frac{V_1\sin(\phi_1)+V_2\sin(\phi_2')}{V_1\cos(\phi_1)+V_2\cos(\phi_2')}\right)$$

$$\mathbf{V}=V\measuredangle\phi$$

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10) Vekselstrømanalyse 3.C

10.1) $R_\beta = \frac{1}{G_\beta} = 4$ $X_\gamma = \omega L_\gamma = 2$ $X_\delta = -\frac{1}{\omega_f C_\delta} = \div 2{,}5$

$G_\alpha = \frac{1}{R_\alpha} = 0{,}2$ $B_\gamma = -\frac{1}{X_\gamma} = -\frac{1}{\omega_f L_\gamma} = \div 0{,}5$ $B_\delta = -\frac{1}{X_\delta} = \omega_f C_\delta = 0{,}4$

$Z_\alpha = R_\alpha$ $Z_\beta = R_\beta$

$Z_\gamma = j X_\gamma = j \omega_f L_\gamma = 2j$ $Z_\delta = j X_\delta = -j \frac{1}{\omega_f C_\delta} = \div 2{,}5j$

$Y_\alpha = \frac{1}{Z_\alpha} = \frac{1}{R_\alpha} = G_\alpha = 0{,}2$ $Y_\beta = \frac{1}{Z_\beta} = \frac{1}{R_\beta} = G_\beta = 0{,}25$

$Y_\gamma = \frac{1}{Z_\gamma} = -j \frac{1}{X_\gamma} = j B_\gamma = -j \frac{1}{\omega_f L_\gamma}$ $Y_\delta = \frac{1}{Z_\delta} = -j \frac{1}{X_\delta} = j B_\delta = j \omega_f C_\delta$

10.2) $R_{ser} = R_\alpha + R_\beta = 9$ $X_{ser} = X_\gamma + X_\delta = \div 0{,}5$ $Z_{ser} = R_{ser} + j X_{ser} = 9 \div 0{,}5j$

$G_{ser} = \frac{1}{R_{ser}} = \frac{1}{\frac{1}{G_\alpha} + \frac{1}{G_\beta}} = 0{,}11$ $B_{ser} = -\frac{1}{X_{ser}} = \frac{1}{\frac{1}{B_\gamma} + \frac{1}{B_\delta}} = 2$

$Y_{ser} = \frac{1}{Z_{ser}} = \frac{1}{\frac{1}{G_{ser}} + \frac{1}{j B_{ser}}} = 0{,}11 + 0{,}0062i$

10.3) $G_{par} = G_\alpha + G_\beta = 0{,}45$ $B_{par} = B_\gamma + B_\delta = \div 0{,}1$ $Y_{par} = G_{par} + j B_{par} = 0{,}45 \div 0{,}1j$

$R_{par} = \frac{1}{G_{par}} = \frac{1}{\frac{1}{R_\alpha} + \frac{1}{R_\beta}} = 2{,}22$ $X_{par} = -\frac{1}{B_{par}} = \frac{1}{\frac{1}{X_\gamma} + \frac{1}{X_\delta}} = 10$

$Z_{par} = \frac{1}{Y_{par}} = \frac{1}{\frac{1}{R_{ser}} + \frac{1}{j X_{ser}}} = 2{,}12 + 0{,}47j$

10.4) *Sett inn tallverdier*

10.5) *Negative verdier:* X_δ B_γ X_{ser} B_{par}

Verdier med negativ vinkel: Z_δ Y_γ Z_{ser} Y_{par}

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11) Vekselstrømanalyse 3.D

11.1) $X_{C_1}=-\frac{1}{\omega_f C_1}$ $X_{L_1}=\omega_f L_1$

Beregner først impedansen til parallellkoblingen:

$$Z_{par}=\left(R_2+j X_{C_1}\right)\|\left(j X_{L_1}\right)$$

$$Z_{par}=\frac{\left(R_2+j X_{C_1}\right)\cdot\left(j X_{L_1}\right)}{\left(R_2+j X_{C_1}\right)+\left(j X_{L_1}\right)}$$

$$Z_{par}=\frac{-X_{C_1}X_{L_1}+j R_2 X_{L_1}}{R_2+j\left(X_{C_1}+X_{L_1}\right)} = 40+20j$$

Utgår!

$$Z_{par}=\frac{-X_{C_1}X_{L_1}+j R_2 X_{L_1}}{R_2+j\left(X_{C_1}+X_{L_1}\right)}\cdot\frac{R_2-j\left(X_{C_1}+X_{L_1}\right)}{R_2-j\left(X_{C_1}+X_{L_1}\right)}$$

$$Z_{par}=\frac{-R_2 X_{C_1}X_{L_1}+R_2 X_{L_1}\left(X_{C_1}+X_{L_1}\right)}{R_2^2+\left(X_{C_1}+X_{L_1}\right)^2}+j\frac{R_2^2 X_{L_1}+X_{C_1}X_{L_1}\left(X_{C_1}+X_{L_1}\right)}{R_2^2+\left(X_{C_1}+X_{L_1}\right)^2}$$

$$R_{par}=\frac{X_{L_1}}{R_2^2+\left(X_{C_1}+X_{L_1}\right)^2}$$

$$X_{par}=\frac{R_2^2 X_{L_1}+X_{L_1}X_{C_1}^2+X_{L_1}^2 X_{C_1}}{R_2^2+\left(X_{C_1}+X_{L_1}\right)^2}$$

$$Z_{par}=R_{par}+j X_{par} = 40+20j$$

$$Z_{ab}=R_1+R_{par}+j X_{par}$$

$$R_{ab}=R_1+R_{par} \qquad X_{ab}=X_{par}$$

$$Z_{ab}=R_{ab}+j X_{ab} = 44+20j$$

$$Z_{ab}=\sqrt{R_{ab}^2+X_{ab}^2}\measuredangle atan\left(\frac{X_{ab}}{R_{ab}}\right) = 48{,}33 \measuredangle 24{,}4^\circ$$

12) Vekselstrømanalyse 3.E

12.1) Åpen krets:

$$\boldsymbol{V}_{åk}=\boldsymbol{V}_s\frac{jX_C}{R+jX_L+jX_C}$$

Kortslutning:

$$\boldsymbol{I}_{ks}=\frac{\boldsymbol{V}_s}{R+jX_L}$$

$$\boldsymbol{V}_{Th}=\boldsymbol{V}_{åk}=\boldsymbol{V}_s\frac{jX_C}{R+jX_L+jX_C}$$

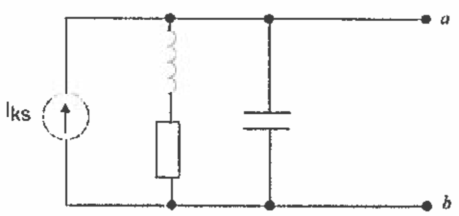
$$Z_{Th}=\frac{\boldsymbol{V}_{åk}}{\boldsymbol{I}_{ks}}=\frac{RX_C^2}{R^2+(X_C+X_L)^2}+j\frac{R^2X_C+X_L^2X_C+X_LX_C^2}{R^2+(X_C+X_L)^2} = 3{,}79 \div 14{,}73j$$

Alternativ Løsning:

Kortslutning:

$$\boldsymbol{I}_{ks}=\frac{\boldsymbol{V}_s}{R+jX_L}$$

Norton Ekvivalent:



$$Z_{Th}=(R+jX_L)\|jX_C=\frac{RX_C^2}{R^2+(X_C+X_L)^2}+j\frac{R^2X_C+X_L^2X_C+X_LX_C^2}{R^2+(X_C+X_L)^2}$$

$$\boldsymbol{V}_{Th}=\boldsymbol{I}_{ks}\cdot Z_{Th}$$

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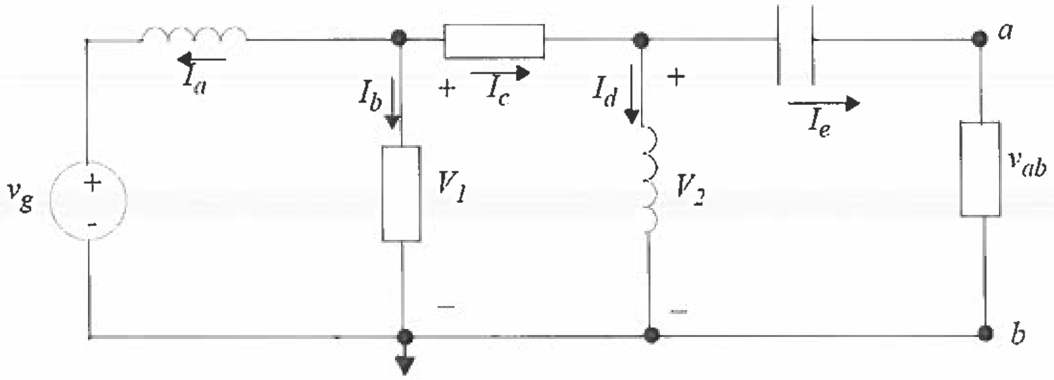
13) Vekselstrømanalyse 3.F

13.1)



$$V_g = \frac{\hat{V}_g \measuredangle \phi_g}{\sqrt{2}}$$

$$X_{L_1} = \omega_f L_1 \qquad X_{L_2} = \omega_f L_2 \qquad X_C = -\frac{1}{\omega_f C}$$

$$I_a = \frac{V_1 - V_g}{jX_{L_1}} \quad I_b = \frac{V_1}{R_1} \quad I_c = \frac{V_1 - V_2}{R_2} \quad I_d = \frac{V_2}{jX_{L_2}} \quad I_e = \frac{V_2}{R_3 + jX_C}$$

$$I_a + I_b + I_c = 0$$

$$\frac{V_1 - V_g}{jX_{L_1}} + \frac{V_1}{R_1} + \frac{V_1 - V_2}{R_2} = 0$$

$$\left(\left(\frac{R_2}{R_1} + 1\right) - j\left(\frac{R_2}{X_{L_1}}\right)\right)V_1 + \left(j\frac{R_2}{X_{L_1}}\right)V_g = V_2$$

$$K_1 = \left(\frac{R_2}{R_1} + 1\right) - j\left(\frac{R_2}{X_{L_1}}\right) = 2{,}2 - 6j \qquad K_2 = j\frac{R_2}{X_{L_1}} = 6j$$

$$K_1 V_1 + K_2 V_g = V_2$$

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$$I_d + I_e - I_c = 0$$

$$\frac{V_2}{jX_{L_2}} + \frac{V_2}{R_3 + jX_C} - \frac{V_1 - V_2}{R_2} = 0$$

$$\left(\left(1 + \frac{R_2 R_3}{R_3^2 + X_C^2}\right) - j\left(\frac{R_2 X_C}{R_3^2 + X_C^2} + \frac{R_2}{X_{L_2}}\right)\right) V_2 = V_1$$

$$K_3 = \left(1 + \frac{R_2 R_3}{R_3^2 + X_C^2}\right) - j\left(\frac{R_2 X_C}{R_3^2 + X_C^2} + \frac{R_2}{X_{L_2}}\right) = 1{,}48 \div 2{,}76j$$

$$K_3 V_2 = V_1$$

$$V_2 = K_1 K_3 V_2 + K_2 V_g$$

$$V_2 = \frac{K_2}{1 - K_1 K_3} V_g$$

$$, V_g = \frac{\hat{V}_g}{\sqrt{2}} \measuredangle \phi_g = 28{,}28 \measuredangle \div \frac{\pi}{3}$$

[illegible]

$$V_{ab} = \left(\frac{R_3}{R_3 + jX_C}\right) V_2$$

$$V_{ab} = \left(\left(\frac{R_3^2}{R_3^2 + X_C^2}\right) - j\left(\frac{R_3 X_C}{R_3^2 + X_C^2}\right)\right) V_2$$

$$K_4 = \left(\frac{R_3^2}{R_3^2 + X_C^2}\right) - j\left(\frac{R_3 X_C}{R_3^2 + X_C^2}\right)$$

$$V_{ab} = K_4 V_2 \qquad K_4 = 0{,}8 + 0{,}4j$$

$$V_{ab} = \frac{K_2 K_4}{1 - K_1 K_3} V_g = K_5 V_g$$

$$V_{ab} = V_{ab} \measuredangle \phi_{ab} \qquad \hat{V}_{ab} = \sqrt{2}\, V_{ab}$$

$$v_{ab}(t) = \hat{V}_{ab} \cdot \cos(\omega_f t + \phi_{ab})$$

$\cancel{, K_5 = 1{,}21 - 0{,}436j}$

$\cancel{V_{ab} = 36{,}37 \measuredangle \div 79{,}8^\circ}$

$\cancel{\hat{V}_{ab} = 51{,}46 \text{ V}}$

$K_5 = 0{,}0875 - 0{,}268j$

$V_{ab} = -5{,}33 - 5{,}94j = 7{,}98 \measuredangle -131{,}9^\circ$

$\hat{V}_{ab} = 11{,}28$