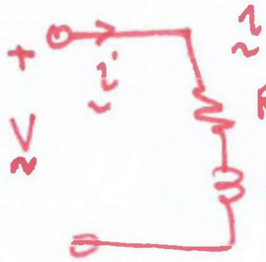
DEVRE TEORİSİ (SSH'de GÜÇ-ENERJİ-KOMPANZASYON) 1

[ÖZET]

BİLGİ:

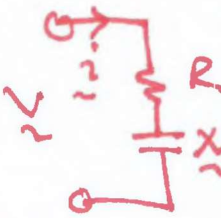
$\tilde{i} = |i| \angle \theta_i$

$\tilde{V} = |V| \angle \theta_v$



$[\tilde{z} = R + jX_L]$

$\tilde{z}$ → Empedans; R → Direnç; X_L → Reaktans (endüktif)



$(\tilde{z} = R - jX_C)$

$\tilde{z}$ → Empedans; R → Direnç; X_C → Kapasitif Reaktans

$$\tilde{S} = \tilde{V} * \tilde{I}^* = |V||I| \angle \theta_v - \theta_i$$

$$= |V|.|I|. \angle \varphi \quad \text{(faz açısı)}$$

$$\tilde{S} = \underbrace{|V||I|.\cos\varphi}_{P} + j\underbrace{|V|.|I|.\sin\varphi}_{Q}$$

$\tilde{S}$ → [Kompleks Güç VA, kVA, ...]

P (Aktif Güç) [W - kW ..]

Q → [VAr, kVAr, ..]

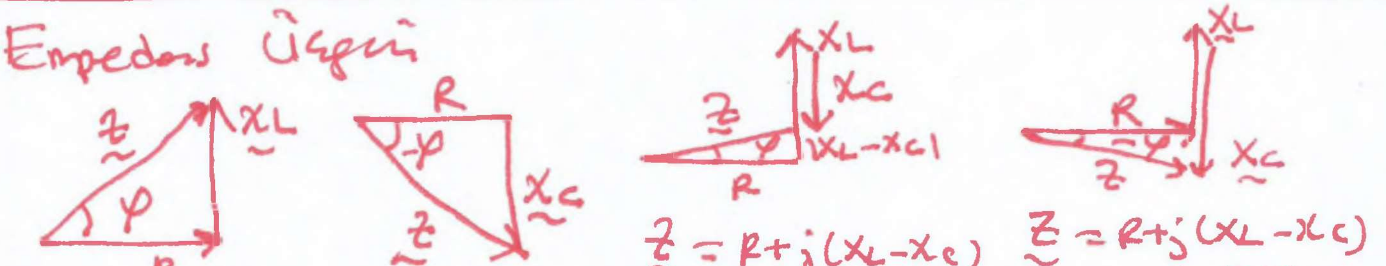
$$\left[\begin{array}{l} P = R.|i|^2 \\ Q = X.|i|^2 \\ |S| = |Z|.|i|^2 \\ |S| = \sqrt{P^2 + Q^2} \end{array}\right]$$

$|S| = |V|.|I|$ [VA]

(Görünür (Zâhiri) Güç)

$\cos\varphi$ [Güç Faktörü]

Empedans Üçgeni



$\tilde{z} = R + jX_L$ (endüktif)

$\tilde{z} = R - jX_C$ (kapasitif)

$\tilde{z} = R + j(X_L - X_C)$, $X_L > X_C$

$\tilde{z} = R + j(X_L - X_C)$, $X_C > X_L$

$(X_L = X_C)$ (omik)

(omik) $(X_L = X_C = 0)$

$$\tilde{Y} = \frac{1}{\tilde{z}} = G + jB$$

$\tilde{Y}$ → Admitans; G → Kondüktans (İletkenlik); B → Süseptans

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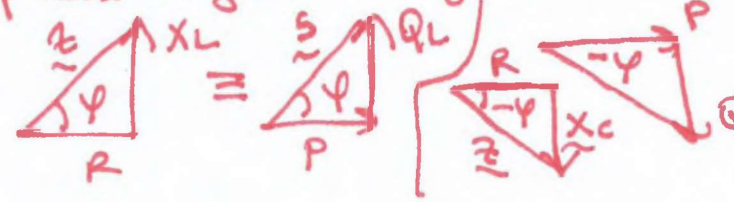
Güç Üçgeni (Empedans üçgeni ile aynı özelliklere sahip)

R varsa P verir

X_L varsa Q_L verir

X_C varsa Q_C verir

R, X varsa → S verir



gibi

KOMPANZASYON

$Q_C = P * (\tan\varphi_1 - \tan\varphi_2)$ ← $\cos\varphi_1$'i $\cos\varphi_2$'ye getirmek için Gerekli kond. gücü

(Gerekli kondansatör gücü)

Yüke paralel bağlanır.

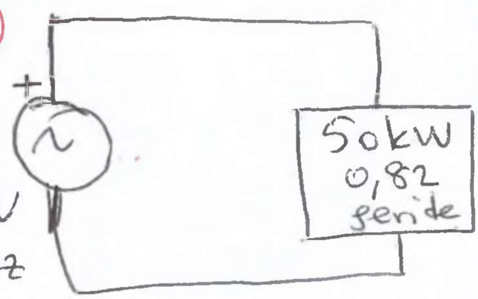
$Q_C = w.C.V^2 \Rightarrow \boxed{C = \frac{Q_C}{w.V^2}}$ Gerekli C değeri

$\cos\varphi_2 = 1$ ise tam kompanzasyon denir.

Ç.i, 2

Örnekler

1



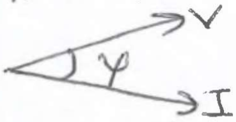
$480\angle 0^\circ$ V
$f = 60$ Hz
olsun.

a) $\cos\varphi_2 = 0{,}95$ için gerekli C, Q_c değerini bulunuz

b) Kompanzasyon öncesi ve sonrası hat akımlarını bulunuz c) Güç üçgenlerini çiziniz.

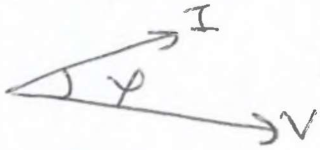
d) Yükün elektriksel eşdeğer parametreleri

geride demek (endüktif) yani, akım açısı, gerilim açısından küçük (geride)



(Endüktif yük durumu)

ileride demek (kapasitif) akım açısı, gerilim açısından ileride (daha büyük)



(kapasitif yük durumu)

omik çalışma ise

$\varphi = 0^\circ$

a) $P = 50$ kW $\qquad |S| = \dfrac{P}{\cos\varphi_1} = 60{,}97$ kVA

$\cos\varphi_1 = 0{,}82 \Rightarrow$
$\sin\varphi_1 =$
$\varphi_1 = \arccos(0{,}82) = 34{,}91^\circ$

$Q_L = |S|\cdot\sin\varphi_1 = 60{,}975 * 0{,}572$

$Q_L \cong 34{,}88$ kVAr

$\cos\varphi_2 = 0{,}95 \Rightarrow \varphi_2 = 18{,}195^\circ$

$\tan\varphi_1 \cong 0{,}7 \qquad \tan\varphi_2 = 0{,}328$

$\omega = 2\cdot 3{,}14\cdot 60 \cong 377$ rad/s

$$Q_C = P * (\tan\varphi_1 - \tan\varphi_2)$$

$$Q_C = 50000(0{,}7 - 0{,}328) = 18600 \text{ VAr}$$

$$Q_C = \omega\cdot C\cdot V^2 \Rightarrow C = \frac{Q_C}{\omega\cdot V^2} = \frac{18600}{377\cdot 480^2} \cong 214\ \mu F$$

b) $P = VI\cos\varphi_1$ (önce)

$I = \dfrac{50000}{480\cdot 0{,}82} \cong 127$ A

$\underset{\sim}{I} = 127\angle -34{,}91^\circ$ A

(sonra)

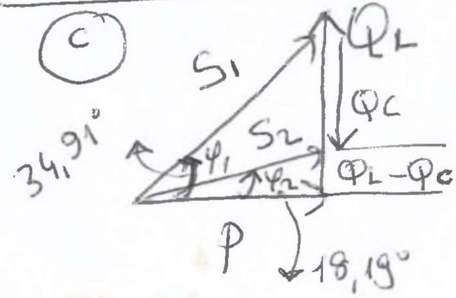
$P = VI\cos\varphi_2$

$50000 = 480\cdot I\cdot 0{,}95$

$I = \dfrac{50000}{480\cdot 0{,}95} = 109{,}65$ A

$\underset{\sim}{I} = 109{,}65\angle -18{,}19^\circ$ A

c)



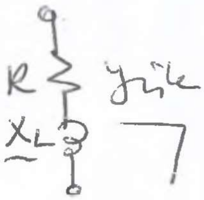
d) Yükün elektriksel eşdeğeri (R,X) cinsinden

$P = RI^2 = 50000 = R\cdot(127)^2$

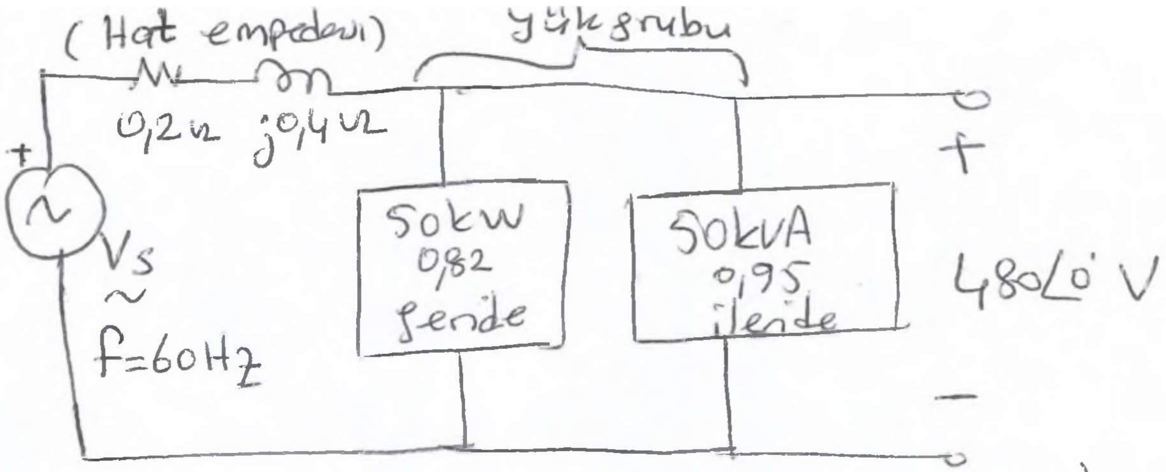
$R = 3{,}1\ \Omega$

$Q = XI^2 = 34880 = X\cdot(127)^2$

$X = 2{,}162\ \Omega$



(2)



a) $\tilde{V}_s$ gerilimini, güç katsayını ($\cos\varphi_1$) bulunuz.

b) $\cos\varphi_b = 0{,}99$ (geride - yük sistemi için) olması için yüke bağlanması gereken C, Q_c değerini bulunuz

c) Kompanzasyon öncesi ve sonrası için hat kayıplarını bulunuz.

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a) 1. yük

$P_1 = 50\,kW$

$|S| = \frac{50}{0{,}82} = 60{,}97\,kVA$

$Q_1 = |S| \cdot \sin\varphi_1 \Rightarrow 60{,}97 * \sin(34{,}91)$

$Q_1 = 34{,}9\,kVAr$ (geride) (+)

2. yük

$|S_2| = 50\,kVA$

$P_2 = 50 * 0{,}95 = 47{,}5\,kW$

$\varphi_2 = 18{,}19$

$\sin\varphi_2 = 0{,}312$

$Q_2 = |S_2| \cdot \sin\varphi_2$

$= 50 * 0{,}312 = 15{,}6\,kVAr$

ileride (−)

$\Sigma P = P1 + P2 = 97{,}5\,kW$

$\Sigma Q = 34{,}9 - 15{,}6$

$\Sigma Q = 19{,}3\,kVAr$

$\tilde{\Sigma S} = \Sigma P + j\,\Sigma Q$

$= 97{,}5 + j\,19{,}3$

$= \underbrace{99{,}39\angle 11{,}2°}_{\varphi\text{ (yük açısı)}}\,kVA$

$\tan\varphi_a = 0{,}198$

$\tilde{V}s = \tilde{Z}h * \tilde{I} + 480\angle 0°$

$\tilde{V}s = (0{,}2 + j0{,}4) * (207{,}06\angle -11{,}2) + 480\angle 0°$

$\tilde{V}s = 541{,}68 \angle 7{,}77\ V$

$\Sigma \tilde{S}_{yük} = \tilde{V} * \tilde{I}^*$

$\tilde{I}^* = \frac{99390\angle 11{,}2°}{480\angle 0°}$

$\tilde{I} = 207{,}06 \angle -11{,}2°\ A$

Kompanzasyon öncesi

$\cos\varphi_b = 0{,}99$

$\varphi_b = 8{,}1$

$\tan\varphi_b = 0{,}142$

b) Yük-sistemi için

$Q_c = \Sigma P * (\tan\varphi_a - \tan\varphi_b)$

$= 97500 * (0{,}198 - 0{,}142)$

$Q_c = 5460\,VAr = w \cdot C \cdot V^2 = 377 \cdot C \cdot 480^2$

$C = \frac{5460}{377 \cdot 480^2} = 62{,}86\,\mu F$

$Q_{yeni} = \Sigma Q - Q_c$

$= 19{,}3 - 5{,}46$

$= 13840\ VAr$

→ devamı ...

$$\Sigma \underset{\sim}{S}_{yük\,yeni} = \Sigma P + j\,\Sigma Q_{yeni}$$

$$= 97{,}5 + j\,13{,}84 \cong 98{,}477\angle 8{,}1^\circ \ kVA$$

$$\Sigma \underset{\sim}{S}_{yeni} = \underset{\sim}{V} * \underset{\sim}{I}^{*}_{yeni}$$

$$\underset{\sim}{I}^{*}_{yeni} = \frac{98477\angle 8{,}1}{480\angle 0} = 205{,}16\angle 8{,}1^\circ \ A$$

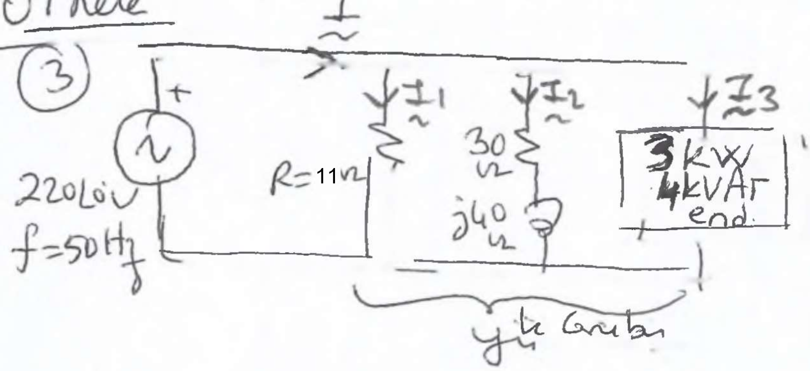
$$\boxed{\underset{\sim}{I}_{yeni} = 205{,}16\angle -8{,}1^\circ \ A}$$

$$P_{hat\,eski} = R_{hat} * |I_{eski}|^2 = (0{,}2) * (207{,}06)^2 = 8575\,W$$

$$P_{hat\,yeni} = R_{hat} * |I_{yeni}|^2 = (0{,}2) * (205{,}16)^2 = 8418\,W$$

fark k gipfiu = 157 W [kazancımız]

Örnek 3



a) Yük grubu için
$\Sigma P, \Sigma Q, \Sigma \underset{\sim}{S}, \cos\varphi_1, \tan\varphi_1 = ?$

b) $\cos\varphi_2 = 0{,}97$ olması için paralel C, Q_C değerlerini bulunuz.

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a) $\underset{\sim}{I}_1 = \frac{220\angle 0}{11} = 20\angle 0\,A$

$P_1 = R\,|I_1|^2 = 11 * 20^2 = 4{,}4\,kW$

$Q_1 = 0\ VAr$

$\underset{\sim}{I}_2 = \frac{220\angle 0}{50\angle 53{,}1} = 4{,}4\angle -53{,}1\,A$

$P_2 = R\,|I_2|^2 = 580{,}8\ W$

$Q_2 = X\,|I_2|^2 = 774{,}4\ VAr\ (+)$

$P_3 = 3\,kW$

$Q_3 = 4\,kVAr$ (end)

$\Sigma P = P_1 + P_2 + P_3 = 4400 + 580{,}8 + 3000 = 7980{,}8\ W$

$\Sigma Q = Q_1 + Q_2 + Q_3 = 0 + 774{,}4 + 4000 = 4774{,}4\ VAr$

$\Sigma S = \Sigma P + j\,\Sigma Q = 7980{,}8 + j\,4774{,}4\ VA \cong 9300\angle 30{,}9^\circ\ VA$

$\cos 30{,}9^\circ = 0{,}858$

$\tan 30{,}9 = 0{,}598$

$\cos\varphi_2 = 0{,}97$

$\varphi_2 = \arccos(0{,}97) = 14{,}07^\circ$

$\tan\varphi_2 = 0{,}25$

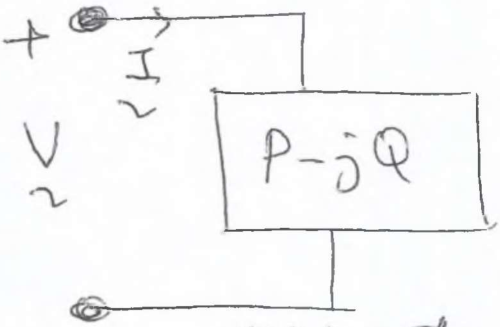
$Q_C = \Sigma P * (\tan\varphi_1 - \tan\varphi_2) = 7980{,}8\,(0{,}598 - 0{,}25) = 2777{,}3\ VAr$

$C = \frac{Q_C}{\omega V^2} = \frac{2777{,}3}{2\pi 50 \cdot 220^2} \cong 182\ \mu F$

Kompanzasyon için özel durum

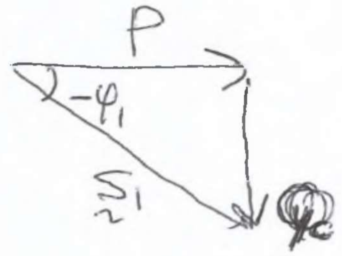
Eğer kapasitif bir yük sistemi var ve endüktif yapılmak isteniyorsa yapılacak işlem şu şekildedir:

Güç üçgeni üzerinde gösterelim

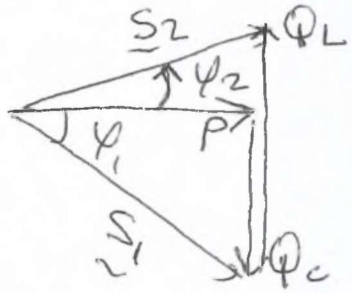


$\cos\varphi_1 = \alpha$ olsun (kapasitif)

Kapasitif yük güç üçgeni



Kompanzasyon için L (bağlanmalı) Q_L eklenecek



$$Q_L - Q_C = P * \tan\varphi_2$$

$$Q_L = Q_C + P * \tan\varphi_2$$

$$Q_L = P * \tan\varphi_1 + P * \tan\varphi_2$$

$$\boxed{Q_L = P * (\tan\varphi_1 + \tan\varphi_2)}$$

$\tan\varphi_1 = \frac{Q_C}{P}$

$Q_C = P * \tan\varphi_1$

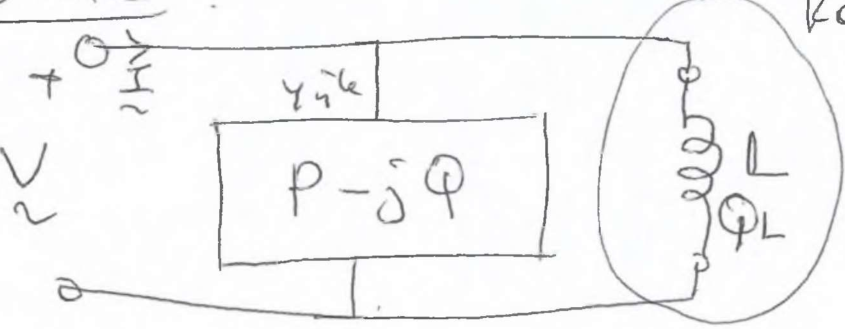
$\tan\varphi_2 = \frac{Q_L - Q_C}{P}$

$Q_L - Q_C = P * \tan\varphi_2$

kapasitif yük sisteminde $\cos\varphi_1$'i endüktif $\cos\varphi_2$'ye getirmek için gerekli endüktif güç (Endüktans gücü)

$$Q_L = \frac{V^2}{X_L} = \frac{V^2}{\omega \cdot L} \Rightarrow \boxed{L = \frac{V^2}{\omega \cdot Q_L}}$$ endüktans değeri

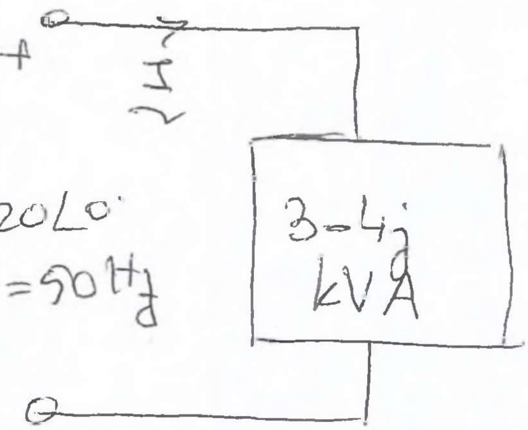
özetle:



Kompanzasyon sistemi

Y.G. hatlarında gerilim yükselmelerinde kullanılır ve reaktör olarak anılır

Örnek (Kapasitif yük - Kompanzasyon)



$220\angle 0°$
$f = 50\,Hz$

Verilen yük sisteminde;

a) ΣP, ΣQ, $\Sigma \underset{\sim}{S}$, $\cos\varphi_1$, $\tan\varphi_1$ =?

b) $\cos\varphi_2$'yi 0,99 (end) yapmak için yüke paralel bağlanması gereken elemanın değerini ve gücünü bulunuz

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$\Sigma P = 3\,kW$

$\Sigma Q = 4\,kVAr\,(-)$

$\underset{\sim}{S} = 3 - j4 = 5\angle{-53{,}1}\ kVA$

(Kapasitif olduğu için endüktans bağlanmalıdır)

$\tan\varphi_1 = \tan(53{,}1°) = 1{,}33$

$\cos\varphi_2 = 0{,}99 \Rightarrow$

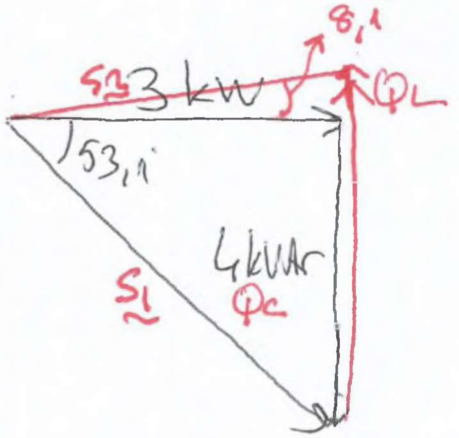
$\varphi_2 = 8{,}1°$

$\tan\varphi_2 = \tan(8{,}1°) = 0{,}142$

$Q_L = \Sigma P * (\tan\varphi_1 + \tan\varphi_2)$

$= 3000 * (1{,}33 + 0{,}142)$

$Q_L = 4{,}416\ kVAr\ (end.)$



$L = \dfrac{V^2}{w \cdot Q_L} = \dfrac{220^2}{314 \cdot 4416}$

$L = 34{,}9\ mH$

$Q_L = \underbrace{|Q_c|}_{} + |Q_L - Q_c|$

$P\tan\varphi_1 + P\cdot\tan\varphi_2$

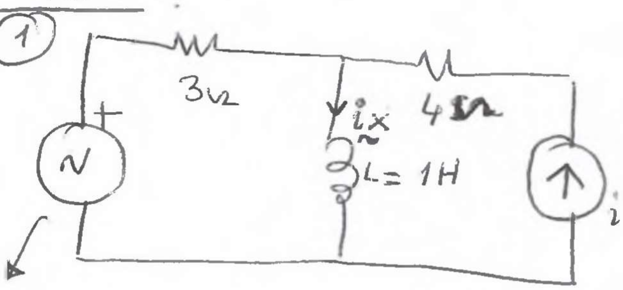
$P * (\tan\varphi_1 + \tan\varphi_2)$

Elde Edilir

(E.i)

SSH'de Elektrik Devreleri ve Çözümleri
(ÇAY–DÜGY – TEOREMLER)---

Örnek 1



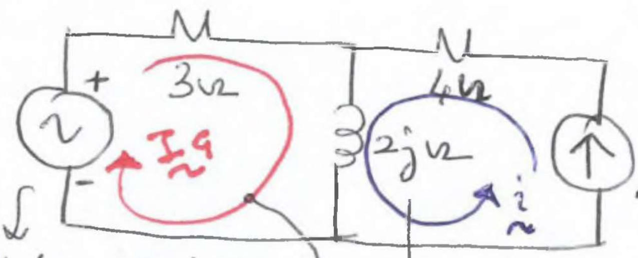
Verilen devrede $\tilde{i}_x$ akımını bulunuz a) (KVL – KCL) ile, b) (ÇAY – DÜGY) ile

$i(t) = 2\sqrt{2}\cos(2t+10^\circ)$ A

$I_m = \sqrt{2} I_{ef}$

$V(t) = 15\sqrt{2}\sin(2t-9)$ V

$w = 2$ rad/s



$\tilde{i} = 2\angle 10^\circ$ A ↓ I_{ef}

$\tilde{V} = 15\angle -99$ ↑ V_{ef}

$\tilde{X}_L = jwL$

$\tilde{X}_L = j\cdot 2\cdot 1 = 2j\,\Omega$

Çözüm

a) KVL (ÇAY ile)

Dönüşüm

$\sin(2t-9) = \cos(90-(2t-9))$
$= \cos(-2t+99) = \cos(2t-99)$

veya $\sin(x) = \cos(90-x)$

$\cos(x) = \sin(x+90)$
$\sin x = \cos(x-90)$

Not: Bir devrede farklı fonksiyonlar (sin, cos) varsa, herhangi birine tümünün dönüşümünün yapılması gerekir.

KVL / $-15\angle -99 + 3\tilde{I}_g + 2j(\tilde{I}_g + \tilde{i}) = 0$

$-15\angle -99 + 3\tilde{I}_g + 2j\tilde{I}_g + 2j(2\angle 10^\circ) = 0$

$-15\angle -99 + \tilde{I}_g(3+2j) + 4j\angle 10^\circ = 0$

$(3+2j)\tilde{I}_g = 15\angle -99 - 4j\angle 10$

$\tilde{I}_g = \dfrac{15\angle -99 - 4j\angle 10}{3+2j} = \dfrac{15\angle -99 - 4\angle 100}{3+2j}$

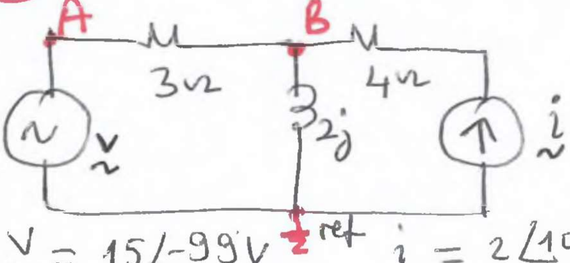
$\tilde{I}_g = 5{,}22\angle -128{,}72^\circ$ A

$\tilde{i}_x = \tilde{I}_g + \tilde{i} = 5{,}22\angle -128{,}72^\circ + 2\angle 10^\circ = 3{,}945\angle -109{,}19$

$i_x(t) = \sqrt{2}\cdot 3{,}945\cos(2t - 109{,}19^\circ)$ A

elde edilir. ✓

b) KCL (DÜGY) ile



$\tilde{V} = 15\angle -99$ V $\tilde{i} = 2\angle 10^\circ$ A

B → KCL

$\dfrac{\tilde{V}_B - 15\angle -99^\circ}{3} + \dfrac{\tilde{V}_B}{2j} - 2\angle 10^\circ = 0$

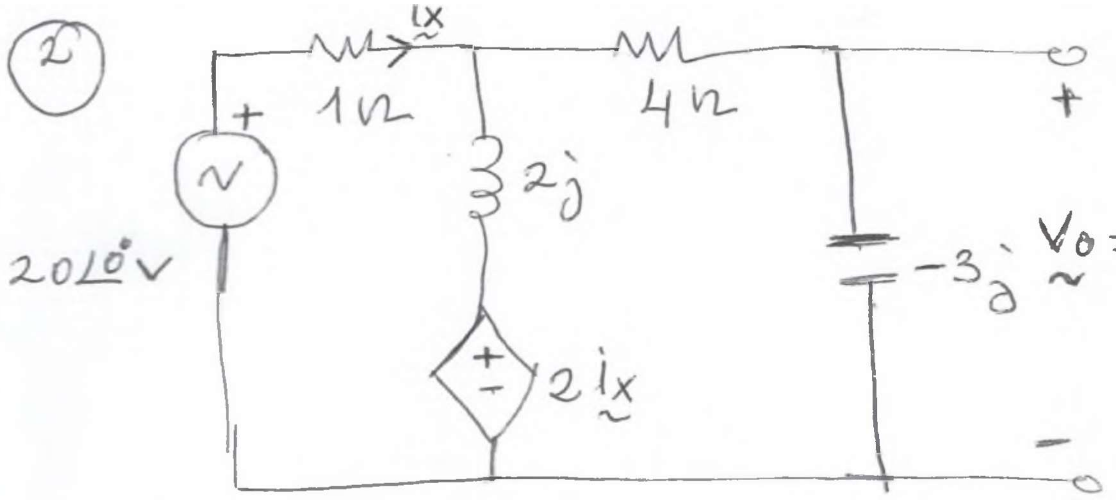
$\tilde{V}_B \cdot \left(\dfrac{1}{3} + \dfrac{1}{2j}\right) = (5\angle -99^\circ + 2\angle 10^\circ) \Rightarrow$
(2j) (3)

$\tilde{V}_B = \dfrac{5\angle -99 + 2\angle 10^\circ}{(3+2j)/(6j)}$

$\tilde{V}_B = \dfrac{5\angle -99 + 2\angle 10}{0{,}6\angle -56{,}3} = 7{,}9\angle -19{,}19$ V

$\tilde{i}_x = \dfrac{\tilde{V}_B}{2j} = \dfrac{7{,}9\angle -19{,}19}{2\angle 90} \cong 3{,}95\angle -109{,}19$ A

(2)



2 (E:İ)

$V_o = ?$

(a) ÇAY (KVL)

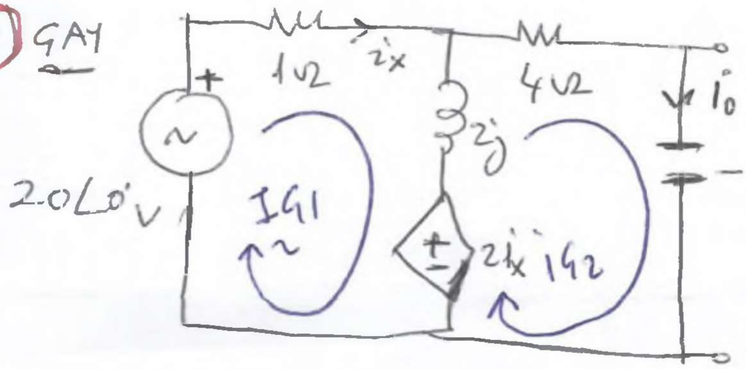
b) DÜGY (KCL)

c) Thevenin T.

d) Norton T.

e) P_{2i_x} (bağımlı k.)

(a) ÇAY



$i_x = I_{G1}$

$I_{G1} \to KVL$

$-20\angle 0° + 1 I_{G1} + 2j(I_{G1} - I_{G2}) + 2 I_{G1} = 0$

$\boxed{I_{G1}\cdot(1+2j+2) + I_{G2}\cdot(-2j) = 20\angle 0°}$ 1. denk.

$I_{G2} \to KVL$

$(4-3j) I_{G2} - 2(I_{G1}) + 2j(I_{G2} - I_{G1}) = 0$

$\boxed{I_{G1}\cdot(-2-2j) + I_{G2}(4-3j+2j) = 0}$ 2. denk.

$(3+2j) I_{G1} - (2j) I_{G2} = 20\angle 0°$

$(-2-2j) I_{G1} + (4-j) I_{G2} = 0$

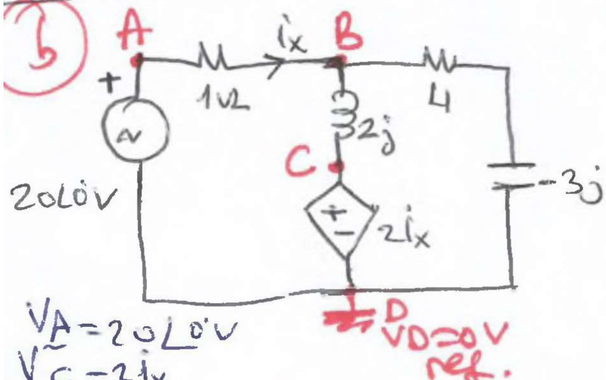
Kramer (Cramer Rule) ile yapalım: (önce matrisel formda düzenleyelim)

$$\begin{bmatrix} 3+2j & -2j \\ -2-2j & 4-j \end{bmatrix} \begin{bmatrix} I_{G1} \\ I_{G2} \end{bmatrix} = \begin{bmatrix} 20\angle 0° \\ 0 \end{bmatrix}$$

$$I_{G2} = \frac{\begin{vmatrix} 3+2j & 20 \\ -2-2j & 0 \end{vmatrix}}{\begin{vmatrix} 3+2j & -2j \\ -2-2j & 4-j \end{vmatrix}} = \frac{40+40j}{12-3j+8j+2-4j+4} = \frac{40+40j}{18+j} = 3,134\angle 41,82°$$

$$\boxed{V_o = (-3j) * (I_{G2}) \qquad V_o = 9,42\angle -48,2° \ A}$$

(b)



$V_A = 20\angle 0°$ V

$V_C = 2i_x$

$= 2\cdot\frac{(V_A - V_B)}{1}$

$= 2\cdot(20\angle 0° - V_B)$

$V_C = 40 - 2V_B$

B → KCL (akım yasası)

0 volt (ref.)

$$\frac{V_B - 20}{1} + \frac{V_B - V_C}{2j} + \frac{V_B - V_D}{4-3j}$$

$$\frac{V_B - 20}{1} + \frac{V_B - 40 + 2V_B}{2j} + \frac{V_B}{4-3j} = 0$$

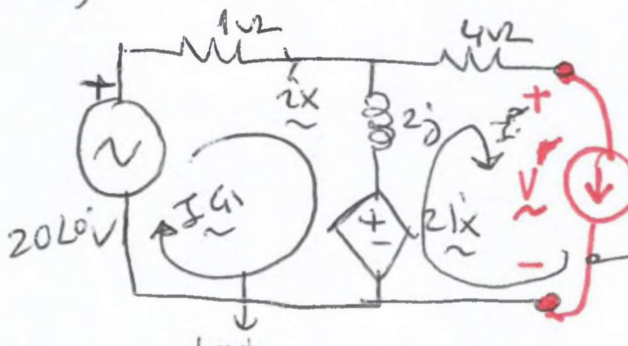
$$V_B\cdot\left(1 + \frac{3}{2j} + \frac{1}{4-3j}\right) = 20 + \frac{40}{2j}$$

$$V_B\cdot(1,8\angle -50°) = (28,284\angle -45°) \Rightarrow$$

$V_B = 15,713\angle +5$ volt $\Rightarrow i_o = \frac{V_B}{4-3j} = 3,143\angle 41,8$ A

$V_o = (-3j)*(i_o) = 9,43(-48,2$

c) Thevenin Teoremi (I^*) ile uyarma



$$\boxed{V^* = Z_{th} \cdot (-I^*) + V_{th}}$$ olur.

$$\boxed{i_x = I_{G1}}$$

$\rightarrow I^* \rightarrow$ KVL

$$V^* - 2 I_{G1} + 2j(I^* - I_{G1}) + 4 I^* = 0$$

$$V^* - 2 \cdot (I_{G1}) - 2j I_{G1} + (2j+4) I^* = 0$$

$$V^* + I_{G1}(-2-2j) + (2j+4) I^* = 0$$

KVL

$$-20 + 1 \cdot I_{G1} + 2j(I_{G1} - I^*) + 2 \cdot (I_{G1}) = 0$$

$$I_{G1} \cdot (1+2+2j) = I^*(2j) + 20$$

$$(3+2j) I_{G1} = 2j(I^*) + 20$$

$$\boxed{I_{G1} = \frac{2j(I^*) + 20}{(3+2j)}}$$

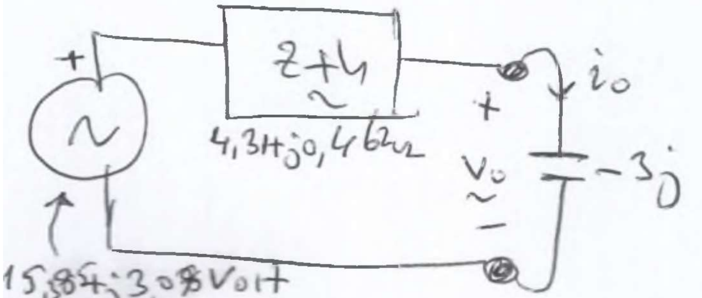
$$V^* + (-2-2j)\left(\frac{2j I^* + 20}{(3+2j)}\right) + (2j+4) I^* = 0$$

$$V^* + I^*\left(\frac{4-4j}{3+2j} + (2j+4)\right) - \left(\frac{40+40j}{3+2j}\right) = 0$$

$$V^* + I^* \underbrace{(4{,}31 + j0{,}462)}_{Z_{th}} - \underbrace{(15{,}385 + j3{,}08)}_{V_{th}} = 0$$

$$V^* = \underbrace{(4{,}31 + j0{,}462)}_{Z_{th}}(-I^*) + \underbrace{(15{,}385 + j3{,}08)}_{V_{th}}$$

Thevenin Eşd. Devresi



$$i_o = \frac{15{,}385 + j3{,}08}{4{,}31 + j0{,}462 - 3j} = 2{,}34 + j2{,}09 \text{ A}$$

$$= 3{,}136 \angle 41{,}8° \text{ A}$$

$$V_o = (-3j) * i_o = (-3j) * 3{,}136 \angle 41{,}86° = 6{,}27 - j7{,}013 \text{ Volt}$$

$$\boxed{V_o = 9{,}41 \angle -48{,}2° \text{ volt}}$$

d) Norton : $I_N = \dfrac{V_{th}}{Z_{th}} = \dfrac{15{,}385 + j3{,}08}{4{,}31 + j0{,}462} \cong 3{,}6 + j0{,}33$ A

$$= 3{,}62 \angle 5{,}2° \text{ A}$$

e) $S_{2ix} = S_b = V_b * i_b^* = (2 \cdot i_x) * (i_b)^* = \left[2 * \left(\frac{V_A - V_B}{1}\right)\right] * \left(\left[\frac{V_B - V_C}{2j}\right]\right)^*$

$V_A = 20\angle 0° V$

$V_B = 15{,}713 \angle 5° V$

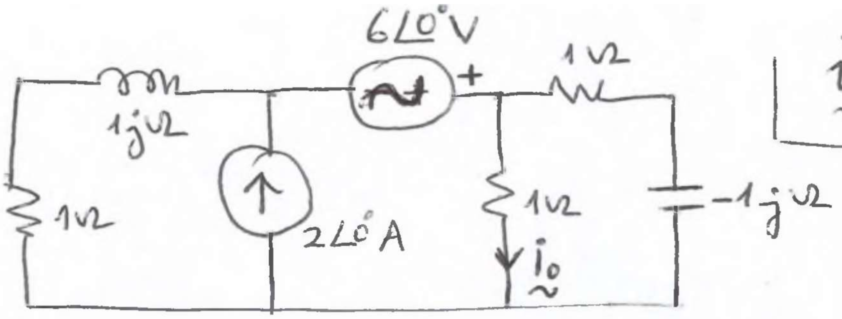
$V_C = 2 i_x = 2 * \left(\frac{V_A - V_B}{1}\right)$

$V_C = 2 * (20\angle 0° - 15{,}713 \angle 5°)$

S_b (Bağımlı K. gücü) $= \left[2 * \underbrace{(20 - 15{,}713 \angle 5°)}_{i_x = \left(\frac{V_A - V_B}{1}\right)}\right] * \left(\underbrace{\left[\frac{15{,}713 \angle 5° - 9{,}115 \angle -17{,}5°}{2j}\right]}_{4{,}04 \angle -59{,}43}\right)^*$

$$S_b = 36{,}82 \angle 41{,}94° \text{ VA}$$

P ... eşlenik

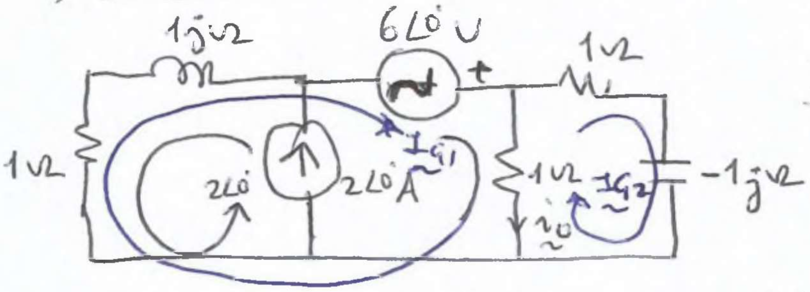
(3) 

E-i (3)

$\tilde{i}_o$ akımını bulunuz
a) GAY , b) DGY
c) Thevenin
d) Norton
e) Süperpozisyon ile bulunuz
f) $\tilde{I}^*$ ile V_{th}, Z_{th} bulunması

a) GAY → KVL ile

$\tilde{I}_{G1}$ ve $\tilde{I}_{G2}$ için KVL



I_{G1} → KVL

$(1+j)\cdot(\tilde{I}_{G1}-2\angle 0^\circ)-6\angle 0^\circ+1\cdot(\tilde{I}_{G1}-\tilde{I}_{G2})=0$

$I_{G1}\cdot(1+j+1)+I_{G2}\cdot(-1)=8+2j$

$\boxed{(2+j)I_{G1}-I_{G2}=8+2j}$ 1. denk.

I_{G2} → KVL

$(1-j)\tilde{I}_{G2}+1\cdot(\tilde{I}_{G2}-\tilde{I}_{G1})=0$

$\boxed{-I_{G1}+(2-j)I_{G2}=0}$ 2. d.

$I_{G1}=(2-j)I_{G2}$ yazılabilir

$(2+j)\cdot(2-j)\tilde{I}_{G2}-\tilde{I}_{G2}=8+2j$

$4\tilde{I}_{G2}=8+2j$

$\boxed{\tilde{I}_{G2}=2+\frac{1}{2}j \text{ A}}$

$\tilde{I}_{G1}=(2-j)(2+\frac{1}{2}j)=4+j-2j+\frac{1}{2}$

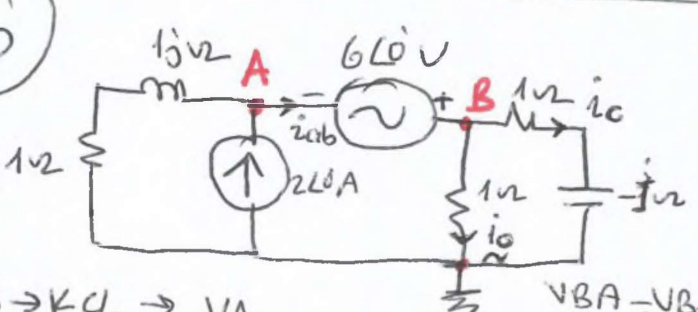
$\boxed{\tilde{I}_{G1}=4,5-j \text{ A}}$

$\tilde{i}_o=\tilde{I}_{G1}-\tilde{I}_{G2}=4,5-j-2-0,5j$

$\boxed{\tilde{i}_o=2,915\angle -30,96^\circ}=\boxed{2,5-1,5j \text{ A}}$

elde edilir.

b)



A → KCL →

$\frac{\tilde{V}_A}{1+j}-2\angle 0^\circ+i_{ab}=0$

$V_{BA}=\tilde{V}_B-\tilde{V}_A$

$6\angle 0^\circ=V_B-V_A$

$\tilde{V}_A=V_B-6\angle 0^\circ$

$\tilde{i}_{ab}=\tilde{i}_o+\tilde{i}_c=\frac{V_B}{1}+\frac{V_B}{1-j}$

$\frac{V_B-6\angle 0^\circ}{1+j}-2\angle 0^\circ+V_B\cdot\left(1+\frac{1}{1-j}\right)=0$

$\tilde{V}_B\left[\frac{1}{1+j}+1+\frac{1}{1-j}\right]=\frac{6\angle 0^\circ}{1+j}+2\angle 0^\circ$

$$\tilde{V}_B=\frac{\frac{6\angle 0^\circ}{1+j}+2\angle 0^\circ}{\frac{1}{1+j}+1+\frac{1}{1-j}}$$

$$\tilde{V}_B=\frac{(8+2j)/(1+j)}{2}$$

$$\tilde{V}_B=\frac{2(4+j)}{2(1+j)}$$

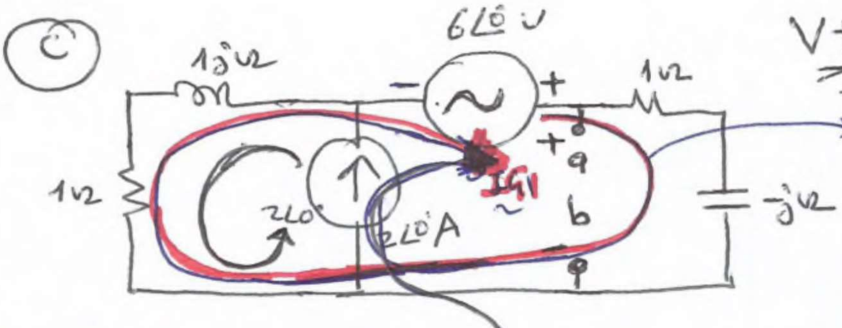
$$\tilde{V}_B=\frac{(4+j)(1-j)}{2}=\frac{4-4j+j+1}{2}$$

$$\tilde{V}_B=\frac{5}{2}-j\frac{3}{2} \text{ Volt}$$

$\boxed{\tilde{i}_o=\frac{\tilde{V}_B}{1}=2,5-1,5j \text{ A}}$

(Sü) 4

c)



V_{th} ($\tilde{V}_{ab}$)

$\tilde{I}_{G1} \rightarrow$ KVL

$$-6\angle 0° + (1-j)\tilde{I}_{G1} + (1+j)(I_{G1} - 2\angle 0°) = 0$$

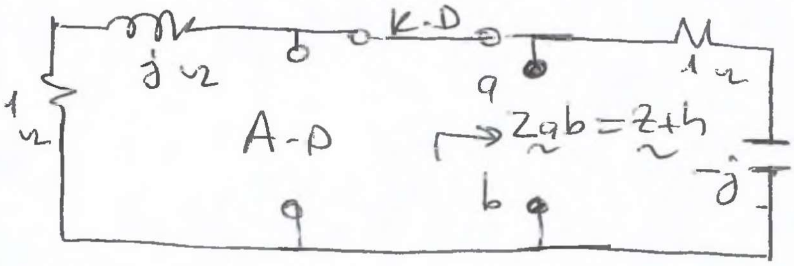
$$\tilde{I}_{G1} \cdot (1-j+1+j) = 6+2+2j$$

$$\tilde{I}_{G1} = \frac{8+2j}{2} = 4+j \text{ A}$$

$$\tilde{V}_{ab} = \tilde{V}_{th} = (1-j) * \overbrace{(4+j)}^{I_{G1}}$$

$$\tilde{V}_{th} = 4-4j+j+1 = 5-3j \text{ Volt}$$

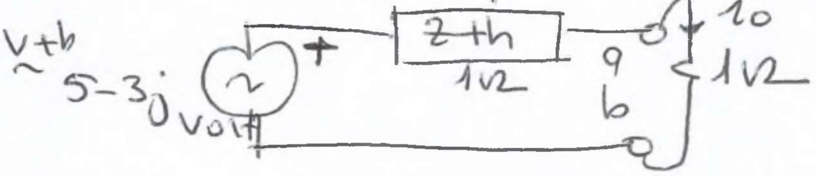
$\tilde{Z}_{th}$ için ↓ $\tilde{I}_{G1} \rightarrow$ KVL



$$\tilde{Z}_{ab} = \tilde{Z}_{th} = (1-j) // (1+j)$$

$$\frac{(1-j)(1+j)}{2} = \frac{2}{2} = 1\,\Omega$$

$$\boxed{\tilde{Z}_{th} = 1 + j0\,\Omega}$$

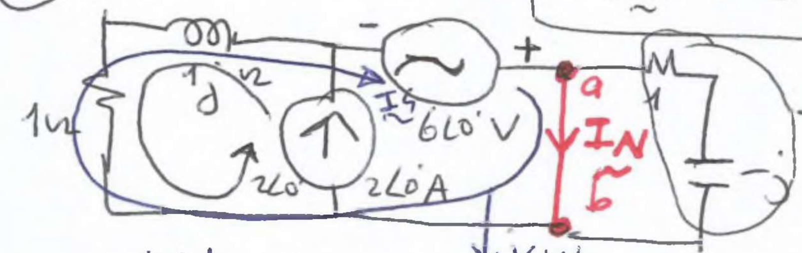


$$\tilde{i}_0 = \frac{5-3j}{2} = 2,5-1,5j \text{ A}$$

elde edilir

d) $\tilde{I}_N$ elde edilir

$$\left(\frac{V_{th}}{\tilde{Z}_{th}} = \tilde{I}_N = \frac{5-3j}{1} = 5-3j \text{ A olmalı!!}\right)$$



→ Kısa devre sebebiyle etkileri yok!

↓ KVL

$$-6\angle 0° + (1+j)(\tilde{I}_G - 2\angle 0°) = 0$$

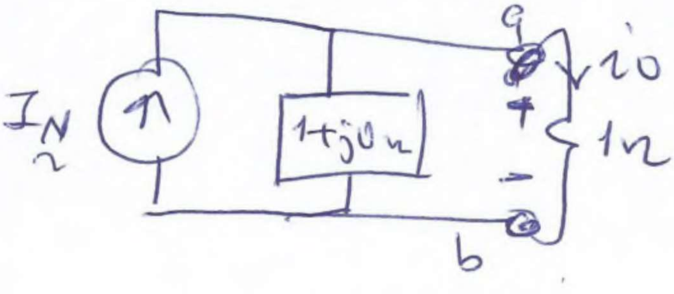
$$\tilde{I}_G \cdot (1+j) = 6+2+2j = 8+2j$$

$$\tilde{I}_G = \frac{8+2j}{1+j} \cdot \frac{1-j}{1-j} = \frac{8-8j+2j+2}{2} = \frac{10-6j}{2} = 5-3j \text{ A}$$

eşlenikle çarpım işlemi

$$\tilde{I}_N = \tilde{I}_G = 5-3j \text{ A}$$

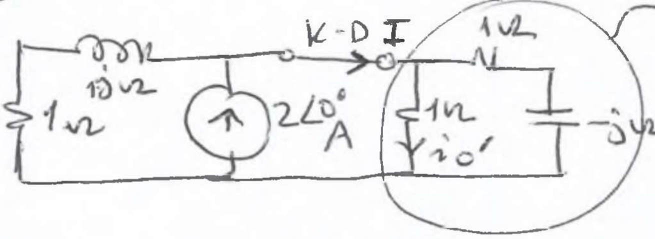
$$\left(\tilde{Z}_N = \tilde{Z}_{th} = 1+j0 \text{ ohm}\right)$$



$$\Rightarrow \tilde{i}_0 = \tilde{I}_N * \frac{1}{1+1}$$

$$\tilde{i}_0 = \frac{5-3j}{2} = 2,5-1,5j \text{ A}$$

(e) $2\angle 0^\circ$ A devrede iken ($6\angle 0^\circ$ V → K-D.) (2.1/5)



$$\underset{\sim}{Z_1} = (1-j) // (1)$$

$$\rightarrow \frac{(1-j)(1)}{2-j} = \frac{1-j}{2-j} \cdot \frac{2+j}{2+j}$$

$$\underset{\sim}{Z_1} = \frac{2+j-2j+1}{5} = \frac{3-j}{5}\ \Omega$$

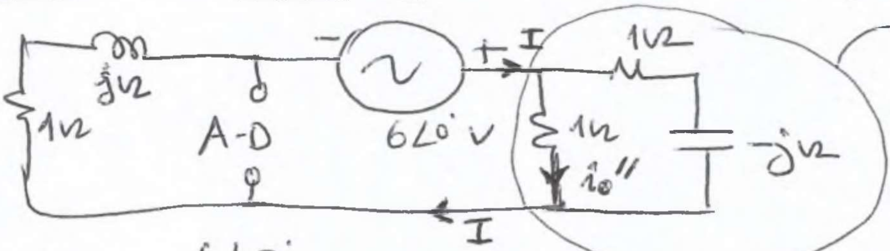
(Ara işlem)

$$\underset{\sim}{I} = (2\angle 0^\circ) * \frac{1+j}{1+j+\underset{\sim}{Z_1}} \Rightarrow$$

$$\underset{\sim}{I} = \frac{2+2j}{1+j+\frac{3-j}{5}} = \frac{2+2j/1}{\frac{5+5j+3-j}{5}} = \frac{10+10j}{8+4j}\ A$$

$$i_o' = \underset{\sim}{I} * \left(\frac{1-j}{2-j}\right) = \frac{10+10j}{8+4j} * \frac{(1-j)}{2-j} = \frac{10-10j+10j+10}{16-8j+8j+4} = \frac{20}{20} = 1\ A$$

$6\angle 0^\circ$ V varken ($2\angle 0^\circ$ A → Açık D.)



$$\underset{\sim}{I} = \frac{6\angle 0^\circ}{1+j+\underset{\sim}{Z_1}} = \frac{6\angle 0^\circ}{1+j+\frac{3-j}{5}} = \frac{6\angle 0^\circ}{\frac{5+5j+3-j}{5}} \Rightarrow$$

$$\underset{\sim}{I} = \frac{30}{8+4j} \Longrightarrow \underset{\sim}{i_o''} = \underset{\sim}{I} * \left(\frac{1-j}{2-j}\right)$$

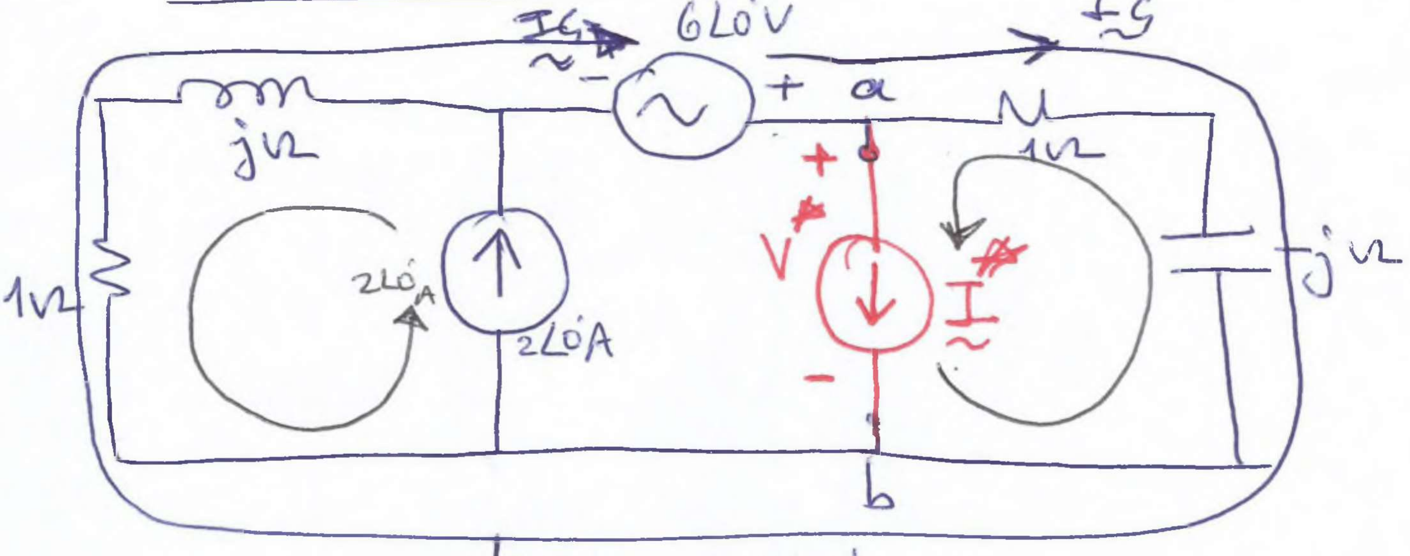
$$\underset{\sim}{i_o''} = \frac{30}{8+4j} * \frac{1-j}{2-j} = \frac{30-30j}{16-8j+8j+4} = \frac{30-30j}{20}$$

$$\underset{\sim}{i_o''} = 1{,}5 - 1{,}5j\ A$$

$$i_o = i_o' + i_o'' = 1 + 1{,}5 - 1{,}5j$$

$$\boxed{\underset{\sim}{i_o} = 2{,}5 - 1{,}5j\ A}$$ elde edilir

(f) $\tilde{I}^{*}$ ile $\tilde{V}_{th}$, $\tilde{Z}_{th}$ bulunması



$\tilde{I}_g \rightarrow$ KUL

$$(1-j)(\tilde{I}_g - I^{*}) + (1+j)(\tilde{I}_g - 2) - 6 = 0$$

$$\tilde{I}_g \cdot (1-j+1+j) = (1-j)I^{*} + (8+2j)$$

$$\tilde{I}_g \cdot (2) = (1-j)I^{*} + (8+2j)$$

$$\boxed{\tilde{I}_g = (0{,}5-0{,}5j)\,I^{*} + (4+j)}$$ bulunur

şimdi de V^{*} için, I^{*} cevresini kullanarak $\tilde{V}^{*}$'ı bulalım.

$$\boxed{V^{*} = \tilde{Z}_{th} \cdot (-\tilde{I}^{*}) + \tilde{V}_{th}}$$ → şeklinde elde edilecek.

$\tilde{I}^{*} \rightarrow$ KUL $\rightarrow$ $(1-j)(\tilde{I}^{*} - \tilde{I}_g) + V^{*} = 0$

$$(1-j)(I^{*} - 0{,}5I^{*} + 0{,}5jI^{*} - 4 - j) + V^{*} = 0$$

$$V^{*} + \tilde{I}^{*}(\cancel{1} - \cancel{j} - \cancel{0{,}5} + \cancel{0{,}5j} + \cancel{0{,}5j} + 0{,}5) + (-4 - j + 4j - 1) = 0$$

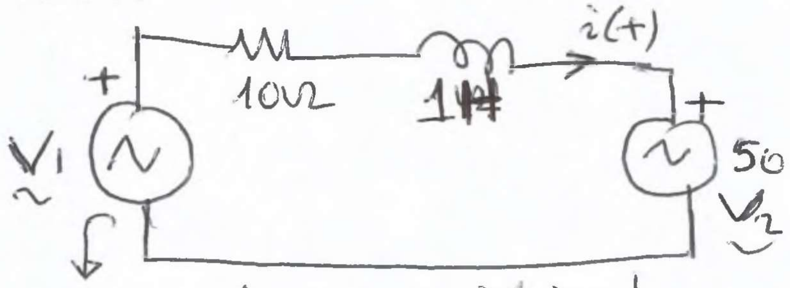
$$V^{*} = (-I^{*})(\underbrace{1}) + (5-3j)$$

$\tilde{Z}_{th} = 1 + j0\ \Omega$ $\quad$ $\tilde{V}_{th} = 5 - 3j$ Volt

$\tilde{I}^{*}$ metodu; hem bağımsız hem de ve özellikle bağımlı k.

(4) (farklı frekanslı devreler için kullanılması zorunlu olan teorem) (Süperpozisyon Teorisi)

Örnek :



$\omega_2 = 20\ rad/s$

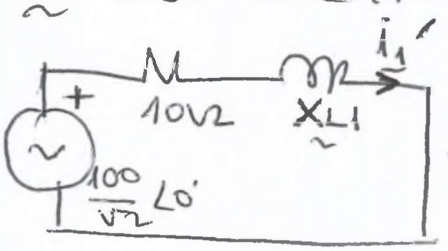
$\omega_1 = 10\ rad/s$

a) $i(t)$ akımını bulunuz.

b) i_{ef} akımını bulunuz.

$$\underset{\sim}{V1} = \frac{100}{\sqrt{2}} \angle 0^\circ \text{ volt} \qquad \underset{\sim}{V2} = \frac{50}{\sqrt{2}} \angle -10^\circ \text{ volt}$$

$\underset{\sim}{V1}$ devrede iken ($\underset{\sim}{V2} \to$ K.D.) $\omega_1 = 10\ rad/s$

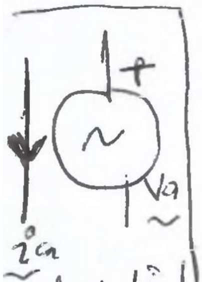


$$\underset{\sim}{X_{L1}} = j\omega_1 . L = j.10.1 = 10j\ \Omega$$

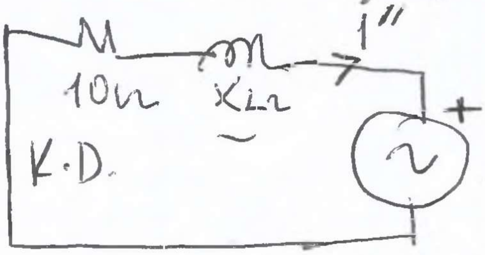
$$\underset{\sim}{i'} = \frac{100}{\sqrt{2}} / (10+10j) = \frac{70{,}71}{10+10j} (A) = 3{,}535 - j3{,}535\ A = 5\angle -45^\circ A$$

$$i'(t) = 5\sqrt{2} \cos(10t - 45^\circ) A$$

$\underset{\sim}{V2}$ devrede iken ($\underset{\sim}{V1} \to$ K.D) $\omega_2 = 20\ rad/s$



$P = \underset{\sim}{V_a} . |i_a|$



$$\underset{\sim}{X_{L2}} = j\omega_2 . L = 20j\ \Omega$$

$$i'' = (-).\frac{(50/\sqrt{2}) \angle -10^\circ}{10+20j} = (-).\frac{35{,}35\angle -10^\circ}{10+20j}$$

$$= (-)*[0{,}45 - 1{,}515j]$$

$$= -0{,}45 + 1{,}515j\ A$$

$$= 1{,}58 \angle 106{,}54^\circ A$$

$$i''(t) = 1{,}58 * \sqrt{2} \cos(20t + 106{,}54^\circ) A$$

Buna göre,

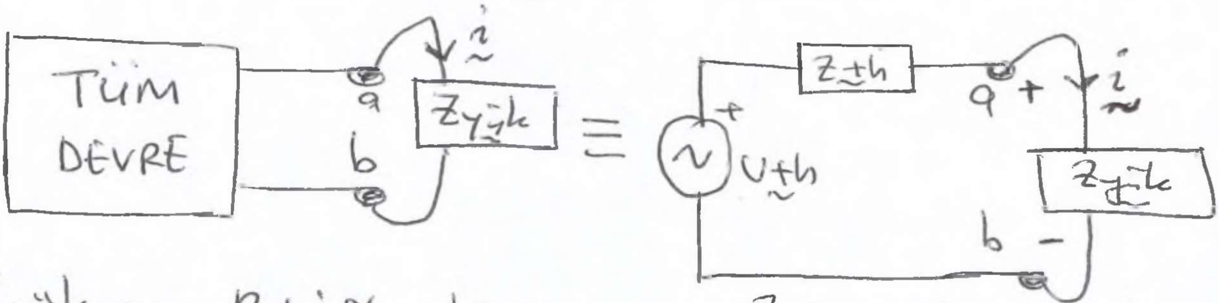
$i(t) = i'(t) + i''(t)$ 'dir.

$$i(t) = 5\sqrt{2} \cos(10t - 45^\circ) + 1{,}58.\sqrt{2} \cos(20t + 106{,}54^\circ) A$$

$$i_{ef} = \sqrt{(5)^2 + (1{,}58)^2} = 5{,}243\ A$$

5 SSH'de Thevenin – Maksimum Güç Teoremi (Σ.1, 8)

BİLGİ



a) $\tilde{Z}_{yük} = R + jX$ olsun. $\tilde{Z}_{th} = R_{th} + jX_{th}$ olsun.

$Z_{yük}$'e max. güç iletebilmek için

$$\tilde{Z}_{yük} = \tilde{Z}_{th}^{*} \quad (\text{eşlenik})$$

$$\boxed{\tilde{Z}_{yük} = R_{th} - jX_{th}} \text{ olur.}$$

$P_{max} = (R_{th}) \cdot |i|^2$

$|i| = \dfrac{|V|}{2R_{th}}$

$P_{max} = \dfrac{V^2}{4R_{th}}$

örneğin; $\tilde{Z}_{th} = 3 + j4\ \Omega$ elde edilmişse

$\tilde{Z}_{yük} = 3 - j4\ \Omega$ olacaktır. (max güç için)

b) $\tilde{Z}_{yük} = R_{yük}$ (sadece reel bileşen) olsun.

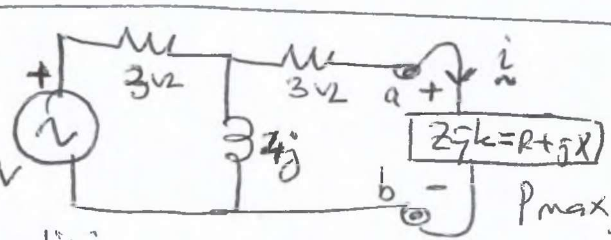
$Z_{yük}$ $R_{yük} = |\tilde{Z}_{th}^{*}| = |R_{th} - jX_{th}| = \sqrt{R_{th}^2 + X_{th}^2}$

örneğin; $\tilde{Z}_{th} = 3 + j4\ \Omega$ ise

$|i| = \left| \dfrac{V}{\tilde{Z}_{th} + R_{yük}} \right|$

max. güç için $\tilde{Z}_{yük} = R_{yük} = |3 - j4| = \sqrt{3^2 + 4^2} = \mathbf{5}\ \Omega$ bulunur.

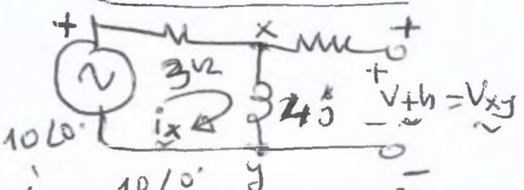
Örnek: 5



a) $Z_{yük} = R + jX$ olsun
b) $\tilde{Z}_{yük} = R$ olsun.

$P_{max, R_{yük}} = ?$

$\tilde{V}_{th}$ elde edilir



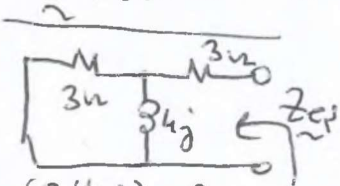
$\tilde{I}_x = \dfrac{10\angle 0°}{5\angle 53{,}1°} = 2\angle -53{,}1°\ A$

$\tilde{V}_{xy} = \tilde{V}_{th} = 4j * \tilde{I}_x$

$\tilde{V}_{xy} = \tilde{V}_{th} = 4\angle 90° * 2\angle -53{,}1°$

$\tilde{V}_{th} = 8\angle 36{,}9°$ volt

$\tilde{Z}_{th}$ elde edilir



$(3 // 4j) + 3$

$= \dfrac{12j}{3+4j} + 3 = \dfrac{12j + 9 + 12j}{3+4j}$

$= \dfrac{9 + 24j}{3+4j} = 5{,}126\angle 16{,}3$

$\tilde{Z}_{th} = 4{,}92 + j1{,}44\ \Omega$

a) $Z_{yük} = R + jX$ ise

$\tilde{Z}_{yük} = \tilde{Z}_{th}^{*} = 4{,}92 - j1{,}44$

$P_{max, R_{yük}} = R_{yük} * |i|^2$

$\tilde{i} = \dfrac{8\angle 36{,}9°}{4{,}92 + 4{,}92} = 0{,}813\angle 36{,}9°\ A$

$P_{max, R_{yük}} = (4{,}92) * (0{,}813)^2$

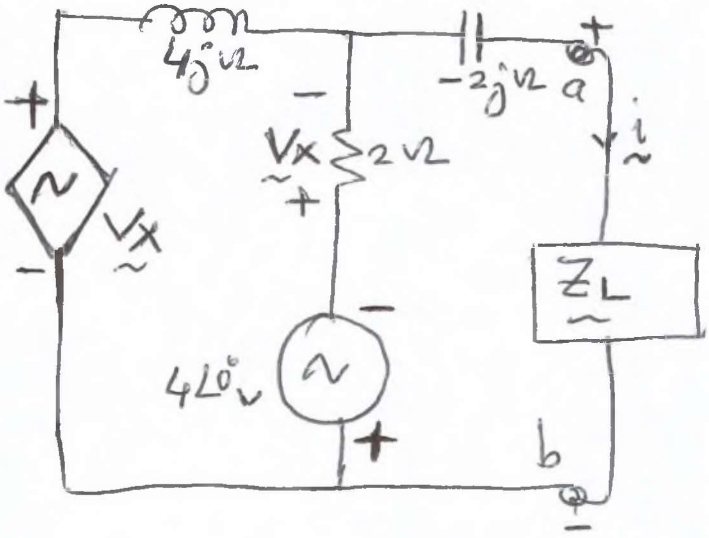
$= 3{,}25\ W$

b) $\tilde{Z}_{yük} = R = |Z_{th}^{*}|$

$R = 5{,}126\ \Omega$

$\dot{i} = \dfrac{8\angle 36{,}9°}{5{,}126\angle 16{,}3 + 5{,}126} = 0{,}79\angle 28{,}75°\ A$

örnek; Bağımlı Kaynaklı – maximum güç | 2.1; 9



$P_{max}, Z_L = ?$

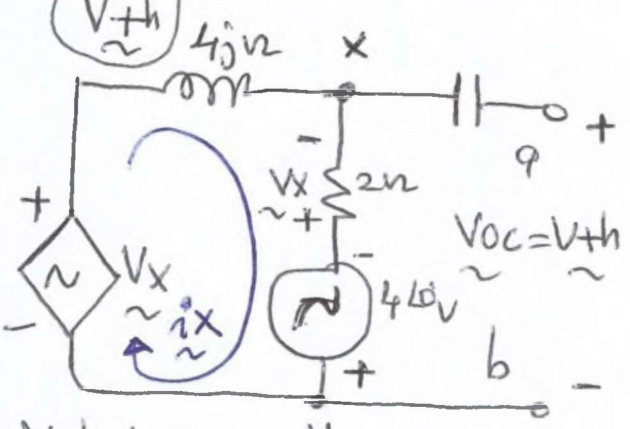
a) $Z_L = R_L + jX_L$
b) $Z_L = R_L$
} ise

öncelikle Z_L dışında kalan bölümün Thevenin Eşdeğer Modelini elde edelim.

1. yol → V_{oc} (V_{th}), I_{sc} (I_N) yöntemi

$I_2 = I_{sc} = I_N$

$V_x = 2 * (I_2 - I_1)$



$V_{ab} = V_{xy}$

$-V_x + 4j\, i_x + 2 \cdot i_x - 4\angle 0^\circ = 0$

$V_x = 2 * (-i_x)$ [ara işlem]

$2 i_x + 4j\, i_x + 2 i_x = 4\angle 0$

$i_x \cdot [4+4j] = 4\angle 0$

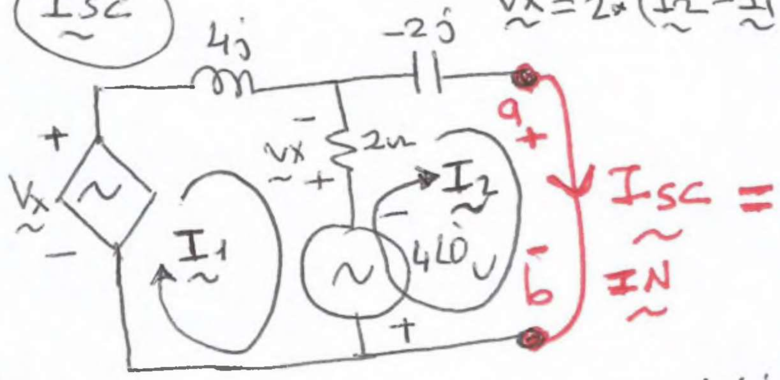
$i_x = \frac{1}{1+j} \cdot \frac{1-j}{1-j} = \frac{1-j}{2}$

$\boxed{i_x = 0{,}5 - 0{,}5j \text{ A}}$

$V_{xy} = 2 \cdot i_x - 4\angle 0$

$= 1 - j - 4\angle 0$

$V_{xy} = -3 - j = 3{,}162\angle -161{,}56^\circ$ V



$I_1 \rightarrow$ KVL $\rightarrow -V_x + 4j I_1 + 2 \cdot (I_1 - I_2) - 4\angle 0 = 0$

$-2I_2 + 2I_1 + 4jI_1 + 2(I_1 - I_2) = 4$

$I_1(4+4j) + I_2(-4) = 4$

$\boxed{I_1(1+j) - I_2 = 1}$ 1. denklem

$I_2 \rightarrow$ KVL $\rightarrow (-2j) I_2 + 4 + 2(I_2 - I_1) = 0$

$I_1(-2) + I_2(2-2j) = -4$

$\boxed{-I_1 + (1-j) I_2 = -2}$ 2. denklem

Denklemleri düzenlersek;

$I_1(1+j) - I_2 = 1$

$(1+j) / -I_1 + (1-j) I_2 = -2$

$+$

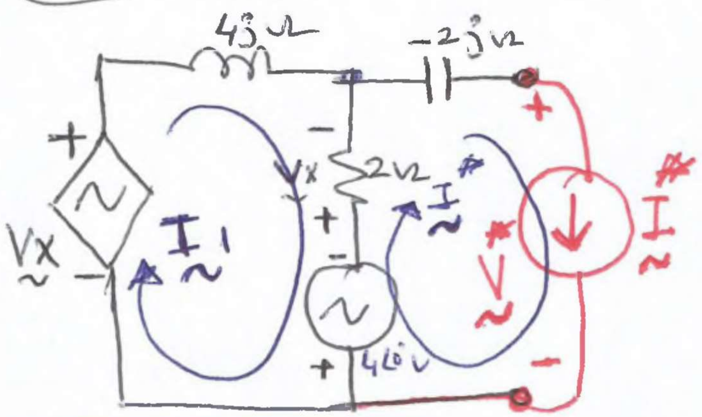
$I_2(-1+2) = 1 - 2 - 2j = -1 - 2j$

$\boxed{I_{sc}} = I_2 = -1 - 2j = 2{,}236\angle -116{,}56^\circ$ A

$Z_{th} = \frac{V_{th}}{I_{sc}} = \frac{3{,}162\angle -161{,}56^\circ}{2{,}236\angle -116{,}56^\circ} = 1{,}414\angle -45^\circ\ \Omega$

(2. yol) $\tilde{I}^*$ ile devreyi uyarma

E.i, 10



$$\boxed{V^* = (\tilde{Z}_{th})(-\tilde{I}^*) + \tilde{V}_{th}}$$

$\tilde{I}_1 \rightarrow$ KVL

$$-\tilde{V}_x + 4j\tilde{I}_1 + 2(\tilde{I}_1 - \tilde{I}^*) - 4 = 0$$

$$\tilde{V}_x = 2\cdot(\tilde{I}^* - \tilde{I}_1)$$

$$-2\tilde{I}^* + 2\tilde{I}_1 + 4j\tilde{I}_1 + 2(\tilde{I}_1 - \tilde{I}^*) = 4$$

$$\tilde{I}_1(4+4j) = \tilde{I}^*(2+2) + 4$$

$$\tilde{I}_1(1+j) = \tilde{I}^* + 1$$

$$\tilde{I}_1 = \frac{1}{(1+j)}\tilde{I}^* + \frac{1}{(1+j)}$$

$$\boxed{\tilde{I}_1 = \left(\frac{1-j}{2}\right)\tilde{I}^* + \left(\frac{1-j}{2}\right)}$$ Ara işlem

Şimdide; $\tilde{I}^*$ çevresi için KVL

$$V^* + 4 + 2\cdot(I^* - \tilde{I}_1) - 2j\,I^* = 0$$

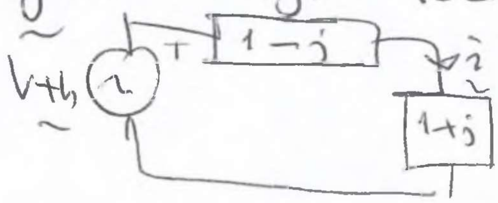
$$V^* + 4 + 2I^* - 2\left[\left(\left(\frac{1-j}{2}\right)I^*\right) + \left(\frac{1-j}{2}\right)\right] - 2jI^* = 0$$

$$V^* + 4 + 2I^* - I^* + jI^* - 1 + j - 2jI^* = 0$$

$$V^* + I^*(2 - 1 + j - 2j) + (4 - 1 + j) = 0$$

$$V^* = (-I^*)\underbrace{\left[1 - j\right]}_{\tilde{Z}_{th}} + \underbrace{\left[-3 - j\right]}_{\tilde{V}_{th}}$$ elde edilir.

a) $\tilde{Z}_{yük} = R + jX$ ise $\tilde{Z}_{yük} = \tilde{Z}_{th}^* = 1 + j$ Ω olur.



$$\tilde{i} = \frac{\tilde{V}_{th}}{2} = \frac{3{,}162\angle -161{,}56}{2} = 1{,}581\angle -161{,}56 \text{ A}$$

$$|\tilde{i}| = 1{,}581 \text{ A}$$

$$P_{max,R_{yük}} = R_{yük}|i|^2 = 1 * (1{,}581)^2 = 2{,}5\text{ W}$$

b) $Z_{yük} = R$ ise

$$R = |\tilde{Z}_{yük}^*| = |R_{yük} + jX_{yük}| = |1+j| = \sqrt{1^2+1^2}$$

$$R = 1{,}414\ \Omega,\quad \tilde{i} = \frac{3{,}162\angle -161{,}56}{1 - j + 1{,}414} = 1{,}21\angle -139^\circ \text{ A}$$

$$P_{max,R} = 1{,}414 * 1{,}21^2 \cong 2\text{ W}$$