Izračun mutual impedanc 4SQ pri razmaku med elementi 1/4 λ
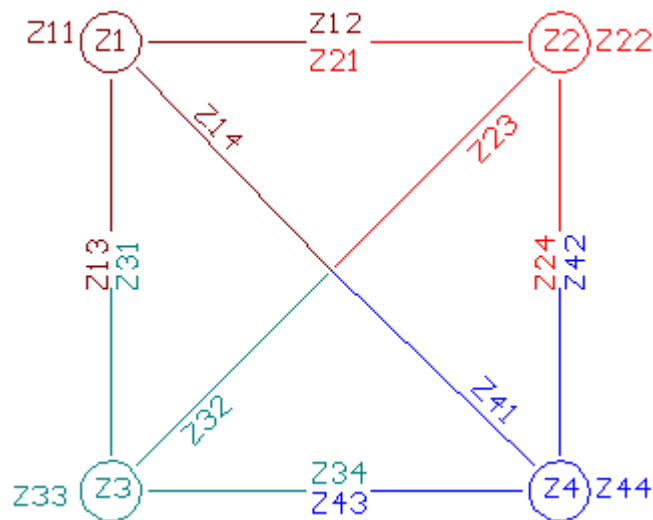

Vnos izmerjenih vrednosti Lastne xx in Medsebojnih (mutual) xy impedanc za vsak element posebej

$Z11 := 21.05 + j \cdot 0.08$

$Z12 := 19.79 + j \cdot 10.7$
$Z21 := 19.78 + j \cdot 10.72$

$Z22 := 21.05 + j \cdot 0.1$

$Z14 := 26.88 + j \cdot 4.466$ $Z23 := 26.86 + j \cdot 4.513$

$Z13 := 19.79 + j \cdot 10.7$
$Z31 := 19.78 + j \cdot 10.72$

$Z24 := 19.8 + j \cdot 10.72$
$Z42 := 19.79 + j \cdot 10.74$

$Z32 := 26.87 + j \cdot 4.408$ $Z41 := 26.87 + j \cdot 4.513$

$Z33 := 21.05 + j \cdot 0.1041$

$Z34 := 19.79 + j \cdot 10.72$
$Z43 := 19.79 + j \cdot 10.73$

$Z44 := 21.06 + j \cdot 0.1212$

Izračun medsebojnih Impedanc Elementa X proti Elementu Y

$Zm21 := \sqrt{Z11 \cdot (Z22 - Z21)}$ $Zm12 := \sqrt{Z22 \cdot (Z11 - Z12)}$

$Zm23 := \sqrt{Z33 \cdot (Z22 - Z23)}$ $Zm13 := \sqrt{Z33 \cdot (Z11 - Z13)}$

$Zm24 := \sqrt{Z44 \cdot (Z22 - Z24)}$ $Zm14 := \sqrt{Z44 \cdot (Z11 - Z14)}$

$Zm31 := \sqrt{Z11 \cdot (Z33 - Z31)}$ $Zm41 := \sqrt{Z11 \cdot (Z44 - Z41)}$

$Zm32 := \sqrt{Z22 \cdot (Z33 - Z32)}$ $Zm42 := \sqrt{Z22 \cdot (Z44 - Z42)}$

$Zm34 := \sqrt{Z44 \cdot (Z33 - Z34)}$ $Zm43 := \sqrt{Z33 \cdot (Z44 - Z43)}$

Izračunane vrednosti Medsebojnih impedanc.

$Zm12 = 11.241 - 9.938j$ $Zm21 = 11.241 - 9.939j$

$Zm13 = 11.242 - 9.937j$ $Zm23 = 3.984 - 11.735j$

$Zm14 = 3.962 - 11.745j$ $Zm24 = 11.243 - 9.94j$

$Zm31 = 11.239 - 9.937j$ $Zm41 = 3.96 - 11.732j$ Stranica

$Zm34 = 11.246 - 9.933j$ $Zm42 = 11.245 - 9.933j$ Stranica

$Zm32 = 3.892 - 11.714j$ $Zm43 = 11.242 - 9.927j$ Diagonala

$$I1p := 0.9 \qquad\qquad I2p := 0.9$$
$$I1\theta := -218 \cdot deg \qquad\qquad I2\theta := -111 \cdot deg$$

$$I3p := 0.9 \qquad\qquad I4p := 1$$
$$I3\theta := -111 \cdot deg \qquad\qquad I4\theta := 0 \cdot deg$$

Pretvorba iz Polar-nega v Kartezični (pravokotni) koordinatni format

$$x1(I1r, I1\theta) := I1r \cdot \cos(I1\theta) \qquad\qquad x2(I2p, I2\theta) := I2p \cdot \cos(I2\theta)$$
$$y1(I1r, I1\theta) := I1r \cdot \sin(I1\theta) \qquad\qquad (y2(I2p, I2\theta) := I2p \cdot \sin(I2\theta))$$
$$I1 := x1(I1p, I1\theta) + j \cdot y1(I1p, I1\theta) \qquad\qquad I2 := x2(I2p, I2\theta) + j \cdot y2(I2p, I2\theta)$$

$$x3(I3p, I3\theta) := I3p \cdot \cos(I3\theta) \qquad\qquad x4(I4p, I4\theta) := I4p \cdot \cos(I4\theta)$$
$$y3(I3p, I3\theta) := I3p \cdot \sin(I3\theta) \qquad\qquad y4(I4p, I4\theta) := I4p \cdot \sin(I4\theta)$$
$$I3 := x3(I3p, I3\theta) + j \cdot y3(I3p, I3\theta) \qquad\qquad I4 := x4(I4p, I4\theta) + j \cdot y4(I4p, I4\theta)$$

$$I1 = -0.709 + 0.554j \qquad\qquad I2 = -0.323 - 0.84j$$

$$I3 = -0.323 - 0.84j \qquad\qquad I4 = 1$$

$$Z1 := Z11 + \frac{I2 \cdot Zm21}{I1} + \frac{I3 \cdot Zm31}{I1} + \frac{I4 \cdot Zm41}{I1} \qquad Z2 := Z22 + \frac{I1 \cdot Zm12}{I2} + \frac{I3 \cdot Zm32}{I2} + \frac{I4 \cdot Zm42}{I2}$$
$$Z1 = 21.992 + 34.952j \qquad\qquad Z2 = 17.977 - 3.838j$$

$$Z3 := Z33 + \frac{I1 \cdot Zm13}{I3} + \frac{I2 \cdot Zm23}{I3} + \frac{I4 \cdot Zm43}{I3} \qquad Z4 := Z44 + \frac{I1 \cdot Zm14}{I4} + \frac{I2 \cdot Zm24}{I4} + \frac{I3 \cdot Zm34}{I4}$$
$$Z3 = 18.065 - 3.862j \qquad\qquad Z4 = 0.807 - 1.84j$$

Napetost v točki napajanja elementa

$$VDrive1 := I1 \cdot Z1 \qquad VDrive1 = -34.964 - 12.603j$$
$$VDrive2 := I2 \cdot Z2 \qquad VDrive2 = -9.023 - 13.867j$$
$$VDrive3 := I3 \cdot Z3 \qquad VDrive3 = -9.072 - 13.933j$$
$$VDrive4 := I4 \cdot Z4 \qquad VDrive4 = 0.807 - 1.84j$$

$$E1 := (I1 \cdot Z11) + (I2 \cdot Zm12) + (I3 \cdot Zm13) + (I4 \cdot Zm14) \qquad E1 = -34.962 - 12.618j$$
$$E2 := (I2 \cdot Z22) + (I1 \cdot Zm21) + (I3 \cdot Zm23) + (I4 \cdot Zm24) \qquad E2 = -9.072 - 13.943j$$
$$E3 := (I3 \cdot Z33) + (I1 \cdot Zm31) + (I2 \cdot Zm32) + (I4 \cdot Zm34) \qquad E3 = -9.018 - 13.87j$$
$$E4 := (I4 \cdot Z44) + (I1 \cdot Zm41) + (I2 \cdot Zm42) + (I4 \cdot Zm43) \qquad E4 = 24.021 - 5.536j$$

Napetost in njeno fazo konvertiramo iz Pravokotne v Polarno vrednost za vsak element posebej.

$$x1 := \operatorname{Re}(VDrive1) \qquad\qquad y1 := \operatorname{Im}(VDrive1)$$
$$r(x1, y1) := \sqrt{x1^2 + y1^2} \qquad\qquad \theta(x1, y1) := \operatorname{angle}(x1, y1)$$
$$\theta(x1, y1) = 199.822 \cdot deg$$

$$Angle := \text{if}\,[(\theta(x1, y1) \le \pi), (\theta(x1, y1)), \theta(x1, y1) - (2 \cdot \pi)]$$

$$\boldsymbol{U1 =} \quad r(x1, y1) = 37.166 \quad \boldsymbol{V} \qquad Angle = -160.178 \cdot deg$$

$x2 := Re(VDrive2)$ $\qquad$ $y2 := Im(VDrive2)$

$r(x2, y2) := \sqrt{x2^2 + y2^2}$ $\qquad$ $\theta(x2, y2) := angle(x2, y2)$

$\qquad\qquad\qquad\qquad\qquad$ $\theta(x2, y2) = 236.948 \cdot deg$

$Angle := if[(\theta(x2, y2) \leq \pi), (\theta(x2, y2)), \theta(x2, y2) - (2 \cdot \pi)]$

U2 = $\quad r(x2, y2) = 16.544$ $\quad$ **V** $\qquad$ $Angle = -123.052 \cdot deg$

$x3 := Re(VDrive3)$ $\qquad$ $y3 := Im(VDrive3)$

$r(x3, y3) := \sqrt{x3^2 + y3^2}$ $\qquad$ $\theta(x3, y3) := angle(x3, y3)$

$\qquad\qquad\qquad\qquad\qquad$ $\theta(x3, y3) = 236.932 \cdot deg$

$Angle := if[(\theta(x3, y3) \leq \pi), (\theta(x3, y3)), \theta(x3, y3) - (2 \cdot \pi)]$

U3 = $\quad r(x3, y3) = 16.626$ $\quad$ **V** $\qquad$ $Angle = -123.068 \cdot deg$

$x4 := Re(VDrive4)$ $\qquad$ $y4 := Im(VDrive4)$

$r(x4, y4) := \sqrt{x4^2 + y4^2}$ $\qquad$ $\theta(x4, y4) := angle(x4, y4)$

$\qquad\qquad\qquad\qquad\qquad$ $\theta(x4, y4) = 293.676 \cdot deg$

$Angle := if[(\theta(x4, y4) \leq \pi), (\theta(x4, y4)), \theta(x4, y4) - (2 \cdot \pi)]$

U4 = $\quad r(x4, y4) = 2.009$ $\quad$ **V** $\qquad$ $Angle = -66.324 \cdot deg$ $\qquad\qquad$ $U4\theta := Angle \cdot \dfrac{180}{\pi}$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $U4\theta = -66.324$

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          V primeru nesimetrije sistema
  zgoraj uporabim vrednosti medsebojnih Impedanc  21,31,41
.          Tukaj pa njihove nasprotne vrednosti   12,13,14  itd.
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$Z1a := Z11 + \dfrac{I2 \cdot Zm12}{I1} + \dfrac{I3 \cdot Zm13}{I1} + \dfrac{I4 \cdot Zm14}{I1}$ $\qquad$ $Z2a := Z22 + \dfrac{I1 \cdot Zm21}{I2} + \dfrac{I3 \cdot Zm23}{I2} + \dfrac{I4 \cdot Zm24}{I2}$

$Z1a = 21.98 + 34.964j$ $\qquad\qquad\qquad\qquad\qquad\qquad$ $Z2a = 18.076 - 3.859j$

$Z3a := Z33 + \dfrac{I1 \cdot Zm31}{I3} + \dfrac{I2 \cdot Zm32}{I3} + \dfrac{I4 \cdot Zm34}{I3}$ $\qquad$ $Z4a := Z44 + \dfrac{I1 \cdot Zm41}{I4} + \dfrac{I2 \cdot Zm42}{I4} + \dfrac{I3 \cdot Zm43}{I4}$

$Z3a = 17.978 - 3.832j$ $\qquad\qquad\qquad\qquad\qquad\qquad$ $Z4a = 0.813 - 1.853j$

$VDrive1a := I1 \cdot Z1a \quad VDrive1a = -34.962 - 12.618j$

$VDrive2a := I2 \cdot Z2a \quad VDrive2a = -9.072 - 13.943j$

$VDrive3a := I3 \cdot Z3a \quad VDrive3a = -9.018 - 13.87j$

$VDrive4a := I4 \cdot Z4a \quad VDrive4a = 0.813 - 1.853j$

Srednja vrednosti Impedanc Z1 & Z1a; Z2 & Z2a; Z3 & Z3a Z4 & Z4a

$Z1sr := \dfrac{(Z1 + Z1a)}{2}$ $\qquad\qquad\qquad\qquad$ $Z2sr := \dfrac{(Z2 + Z2a)}{2}$

$Z1sr = 21.986 + 34.958j$ $\qquad\qquad\qquad\qquad$ $Z2sr = 18.027 - 3.848j$

$Z3sr := \dfrac{(Z3 + Z3a)}{2}$ $\qquad\qquad\qquad\qquad$ $Z4sr := \dfrac{(Z4 + Z4a)}{2}$

$Z3sr = 18.022 - 3.847j$ $\qquad\qquad\qquad\qquad$ $Z4sr = 0.81 - 1.847j$

$\text{V1sr} := \text{I1} \cdot \text{Z1sr} \quad \text{V1sr} = -34.963 - 12.61\text{j}$

$\text{V2sr} := \text{I2} \cdot \text{Z2sr} \quad \text{V2sr} = -9.048 - 13.905\text{j}$

$\text{V3sr} := \text{I3} \cdot \text{Z3sr} \quad \text{V3sr} = -9.045 - 13.901\text{j}$

$\text{V4sr} := \text{I4} \cdot \text{Z4sr} \quad \text{V4sr} = 0.81 - 1.847\text{j}$

Srednje vrednosti napetosti in njenih faz iz Pravokotnega v Polarni format

$\text{x1} := \text{Re}(\text{V1sr}) \qquad\qquad \text{y1} := \text{Im}(\text{V1sr})$

$r(\text{x1}, \text{y1}) := \sqrt{\text{x1}^2 + \text{y1}^2} \qquad \theta(\text{x1}, \text{y1}) := \text{angle}(\text{x1}, \text{y1})$

$$\theta(\text{x1}, \text{y1}) = 199.833 \cdot \text{deg}$$

$\text{Angle} := \text{if}\left[(\theta(\text{x1}, \text{y1}) \leq \pi), (\theta(\text{x1}, \text{y1})), \theta(\text{x1}, \text{y1}) - (2 \cdot \pi)\right]$

U1sr = $r(\text{x1}, \text{y1}) = 37.167$ **V** $\text{Angle} = -160.167 \cdot \text{deg}$

$\text{x2} := \text{Re}(\text{V2sr}) \qquad\qquad \text{y2} := \text{Im}(\text{V2sr})$

$r(\text{x2}, \text{y2}) := \sqrt{\text{x2}^2 + \text{y2}^2} \qquad \theta(\text{x2}, \text{y2}) := \text{angle}(\text{x2}, \text{y2})$

$$\theta(\text{x2}, \text{y2}) = 236.949 \cdot \text{deg}$$

$\text{Angle} := \text{if}\left[(\theta(\text{x2}, \text{y2}) \leq \pi), (\theta(\text{x2}, \text{y2})), \theta(\text{x2}, \text{y2}) - (2 \cdot \pi)\right]$

U2sr = $r(\text{x2}, \text{y2}) = 16.59$ **V** $\text{Angle} = -123.051 \cdot \text{deg}$

$\text{x3} := \text{Re}(\text{V3sr}) \qquad \text{y3} := \text{Im}(\text{V3sr})$

$r(\text{x3}, \text{y3}) := \sqrt{\text{x3}^2 + \text{y3}^2}$

$\theta(\text{x3}, \text{y3}) := \text{angle}(\text{x3}, \text{y3})$

$$\theta(\text{x3}, \text{y3}) = 236.95 \cdot \text{deg}$$

$\text{Angle} := \text{if}\left[(\theta(\text{x3}, \text{y3}) \leq \pi), (\theta(\text{x3}, \text{y3})), \theta(\text{x3}, \text{y3}) - (2 \cdot \pi)\right]$

U3sr = $r(\text{x3}, \text{y3}) = 16.585$ **V** $\text{Angle} = -123.05 \cdot \text{deg}$

$\text{x4} := \text{Re}(\text{V4sr})$

$\text{y4} := \text{Im}(\text{V4sr})$

$r(\text{x4}, \text{y4}) := \sqrt{\text{x4}^2 + \text{y4}^2}$

$\theta(\text{x4}, \text{y4}) := \text{angle}(\text{x4}, \text{y4})$

$$\theta(\text{x4}, \text{y4}) = 293.679 \cdot \text{deg}$$

$\text{Angle} := \text{if}\left[(\theta(\text{x4}, \text{y4}) \leq \pi), (\theta(\text{x4}, \text{y4})), \theta(\text{x4}, \text{y4}) - (2 \cdot \pi)\right]$

U4sr = $r(\text{x4}, \text{y4}) = 2.017$ **V** $\text{Angle} = -66.321 \cdot \text{deg}$

$\text{Z1} = 21.992 + 34.952\text{j}$	$\text{Z1a} = 21.98 + 34.964\text{j}$	$\text{Z1sr} = 21.986 + 34.958\text{j}$
$\text{Z2} = 17.977 - 3.838\text{j}$	$\text{Z2a} = 18.076 - 3.859\text{j}$	$\text{Z2sr} = 18.027 - 3.848\text{j}$
$\text{Z3} = 18.065 - 3.862\text{j}$	$\text{Z3a} = 17.978 - 3.832\text{j}$	$\text{Z3sr} = 18.022 - 3.847\text{j}$
$\text{Z4} = 0.807 - 1.84\text{j}$	$\text{Z4a} = 0.813 - 1.853\text{j}$	$\text{Z4sr} = 0.81 - 1.847\text{j}$