전력공학1 Summary

$$\sin x \cos y = \frac{1}{2}\{\sin(x+y) + \sin(x-y)\}$$

$$\cos x \sin y = \frac{1}{2}\{\sin(x+y) - \sin(x-y)\}$$

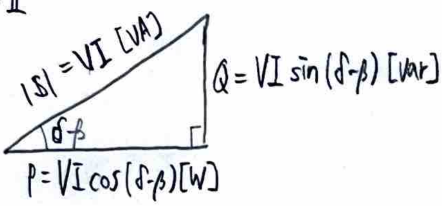
$$\cos x \cos y = \frac{1}{2}\{\cos(x+y) + \cos(x-y)\}$$

$$\sin x \sin y = -\frac{1}{2}\{\cos(x+y) - \cos(x-y)\}$$

$$P_{RLC}(t) = \underbrace{VI_R\{1+\cos[2(\omega t+\delta)]\}}_{P_R(t)} + \underbrace{VI_X \sin[2(\omega t+\delta)]}_{P_X(t)} \ [W]$$

Average Power : $VI_{RLC}\cos(\delta-\beta)$

$$S = VI^*$$



Network Equations

$$YV = I$$

↳ Y bus matrix로 표현

3상에서는 선간전압을 기본으로 사용

<상전압>

$$\begin{cases} E_{an} = E\angle 0^\circ \\ E_{bn} = E\angle -120^\circ \\ E_{cn} = E\angle -240^\circ = E\angle 120^\circ \end{cases}$$

<선간전압>

$$E_{ab} = E\sqrt{3}\angle 30^\circ$$

$$E_{bc} = E\sqrt{3}\angle -90^\circ$$

$$E_{ca} = E\sqrt{3}\angle -210^\circ = E\sqrt{3}\angle 150^\circ$$

선간전압은 상전압보다 크기는 $\sqrt{3}$배 크고 위상은 30° 앞선다.

<선전류 = Y부하전류(상전류)>

$$I_a = I_{AB} - I_{CA} = \sqrt{3}I_{AB}\angle -30^\circ$$

$$I_b = I_{BC} - I_{AB} = \sqrt{3}I_{BC}\angle -30^\circ$$

$$I_c = I_{CA} - I_{BC} = \sqrt{3}I_{CA}\angle -30^\circ$$

Δ부하 전류

$$I_{AB}$$

$$I_{BC}$$

$$I_{CA}$$

$$Z_\Delta = 3Z_Y$$

$$Z_Y = \frac{Z_\Delta}{3}$$

선전류는 Δ부하 전류보다 크기는 $\sqrt{3}$배 크고 위상은 30° 뒤진다.

$$P_{3\phi}(t) = P_{3\phi} = 3V_{LN}I_L\cos(\delta-\beta) = \sqrt{3}V_{LL}I_L\cos(\delta-\beta) \ [W]$$

$$a_t = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$$

$$\text{if } a_t = e^{j\theta} \rightarrow a_t = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2^*}{I_1^*}$$

Per-Unit System

$$\boxed{S_{base1\phi}} = P_{base1\phi} = Q_{base1\phi}$$

$$I_{base} = \frac{S_{base1\phi}}{V_{baseLN}}, \quad Z_{base} = \frac{V_{baseLN}^2}{S_{base1\phi}}$$

$$Z_{p.u.new} = \frac{Z_{actual}}{Z_{basenew}} = \frac{Z_{p.u.old}\cdot Z_{baseold}}{Z_{basenew}}$$

$$= Z_{p.u.old}\left(\frac{V_{baseold}^2}{S_{baseold}}\right)\left(\frac{S_{basenew}}{V_{basenew}^2}\right)$$

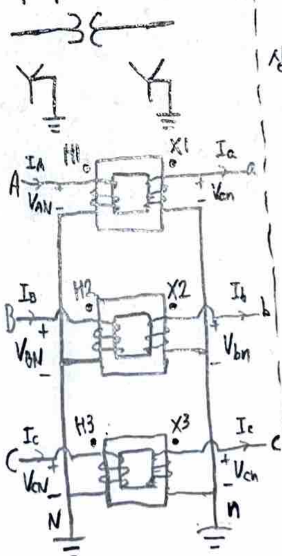
$$= Z_{p.u.old}\left(\frac{V_{baseold}}{V_{basenew}}\right)^2\left(\frac{S_{basenew}}{S_{baseold}}\right)$$

$$\boxed{S_{base3\phi} = 3\cdot S_{base1\phi}} = P_{base3\phi} = Q_{base3\phi}$$

$$V_{baseLN} = \frac{V_{baseLL}}{\sqrt{3}}$$

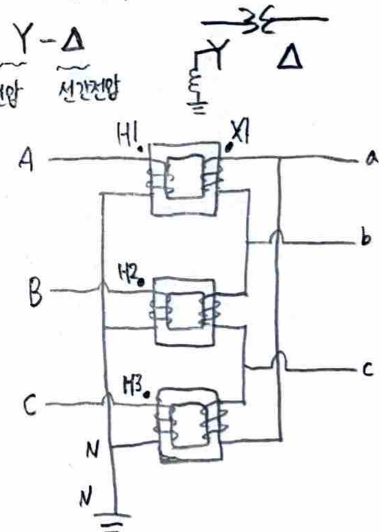
$$\left.\begin{aligned} I_{base} &= \frac{S_{base1\phi}}{V_{baseLN}} = \frac{S_{base3\phi}}{\sqrt{3}V_{baseLL}} \\ Z_{base} &= \frac{V_{baseLN}^2}{S_{base1\phi}} = \frac{V_{baseLL}^2}{S_{base3\phi}} \end{aligned}\right\} ☆$$

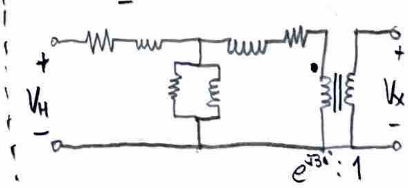
Y-Y



Y-Δ

상전압 선간전압





Y-Δ

3 phase : 2.0 MVA ; 13.8-kV Y / 2.5-kV Δ ; $\frac{2.0M}{13.8k}$-A Y / $\frac{2.0M}{2.5k}$-A Δ

1 phase : 0.667 MVA ; $\frac{13.8}{\sqrt{3}}$-kV : 2.5-kV ; $\frac{0.667M}{\frac{13.8}{\sqrt{3}}k}$-A : $\frac{0.667M}{2.5k}$-A

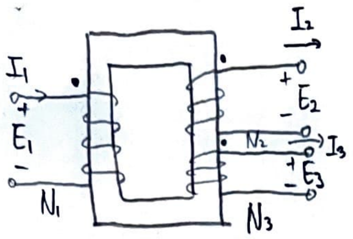
Y-Y

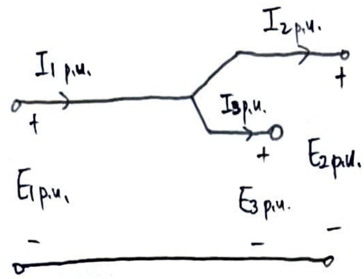
3 phase : 2.0 MVA ; 13.8-kV Y / 2.5-kV Y ;

1 phase : 0.667 MVA ; $\frac{13.8}{\sqrt{3}}$-kV : $\frac{2.5}{\sqrt{3}}$-kV ;

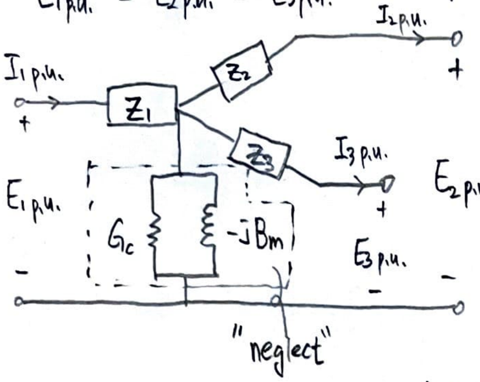
비슷하게 풀이

* Three-Winding Transformers



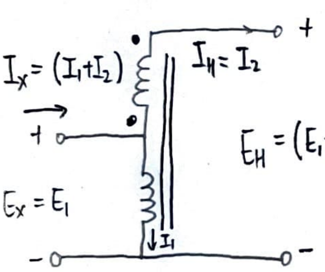


- $E_1 I_1^* = E_2 I_2^* + E_3 I_3^*$ $\Leftarrow$ $N_1 I_1 = N_2 I_2 + N_3 I_3$
- $E_{1\,p.u.} = E_{2\,p.u.} = E_{3\,p.u.}$ $\quad E_1 : E_2 : E_3 = N_1 : N_2 : N_3$



$$Z_{12} = Z_1 + Z_2 \qquad\qquad Z_1 = \frac{1}{2}(Z_{12} + Z_{13} - Z_{23})$$
$$Z_{13} = Z_1 + Z_3 \quad \Rightarrow \quad Z_2 = \frac{1}{2}(Z_{12} + Z_{23} - Z_{13})$$
$$Z_{23} = Z_2 + Z_3 \qquad\qquad Z_3 = \frac{1}{2}(Z_{13} + Z_{23} - Z_{12})$$

* Autotransformer

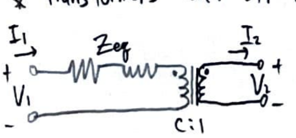


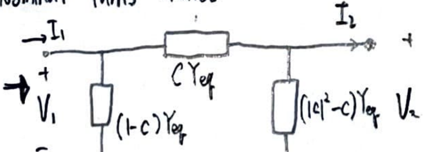
$E_H = (E_1 + E_2)$

Advantage : smaller series voltage drop

Disadvantage : higher short-circuit current

* Transformers with Off-Nominal Turns Ratios





$$\begin{bmatrix} I_1 \\ -I_2 \end{bmatrix} = \begin{bmatrix} Y_{eq} & -cY_{eq} \\ -c^* Y_{eq} & |c|^2 Y_{eq} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

* GMD (Geometric Mean Distance)

$$D_{xy} = \sqrt[NM]{\prod_{k=1}^{N} \prod_{m=1'}^{M} D_{km}}$$

$D_{11} = D_{22} = D_{33} = r_x'$
$= e^{-1/4} r_x = 0.7788\, r_x$

$1\text{m} = 3.28\text{ft}$

* GMR (Geometric Mean Radius)

$$D_{xx} = \sqrt[N^2]{\prod_{k=1}^{N} \prod_{m=1}^{N} D_{km}} \qquad D_{yy} = \sqrt[M^2]{\prod_{k=1'}^{M} \prod_{m=1'}^{M} D_{km}}$$

$$L = L_x + L_y = (2\times10^{-7}) \ln \frac{D_{xy}}{D_{xx}} + (2\times10^{-7}) \ln \frac{D_{xy}}{D_{yy}}$$

* Transposition (연가)

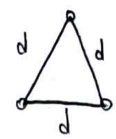
$$\lambda_a = 2\times10^{-7} I_a \ln \frac{\sqrt[3]{D_{12} D_{23} D_{31}}}{D_s} \quad [\text{Wb-t/m}]$$

$$L_a = 2\times10^{-7} \ln \frac{\sqrt[3]{D_{12} D_{23} D_{31}}}{D_s} = 2\times10^{-7} \ln \frac{D_{eq}}{D_s} \quad [\text{H/m per phase}]$$

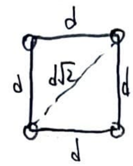
⟨ ☆ D_s = GMR ⟩

* Bundled Conductors

$D_{SL2} = \sqrt{D_s d}$



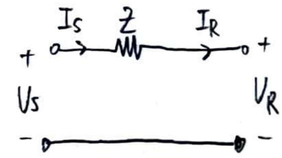
$D_{SL3} = \sqrt[3]{D_s d^2}$ $\qquad L_a = 2\times10^{-7} \ln \frac{D_{eq}}{D_{SL}}$ [H/m]



$D_{SL4} = 1.0905 \sqrt[4]{D_s d^3}$

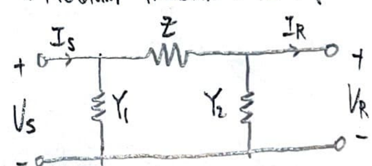
* Two-Port Network (4단자망)

- Short Transmission Line ($0 \sim 25$km)



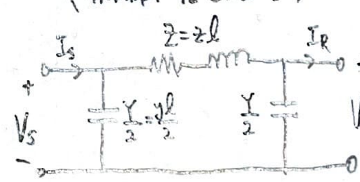
$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

- Medium Transmission Line ($25 \sim 250$km)



$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} (1+Y_2 Z) & Z \\ (Y_1 + Y_2 + Y_1 Y_2 Z) & (1+Y_1 Z) \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

⟨ nominal π circuit ⟩



$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} (1+\frac{YZ}{2}) & Z \\ Y(1+\frac{YZ}{4}) & (1+\frac{YZ}{2}) \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

* Voltage Regulation (전압조정률)

$$\text{percent VR} = \frac{|V_{RNL}| - |V_{RFL}|}{|V_{RFL}|} \times 100$$

* Hyperbolic Function

$$\sinh(x) = \frac{e^x - e^{-x}}{2}, \quad \cosh(x) = \frac{e^x + e^{-x}}{2}, \quad \tanh(x) = \frac{\cosh(2x) - 1}{\sinh(2x)}$$

$$\frac{\sinh(2x)}{\cosh(2x)+1} = \frac{\cosh(2x)-1}{\sinh(2x)}$$

* Transmission Line Differential Equations
(Uniformly Distributed TR Line)

$$\begin{bmatrix} V(l) \\ I(l) \end{bmatrix} = \begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} \cosh(\gamma l) & Z_c \sinh(\gamma l) \\ \frac{1}{Z_c}\sinh(\gamma l) & \cosh(\gamma l) \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$\left(\gamma = \sqrt{zy}, \quad Z_c = \sqrt{\frac{z}{y}} \right)$$

$\Updownarrow$

$$\begin{bmatrix} (1+\frac{Y'Z'}{2}) & Z' \\ Y'(1+\frac{Y'Z'}{4}) & (1+\frac{Y'Z'}{2}) \end{bmatrix}$$

$$Z' = Z \cdot \frac{\sinh(\gamma l)}{\gamma l} = Z \cdot F_1$$

$$\frac{Y'}{2} = \frac{Y}{2} \cdot \left(\frac{\tanh(\gamma l/2)}{\gamma l/2} \right) = \frac{Y}{2} \cdot F_2$$

⟨ Equivalent π-circuit ⟩