Winding Impedance calculations for three winding autotransformer

$MVA := 1000kW$

Useful Constants

V_l is l-l since will be in Delta

$V_h := \frac{525 \cdot kV}{\sqrt{3}}$ $V_m := \frac{241.5 \cdot kV}{\sqrt{3}}$ $V_l := 34.5 \cdot kV$ $S_b := 100 \cdot MVA$

Test Impedances, found at bases listed next to numbers (in percent), Note Zhm and Zhl are reversed from the other cases

$X_{hm} := 7.94$	448 MVA
$X_{hl} := 3.46$	25 MVA
$X_{ml} := 2.98$	25 MVA

Convert test impedances to 100 MVA Base (answers still in percent), based on the data from data sheets regarding H/L and H/M

$X_{hlnew} := \frac{100}{25} \cdot X_{hl}$ $X_{hlnew} = 13.84$

$X_{hmnew} := \frac{100}{448} \cdot X_{hm}$ $X_{hmnew} = 1.772$

$X_{mlnew} := \frac{100}{25} \cdot X_{ml}$ $X_{mlnew} = 11.92$

Find Xh, Xm, and Xl to find Xi, Xii, Xiii

$X_h := (0.5) \cdot (X_{hlnew} + X_{hmnew} - X_{mlnew})$ $X_h = 1.846$

$X_m := (0.5) \cdot (X_{hmnew} + X_{mlnew} - X_{hlnew})$ $X_m = -0.074$

$X_l := (0.5) \cdot (X_{mlnew} + X_{hlnew} - X_{hmnew})$ $X_l = 11.994$

Define a constant: $r := \frac{(V_h - V_m)}{V_h}$ $r = 0.54$

$$X_i := \left(\frac{1}{r}\right)^2 \cdot X_h + \frac{(1-r)}{r^2} \cdot X_m \qquad X_i = 6.215$$

$$X_{ii} := \left(\frac{1}{r}\right) \cdot X_m \qquad X_{ii} = -0.137$$

$$X_{iii} := X_l - \frac{1-r}{r} \cdot X_m \qquad X_{iii} = 12.057$$

Now convert Xi, xii, and Xiii to Ohms (convert Xi's from Percent to Per Unit too)

$$X_{iohm} := \frac{3 \cdot \left(V_h - V_m\right)^2}{S_b} \cdot \frac{X_i}{100} \qquad X_{iohm} = 49.949\,\text{ohm}$$

$$Li := \frac{X_{iohm}}{2 \cdot \pi \cdot 60\text{Hz}} \qquad Li = 132.493\,\text{mH}$$

$$X_{iiohm} := \frac{3 \cdot \left(V_m\right)^2}{S_b} \cdot \frac{X_{ii}}{100} \qquad X_{iiohm} = -0.797\,\text{ohm}$$

$$L_{ii} := \frac{\left(X_{iiohm}\right)}{2 \cdot \pi \cdot 60\text{Hz}} \qquad L_{ii} = -2.115\,\text{mH}$$

$$X_{iiiohm} := \frac{3 \cdot \left(V_l\right)^2}{S_b} \cdot \frac{X_{iii}}{100} \qquad X_{iiiohm} = 4.305\,\text{ohm}$$

$$L_{iii} := \frac{X_{iiiohm}}{2 \cdot \pi \cdot 60\text{Hz}} \qquad L_{iii} = 11.42\,\text{mH}$$

Convert test impedances to autotransformer

$$Z_{i\_ii} := X_{hmnew} \cdot \left(\frac{V_h}{V_h - V_m} \right)^2 \qquad Z_{i\_ii} = 6.078$$

$$Z_{ii\_iii} := X_{mlnew} \qquad Z_{ii\_iii} = 11.92$$

$$Z_{i\_iii} := X_{hmnew} \cdot \left[\frac{V_h \cdot V_m}{\left(V_h - V_m\right)^2} \right] + X_{hlnew} \cdot \left(\frac{V_h}{V_h - V_m} \right) - X_{mlnew} \cdot \left(\frac{V_m}{V_h - V_m} \right)$$

$$Z_{i\_iii} = 18.271$$

Now find Zi, Zii, Ziii, solving the matrix Z123 = Transpose[Zi,Zii,Ziii] and

Zi_ii = Zi+Zii

Zi_iii= Zi+Ziii

Zii_iii=Zii+Ziii

$$Zauto := \begin{pmatrix} Z_{i\_ii} \\ Z_{i\_iii} \\ Z_{ii\_iii} \end{pmatrix} \qquad Acoup := \begin{pmatrix} 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{pmatrix}$$

$$Z123 := \text{lsolve}(Acoup, Zauto)$$

$$Z123 = \begin{pmatrix} 6.215 \\ -0.137 \\ 12.057 \end{pmatrix}$$

$$Zialt := Z123_0 \qquad Zialt = 6.215$$

$$Ziialt := Z123_1 \qquad Ziialt = -0.137$$

$$Ziiialt := Z123_2 \qquad Ziiialt = 12.057$$