Transformer Examples

MVA := 1000kW

Given a three phase, 24kV:230kV, 150 MVA delta to Y-grounded transformer. The 24kV winding has an X/R ratio of 10, and a leakage reactance of 5.5%. The 230kV winding has an X/R ratio of 12 and a leakage reactance of 7%. The core loss term is equivalent to 50kW per phase on the wye side with rated voltage across the core loss resistor. The magnetizing inductance is 20kΩ at rated voltage referred to the HV side.

\[ V_{LV} := 24kV \]
\[ \omega := 2\pi \cdot 60Hz \]
\[ V_{HV} := 230kV \]
\[ S_{rated} := 150MVA \]

\[ Z_{BLV} := \frac{V_{LV}^2}{S_{rated}} \]
\[ Z_{BHV} := \frac{V_{HV}^2}{S_{rated}} \]

LV winding resistance and leakage reactance:

\[ X_{LV} := 5.5\% \]
\[ X_{LVohm} := X_{LV} \cdot Z_{BLV} \]
\[ X_{LVohm} = 0.21\Omega \]

\[ L_{LV} := \frac{X_{LVohm}}{\omega} \]
\[ L_{LV} = 0.56\cdot mH \]

\[ R_{LV} := \frac{X_{LVohm}}{10} \]
\[ R_{LV} = 0.021\Omega \]

However, these values are for a Y equivalent winding, now get delta equivalent values:

\[ L_{LV\Delta} := 3 \cdot L_{LV} \]
\[ L_{LV\Delta} = 1.681\cdot mH \]

\[ R_{LV\Delta} := 3 \cdot R_{LV} \]
\[ R_{LV\Delta} = 0.063\Omega \]

HV winding resistance and leakage reactance:

\[ X_{HV} := 7\% \]
\[ X_{HVohm} := X_{HV} \cdot Z_{BHV} \]
\[ X_{HVohm} = 24.69\Omega \]

\[ L_{HV} := \frac{X_{HVohm}}{\omega} \]
\[ L_{HV} = 65.483\cdot mH \]
$R_{HV} := \frac{X_{HV\text{Ohm}}}{12}$

$R_{HV} = 2.057 \Omega$

Shunt branches:

$P_{\text{core}} := 3 \cdot 50 \text{kW}$  
Multiply by three since given per phase.

$R_{\text{core}} := \frac{V_{HV}^2}{P_{\text{core}}}$  
$R_{\text{core}} = 352.67 \cdot \text{k}\Omega$

Alternate way:

$$R_{\text{core\_alt}} := \frac{\left(\frac{V_{HV}}{\sqrt{3}}\right)^2}{50 \text{ kW}}$$

$R_{\text{core\_alt}} = 352.67 \cdot \text{k}\Omega$

$X_{m} := 20 \Omega$

$L_{m} := \frac{X_{m}}{\omega}$  
$L_{m} = 53.05 \text{ H}$

But we don't enter $L_{m}$ directly. If we are entering $V$ vs $I$ for the characteristic:

$V_{\text{rms1}} := \frac{V_{HV}}{\sqrt{3}}$  
$V_{\text{rms1}} = 132.79 \text{ kV}$

$I_{\text{rms1}} := \frac{V_{\text{rms1}}}{X_{m}}$  
$I_{\text{rms1}} = 6.6395 \text{ A}$

Or for peak flux versus peak current

$$\Phi_{\text{mag}} := \frac{V_{\text{rms1}}}{2 \cdot \pi \cdot 60 \text{ Hz}}$$

$\Phi_{\text{mag}} = 352.24 \text{ Wb}$

$\text{Imag\_pk} := \sqrt{2} \cdot I_{\text{rms1}}$  
$\text{Imag\_pk} = 9.39 \text{ A}$

$\Phi_{\text{pk}} := \sqrt{2} \Phi_{\text{mag}}$  
$\Phi_{\text{pk}} = 498.14 \text{ Wb}$

Since the transformer model puts the magnetizing branch and core loss term on the primary winding, we will need to put the primary winding on the HV side when entering data.
ATPDraw Implementation:
Using the saturable transformer:
- Note that the 0,0 point was added to get the appropriate plot, but the program will add it internally when running the case.

<table>
<thead>
<tr>
<th>I [A]rms</th>
<th>U [V]rms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6335</td>
<td>132.8</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

![Graph showing a linear relationship between I [A]rms and U [kV]rms]
**Autotransformer case:**

![Autotransformer Diagram]

360V

Autotransformer case:

(f ile lect36A.plt; x-var t)

v:HV   v:HV    v:LV    v:LV

0   10   20   30   40   50

[ms]

-400  -300  -200  -100   0   100   200   300   400

[V]
Ground Transformer Example

Ground Transformer Resistor Current for SLG fault

Phase currents to the transformer for SLG fault (note all in phase):
Ground transformer resistor current for a three phase fault:
**PSCAD Implementation:**

![Diagram of transformer connections]

**Main dialog box**
- Note per unit leakage reactance
- No load losses are from open circuit test
- Copper losses are from rated current through the winding resistances as above
- Note that ideal transformer not selected.

*Note that three phase transformer uses RMS L-L voltages for ratio and to convert per unit values to ohms and mH*
Saturation was not enabled. So the only line that means anything here is the magnetizing current.

- Note that unless the transformer is specified as ideal the magnetizing current cannot be set to zero.

**Autotransformer case:**

- Using default transformer parameters other than turns ratio

\[ V_{\text{prim}} := 240 \text{kV} \]

\[ V_{\text{sec}} := 120 \text{kV} \]