ECE 524: 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.

\[ V_{LV} := 24kV \]
\[ V_{HV} := 230kV \]
\[ S_{rated} := 150MVA \]

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

LV winding resistance and leakage reactance:

\[ X_{LV} := 5.5\% \]
\[ X_{LVohm} := X_{LV} \cdot Z_{BLV} \quad X_{LVohm} = 0.21\Omega \]
\[ L_{LV} := \frac{X_{LVohm}}{\omega} \quad L_{LV} = 0.56\text{mH} \]
\[ R_{LV} := \frac{X_{LVohm}}{10} \quad R_{LV} = 0.021\Omega \]

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

\[ L_{LV\Delta} := 3 \cdot L_{LV} \quad L_{LV\Delta} = 1.681\text{mH} \]
\[ R_{LV\Delta} := 3 \cdot R_{LV} \quad R_{LV\Delta} = 0.063\Omega \]

HV winding resistance and leakage reactance:

\[ X_{HV} := 7\% \]
\[ X_{HVohm} := X_{HV} \cdot Z_{BHV} \quad X_{HVohm} = 24.69\Omega \]
\[ L_{HV} := \frac{X_{HVohm}}{\omega} \quad L_{HV} = 65.483\text{mH} \]
\[ R_{HV} := \frac{X_{HV \text{ ohm}}}{12} \quad R_{HV} = 2.057 \, \Omega \]

Shunt branches:

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

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

Alternate way:

\[ R_{\text{core alt}} := \left( \frac{\left( \frac{V_{HV}}{\sqrt{3}} \right)^2}{50 \text{kW}} \right) \quad R_{\text{core alt}} = 352.67 \cdot \text{k}\Omega \]

\[ X_m := 20 \text{k}\Omega \quad L_m := \frac{X_m}{\omega} \quad L_m = 53.05 \, \text{H} \]

But we don’t enter \( L_m \) directly. If we are entering \( V \) vs \( I \) for the characteristic:

\[ V_{\text{rms1}} := \frac{V_{HV}}{\sqrt{3}} \quad V_{\text{rms1}} = 132.79 \cdot \text{kV} \]

\[ I_{\text{rms1}} := \frac{V_{\text{rms1}}}{X_m} \quad I_{\text{rms1}} = 6.6395 \, \text{A} \]

Or for peak flux versus peak current

\[ \Phi_{\text{mag}} := \frac{V_{\text{rms1}}}{2 \cdot \pi \cdot 60 \text{Hz}} \quad \Phi_{\text{mag}} = 352.24 \, \text{Wb} \]

\[ \text{Imag}_\text{pk} := \sqrt{2} \cdot I_{\text{rms1}} \quad \text{Imag}_\text{pk} = 9.39 \, \text{A} \]

\[ \Phi_{\text{pk}} := \sqrt{2} \Phi_{\text{mag}} \quad \Phi_{\text{pk}} = 498.14 \, \text{Wb} \]

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:

![Component: SATTRAFO](image)

**Attributes**

- **U [V]**: 132.79, 24
- **R [ohm]**: 2.057, 0.063
- **L [mH, ohm]**: 65.483, 1.881

**Characteristics**

- **NODE**: Primary, Secondary, Starpoint, Prim-N
- **PHASE**: 3
- **NAME**: 
  - Primary: 3
  - Secondary: 3
  - Starpoint: 3
  - Prim-N: 1

**Coupling**: Y

**Phase shift**: 330

**I(0) = 9.39**

**F(0) = 458.14**

**Order**: 0

**Label**: 

**Comment**: 

**Output**: 0 - No

- **Hide**
- **Lock**

**Buttons**: 

- Edit definitions
- OK
- Cancel
- Help
Note that the 0,0 point was added to get the appropriate plot, but the program will add it internally when running the case.
**Autotransformer case:**

![Autotransformer Diagram]

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:**

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

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

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