Transformer Restricted Earth Fault Protection Example

$MVA := MW \qquad S_{RATED} := 300MVA \qquad V_{HV} := 230kV \qquad V_{LV} := 24kV$

$$I_{RATED\_HV} := \frac{S_{RATED}}{\sqrt{3}\cdot V_{HV}} \qquad I_{RATED\_HV} = 753.07\,A$$

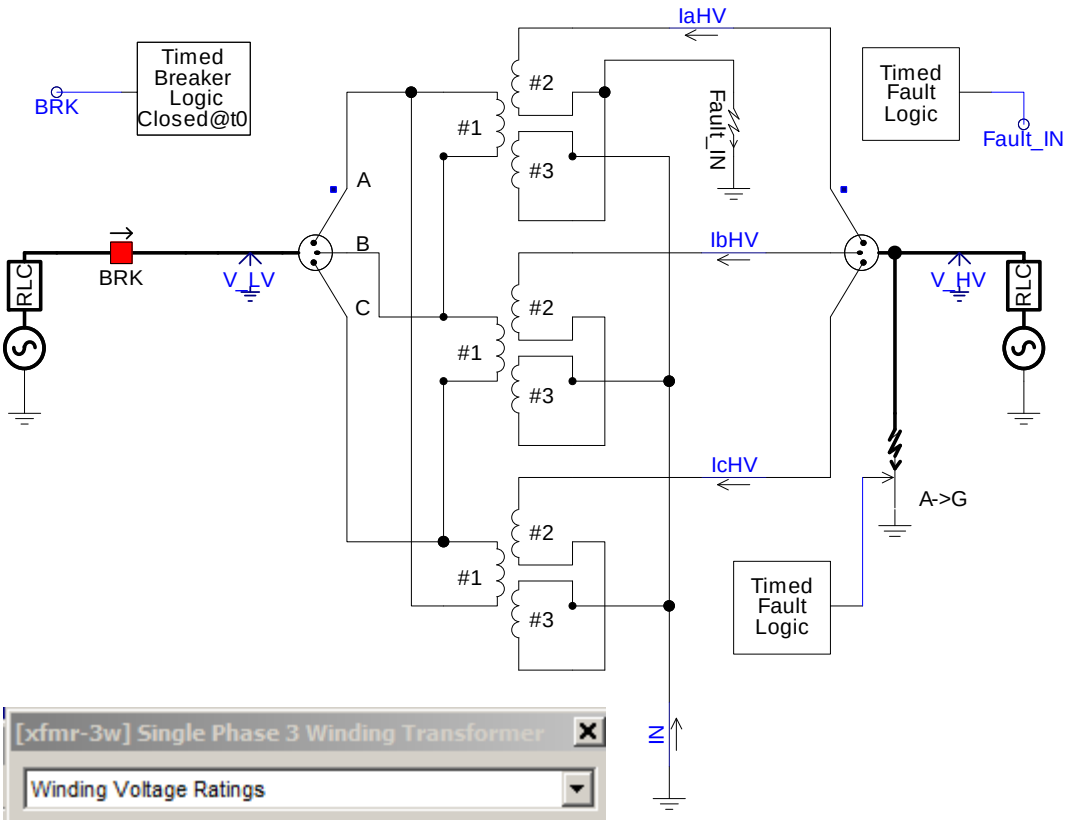
$$CTR_{Neutral} := \frac{800}{5} \qquad CTR_{phase} := \frac{800}{5}$$

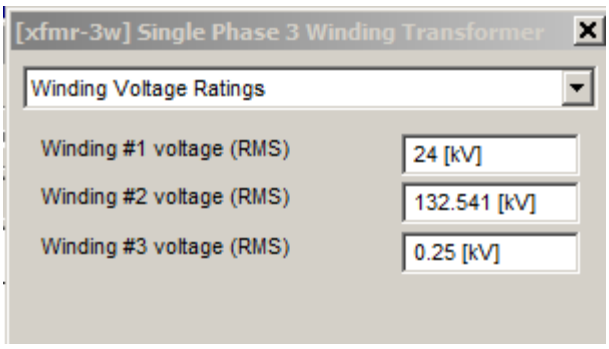
$Num_{TurnsHV} := 531$

$Num_{TurnsLV} := 96$

$$V\_per\_turn_{HV} := \frac{\left(\frac{230kV}{\sqrt{3}}\right)}{Num_{TurnsHV}} \qquad V\_per\_turn_{HV} = 0.25\cdot kV$$

PSCAD/EMTDC Model:





Transformer Winding Voltage Dialog:

Prefault load current: $I_{PF\_A} := 78.7A \cdot e^{j \cdot 130.1deg}$

$I_{PF\_B} := 78.7A \cdot e^{j \cdot 10.1deg}$

$I_{PF\_C} := 78.7A \cdot e^{-j \cdot 109.9deg}$ $\quad I_{PF\_A} + I_{PF\_B} + I_{PF\_C} = 0\,A$

Case 1: External SLG Fault on Y side

$I_{SLG\_A} := 2022.7A \cdot e^{j \cdot 36.8deg}$

$I_{SLG\_B} := 756.5A \cdot e^{j \cdot 28.2deg}$

$I_{SLG\_C} := 623.8A \cdot e^{-j \cdot 25.6deg}$

Neutral CT current:

$I_{N\_SLG} := 3390.2A \cdot e^{-j \cdot 147.1deg}$

$I_{R\_SLG} := I_{SLG\_A} + I_{SLG\_B} + I_{SLG\_C}$ $\quad |I_{R\_SLG}| = 3131.33\,A$ $\quad \arg(I_{R\_SLG}) = 24.52 \cdot deg$

$I_{NSLG\_sec} := \frac{I_{N\_SLG}}{CTR_{Neutral}}$ $\quad I_{RSLG\_sec} := \frac{I_{R\_SLG}}{CTR_{phase}}$

$Torque_{REF\_SLG} := Re\left(I_{NSLG\_sec} \cdot \overline{I_{RSLG\_sec}}\right)$ $\quad Torque_{REF\_SLG} = -410.25\,A^2$

- Large negative torque implies fault is out of zone.

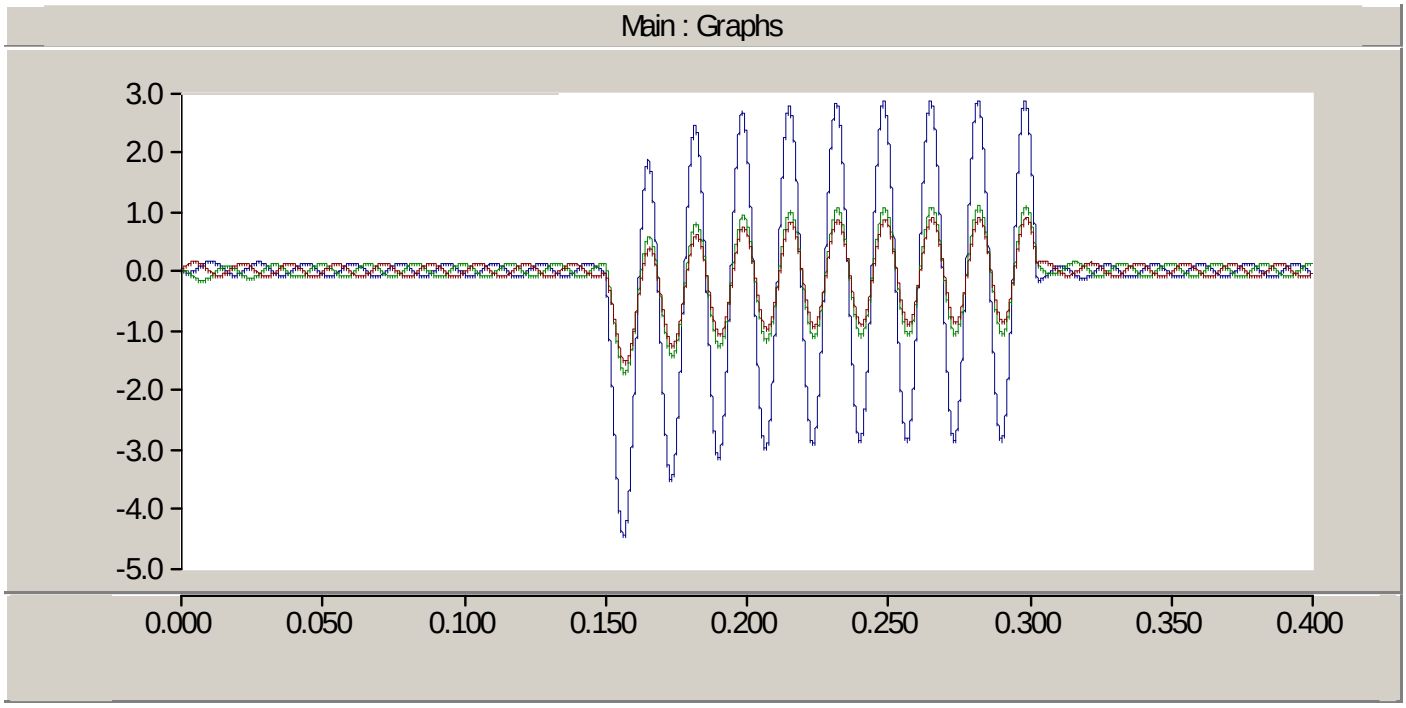
Alternate approach:

$I_{OP\_SLG} := |I_{NSLG\_sec} + I_{RSLG\_sec}|$ $\quad I_{OP\_SLG} = 3.39\,A$

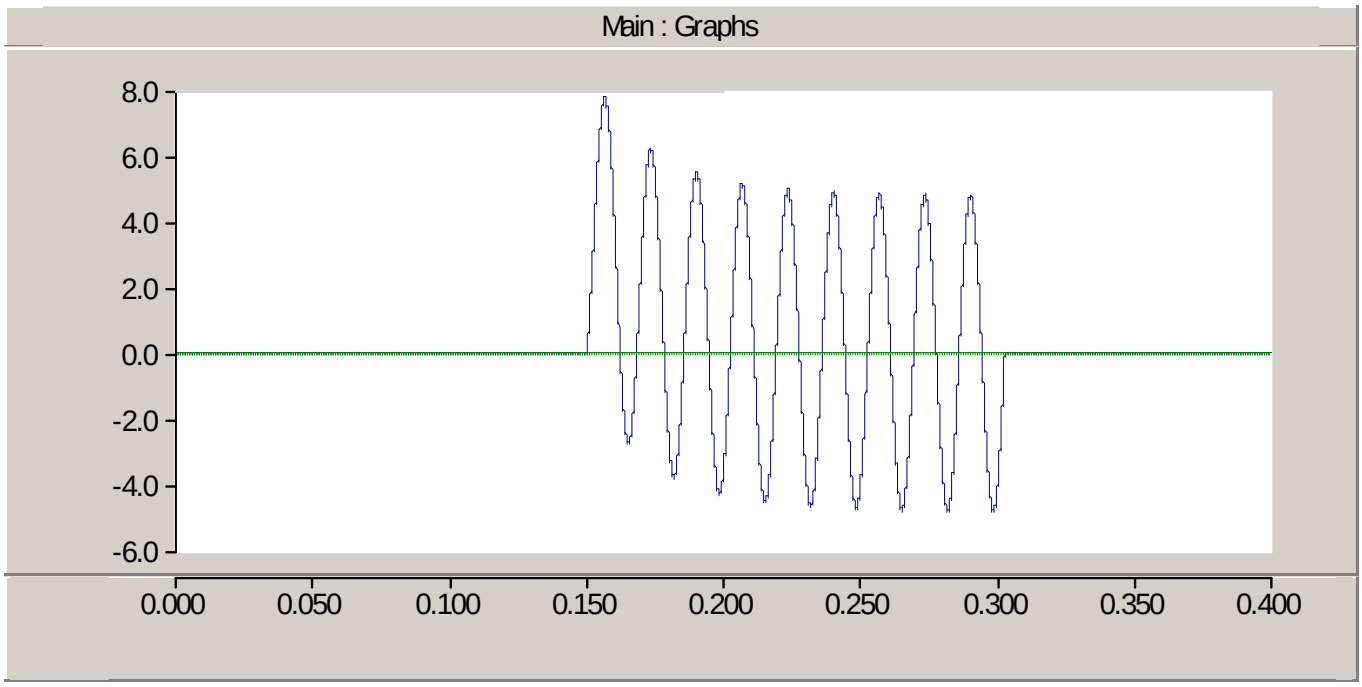
$I_{RT\_SLG} := |I_{NSLG\_sec}| + |I_{RSLG\_sec}|$ $\quad I_{RT\_SLG} = 40.76\,A$

$\frac{I_{OP\_SLG}}{I_{RT\_SLG}} = 0.08$ Would restrain and not trip

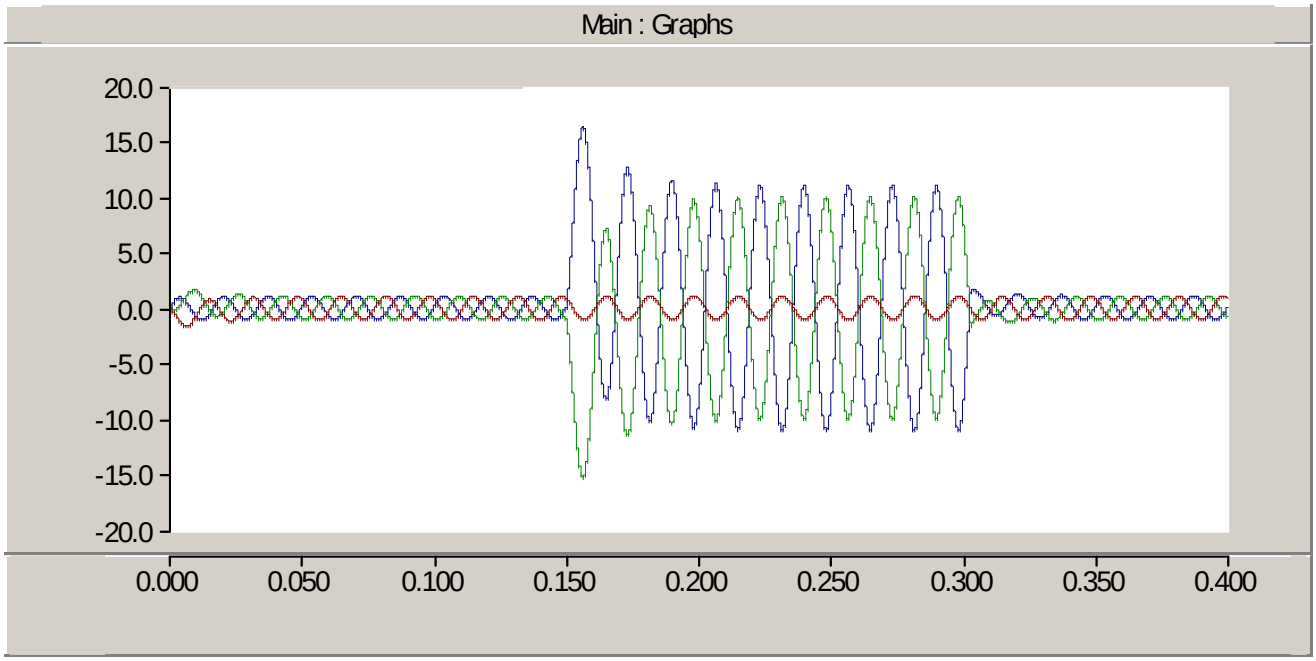
High voltage side currents (kA)



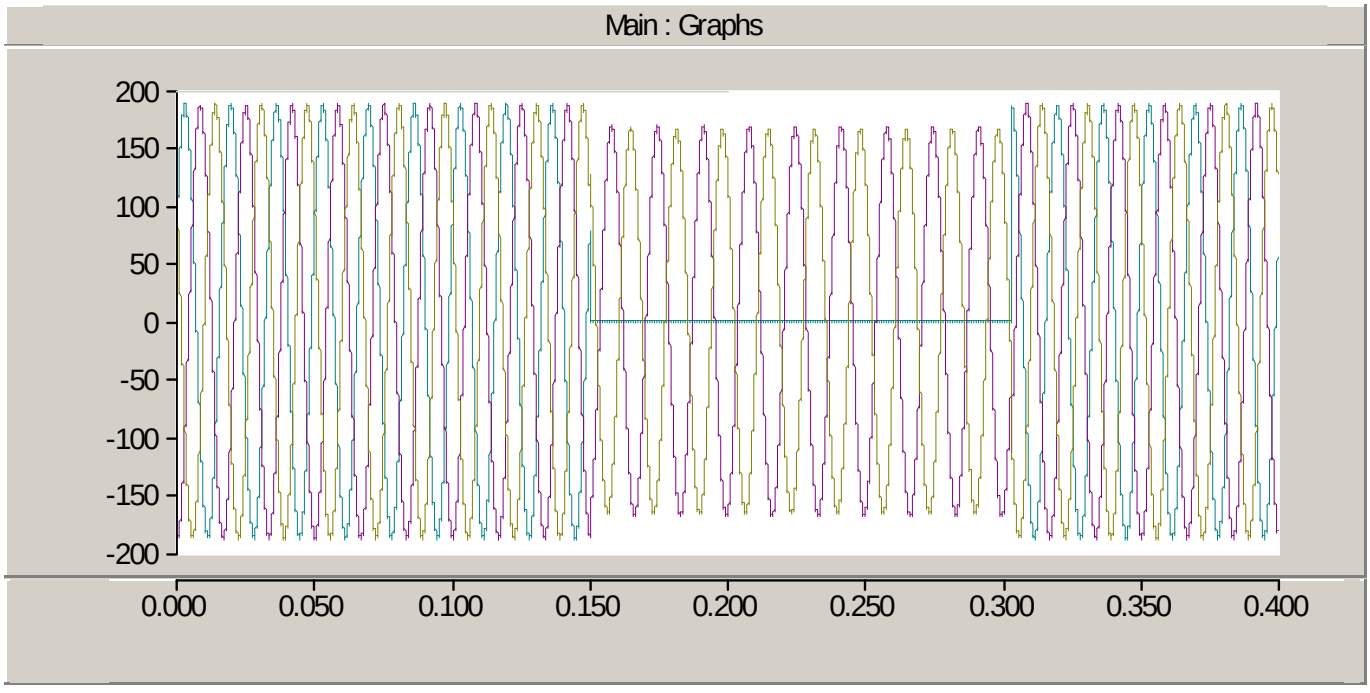
Neutral Current (kA)



Low voltage side line currents (kA):



High voltage side line to ground voltages (kV)



Case 2: Restricted earth fault with turn up from neutral

$$I_{REF\_A} := 57.58A \cdot e^{j \cdot 136.55deg}$$

$$I_{REF\_B} := 77.31A \cdot e^{j \cdot 16.1deg}$$

$$I_{REF\_C} := 72.78A \cdot e^{-j \cdot 114.3deg}$$

Neutral CT current:

$$I_{N\_REF} := 24912.1A \cdot e^{j \cdot 115.3deg}$$

$$I_{R\_REF} := I_{REF\_A} + I_{REF\_B} + I_{REF\_C} \qquad \left|I_{R\_REF}\right| = 5.87\,A \qquad \arg\left(I_{R\_REF}\right) = -64.49 \cdot deg$$

$$I_{NREF\_sec} := \frac{I_{N\_REF}}{CTR_{Neutral}} \qquad I_{RREF\_sec} := \frac{I_{R\_REF}}{CTR_{phase}}$$

$$Torque_{REF} := Re\left(I_{NREF\_sec} \cdot \overline{I_{RREF\_sec}}\right) \qquad Torque_{REF} = -5.71\,A^2$$

- Small torque implies fault might in zone.

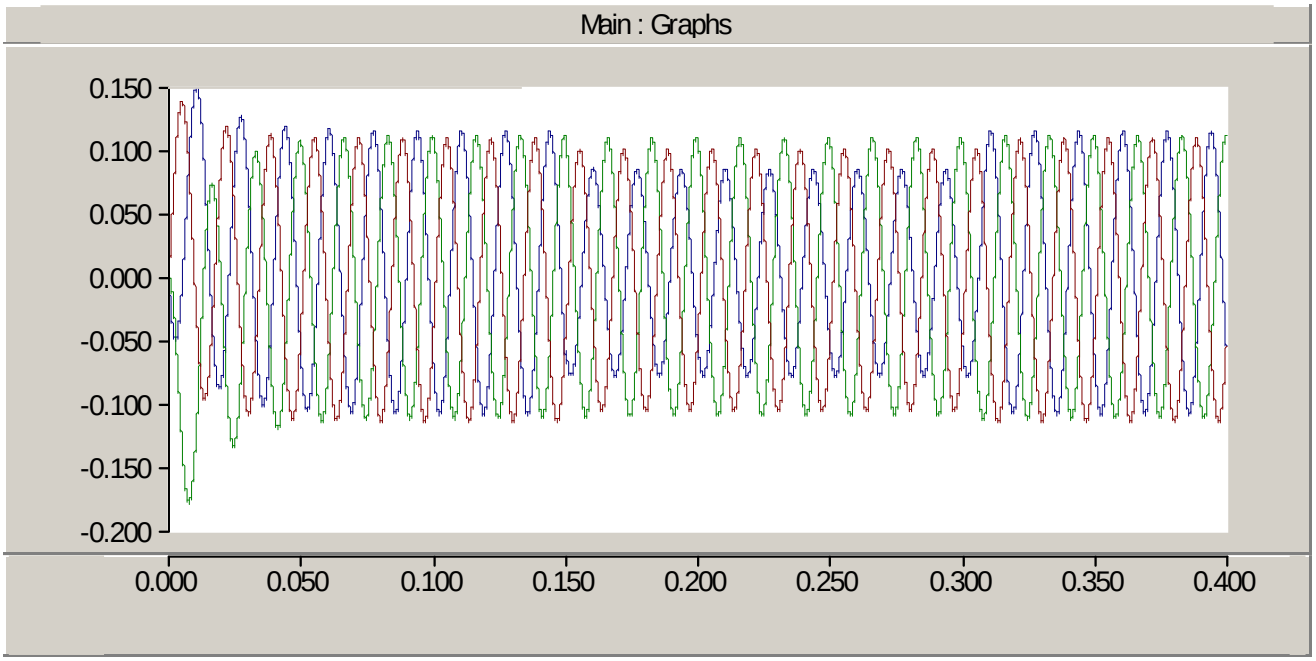
Alternate approach:

$$I_{OP\_REF} := \left|I_{NREF\_sec} + I_{RREF\_sec}\right| \qquad I_{OP\_REF} = 155.66\,A$$

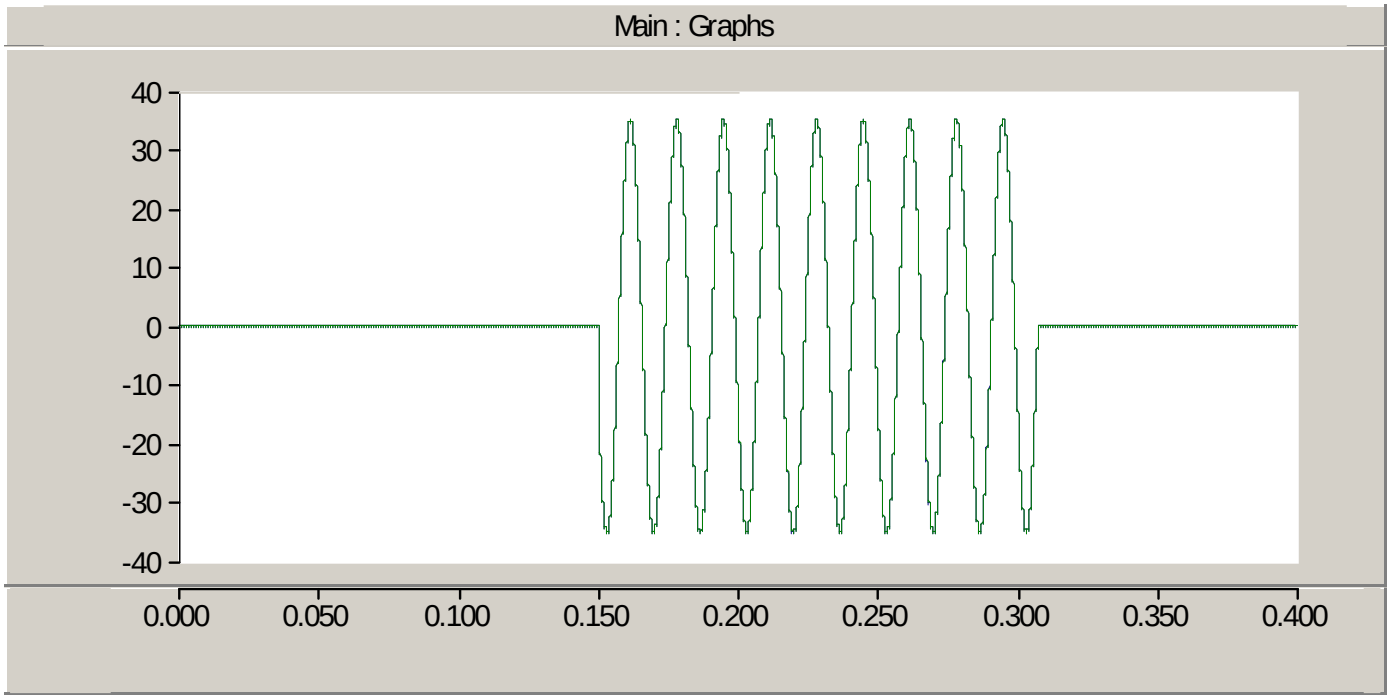
$$I_{RT\_REF} := \left|I_{NREF\_sec}\right| + \left|I_{RREF\_sec}\right| \qquad I_{RT\_REF} = 155.74\,A$$

$$\frac{I_{OP\_REF}}{I_{RT\_REF}} = 1$$ Clearer indicator

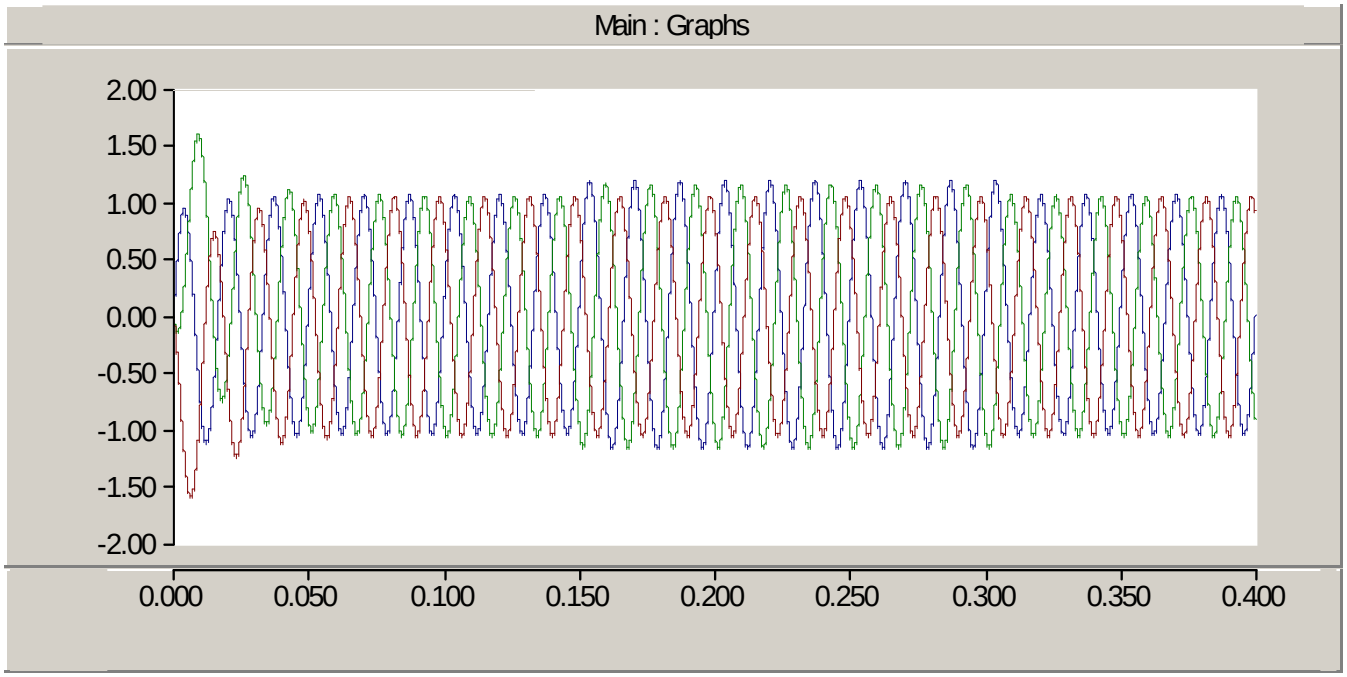
High voltage side transformer currents (kA):



Neutral current and fault current (kA)



Low voltage side line currents (kA)



High voltge side line to ground voltages (kV)