Plots of MathCAD Results:

\[ T_n := \frac{1}{f_n} \]

\[ v_{c\text{NoR}} \left( \frac{T_n}{2} \right) = 56.34 \text{ kV} \]

\[ T_d := \frac{1}{f_d} \]

\[ v_c \left( \frac{T_d}{2} \right) = 33.8 \text{ kV} \]

\[ 1.2V_m = 33.8 \text{ kV} \]

\[ \text{RRRV}_{\text{damp}} := 1.2 \cdot V_m \cdot \frac{2}{T_d} \]

\[ \text{RRRV}_{\text{damp}} = 1.51 \frac{kV}{\mu s} \]

ATP Results (note that source resistance included):

[Diagram of electrical circuit with labels: 0.0992 ohm, 3.157 mH, VC, 546.75 ohm, 12.7 nF, VS, UI+, RBREAK, FAULT, 28.169 kV pk]
Switch voltage without resistor in the circuit (with source resistance included)

- 60Hz resistance
- with skin effect there will be more damping

Zoom in on the peak voltage (if no source resistance-slight decrease $V_{\text{max}}=56.16\text{kV}$)

\[ V_{pk} := 56.340\text{kV} \]
\[ V_s := 28.168\text{kV} \]

Resonant frequency (estimated from time between peaks)

\[ T_1 := 3.9659 \cdot 10^{-3} \text{ sec} \quad T_2 := 4.0057 \cdot 10^{-3} \text{ sec} \quad f_0 := \frac{1}{T_2 - T_1} \quad f_0 = 25.13\cdot\text{kHz} \]
Now add the TRV resistor - to reduce \textit{overshoot} a \textit{delay TRV}

\[ V_{\text{max}} := 33.691 \text{kV} \]

\[ \frac{V_{\text{max}}}{V_{m}} = 1.2 \]

- EMTDC Results

\begin{itemize}
  \item BRK1 Timed Breaker Logic
      \begin{itemize}
        \item Closed at $t_0$
      \end{itemize}
  \item BRK2 Timed Breaker Logic
      \begin{itemize}
        \item Closed at $t_0$
      \end{itemize}
\end{itemize}

\begin{align*}
R &= 0.0992 \text{ ohm} \\
V_S &= 0.003157 \text{ H}
\end{align*}
- We looked at worst case for TRV, for a solidly grounded system.

- Factors that influence, and reduce peak TRV (and recover voltage):
  - Damping: natural resistance in circuit & skin effect
    - influences eventual decay
Fault location farther away...

$V_{cap(0^-)} + 2\Delta V$

$
\begin{align*}
V_m + \Delta V \\
\text{Lowers RRRV substantially}
\end{align*}
$

If $V_{cap(0^-)} ph = \frac{V_m}{n}$

$RRRV = 1.5V_m$

$t = 0^-$

$V_{cap} = V_{lineside}$

If $m = 0$, $V_{lineside} = 0$
fault resistance

- voltage divider - so \( V_c(0^-) \neq 0 \)
- changes angle of fault current

\[
I_f = \frac{V}{z_0 + m2L + R_f}
\]

For example let's say \( \Theta_{If} = -75^\circ \)
\( (V_s - 86^\circ \text{ if } R_f = 0) \)

\( V_{cap \ (t)} \) before clears

Smaller \( \Delta V \) since off the peak
DC offset in fault current

This also means voltage $v_s(t)$ is not at peak for these current zeros - reduces TRV
Repeat with a DC offset in the current when breaker clears:

\[ V_{pk} := 53.773 \text{kV} \]

(reduced peak only by \( 2.6 \text{kV} \))
- Another big factor will be grounding of 3D system
  - we have looked only at solidly grounded so far
  - allowed per phase analysis
- Each phase will have similar TRV.
- They will just start at different times.
Suppose source is ungrounded.