Magnetizing Inrush Current

\[ V = N \frac{d\phi}{dt} \]
When breaker closed to energize transformer, the difference between residual flux and applied "flux" due to source leads to inrush current

--- 6-8 times normal current

- last
- 1-5 sec
- DC offset
- 2nd harmonic
- 5th
Protection of equipment

\[ I_{\text{meas}} + I_{\text{harm}} - I_{\text{high}} \rightarrow 0 \text{ or } 1 \]

\[ \text{Instantaneous over} \quad \text{50 or different} \quad 87 \]

\[ \text{2nd harm current} \]

\[ \text{sum to 0 unless internal fault} \]
Auto transformers

\[ V_1 = V_H + V_X \]
\[ V_2 = V_X \]
\[ I_1 = I_H \]
\[ I_2 = I_H + I_X \]
\[ V_1 = V_H + V_H \left( \frac{N_X}{N_H} \right) \]

\[ = V_H \left( \frac{N_H + N_X}{N_X} \right) \]

Boost Factor - also effective turns ratio of the auto transformer

- 30° transformer
- often \( y - y \)
Example 2

An autotransformer is used to connect a 12.6-kV distribution system line to a 13.8kV distribution line. It must be capable of handling 2000 kVA. There are three phases, connected Y-Y with their neutrals solidly grounded.

(a) What must the Nc/Nse turns ratio be to accomplish this connection?

\[
\begin{align*}
V_h &= \frac{13.8\text{kV}}{\sqrt{3}} = 7.97\text{ kV} \\
V_L &= \frac{12.6\text{kV}}{\sqrt{3}} = 7.27\text{ kV}
\end{align*}
\]

Approximate the number of turns with the voltage across winding

\[N_c := V_L \quad \frac{N_c}{N_{se}} = 10.5\]

(b) How much apparent power must the windings of each autotransformer handle?

\[\text{Power}_{\text{Advantage}} := \frac{N_c + N_{se}}{N_{se}} \quad \text{Power}_{\text{Advantage}} = 11.5\]

Per phase ratio

\[S_w := \frac{2000\text{kVA}}{3\cdot\text{Power}_{\text{Advantage}}} \quad S_w = 57.97\text{ kVA}\]

(c) If one of the autotransformers were reconnected as an ordinary transformer, what would the ratings be?

\[V_{prim} := N_c \quad V_{prim} = 7.27\text{ kV}\]
\[V_{sec} := N_{se} \quad V_{sec} = 692.82\text{ V}\]

Will have the same turns ratio:

\[T_{\text{ratio}} := \frac{V_{prim}}{V_{sec}} \quad T_{\text{ratio}} = 10.5\]

\[S_w = 57.97\text{ kVA}\]