Topics for Today:

• Announcements
  • Matlab -- Off-campus use remote desktop: dl-matlab.mtu.edu
  • Learning Center hrs: 4:05pm-5:55pm Wednesday, Friday
  • TA Office Hrs: EERC SB27 - to be confirmed.
  • Office: EERC 614. Phone: 906.487.2857
  • Matlab exercises to be posted on web page.
  • Recommended problems from Ch.2, solutions posted

• XFMR, Chapter 2 - Transformers and circuits w/transformers
  • Pre-Req Videos 3-6 - View them, study notes!
  • Single phase ideal transformer is building block - V, I, dot convention!
  • 3-phase transformer banks and phase shifts (ANSI/IEEE vs. IEC)
  • Standard 30° shift transformers, non-standard connections
  • Pos/neg sequence phase shifts, sequence networks.
  • Autotransformers
  • Load Tap Changing (LTC) transformers
  • Phase shifting transformers
  • Paralleling transformers with a) unlike impedances; b) unlike tap positions
  • Three-winding transformers
\[ a_{eff} = \frac{V_{LN\, PRI}}{V_{LN\, SEC}} = \frac{V_{CC\, PRI}}{V_{LL\, SEC}} \]
3-PHASE XFMNR BANKS

Ex: Δ-Y

From: Review Lecture 5

CCW
SEQUENCE NETWORKS
FOR TRANSFORMERS

\[
\begin{align*}
&x_1
\quad I_0
\quad I_1
\quad I_2
\end{align*}
\]
Per Phase Equivalent:

- \( V_{AN} \)
- \( L-N \) per phase equivalent
- Per Unit Values: 
  
  \[
  \begin{array}{cccc}
    \gamma & P & Q \\
    \zeta & S & S \\
    \gamma & P & Q \\
  \end{array}
  \]
TRAP: Text books have "cook-book" egns assuming that all transformers are std. 30°. WRONG!

MANY OTHER OPTIONS ±30°, ±90°, ±150°, Δ-Y, Y-Δ
open if \( \Delta \) is ungrounded.

\[ \text{open? (if } \Delta \text{ is open)} \]

Zero Ref.
$Z = \Rightarrow 1 \parallel \frac{1}{Z} \Rightarrow Z = \infty$

$Z = \infty$

$Z_{in} \Rightarrow Z_{C} \Rightarrow Z \Rightarrow \frac{1}{Z_{C}} \Rightarrow Z_{in} = R + j\omega L + Z_{C}$
\[ V_{\text{Drop}} = 3I_{A0}Z_N = V_{NG} \]
triplen harmonics
buried tertiary
buried delta

delta: - trap triplen harmonics
- Zero seq Circ path
- Aux power (Station service)
- Protection
  - CTs
\[ \alpha_{\text{eff}} = \frac{\overline{V}_{\text{LN/PR1}}}{\overline{V}_{\text{LL/SEC}}} = \frac{\overline{V}_{\text{CL/PRI}}}{\overline{V}_{\text{LL/SEC}}} \]
Harmonics:

3, 6, 9...

1, 4, 7...

2, 5, 8...

\[ \Rightarrow \quad \uparrow \text{xfrm in rash} \]

Seq:

0

1

2
Factory Test Report

- S.C. Impedance (VR, S.C. Studies)
- Loss Evaluations
  - No-load Losses (Core) $R_c$
  - Load Losses $R_1 + R_2a^2$

\[ \frac{V^2}{R_c} \]

\[ I^2R \]

\[ R_1, jX_1 \]

\[ jX_2, R_2 \]

\[ R_c \]

\[ R_3 \]

\[ jX_M \]
\[ Z_{sc, P-S} = \frac{V_{sc}}{I_{sc}} \]

\[ Z_{BASE} = \frac{U_{LLC}^2}{MVA} \]

\[ 420^2 = \frac{300}{300} \]
Binary S.C. Tests

<table>
<thead>
<tr>
<th>Case</th>
<th>MVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-S</td>
<td>300</td>
</tr>
<tr>
<td>P-T</td>
<td>100</td>
</tr>
<tr>
<td>S-T</td>
<td>100</td>
</tr>
</tbody>
</table>

Reactance

\[
\begin{align*}
\text{P} & \quad \frac{\text{P}}{\text{S}} \\
15.95\% & \quad 93.85 \\
8.70\% & \quad 153.8 \\
2.617\% & \quad 4.97
\end{align*}
\]

"Star Egniv"

For 100 MVA System Base

\[
\text{P} \quad jX_p \quad jX_s \quad jX_T
\]
Convert to 100 MVA Base

\[
Z_{pu} = \frac{Z_r}{Z_{BASE}} = \frac{Z_r}{V_{BASE}^2}
\]

0. \( Z_r = Z_{pu} \times Z_{BASE,0,0} \)

1. \( Z_{pu,100} = \frac{Z_r}{Z_{BASE,NEW}} = \frac{Z_r}{100} \)

\[
Z_{BASE} = \frac{420^2}{100}
\]
\[
\bar{Z}_{ps} = \bar{Z}_p + \bar{Z}_s \\
\bar{Z}_{pr} = \bar{Z}_p + \bar{Z}_r \\
\bar{Z}_{sr} = \bar{Z}_s + \bar{Z}_T \\
\]

Solve for \(\bar{Z}_p, \bar{Z}_s, \bar{Z}_T\)

Diagram:
- P \rightarrow Z_p \rightarrow \bar{Z}_s \rightarrow \bar{Z}_T \rightarrow \bar{Z}_p \rightarrow S

Transform

EE 5240
APPENDIX C: TRANSFORMER FACTORY TEST REPORT

TRANSFORMER TEST REPORT

Date of Test: 6/3/72
Customer's Order: C-67899
Our Order: C-01070-5

Type OA/POA/OFA Phase 3 Cycles 60. Rise 55°/65°. Tape See N.F., Dwg. #307256. Spec. 13013


<table>
<thead>
<tr>
<th>Serial Number</th>
<th>Guarantee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarity</td>
<td>See N.F., Dwg. #307256</td>
</tr>
<tr>
<td>Transformer Core: 345000-118000 Volts, 391 MVA</td>
<td></td>
</tr>
<tr>
<td>Core Loss @ 100% Voltage</td>
<td>78750</td>
</tr>
<tr>
<td>Total Loss @ Full Load 100% Voltage</td>
<td>123000</td>
</tr>
<tr>
<td>% Exciting Current @ 100% Voltage</td>
<td>1.0</td>
</tr>
<tr>
<td>% Impedance @ 75°C</td>
<td>2.1</td>
</tr>
<tr>
<td>% Resistance @ 75°C</td>
<td>0.12</td>
</tr>
<tr>
<td>% Regulation @ 100% P.F. Full Load</td>
<td>0.32</td>
</tr>
<tr>
<td>% Regulation @ 85% P.F. Full Load</td>
<td>3.9</td>
</tr>
<tr>
<td>% Efficiency @ Full Load 100% P.F.</td>
<td>99.77</td>
</tr>
<tr>
<td>% Efficiency @ Full Load 100% P.F.</td>
<td>99.77</td>
</tr>
<tr>
<td>Total K.W. Resistance in Ohms @ 75°C (Series Wdg. - Tap &quot;A&quot;)</td>
<td>0.6756</td>
</tr>
<tr>
<td>Total K.V. Resistance in Ohms @ 75°C (Parallel Wdg.)</td>
<td>0.1358</td>
</tr>
<tr>
<td>Total T. V. Resistance in Ohms @ 75°C</td>
<td>0.0170</td>
</tr>
<tr>
<td>% Impedance @ 75°C (345000-118000 Volts)</td>
<td>55.9</td>
</tr>
<tr>
<td>% Impedance @ 75°C (118000-138000 Volts)</td>
<td>12.1</td>
</tr>
</tbody>
</table>

Insulation Tests:

- and to H.V.
  - M.V. to L.V. and Core Volts for 1 Min. | 50000 |
  - T. V. to Core Volts for 1 Min. | 50000 |
- Induced Voltage in H.V. Winding Line to Ground | 150000 |
- Induced Voltage in H. V. Winding Line to Line | 150000 |

Temperature Rise:

- Copper Rise Corrected to Shutdown °C | 58.6 |
- Oil Rise °C | 51.6 |

Remarks:

- KVA @ 65°C Rise: H.V. and L.V. 330000/60000/550000. T.V. - 66000/110000/110000.
- ** The Core Loss Value Exceeding Guarantee was submitted to and accepted by the customer.

Unless otherwise specified the above tests are in accordance with the latest A. S. A. and N. E. M. A. Standards.

- Age 2 for additional test performance data.
\[ Z_{ps} \frac{MVA}{296} \quad 6.21\% \quad \text{in 100-MVA Base} \]
\[ Z_{pt} \quad 77 \quad 55.97\% \]
\[ Z_{st} \quad 77 \quad 42.1\% \]

Note:
\[ p: \ 296 \quad MVA \]
\[ s: \ 296 \quad MVA \]
\[ t: \ 77 \quad MVA \]
ON PER-PHASE BASIS:

Auto-A

\[
H \xrightarrow{Z_{1h}} \xrightarrow{Z_m} M
\]

\[
Z_c \xrightarrow{1:1 \pm 30^\circ} L
\]

POS SEQ

NEG SEQ