Topics for Today:

• Announcements
  • Matlab -- Off-campus use remote desktop: dl-matlab.mtu.edu
  • Learning Center hrs: 4:05pm-5:55pm Wednesday, Friday
  • 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
\[ q_{\text{eff}} = \frac{|V_{\text{LL/PR}}/V_{\text{LL/SEC}}|}{|V_{\text{LL/PR}}|/|V_{\text{LL/SEC}}|} \]
SEQUENCE NETWORKS FOR TRANSFORMERS
Per Phase Equiv:

- \( V_{AN} \)
- \( L-N \) per phase equiv
- Per Unit Values:
  - \(-V\)
  - \(-I\)
  - \(-Z\)
  - \(-S\)
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
\[ V_{\text{drop}} = 3I_{\text{A0}}Z_N = V_{\text{NG}} \]

\[ I_N = 3I_{\text{A0}} \]
triplen harmonics
buried tertiary
buried delta

delta: - trap triplen harmonics
   - zero seq circ path
   - Aux power (station service)
   - Protection
   - CTs
a_{eff} = 1

\frac{\text{Vcc|pri}}{\text{Vll|sec}} = \frac{\text{Vll|pri}}{\text{Vll|sec}}
Zero ref.

Harmonics:

3, 6, 9...

1, 4, 7...

2, 5, 8...

↑ xfrmr inrash

SEQ

0

1

2
Factory Test Report

- S.C. Impedance (VR, S.C. Studies)
- Loss Evaluations
  - No-load Losses (Core) $R_c$
  - Load Losses $R_1 + R_2 a^2$

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

\[ I^2 R \]

\[ R_1 \quad jX_1 \]

\[ R_c = \frac{1}{jX_M} \]

\[ jX_2 \quad R_2 \quad \text{Core} \]

\[ a : 1 \]
Binary S.C. Tests

- P-S: 300 MVA
- P-T: 100 MVA
- S-T: 100 MVA

Reactance
- \( R = \frac{15.95\%}{93.85} \)
- \( X = \frac{8.76\%}{153.8} \)
- \( Z = \frac{2.617\%}{4.97} \)

\( \text{"Star Eguiv" for 100 MVA System Base} \)
Convert to 100 MVA Base

\[ Z_p = \frac{Z_r \times V_{base}}{V_{base}^2} \]

\[ Z_{new} = \frac{Z_{base, new}}{Z_{base, old}} \]

\[ Z_{new} = \frac{420^2}{100} \]

\[ Z_{base, new} = 420^2 \]
Solve for $E_p, E_s, Z_F$

$E_{ps} = E_p + E_s$

$E_{pr} = E_p + Z_F$

$Z_{sr} = Z_s + Z_F$

Transformer

Diagram shows an alternating current (AC) circuit with labeled components.
# APPENDIX C: TRANSFORMER FACTORY TEST REPORT

## TRANSFORMER TEST REPORT

Date of Test  
6/3/74

Customer's Order  
C-67899

Our Order  
C-010705

Type OA/POA/POA  
Phase 3

Cycles  
60  
Rise 65°/65°

Length  
Spec. 13018

H. V. Volts  
34,500  
Grd. Y/192000

L. V. Volts  
118000  
Grd. Y/63000

T. V. Volts  
138000

KVA  
225000/391,000/420,000 *

KVA  
77000/102567/128333 *

### Transformer Test Report

<table>
<thead>
<tr>
<th>Serial Number</th>
<th>3-40/070-5</th>
<th>Guarantee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarity</td>
<td>340/340</td>
<td>330/330</td>
</tr>
<tr>
<td>W.P. Copper Loss @ 100% Voltage</td>
<td>375/290</td>
<td>310/290</td>
</tr>
<tr>
<td>Total Loss @ Full Load 100% Voltage</td>
<td>629/650</td>
<td>60/290</td>
</tr>
<tr>
<td>% Exciting Current @ 100% Voltage</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>% Impedance @ 75°C</td>
<td>6.21</td>
<td>6.30</td>
</tr>
<tr>
<td>% Resistance @ 75°C</td>
<td>0.123</td>
<td>0.124</td>
</tr>
<tr>
<td>% Regulation @ Full Load</td>
<td>0.32</td>
<td>0.33</td>
</tr>
<tr>
<td>% Regulation @ 85% Full Load</td>
<td>0.32</td>
<td>0.33</td>
</tr>
<tr>
<td>Efficiency @ Full Load 100% P.F.</td>
<td>99.77</td>
<td>99.75</td>
</tr>
<tr>
<td>Efficiency @ Full Load 85% P.F.</td>
<td>99.77</td>
<td>99.75</td>
</tr>
<tr>
<td>Efficiency @ Load 100% P.F.</td>
<td>99.77</td>
<td>99.75</td>
</tr>
<tr>
<td>Efficiency @ Load 85% P.F.</td>
<td>99.77</td>
<td>99.75</td>
</tr>
<tr>
<td>Total K.W. Resistance in Ohms @ 75°C (Series Wdg. - Tap &quot;A&quot;)</td>
<td>0.57/55</td>
<td>0.55</td>
</tr>
<tr>
<td>Total K.V. Resistance in Ohms @ 75°C (Neutral Wdg.</td>
<td>0.15/55</td>
<td>0.15</td>
</tr>
<tr>
<td>Total T.V. Resistance in Ohms @ 75°C</td>
<td>0.01/90</td>
<td>0.01/90</td>
</tr>
</tbody>
</table>

### Insulation Tests

- H.V. @ L.V. and Core Volts for 1 Min.  
- 50000  
- 50000

- T.V. to Core Volts for 1 Min.  
- 10000  
- 10000

- Induced Voltage in H.V. Winding Line to Ground  
- 560000  
- 560000

- Induced-Current Voltage in H.V. Winding Line to Line  
- 575000  
- 575000

### Temperature Rise

<table>
<thead>
<tr>
<th>Connected</th>
<th>362000-118000 Volts</th>
<th>Wgt.</th>
<th>296</th>
<th>391</th>
<th>490</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper Rise Corrected to Shutdown °C</td>
<td>51.1</td>
<td>43.3</td>
<td>47.5</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>

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

Remarks:

- KVA @ 65°C Rise: H.V. and L.V. 330000/480000/550000  
- T.V. - 660/20/118/71/1733

- Transformer satisfactorily withstand Impulse Test. See Impulse Test Report.


* For additional test performance data.
Note:  
\[ P: \frac{296}{MVA} \]
\[ S: 296 \quad MVA \]
\[ T: 77 \quad MVA \]