Ongoing List of Topics:

- URL: http://www.ece.mtu.edu/faculty/bamork/EE5223/index.htm
- Labs - EE4224/5224 - First pre-Lab Wed 11am or Fri 8am Week 3
- Term Project - form teams of ~3, begin in week 4 or 5.
- Radial Protection (read sections 12.5, 12.6, also G&S Ch.10)
- CTs - pedestal vs. bushing
- CT saturation & accuracy, ratios, multi-ratio CTs
- MOCTs - Magneto-Optic Current Transformers
Insulators:
- Station Post
- Stahloff
- Suspension/Bell

4: 69 kV
7: 115 kV
11-13: 230 kV

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insulation, for example synthetic resin bonded paper or resin impregnated paper, may have very short lower ends compared with oil impregnated paper types in which the porcelain lower end is relatively long due to limitations of the permissible axial stress on porcelain.
<table>
<thead>
<tr>
<th>INDOOR TERMINALS</th>
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</table>
c. Cast epoxy bushing plate.

<table>
<thead>
<tr>
<th>OUTDOOR TERMINALS</th>
</tr>
</thead>
</table>
d. H.V. 
e. & f. L.V.

<table>
<thead>
<tr>
<th>OUTDOOR H.V. TERMINALS</th>
</tr>
</thead>
</table>
g. 
h. 
j.

<table>
<thead>
<tr>
<th>CABLE BOXES</th>
</tr>
</thead>
</table>
m. With a disconnecting chamber.

**Figure 4.1 Typical terminal arrangements. Precise constructional details not shown**

- Whether the h.v. winding will be operated unearthed.
- Apparatus or material to be tested.
- Voltage tests – magnitude and duration.
- If to be used with a rectifier or similar specialised equipment
Bushings - HV Lead

Connections into equipment.

4-Bolt Pad

Porcelain Bushing

Dry: Porcelain

"Wet": Oil-Filled

Bushing

Collar

Sheet metal tank

Bushing Well

CTs - "Bolted" Type

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Insulator:
- Creep Distance or Tracking Distance

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Basic CT:

PRI

SEC 240 turns

5A

R1 jXلن

R2 jXلن

PRI

R

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Typical CT Equivalent Circuit

\[ \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1} \]

\[ Z_B = \text{total "Burdan"} \]
CT Secondary

240 turns

Multi-Ratio CTs

X1 - X5 1200/5

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Current Transformers

(Current ratio is always specified, ex: 100/5 or 1200/5)

Note: \( X_L \) in pri & sec often neglected, as is \( R_c \) (core loss).

"T" and "L" ratings given in book are obsolete. (OLD ASA STANDARDS).

"T" - performance of CT must be measured. (Not seen very often).

"C" - performance can be calculated. (This type is most usual).

Ex: 70C800:

\[ |I_B| \text{ is within } \pm 10\% \text{ of } |I_2| \text{ for a secondary current of } 20 \times \text{ rated.} \]

("Rated" is almost always 5A)

The corresponding burden voltage for this CT is 800V \( \Rightarrow \) Burden must be 8.2Ω.

i.e. \( |I_2| = 100A \)

Standard burden designations:

\[
\begin{align*}
C100 & \rightarrow B-1 : 1.0 \ 60^\circ 52 \\
C200 & \rightarrow B-2 : 2.0 \ 60^\circ 52 \\
C400 & \rightarrow B-4 : 4.0 \ 60^\circ 52 \\
C800 & \rightarrow B-8 : 8.0 \ 60^\circ 52 \\
\end{align*}
\]

\[ PF = 0.5 \text{ lag} \]
Problem:
- Current thru \( Z_b \) causes voltage drop. \( -6 \angle 60^\circ \text{VA} \)
- If voltage across \( LM \) \( \neq 0 \)
  then \( Im \neq 0 \) \( \Rightarrow \) Measurement Error.

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\[ I_2' - I_e = I_2 \]

Current flowing into relay. Magnetizing Current

Iterative method -
- Assume \( I_e = 0 \) (initially)
- Calculate \( E_{se} = I_2 Z_B \)
- Pick \( I_e \) off CT curves

\[ I_2 = I_2' - I_e \]
0) $I_e = 0$, $I_2 = 70\text{ Amps}$

$Z_B = 6 \angle 60^\circ = 6Z$

$E_{se} = (70)(6 \angle 60^\circ) = 420 \angle 60^\circ \text{ V}$

1) From curves: $I_e = 8\text{ A}$

$I_2 = I_2' - I_e = 70 - 8 = 62\text{ A}$

$E_{se} = (62)(6 \angle 60^\circ) = 372 \angle 60^\circ \text{ V}$

2) From curves: $I_e = 1.5\text{ A}$

$I_2 = I_2' - I_e = 70 - 1.5 = 68.5\text{ A}$

$E_{se} = 411\text{ V}$

3) From curve: $I_0 = 5\text{ A}$

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Check: 70°

[Diagram of a circuit with labels and equations]

\[ \tilde{I}_2 = 70° \left( \frac{\tilde{Z}_L}{\tilde{Z}_B + \tilde{Z}_L} \right) \]

What is \( \tilde{Z}_L \)? = 

\[ \frac{E_{se}}{\tilde{I}_e} \]

70°

Mag of \( \tilde{I}_2 \) is usually very close. But angle is off a bit.

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RCF: Ratio Correction Factor

CT ratio: \( \frac{500}{5} = 100 \)
Actual Ratio: \( \frac{7000}{66} = 106 \)

\[ RCF = 1.06 \]

Actual Ratio can be estimated using RCF curves.

\[ \text{Actual} = \text{Ideal} \times RCF = \frac{I_{PRI}}{I_B} \]

\[ \therefore RCF \text{ is always } > 1.0 \]
**McGraw-Edison**

**Power Systems Group**

**BTCT Ratio Correction Factor Curves**

ASA Standard B-8 (8 Ohms, 50 Percent PF Lag) Sec Burden

<table>
<thead>
<tr>
<th>Marked Ratio</th>
<th>Sec. Turns</th>
<th>Sec. Taps</th>
</tr>
</thead>
<tbody>
<tr>
<td>100/5</td>
<td>20</td>
<td>X_2-X_3</td>
</tr>
<tr>
<td>200/5</td>
<td>40</td>
<td>X_1-X_2</td>
</tr>
<tr>
<td>300/5</td>
<td>60</td>
<td>X_1-X_3</td>
</tr>
<tr>
<td>400/5</td>
<td>80</td>
<td>X_4-X_5</td>
</tr>
<tr>
<td>500/5</td>
<td>100</td>
<td>X_3-X_4</td>
</tr>
<tr>
<td>600/5</td>
<td>120</td>
<td>X_2-X_4</td>
</tr>
<tr>
<td>800/5</td>
<td>160</td>
<td>X_1-X_4</td>
</tr>
<tr>
<td>900/5</td>
<td>180</td>
<td>X_3-X_5</td>
</tr>
<tr>
<td>1000/5</td>
<td>200</td>
<td>X_2-X_5</td>
</tr>
<tr>
<td>1200/5</td>
<td>240</td>
<td>X_1-X_5</td>
</tr>
</tbody>
</table>

*Type OE-1200*

*DWG. NO. A-422534*

*OCB Type-*

*Frequency 60 Cycles*

*Maximum Ratio 1200/5*

*Total Sec. Turns 240*

*Sec. Res. .0027 Ohms/Turn @ 75°C*

ASA Accuracy 10C800

\[ V_{B} = 800V_{\text{Max}} \]

**Desert Generation & Transmission Order C-06.** 5 To be used on H1, H2, H3 H.V. Bushings.

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**PERCENT RATED CURRENT**

**DWG. NO. RCF-422534-8C**

Dotted line - secondary coordinate

Solid line - primary coordinate

Ref - LF - 7
The magnetization curves for a 1200:5 10C800 multi-ratio CT are given in your lecture notes. A total burden of 6.0/60° ohms (including the CT winding resistance) is attached to secondary terminals X3-X4 (ratio is set to 500:5). During a fault, 7000A flows in the CT primary.

a) Sketch out the CT circuit, showing the magnetizing inductance, winding resistance, turns ratio, and burden. Label the turns ratio and the value of the winding resistance.

b) Using an iterative technique, determine the magnitude of the current $I_E$ in the exciting branch and the current $I_B$ in the burden. To simplify your calculations, assume that all currents in the CT secondary have the same phase angle.

c) Calculate the CT Ratio Correction Factor (RCF) for this case. Compare to that given by the manufacturer, and explain any differences you might find.

d) Assume that the reactance of the magnetizing branch can be obtained from the ratio $E_{SE}/I_E$ (use the values of $E_{SE}$ and $I_E$ from part b). Using the current divider, calculate the phasor value of the current flowing through the burden. How close is magnitude and angle of the burden current to the estimate in part b? Does the method of part b provide an adequate estimation of the burden current in this case?