EE 5223 - Lecture 6

Fri Jan 20, 2017

Topics for Today:

• URL: [http://www.ece.mtu.edu/faculty/bamork/EE5223/index.htm](http://www.ece.mtu.edu/faculty/bamork/EE5223/index.htm)
• Labs - EE5224 - Starting Monday
• Software - Aspen 2016 V14.3. Remote Desktop: remote.mtu.edu

Lecture Coverage:

• Relaying 3-lines
• Type 51 (inverse time-overcurrent relay) settings
• Instrument transformers: VTs, CTs, CCVTs, MOCTs, etc.
• CTs - pedestal vs. bushing

Next:

• Radial Protection (read sections 12.5, 12.6, also G&S Ch.10)
• CT saturation & accuracy, ratios, multi-ratio CTs
Non-Ideal

- Flux Leakage
- Winding Resistance
- Magnetic Saturation
- Core Losses < Eddy Currents
- Hysteresis
Lenz's Law

- Induced voltage causes a current, if coil is shorted, that produces a flux which cancels the $\frac{d\phi}{dt}$ that induced the voltage in first place.
\[ e_{\text{ind}} = N \frac{d\phi}{dt} = -i_{\text{out}} \]

\[ F \text{araday's} \]

\[ \lim_{t \to 0} \frac{e}{t} = \frac{i}{t} \]

\[ L = \frac{e}{i} \]
- 3Ø AC System (PRI)
- "" (Sec) via CTs, VFS, etc
- "3-Lines"
- dc control schemes ✓
- relay settings, strategies
- Comm / SCADA
- Operational, forensics ∧ relay
- Form "C"
Bushings - HV Lead
Connections into equipment.

4-Bolt Pad

Oil-Level gage

Porcelain Bushing

Dry: Porcelain
"Wet": Oil-Filled

Bushing Collar

Sheet metal

tank

Bushing Well

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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>
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<tr>
<th>INDOOR TERMINALS</th>
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<td>c. - Cast epoxy bushing plate.</td>
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<th>OUTDOOR TERMINALS</th>
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<td>d. - H.V.</td>
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<td>e &amp; f. - L.V.</td>
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<th>OUTDOOR H.V. TERMINALS</th>
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<th>CABLE BOXES</th>
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<td>m. - With a disconnecting chamber.</td>
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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
Insulators:
- Station Post
- Stahloff
- Suspension/Bell

Bus Bar: 60 80

$4: 69\text{ KV}$
$7: 115\text{ KV}$
$11-13: 230\text{ KV}$

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Insulator:
- Creep Distance or Tracking Distance

water drops → Δ

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Lower Voltage Switchgear (15-kV)

Main Bus

→ No CTs here.

→ Draw-out Breaker

→ CTs are all here.

→ Cable connection

→ Radial Line / Cable
No CB?

Zone A  Zone B
Instrument transformers - used to "step down" primary voltages and currents to lower standard levels.

- Current: 0-5A - CT
- Voltage: X1-X3: 0-120V
  X2-X3: 0-69.3V
  Voltage Transformer (VT)
  X1-X3: 0-115V
  X2-X3: 0-66.4V
  CVT or CCVT

Ex:

Note that "PT" designation is obsolete - new designation is "VT". Economics usually point to use of CVT or CCVT for voltages above 69-kV, VTs for lower voltages.

Note that linear couplers, which produce a secondary voltage proportional to the primary current, were in vogue for a while in the 50's & 60's but never caught on. Used mainly in bus differential schemes. Requires special relays (voltage instead of current input) - this additional cost hobbed it. (See p.353, Blackburn)
Basic CT:

PRI

SEC 240 turns

5A

R₁, jX₂₁

R₂, jX₂₂

PRI

Ro

LM

3113

SEC

1200 A
Current ratio: 1200:5

\[ q = \frac{1}{240} \]
$Z_B = \text{total "Burden"}$

Typical CT Equivalent Circuit
CT Secondary

240 turns

X1
40
X2
20
X3
100
X4
80
X5

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these have built-in overcurrent relay units that determine the level of the ac current at and above which their contacts will open. All of these types are used at the lower-voltage level of the power system.

At the higher power system voltages each station at which circuit breakers are installed has a station battery to supply direct current to the breaker trip coils, the control and protective relay circuits as required, emergency alarms and lighting, and so on. In the United States this is generally 125-V dc; 250-V dc is used in some large power stations, and 48-V dc is

Figure 1.10 Typical three-phase ac connections of a set of phase and ground relays for the protection of an ac power system. The relays may be separate, as shown, or combined together in one unit.
Figure 1: External Schematic of Hilo CO Relay for Phase and Ground Overcurrent Protection on a Three Phase System

Figure 2: External Schematic of Hilo CO Relay with ACS Unit for Phase and Ground Protection on a Three Phase System