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 - EE4224/5224 - Underway.
- Software - Aspen 2009 V10.12. confirm operation

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
\[ S_1 = S_2 \]
\[(\text{in}) \quad (\text{out})\]
\[ \tilde{V}_1 \tilde{I}_1 = \tilde{V}_2 \tilde{I}_2^* \]

**Ideal**

**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 voltage in that induced first place.
\[ e_{\text{ind}} = N \frac{d\phi}{dt} = -\frac{dI_2}{dt} \]

Faraday

Lenz
- 3Ø AC System (PRI)
  - "" (Sec) via CTs, VFS, etc
- 3-Line
- dc control schemes
- relay settings, strategies
- Comm/SCADA
- Operational, forensics
  - Form "C" with relay "NO" and relay "NC"
Bushings - HV Lead

Connections into equipment.

4-Bolt Pad

Porcelain Bushing

Dry: Porcelain

"Wet": Oil-Filled

Bushing Collar

Sheet Metal

Tank

Bushing Well

EE 521 - Power Systems Protection

Spring 2001
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.
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
Insulator:
- Creep Distance or Tracking Distance
  
  water drops
Lower Voltage Switchgear (15-KV)

Mezin Bus

Breaker Draw-out

Cable connection

Cable Lintel / Cable

Here are all here.
87B Zone

87B - 86B Trip all Bus 035

86B

865 - 865L

865
Zones of Protection
Instrument transformers - used to "step down" primary voltages and currents to lower standard levels.

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

**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Note that "PT" designation is obsolete - new designation is "VT".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 hobbled it.

(See p. 353, Blackburn)
\[ A = \frac{1}{240} \]

Current ratio: 1200:5
Typical CT Equivalent Circuit

$Z_B = \text{total "Burrden"}$
CT Secondary

240 turns

40 x1
20 x2
100 x3
80 x4

x5

EE 5210 - Power Systems Protection

MichiganTech Instructor: Bruce Mork Phone (906) 487-2857 Email: bamork@mtu.edu
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