EE 5223 - Lecture 6 Fri Jan 20, 2023

Topics for Today:

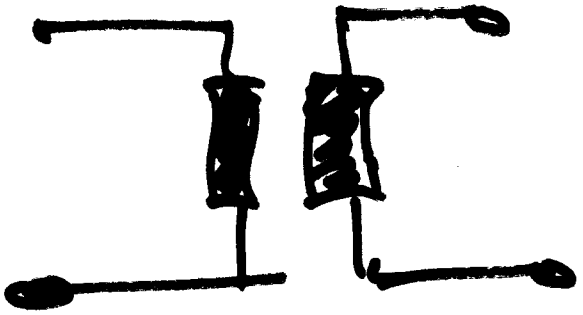
- URL: http://www.ece.mtu.edu/faculty/bamork/EE5223/index.htm
- Labs - EE5224 - Starting next Wednesday
- Software - Aspen 2022 V15.6. Remote Desktop: remote.mtu.edu

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



$$\bar{S}_1 = \bar{S}_2$$

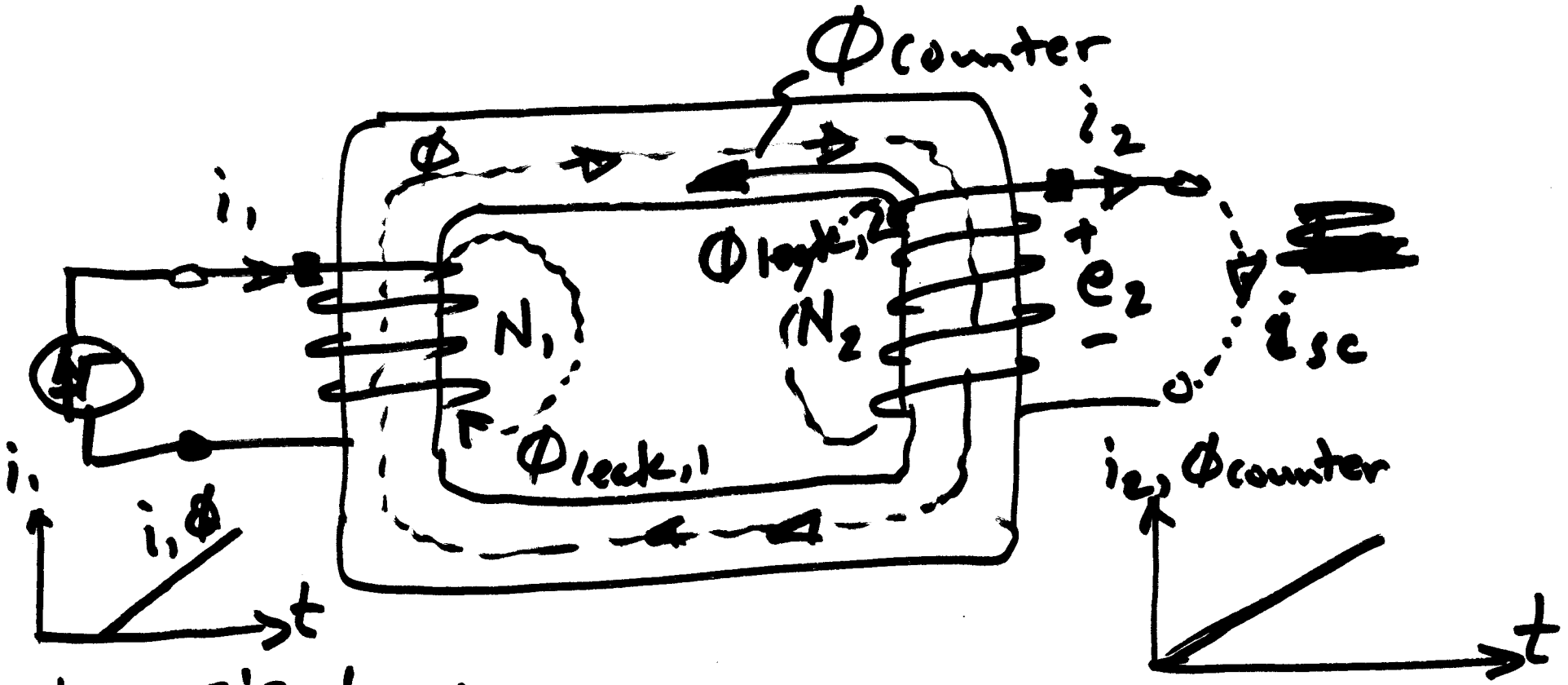
(in) (out)

$$\tilde{V}_1 \tilde{I}_1^* = \tilde{V}_2 \tilde{I}_2^*$$

IDEAL!

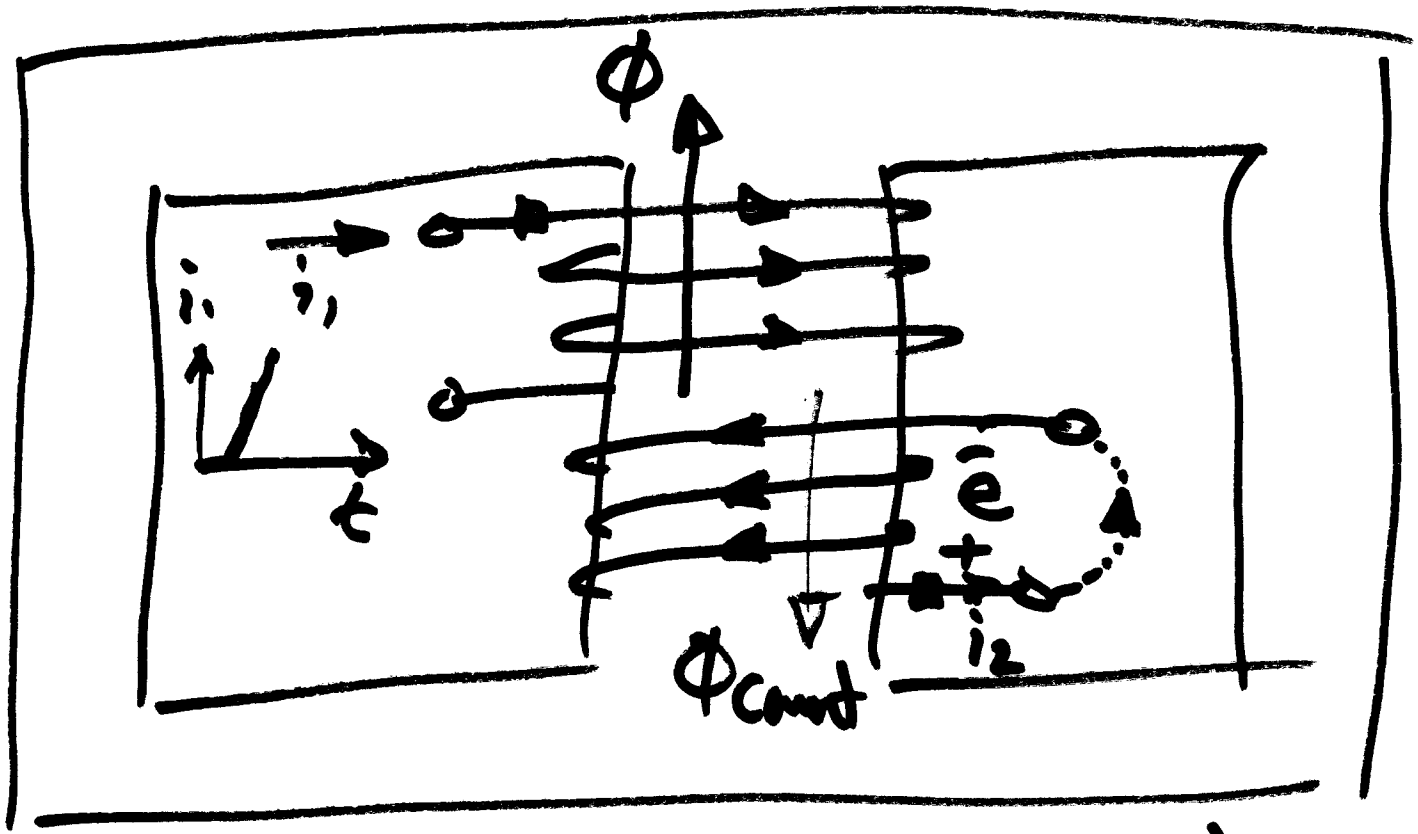
Non-Ideal

- Flux Leakage
- Winding Resistance
- Magnetic Saturation
- Core Losses < Eddy Currents, Hysteresis



Lenz's Law

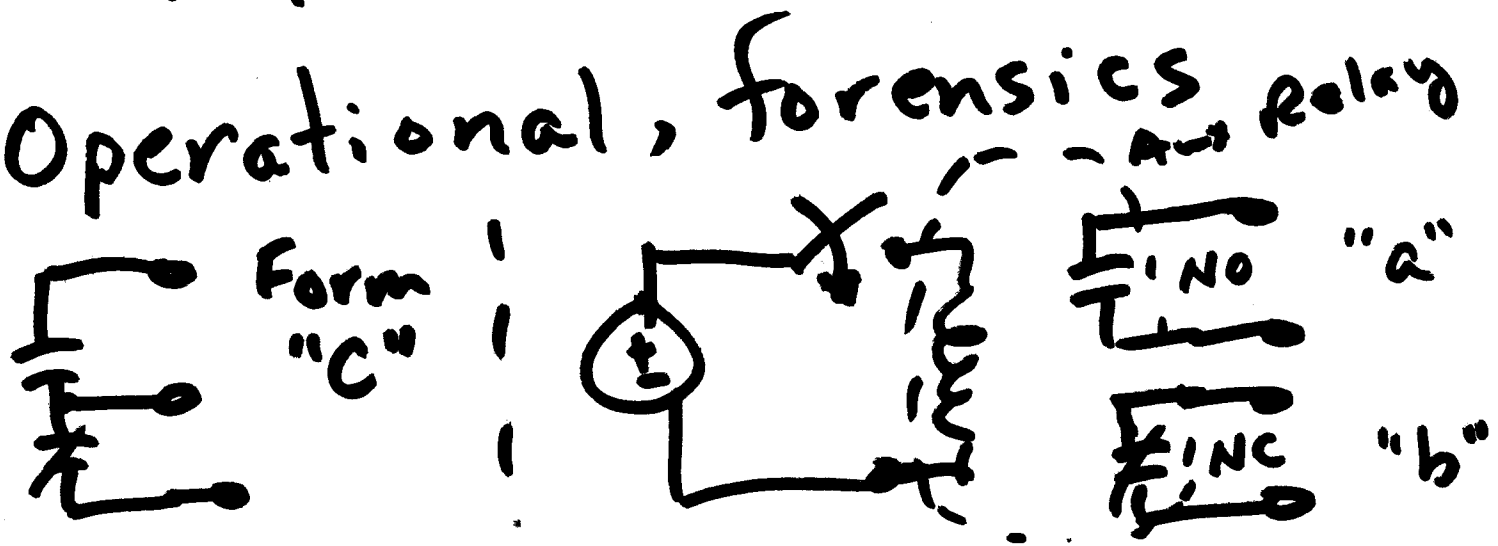
- Induced voltage causes a current, if coil is shorted, that produces a flux which cancels the $\frac{d\Phi}{dt}$ that induced the voltage in first place.



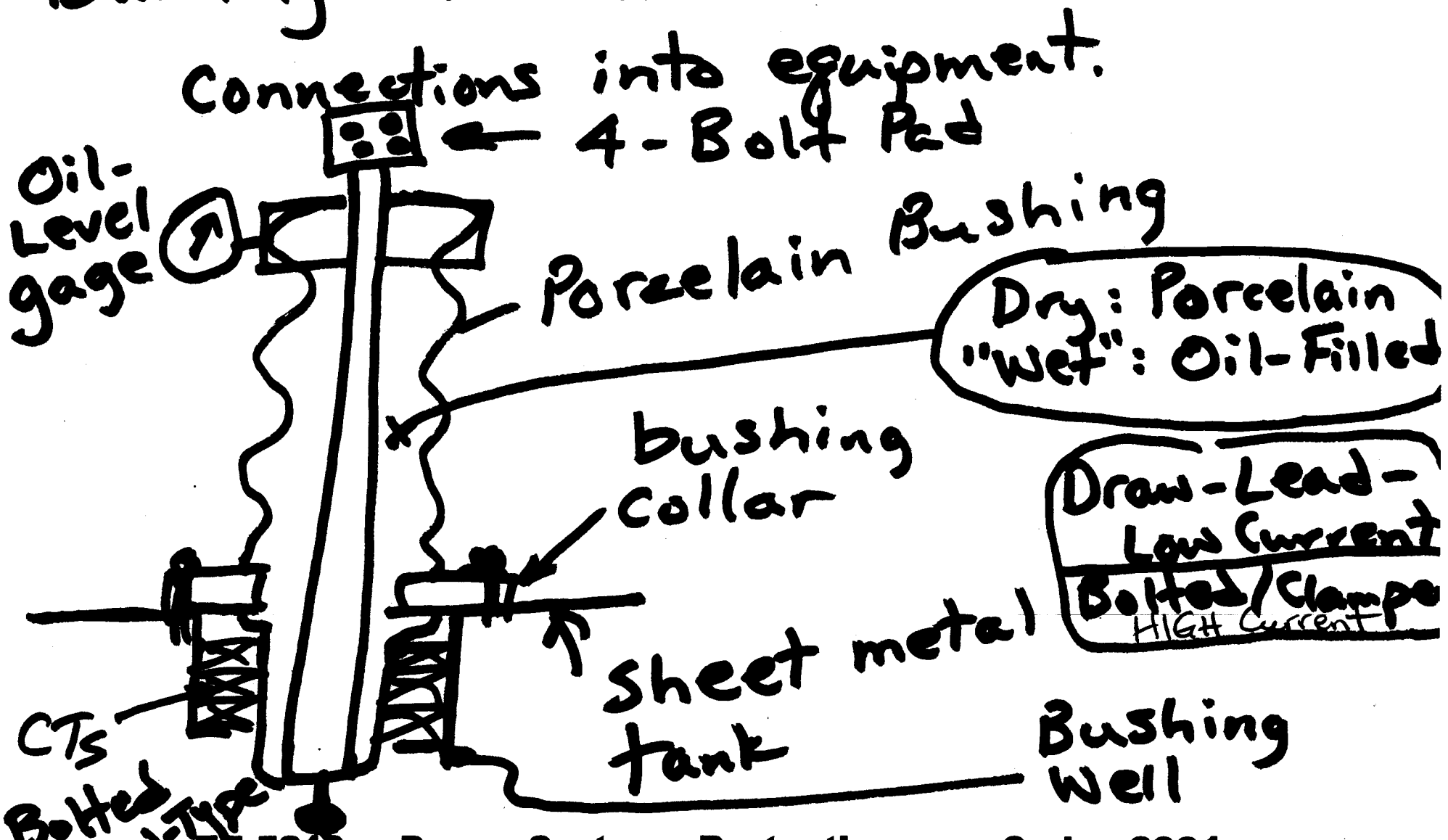
$$e_{ind} = N\frac{d\Phi}{dt} = -\frac{d\lambda}{dt}$$

Faraday — Lenz

- 3φ AC System (PRI)
- " " (Sec) via CTs, VTs, etc
- "3-Lines"
- dc control schemes ✓
- relay settings, strategies ?
- Comm / SCADA
- Operational, forensics



Bushings- HV Lead



J & P Transformer Book

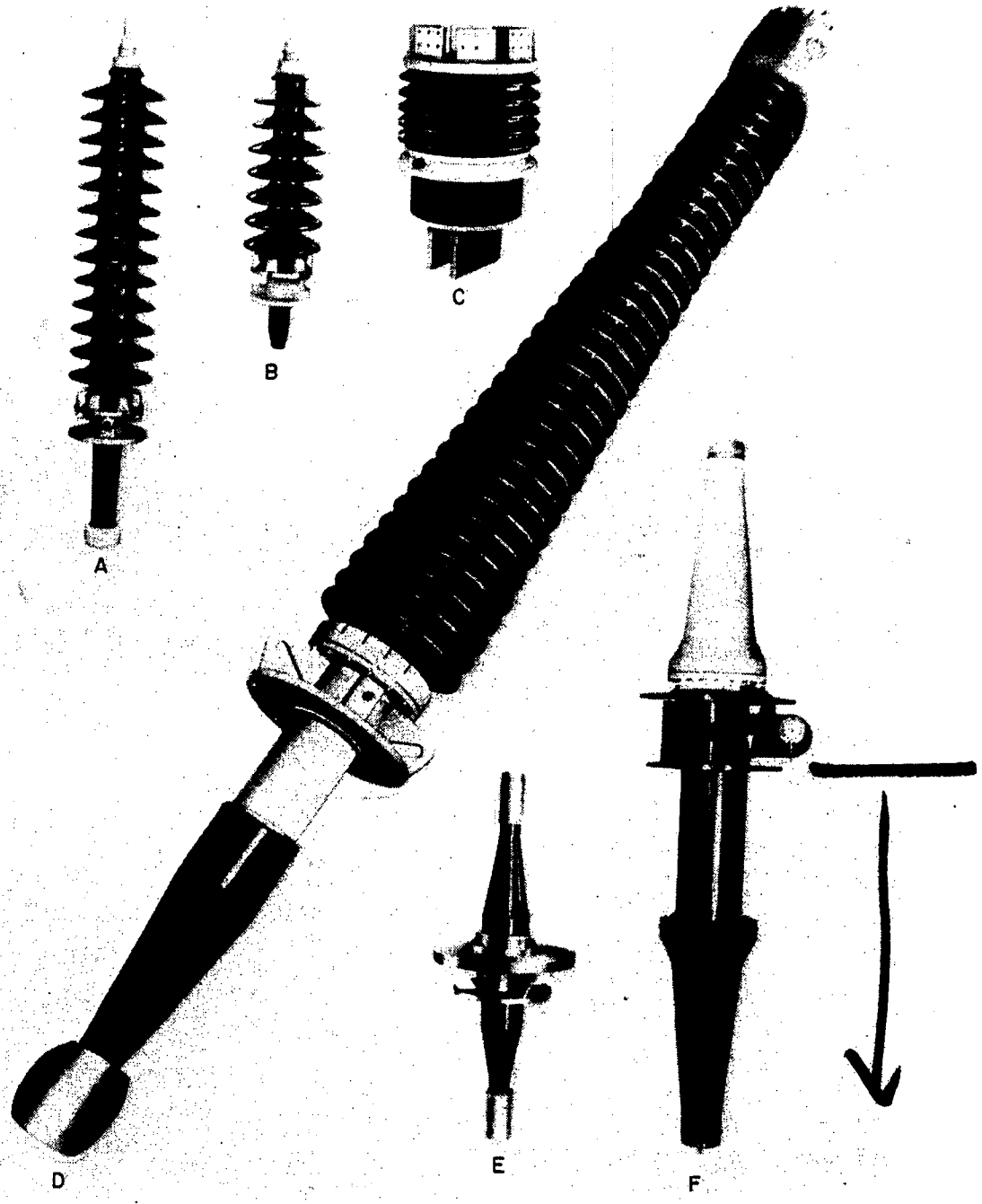


Figure 3.10 Transformer bushings
A. 123 kV, 630 A outdoor bushing with solid insulation
B. 72·5 kV, 630 A outdoor bushing with solid insulation
C. 36 kV, 20 000 A bus-duct bushing with solid insulation
D. 420 kV, 1600 A outdoor bushing with oil impregnated paper insulation
E. 145 kV, 1600 A transformer/gas bushing with solid insulation
F. 420 kV, 2000 A transformer/gas bushing with oil impregnated paper insulation and 810 mm current transformer accommodation

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.

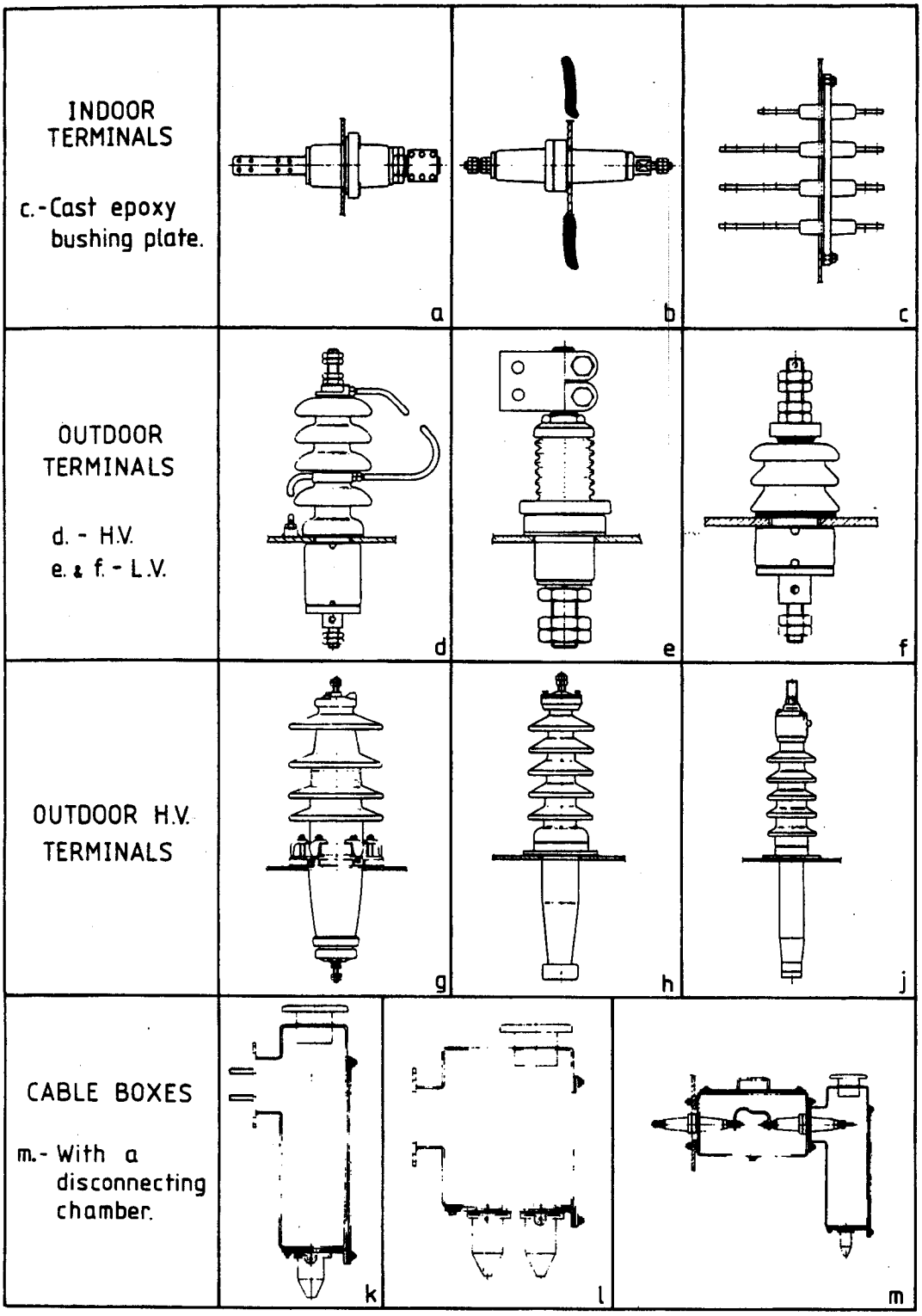
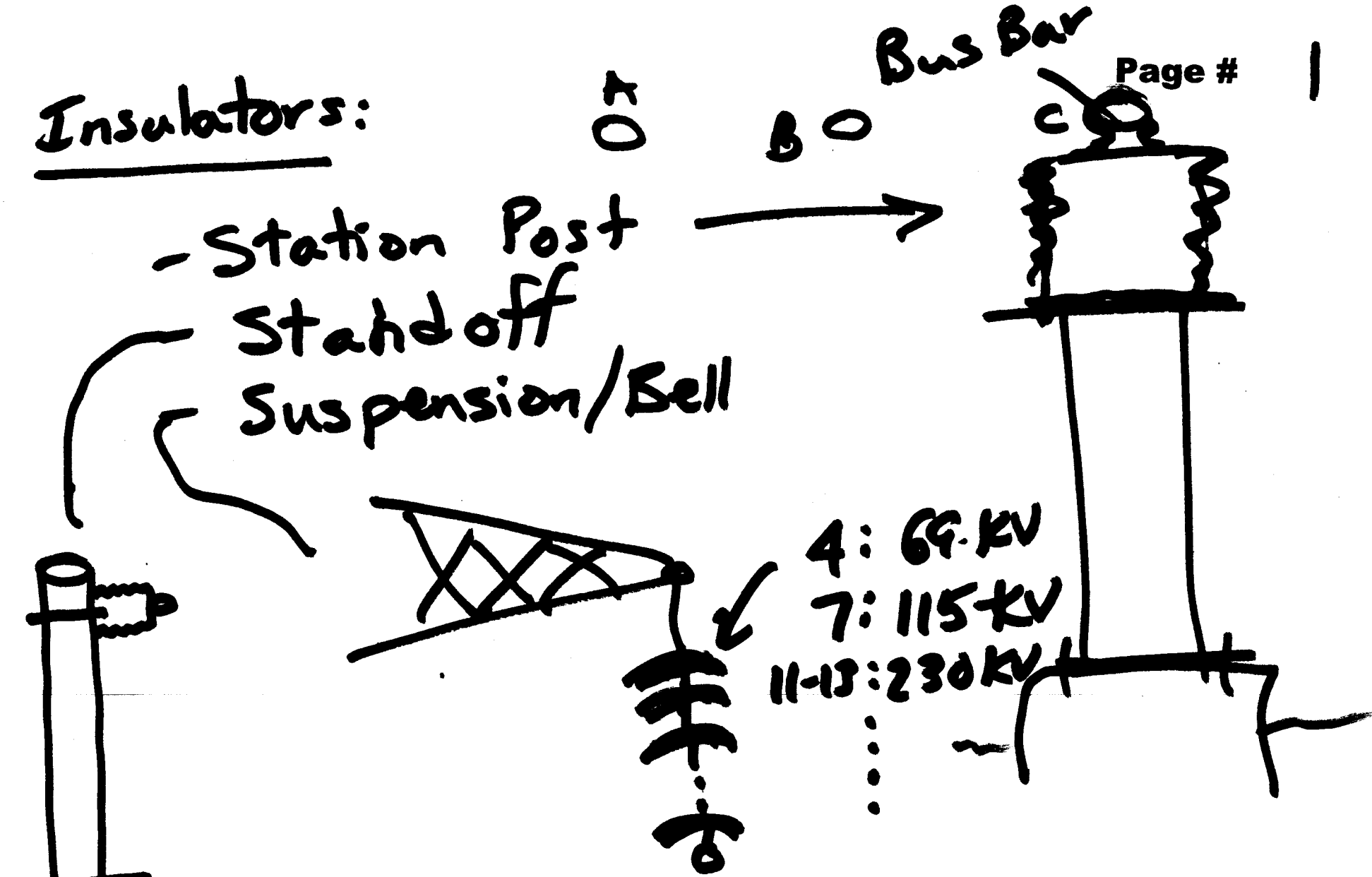


Figure 4.1 Typical terminal arrangements. Precise constructional details not shown

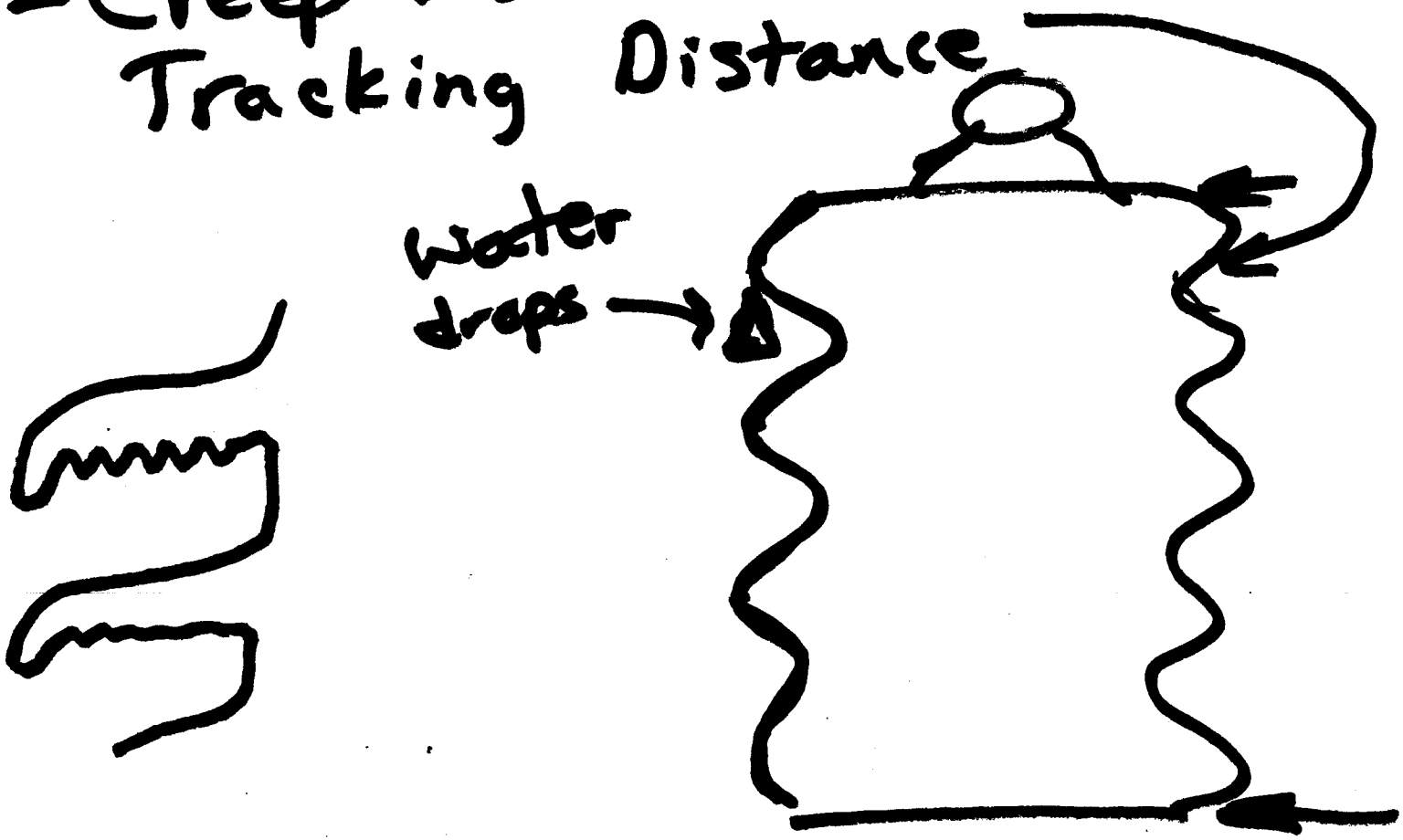
Whether the h.v. winding will be operated unearthed.
Apparatus or material to be tested.
Voltage tests – magnitude and duration.
If to be used with a rectifier or similar specialised equipment

Insulators:

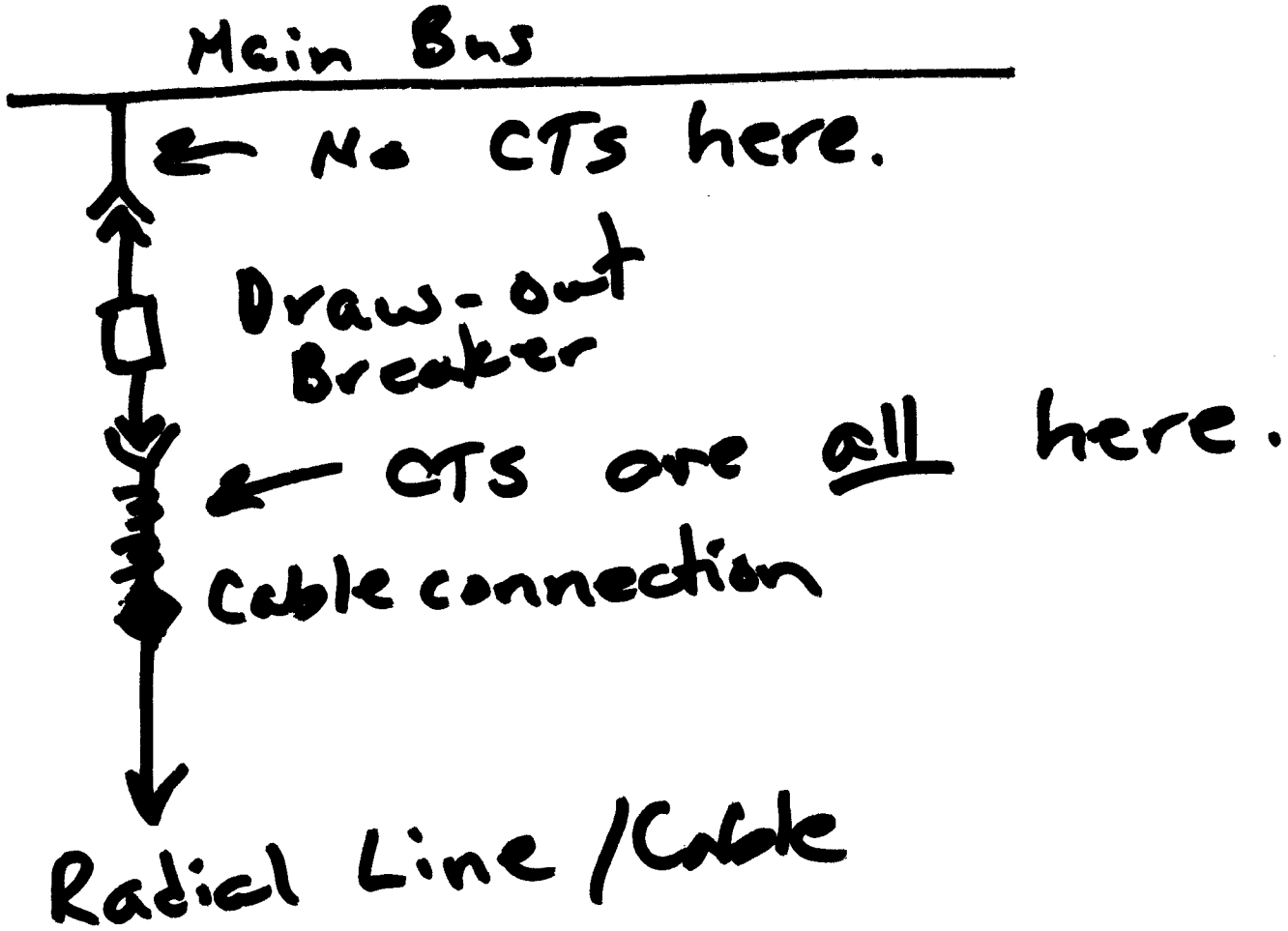

A
B
C
Bus Bar
- Station Post
Stand off
Suspension/Bell
4: 69 KV
7: 115 KV
11-13: 230 KV

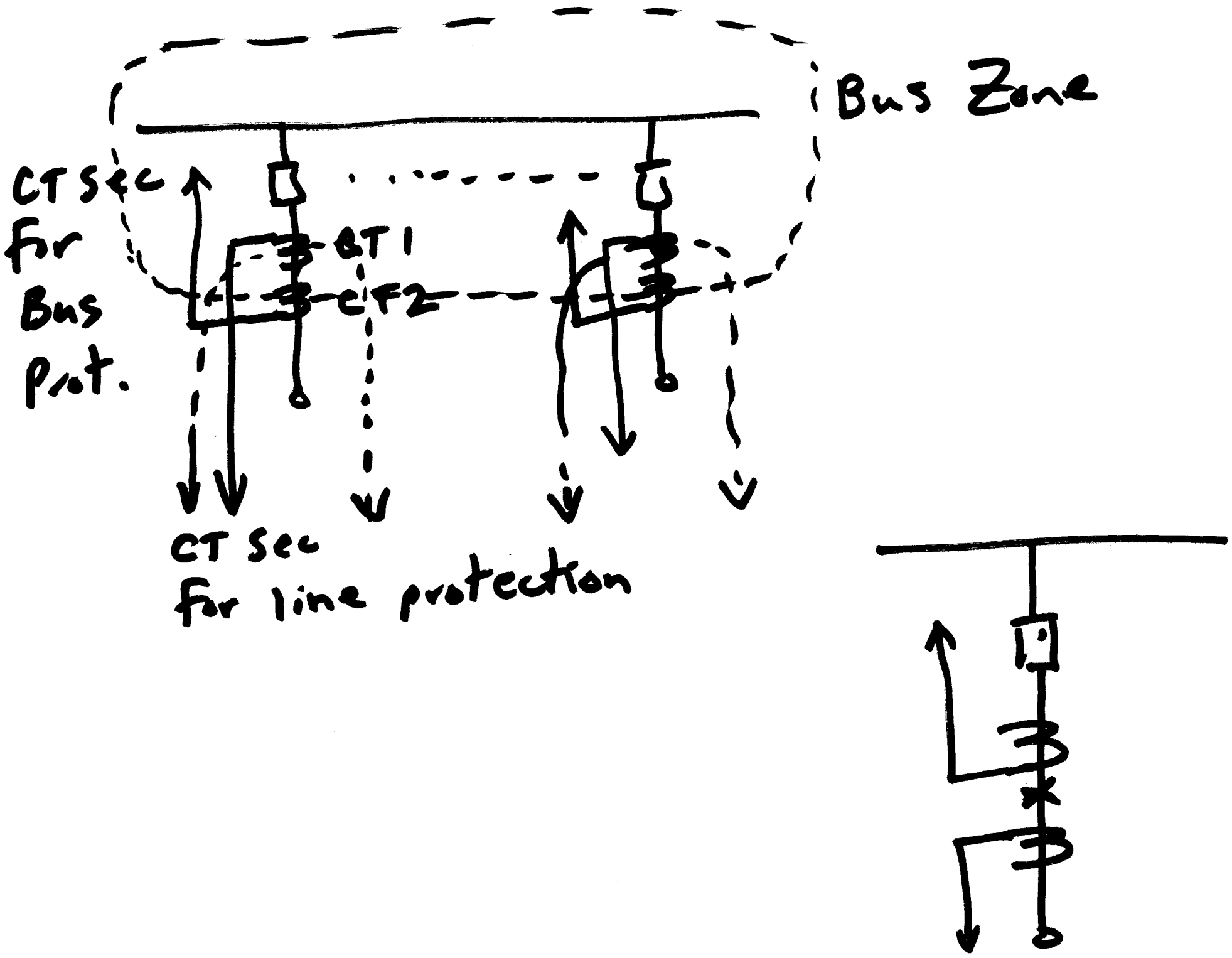
Insulator:

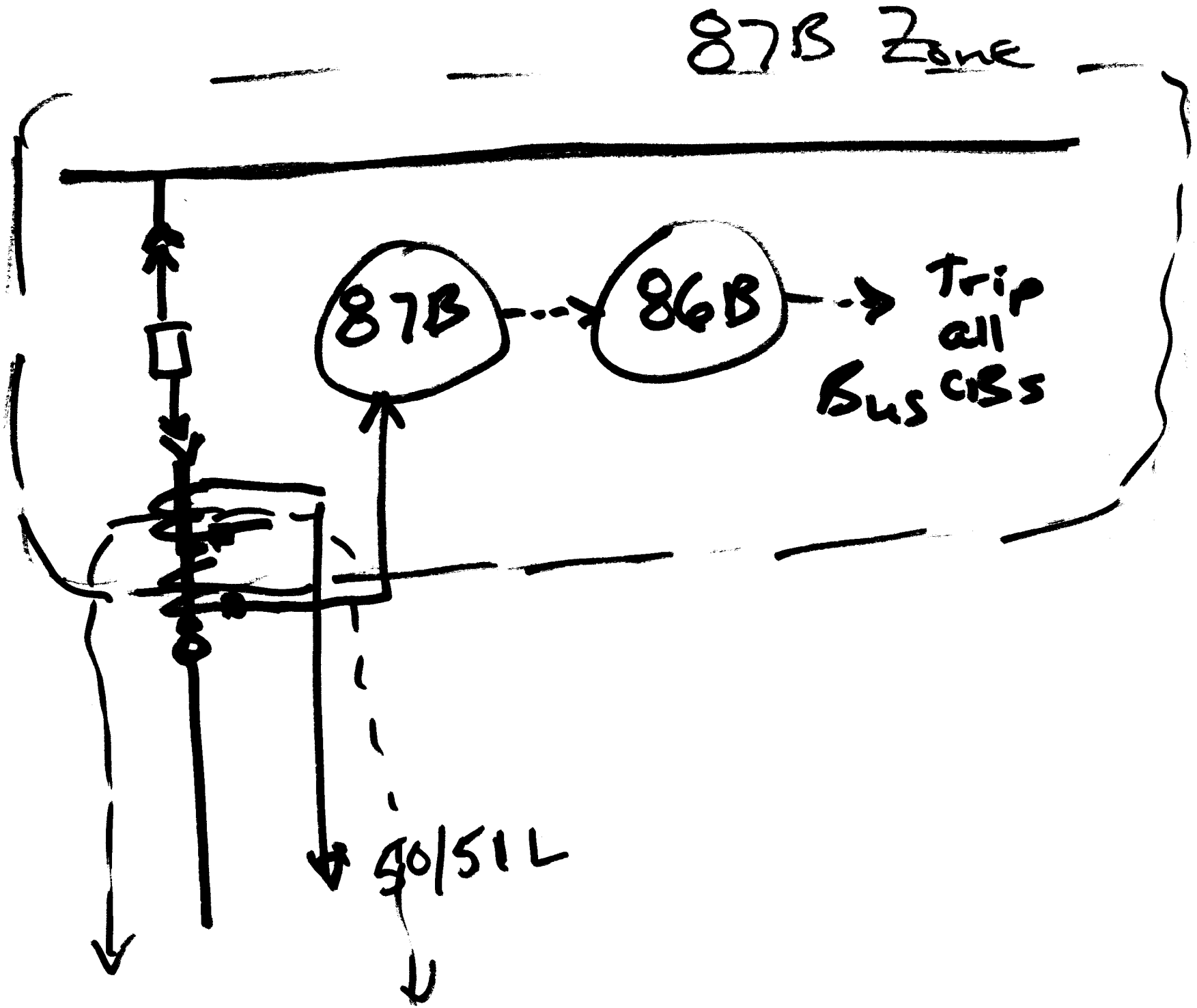
- Creep Distance or Tracking Distance



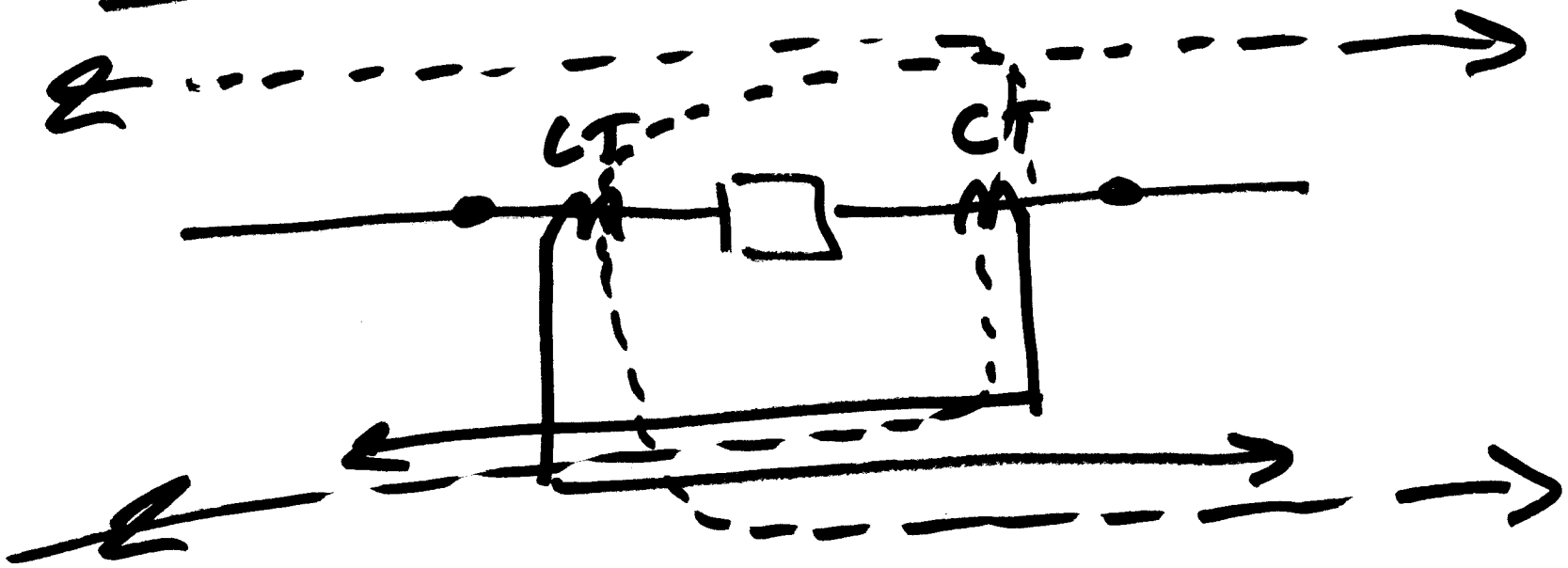
Lower Voltage Switchgear (15-kV)

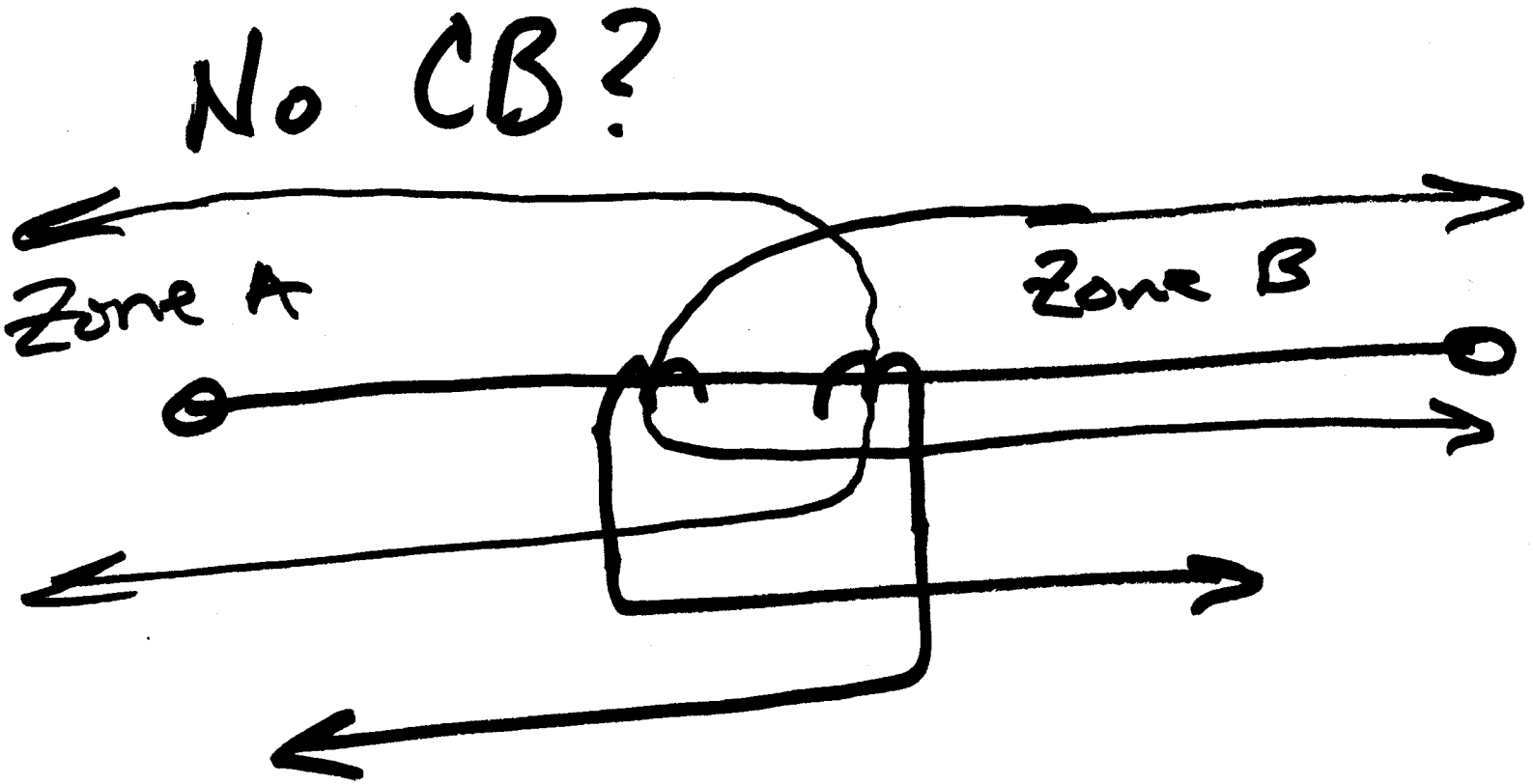



Bus Zone
CT Sec
for
Bus
Prot.
CT 1
CT2
CT Sec
for line protection


87B Zone
87B
86B
Trip
all
Bus CBs
50/51L

Zones of Protection

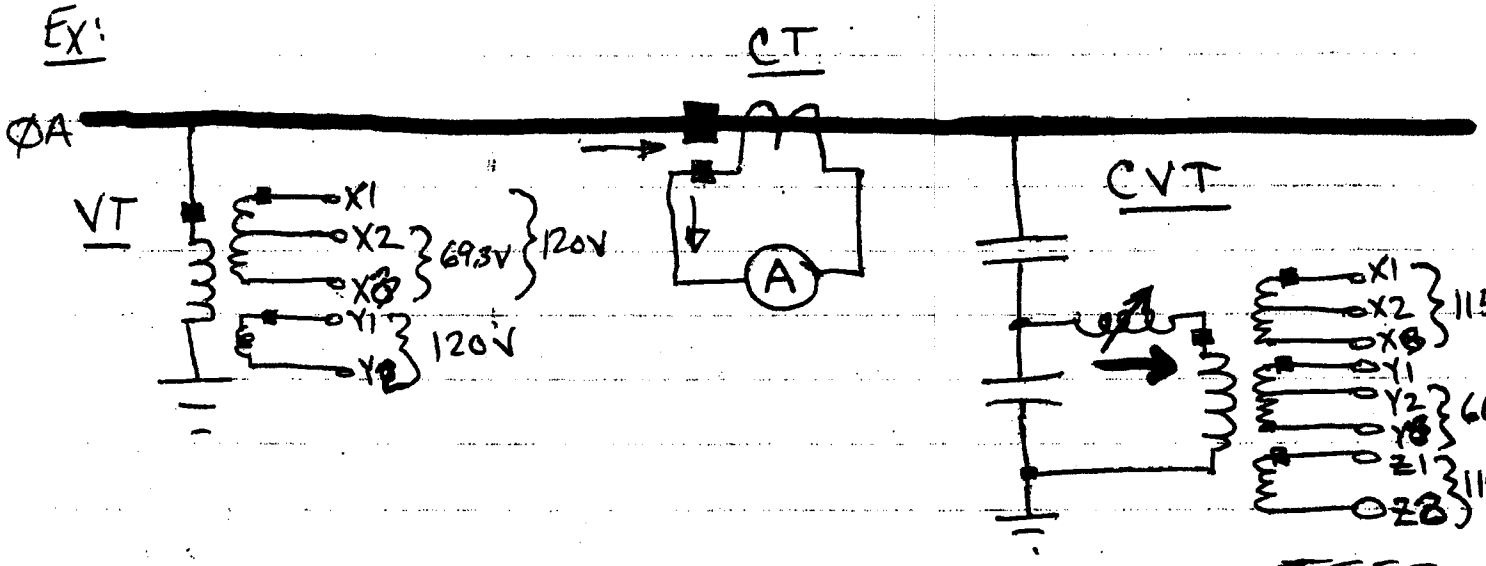



No CB?
Zone A
Zone B

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

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

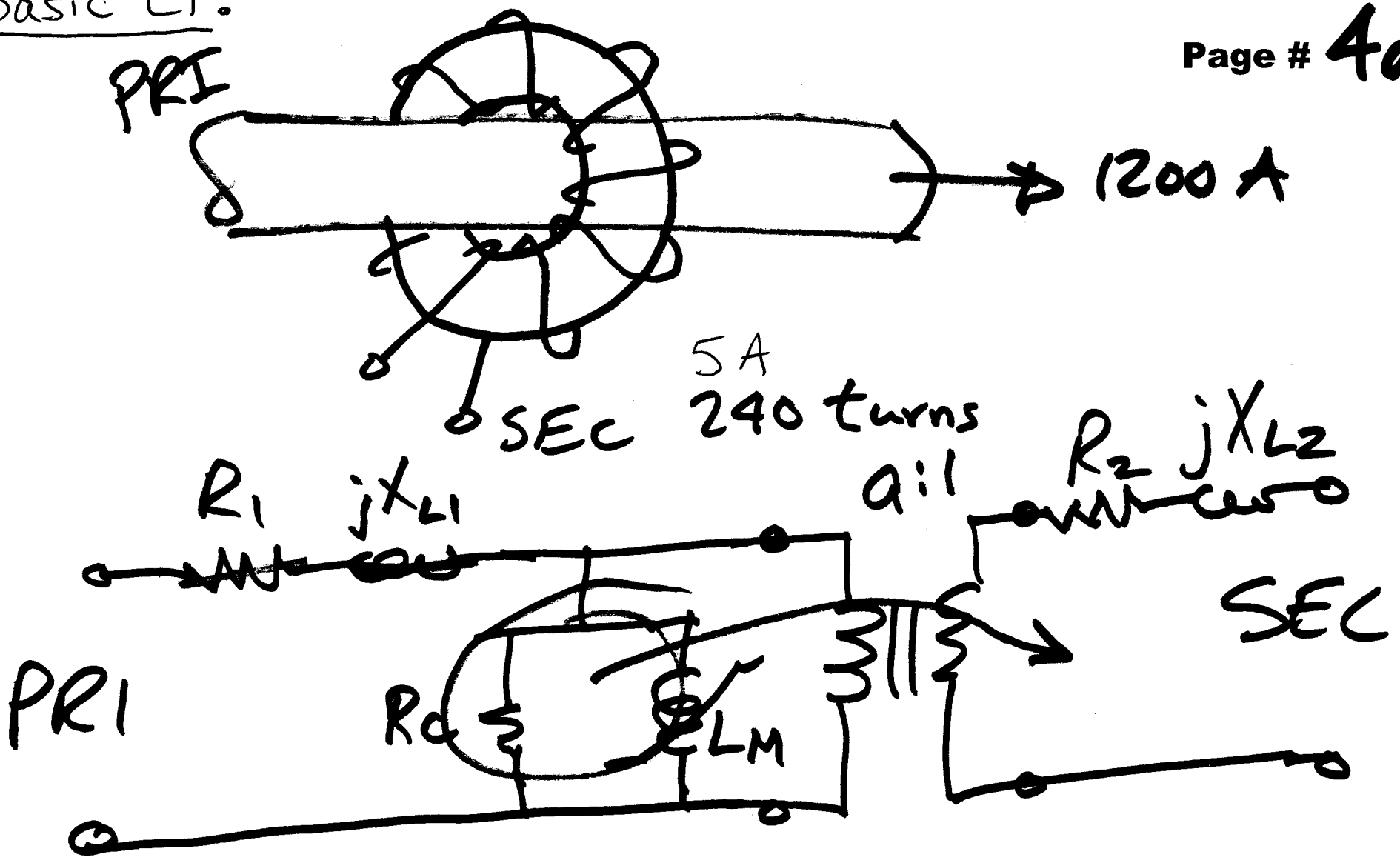
Ex:

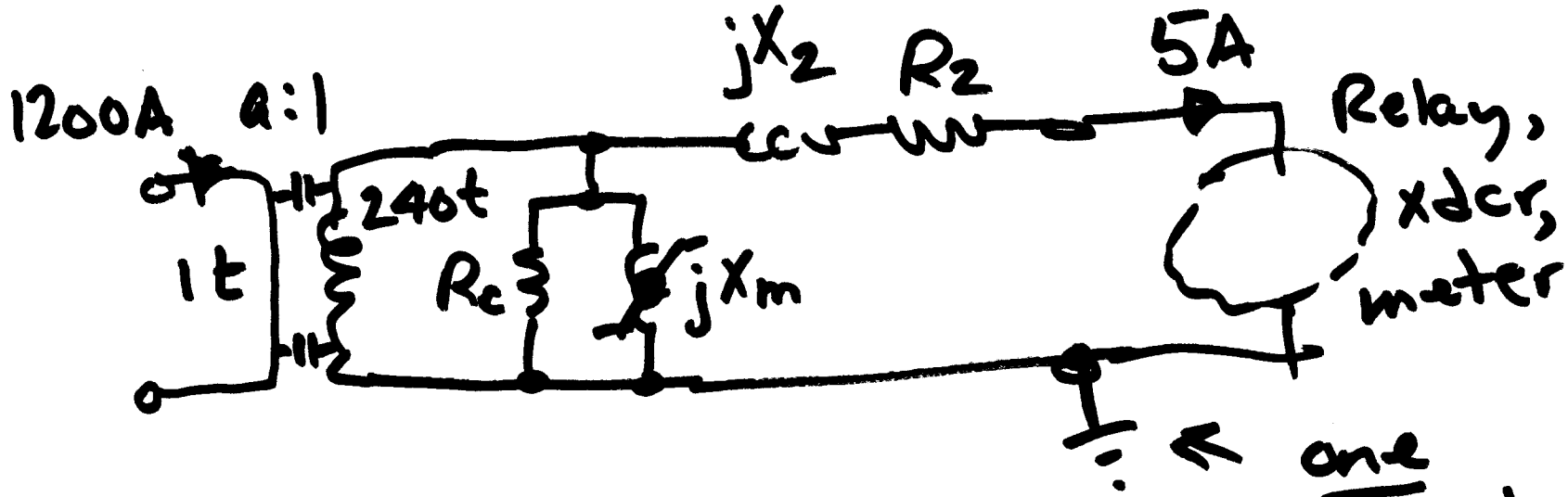


Note that "PT" designation is obsolete - new IEEE designation is "VT". Economics usually point to use of CVT or CCVT for voltages above 69-KV, VTs for lower voltages.

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)

Basic CT:





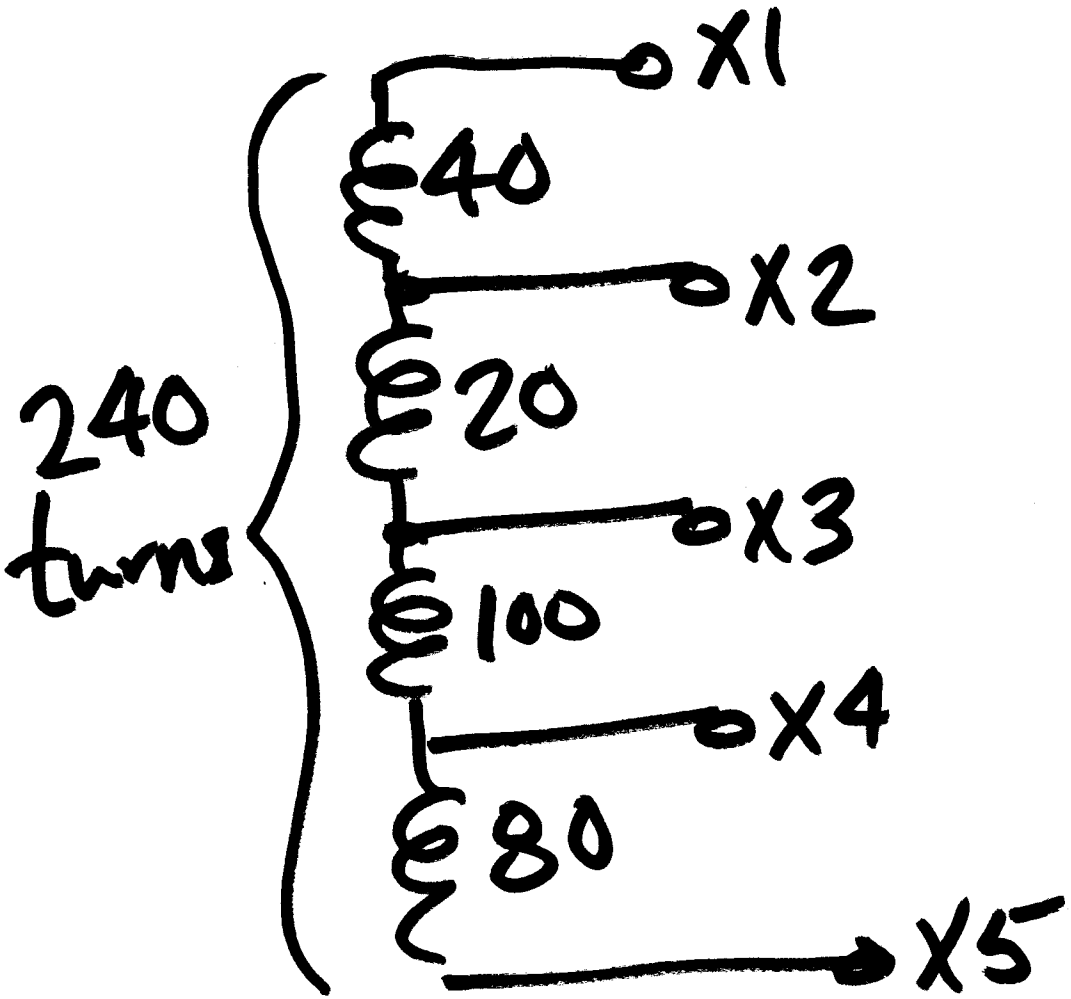
$$a = \frac{1}{240}$$

Current ratio: 1200:5

Z_B = total "Burden"

Typical CT Equivalent Circuit

CT Secondary



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

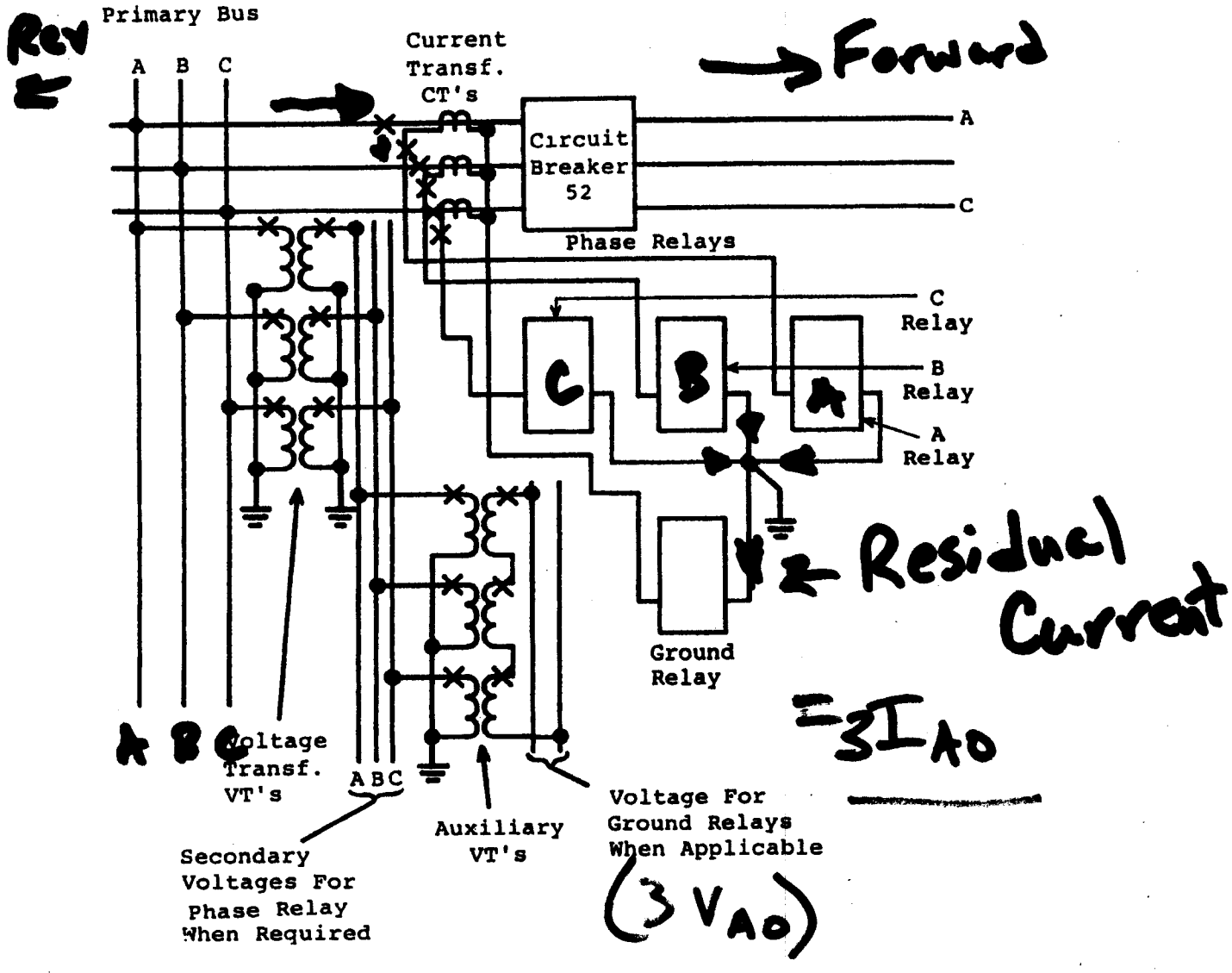


FIGURE 1.10 Typical three-phase ac connections of a set of phase and ground relays for the protection of an ac power system. The relays may be separate, as shown, or combined together in one unit.

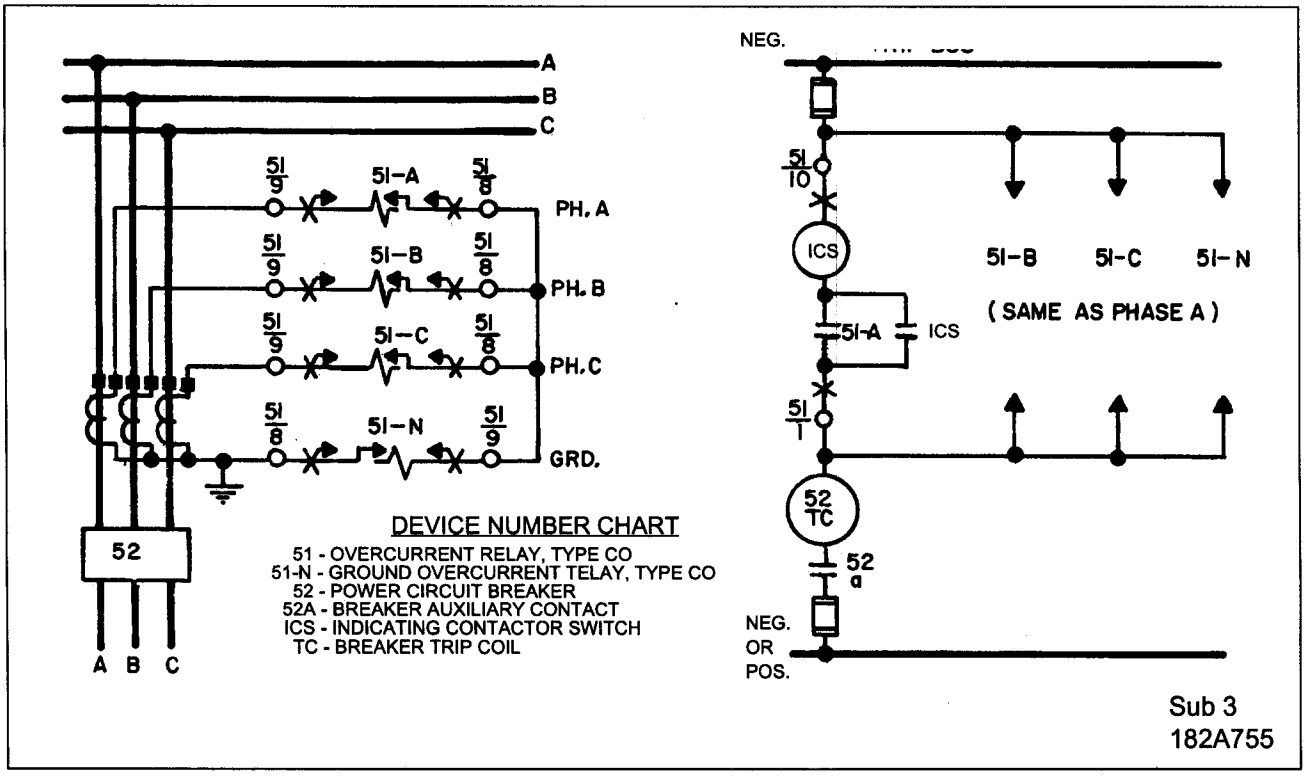


Figure 1: External Schematic of Hilo CO Relay for Phase and Ground Overcurrent Protection on a Three Phase System

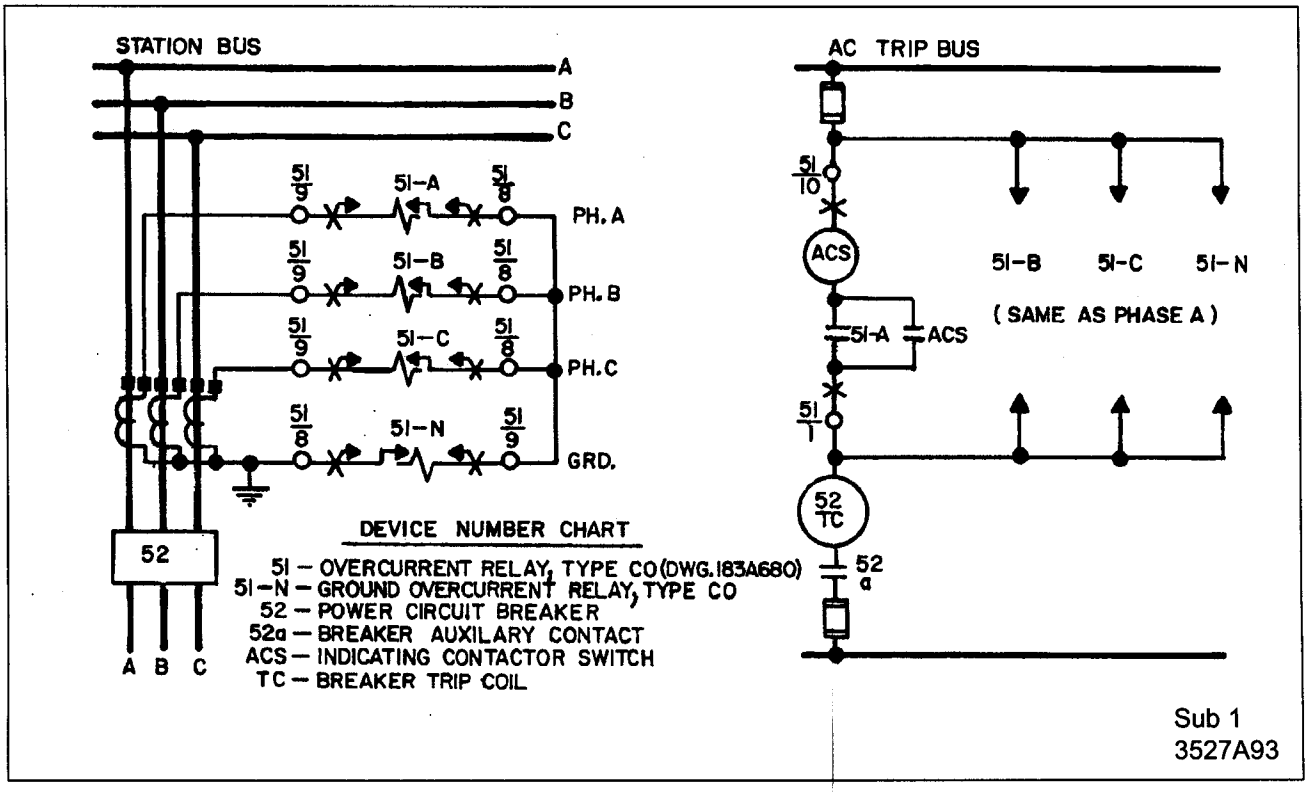


Figure 2: External Schematic of HiLo CO Relay with ACS Unit for Phase and Ground Protection on a Three Phase System