EE 5223 - Lecture 10 Mon Jan 30, 2023

Ongoing List of Topics:

- URL: https://pages.mtu.edu/~bamork/EE5223/
- Labs - EE5224 - Lab 3 - labs resume on Feb 13th. ?
- Term Project - details coming after WC break..
- Software - Aspen One-Liner on remote.mtu.edu. Use on Hmwk 6.

Today:

- CT ratios, MR (multi-ratio) CTs - look at IEEE stds.
- Calculation of measurement error for given ratio & burden.
- Super Bowl 2013 stadium blackout (forensic engineer's report): https://pages.mtu.edu/~bamork/EE5223/130202_Report.pdf

Next:

- Print out MOCT & CCVT handout from web page
- MOCTs - Magneto-Optic Current Transformers
  - Faraday effect, "faraday rotators," Verdet constant
  - shift of polarization angle due to strength of H-field
  - Design kept to low near-linear range
- Linear Couplers, Rogowski Coils
- Voltage & Current relationships during faults, §3.5-3.10

Some Term Project Ideas:

- Browse Table of Contents in your text book for ideas.
- Search IEEE Xplore, IEEE Power & Energy Magazine, IEEE Industry Applications Magazine, Cigre, IEC, etc.
- Ask online students/engineers for suggestions
  - New technologies to figure out, important problems to solve
  - Important concepts that need to be better understood (beyond tech level)
- If you have taken EE5220: use ATP to model CT saturation and relay performance (actual V and I waveforms that relays "see"
  - CT saturation effects
  - Full 3-phase connection of CT, CT secondary cables, and relay burdens.
  - Use library of ATP components available; build your own for your project.
  - Create IEEE Comtrade files, upload to Doble, test the relay!
- Application and testing of a protection scheme (many are possible)
  - Choose scheme and relay(s). First confirm if we have the required relay.
  - Design the protection scheme and provide settings
  - Test in relaying lab (Safety: Buddy rule - never work alone! Access may be limited due to high enrollment, need to schedule/coordinate with Lab TA)
- Substation automation (IEC 61850)
  - PMUs, synchrophasors
  - Digital filters, sampled values "SV"
- Negative sequence polarization methods, Neg seq and REF unbalance detection
- Line differential protection, traveling wave relays
- ____ ??? Other ideas ???

Super Bowl – JAN 3, 2013

- "Power Surge"
- Utility lost power (Entergy, ——)?
- Entergy: All normal.
- NFL: looking into it...
- Problem inside the dome.
- Fire, elevators, gas leak??
- No fire, not smell/smoke near elevator #__?
- Circuit breaker(s) tripped, investigating...

⇓?

⇒ Probable Inference.

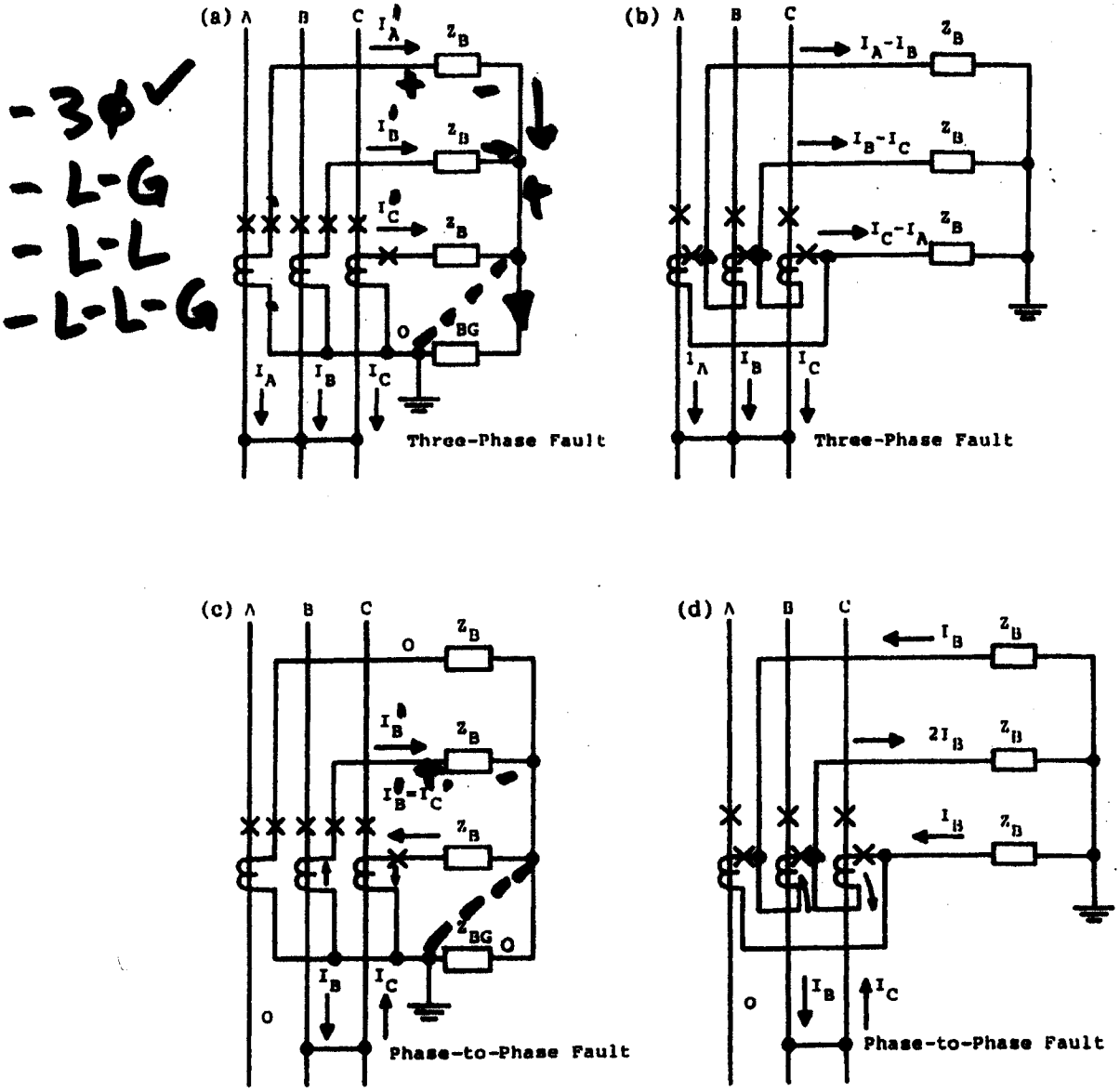


FIGURE 5.10 Burdens on CTs for various types of CT connections and faults. The unexcited CT load is neglected.

5.6.1 CT Ratio Selection for Phase-Connected Equipment

Select the ratio such that the maximum short time or continuous current will not exceed the thermal limits of the CT secondary and connected equipment. The conventional practice, over many years, has been that the secondary

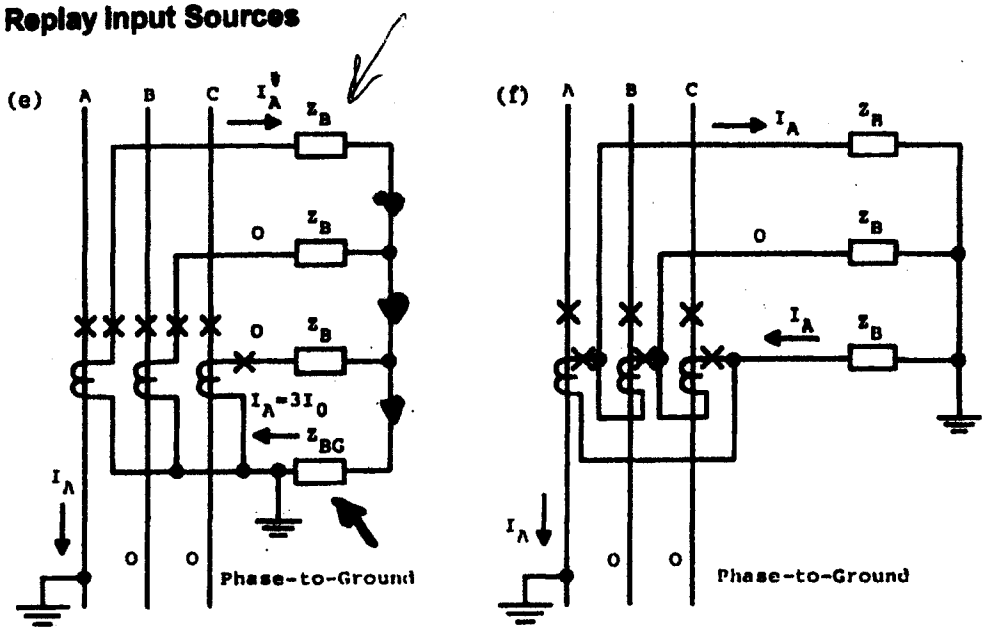


FIGURE 5.10 Continued

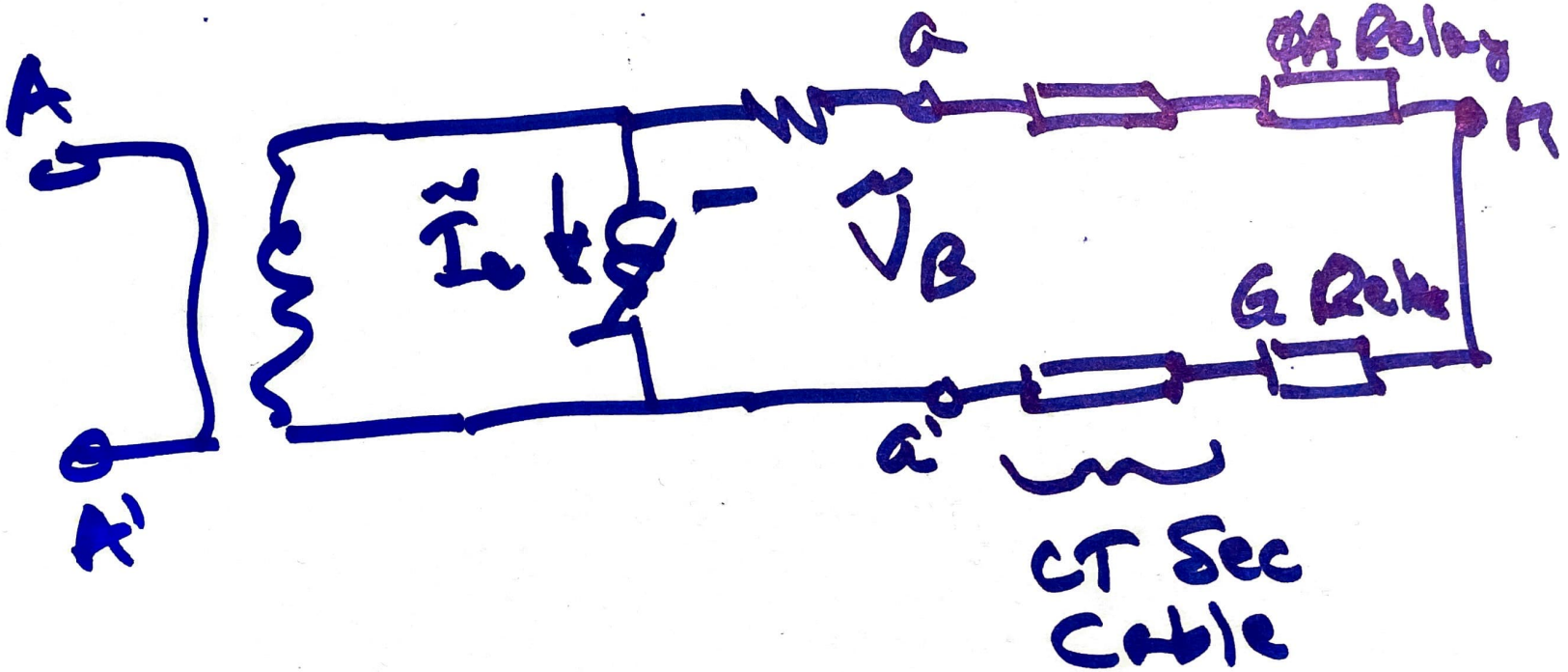
current should be just under 5 A for the maximum load. This was because instruments were often in the same circuit, and they had 5-A movements. Following this practice, select the CT ratio of 100/5 (R_c = 20). This gives a maximum continuous secondary current, when the load is 90 A, of I_s = 90/20 = 4.5 A.

5.6.2 Select the Relay Tap for the Phase-Overcurrent Relays

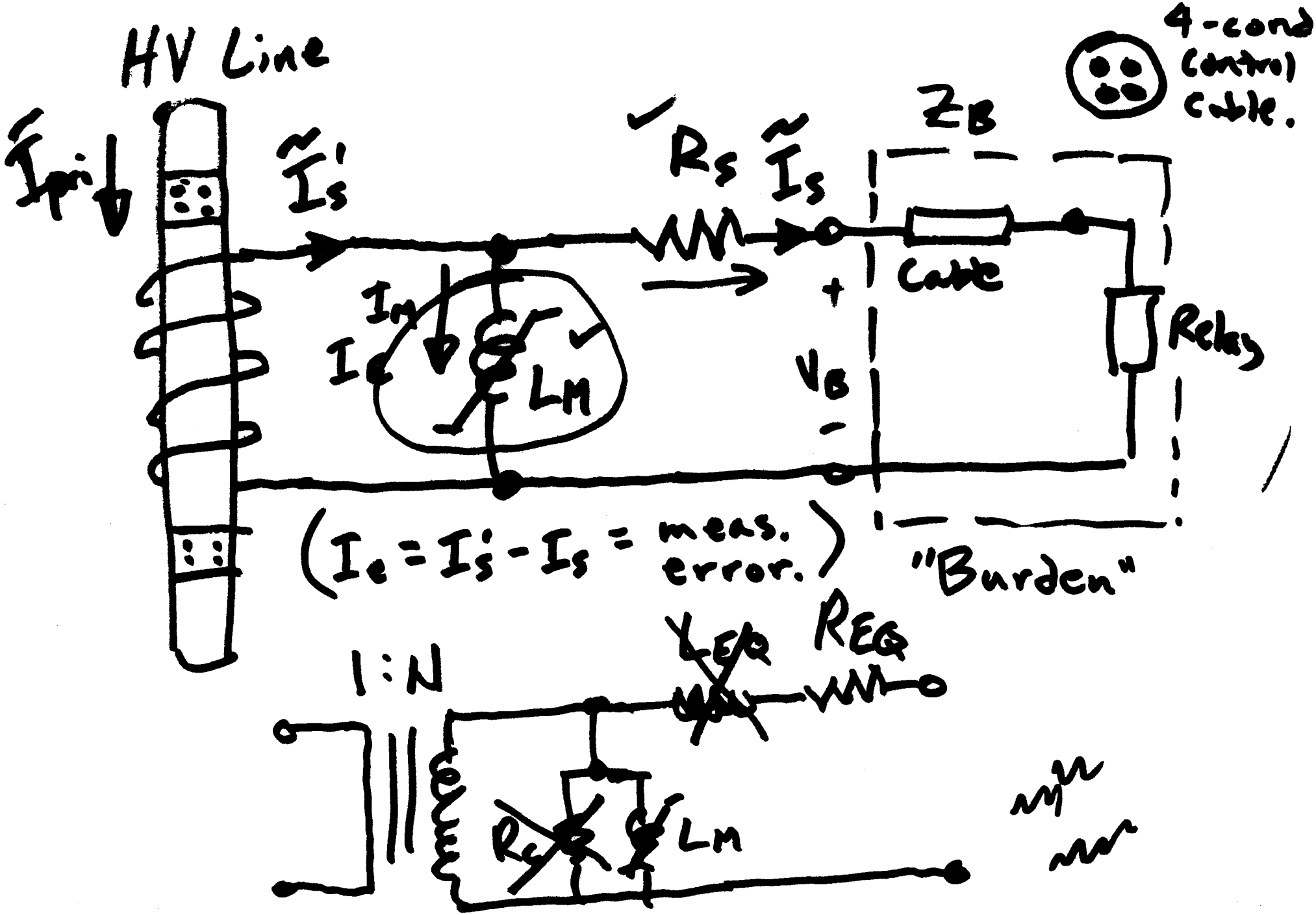
Overcurrent taps represent the minimum pickup or operating current of an overcurrent relay. Thus, a tap is chosen that is higher than the maximum load, in this example, above 4.5 A. How much higher is based on relay characteristics, experience, and judgment. There is no problem if a time overcurrent relay picks up on a cold load, offset currents, or other, provided these currents subside below the relay pickup before it operates. This may be required when the margin between minimum fault and maximum load is small.

Small tap 5 is selected. The ratio above load 5/4.5 = 1.1. This provides a small margin more than any potential increase in the continuous load, but a large margin with inverse-type relays for transient overcurrents, such as a cold load. Minimum fault of 350/20 = 17.5 A, and 17.5/5 = 3.5 times the minimum relay pickup that is desirable for any possible fault restriction.

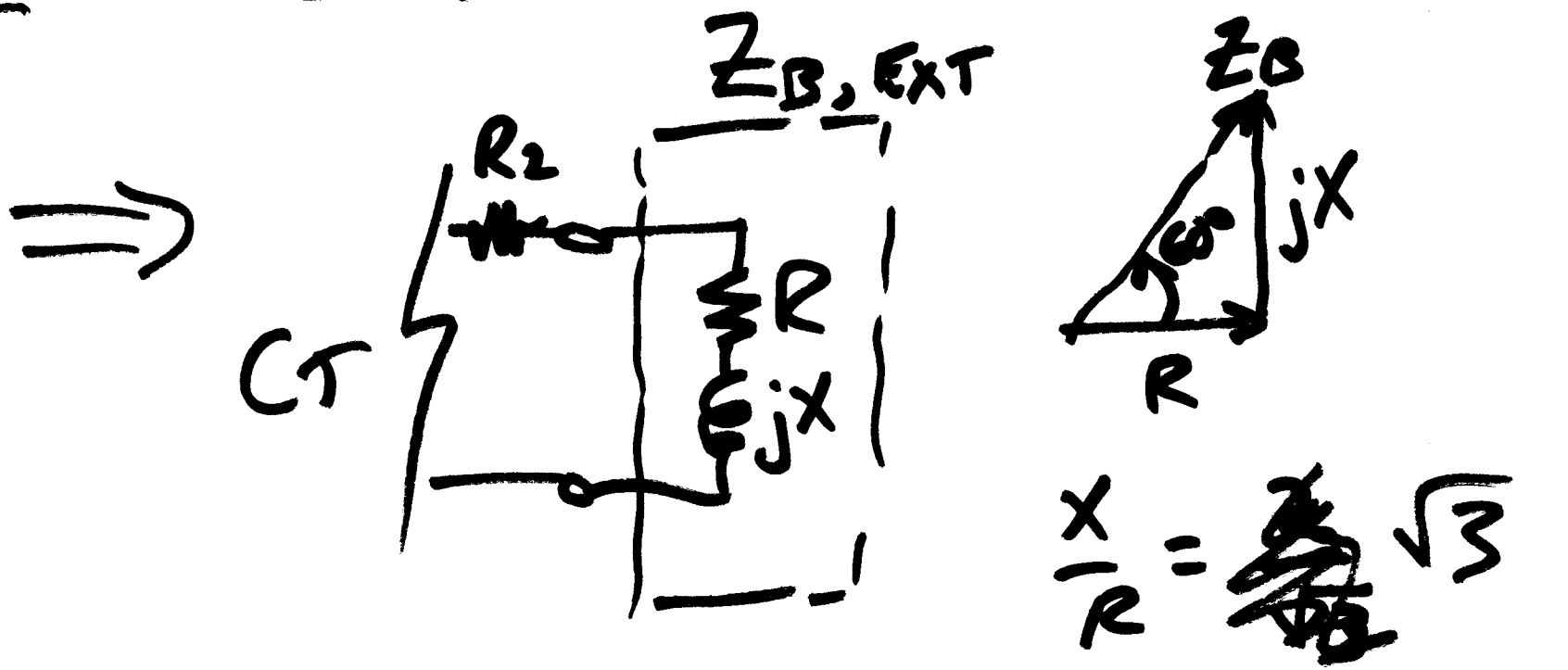
If tap 6 were selected, then the margin above load is greater (6/4.5 = 1.33), but a smaller margin (17.5/6 = 2.9) above the relay pickup.



L - G


HV Line
4-cond control cable.
$\tilde{I}_{pri}$
$\tilde{I}_s'$
R_s $\tilde{I}_s$
Z_B
Cable
Relay
I_m
I_e
L_M
V_B
+
−
$(I_e = I_s' - I_s$ = meas. error.$)$
"Burden"
1:N
Y_{EQ}
R_{EQ}
R_c
L_M

$\underline{Z} = 8\angle 60^\circ\ \Omega$ (B-8) or "C800"

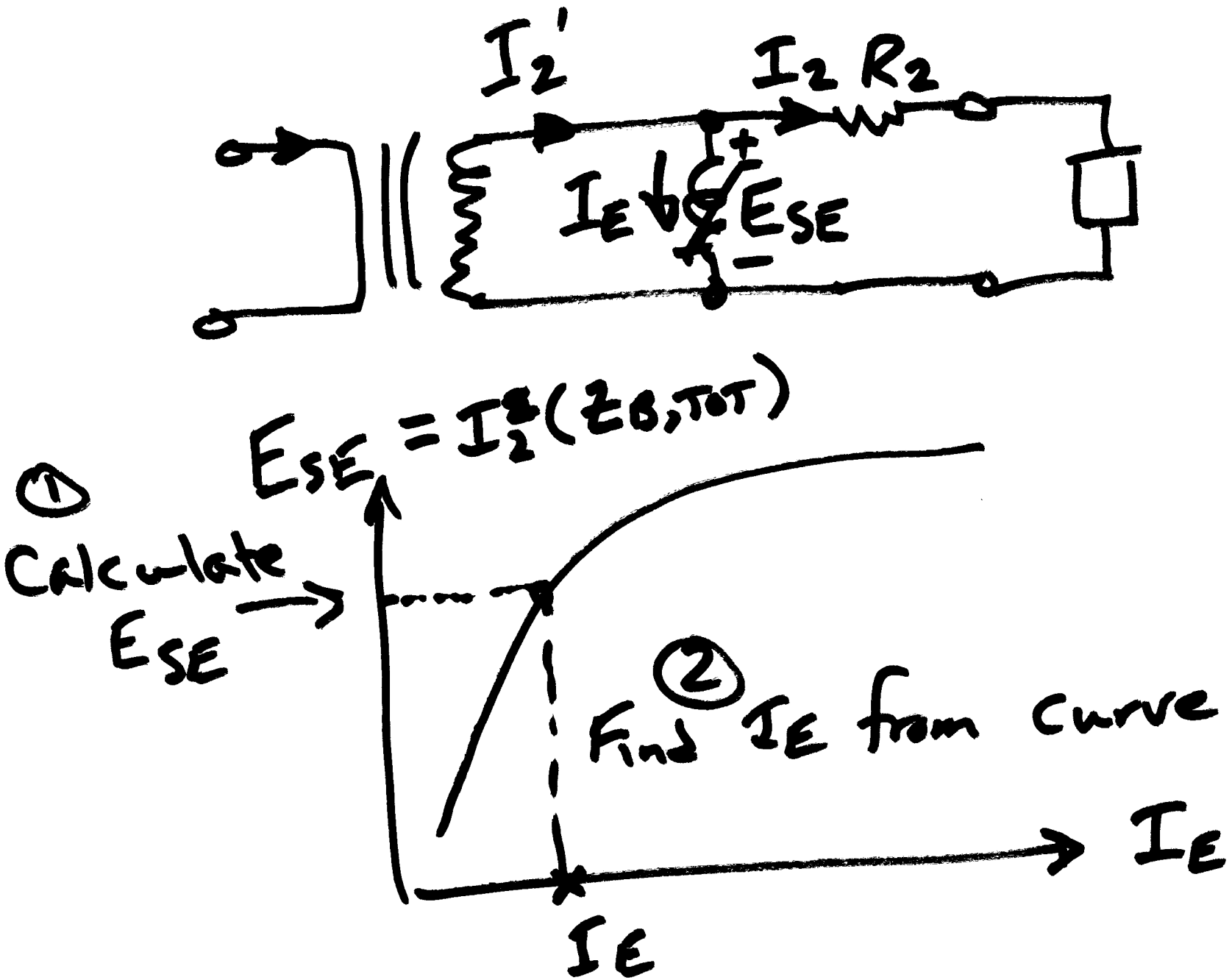


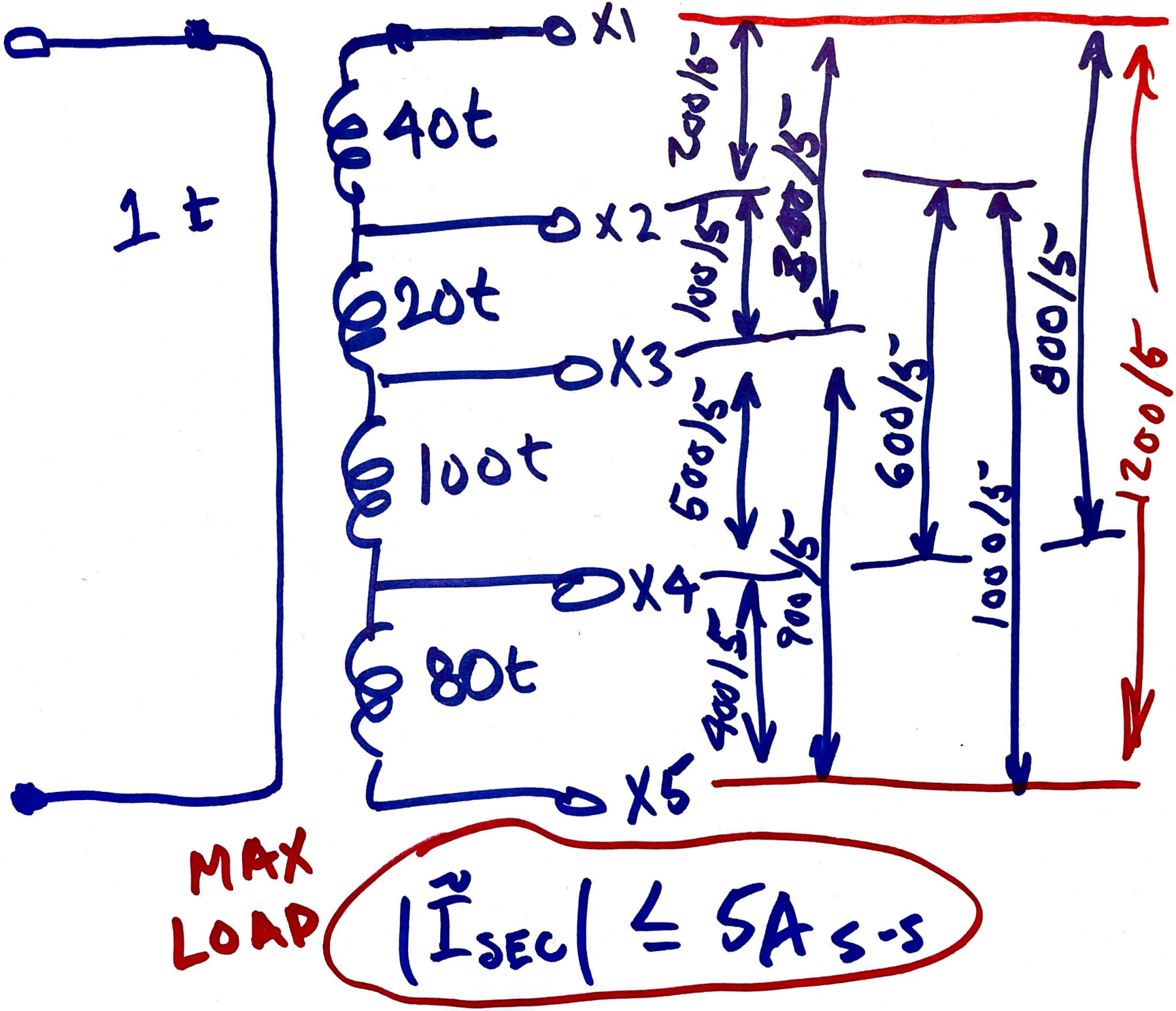
$\frac{X}{R} = \frac{\sqrt{3}}{1}$

@ 100A (20x rated)

↑

5A


I_2'
$I_2 R_2$
+
I_E
E_{SE}
−
$E_{SE} = I_2'(Z_{B,TOT})$
① Calculate E_{SE}
② Find I_E from curve
I_E
I_E


1 t
40t
20t
100t
80t
X1
X2
X3
X4
X5
200/5-
100/5-
300/5-
600/5-
900/5-
600/5-
1000/5-
800/5-
1200/5-
MAX LOAD
$|\vec{I}_{SEC}| \leq 5A_{s-s}$

MR CT 1200/5 Ratio

R_2: .0027Ω/ft