

ECE 526

PROTECTION OF
POWER SYSTEMS II

SESSION no. 2

Transformer Protection

In ECE 525

• Internal Faults

Differential Protection

- Phase currents

- Restraint

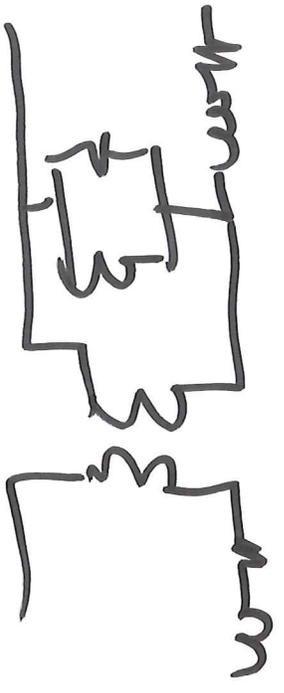
- Tap setting

- Connection compensation matrices

• Harmonic Blocking

or harmonic restraint

• Unrestricted (unrestrained)



Sources of transformer stress

- Vibration
- Thermal cycling
- Local heating / hot spots due to flux
- Heating due to overload or inappropriate cooling
- Through fault currents

Refs: IEEE C37.91 IEEE Guide for Protection of Power Transformers

Other transformer protective elements

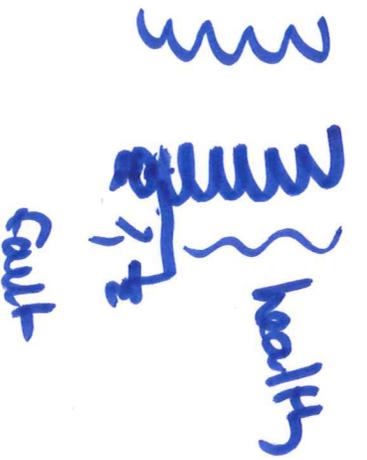
- Restricted earth fault protection
- Overexcitation
- Transformer overcurrent protection
- Turn to turn faults
- Thermal & through fault-monitoring

Restricted earth fault (REF)

$$\frac{D_{Yn}}{3Z_c}$$

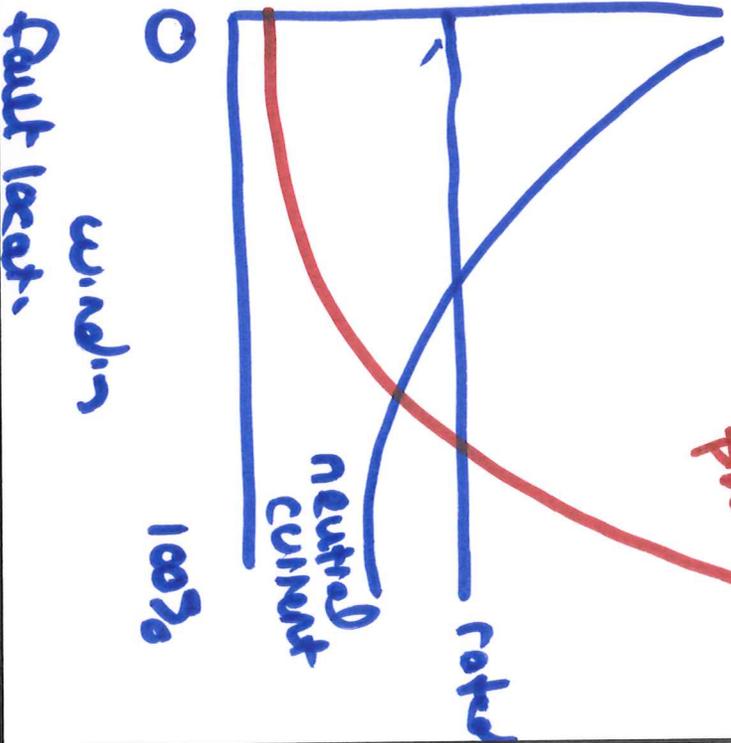
- internal fault close to neutral challenge ground

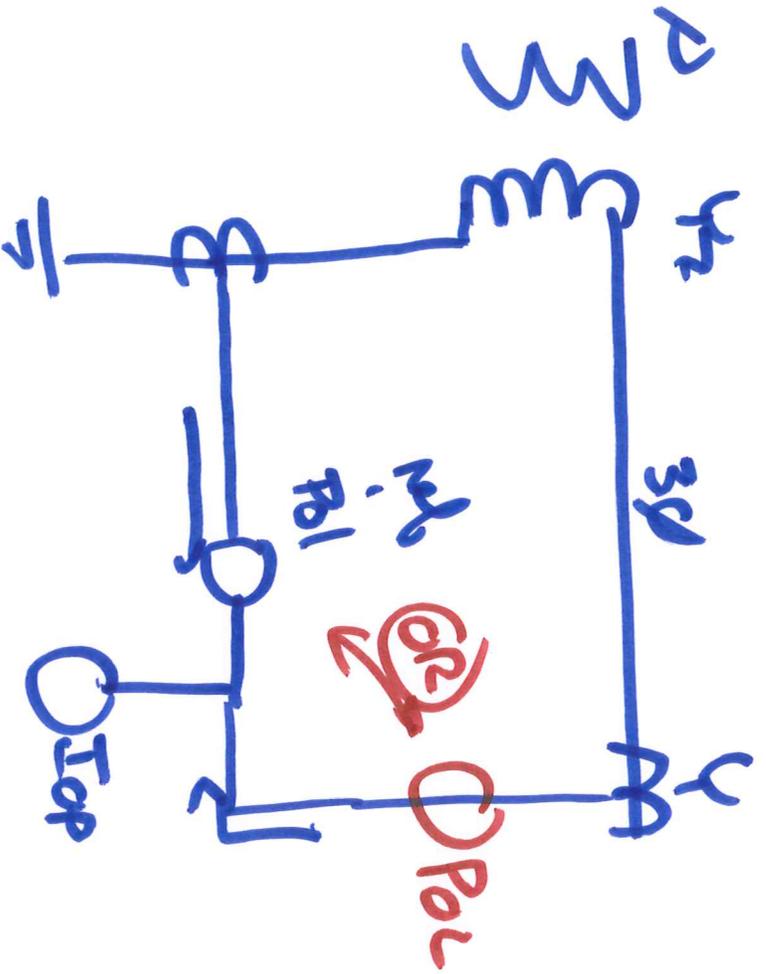
- y-g side



transformer

Terminal Phase





Alternate approach:

$$\bar{I}_A + \bar{I}_B + \bar{I}_C$$

$$I_{OP} := |I_{N_sec} + I_{R_sec}| \quad I_{OP} = 0.323$$

$$I_{RT} := |I_{N_sec}| + |I_{R_sec}| \quad I_{RT} = 30.315$$

$$\frac{I_{OP}}{I_{RT}} = 0.011$$

Note, if we don't reverse the polarity on the phase CT currents we get:

$$I_{OP} := |I_{N_sec} - I_{R_sec}| \quad I_{OP} = 30.314$$

Then $\frac{I_{OP}}{I_{RT}} = 1$ and the relay would operate.

20/27

Over excitation

- over fluxing the core
- pushing into steady state saturation

$$\rightarrow \frac{V}{f}$$

$$e = N \frac{d\phi}{dt}$$

$$\phi = \Phi \cos \omega t$$

$$\frac{d\phi}{dt} = \omega \Phi \sin \omega t$$

$$V = N \frac{d\phi}{dt}$$

~~Overexcitation~~

Overexcitation occurs if

$$\frac{V}{f} > \left(\frac{V/V_{nom}}{f/f_{nom}} \right)$$

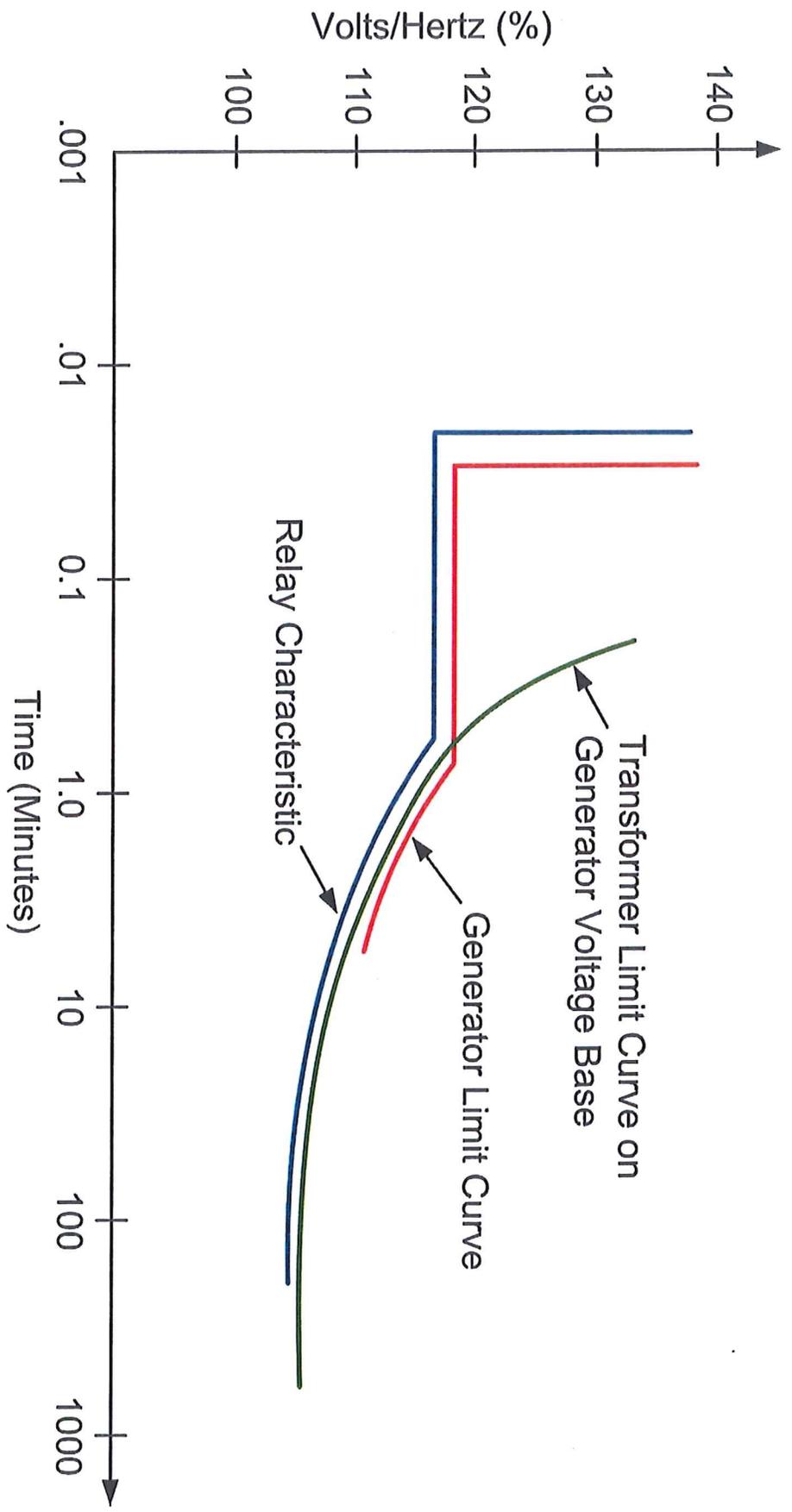
 $V/f > 1.05$ at full load

or 1.1 at no load

- harmonics
 - heating
 - high I_m (excitation current)
 - vibration
- ⇒ Volts/Hz relays (24)

L2 9/22

Overexcitation Protection



Overcurrent Protection

- Thermal & mechanical stresses
- Through faults
- Effects ~~on~~ (damage) cumulative

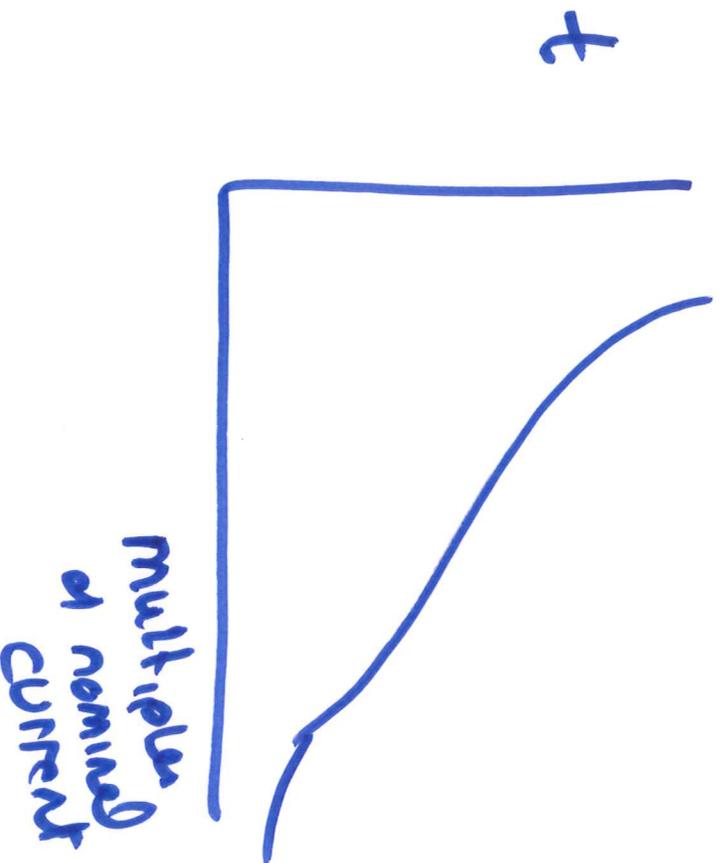
Track: current magnitude

Fault duration

of faults

ISEE CS7.12.00

- Transformer Through-Fault Capability Curves



- Transformer
relays overcurrent
element
coordinated
with line/feeder
protection

L2 12/22

Transformer Categories Per

IEEE C57.12.00

Category	Single-Phase kVA	Three-Phase kVA
I	5 to 500	15 to 500
II	501 to 1,667	501 to 5,000
III	1,668 to 10,000	5,001 to 30,000
IV	Above 10,000	Above 30,000

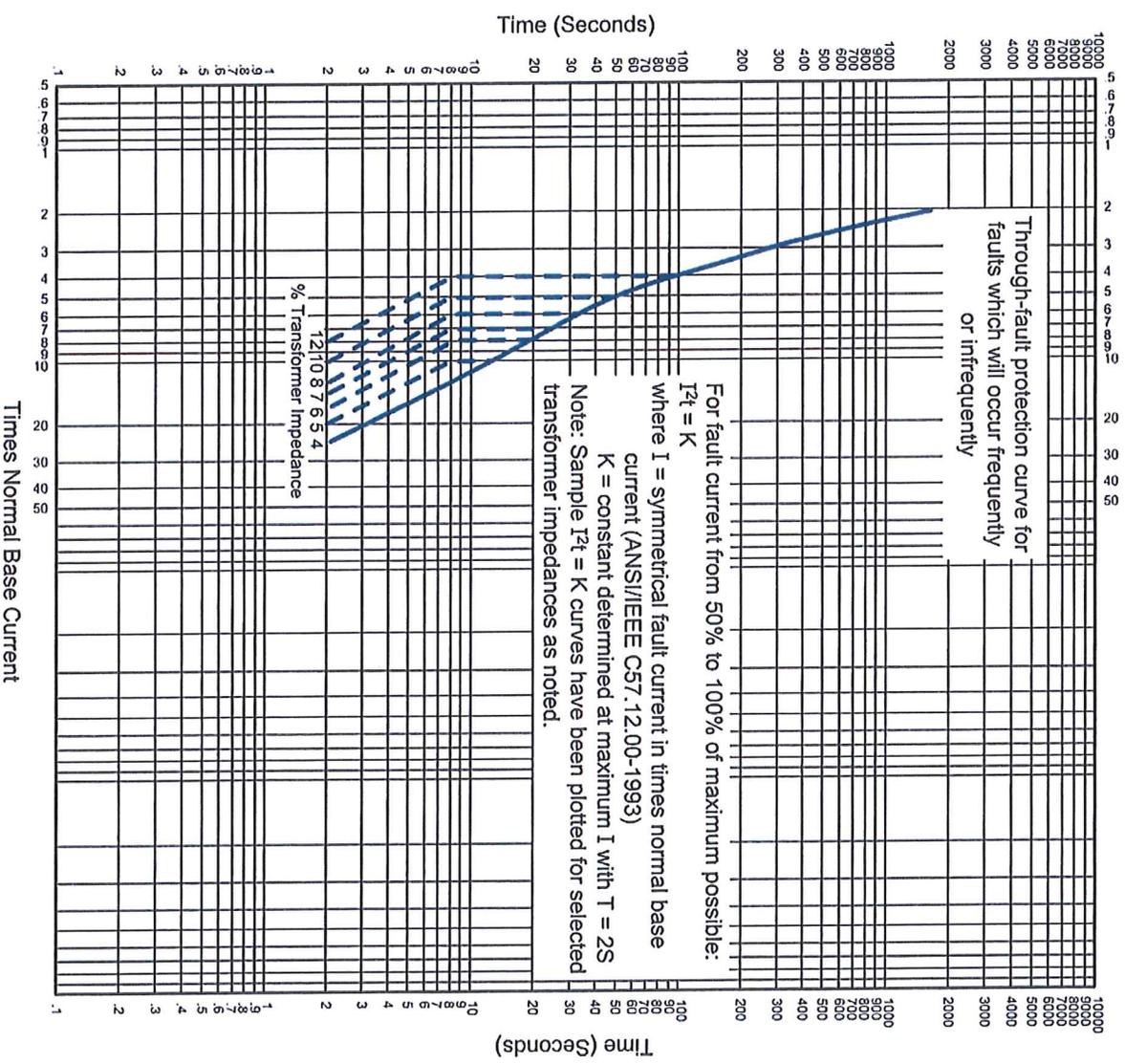
Category IV

Above 10,000 kVA
1-Phase

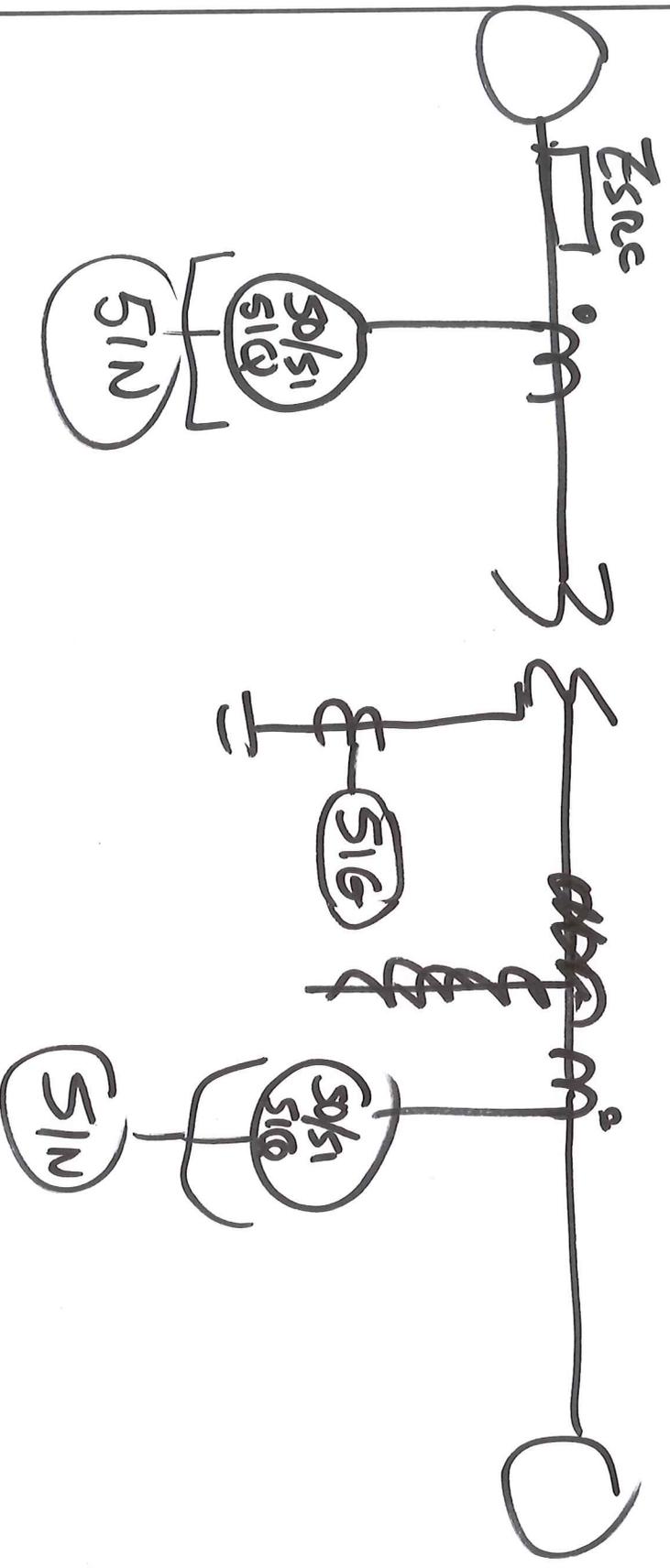
Above 30,000 kVA

3-Phase

Source: IEEE C57.12.00-2010, IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers



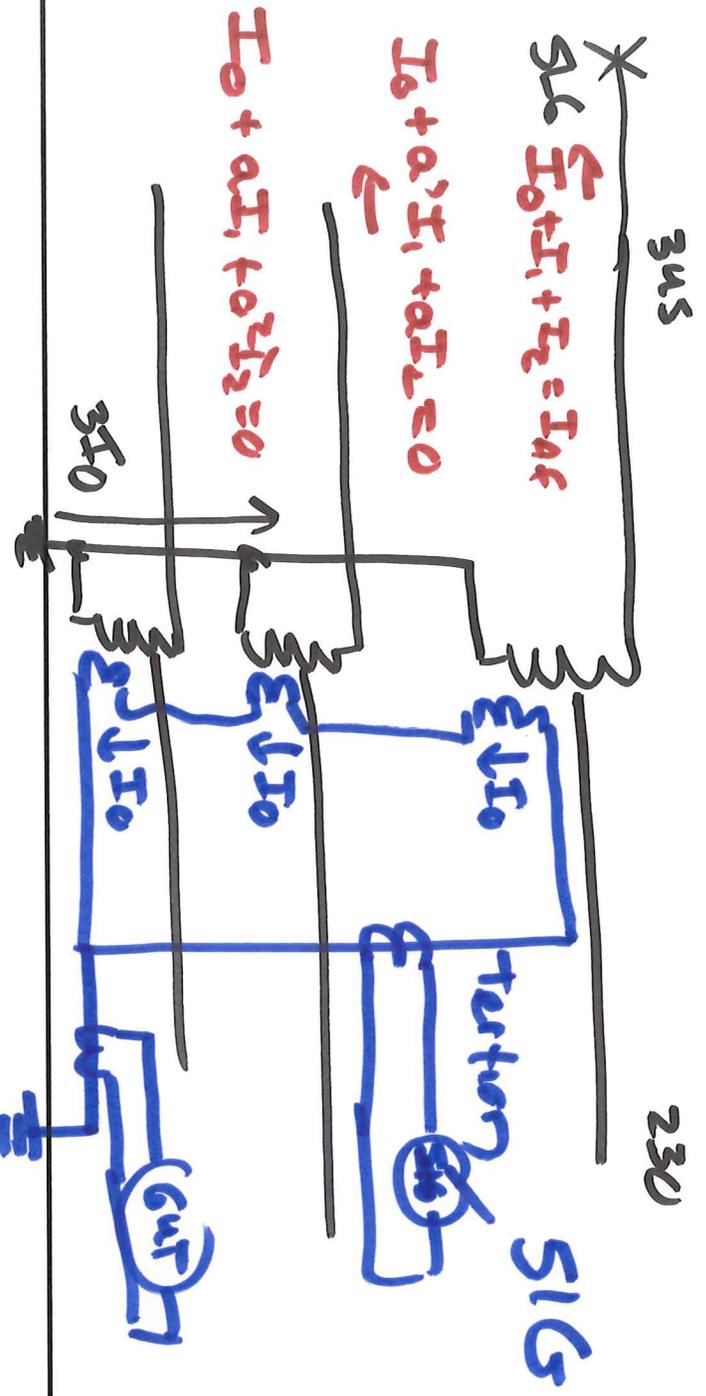
L2 13/22



Transformers Tertiaries



→ Overcurrent protection in tertiary



Transformers with Fuses

- mostly in smaller transformers
- Through Fault
- Internal phase to ground faults
- Create single phase condition if one open

C37.91

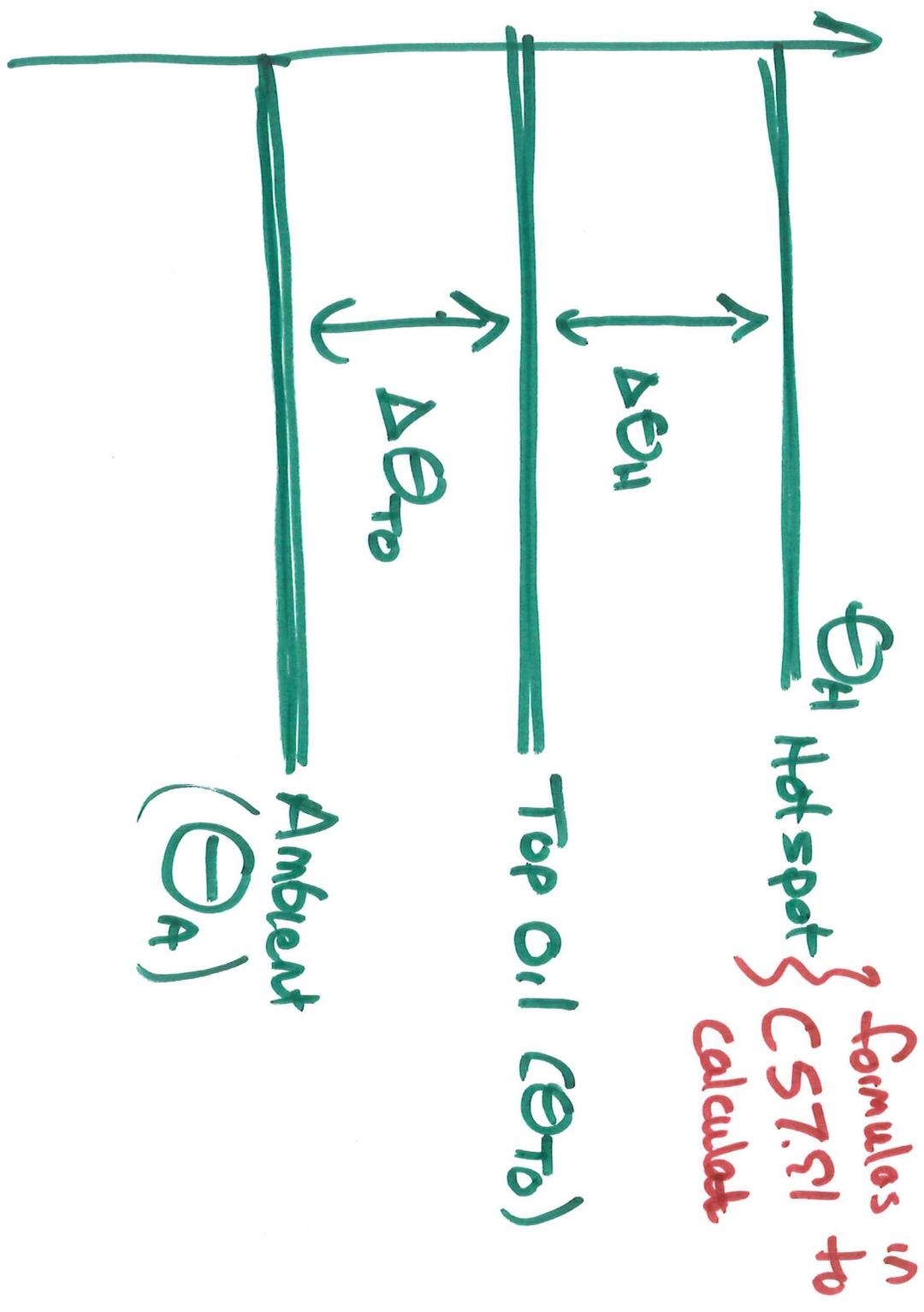
Thermal Monitoring (model)

- Some relays build a thermal model to predict ~~thermal~~ temperatures at points not monitored

-
- System events or operator actions can cause overloads
 - Guidelines in IEEE Standards and operator guides
 - Conservative due to limited measurements

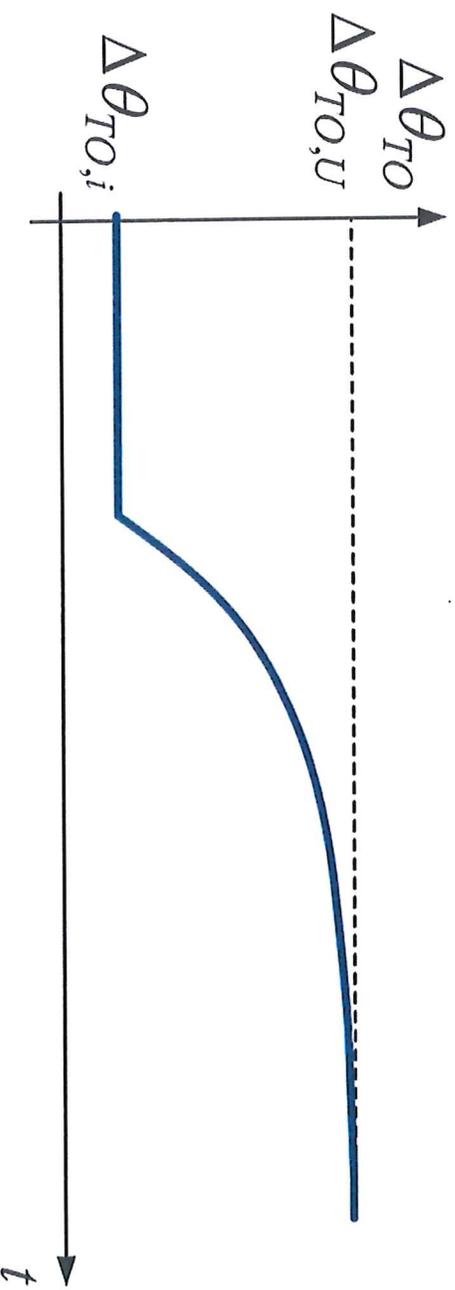
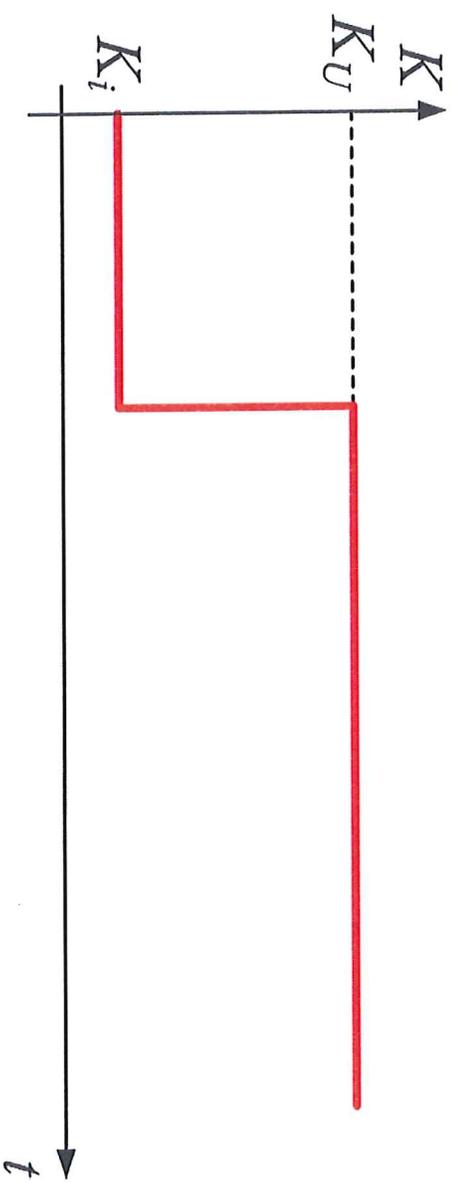
Real Time Thermal Monitoring Combined with model

Temp.



L2 19/22

Thermal Model Response to a Load Step Change



- Hot spot temp is limiting factor for damage

- One hour at 120°C ages insulation equivalent to 27 hrs at 110°C

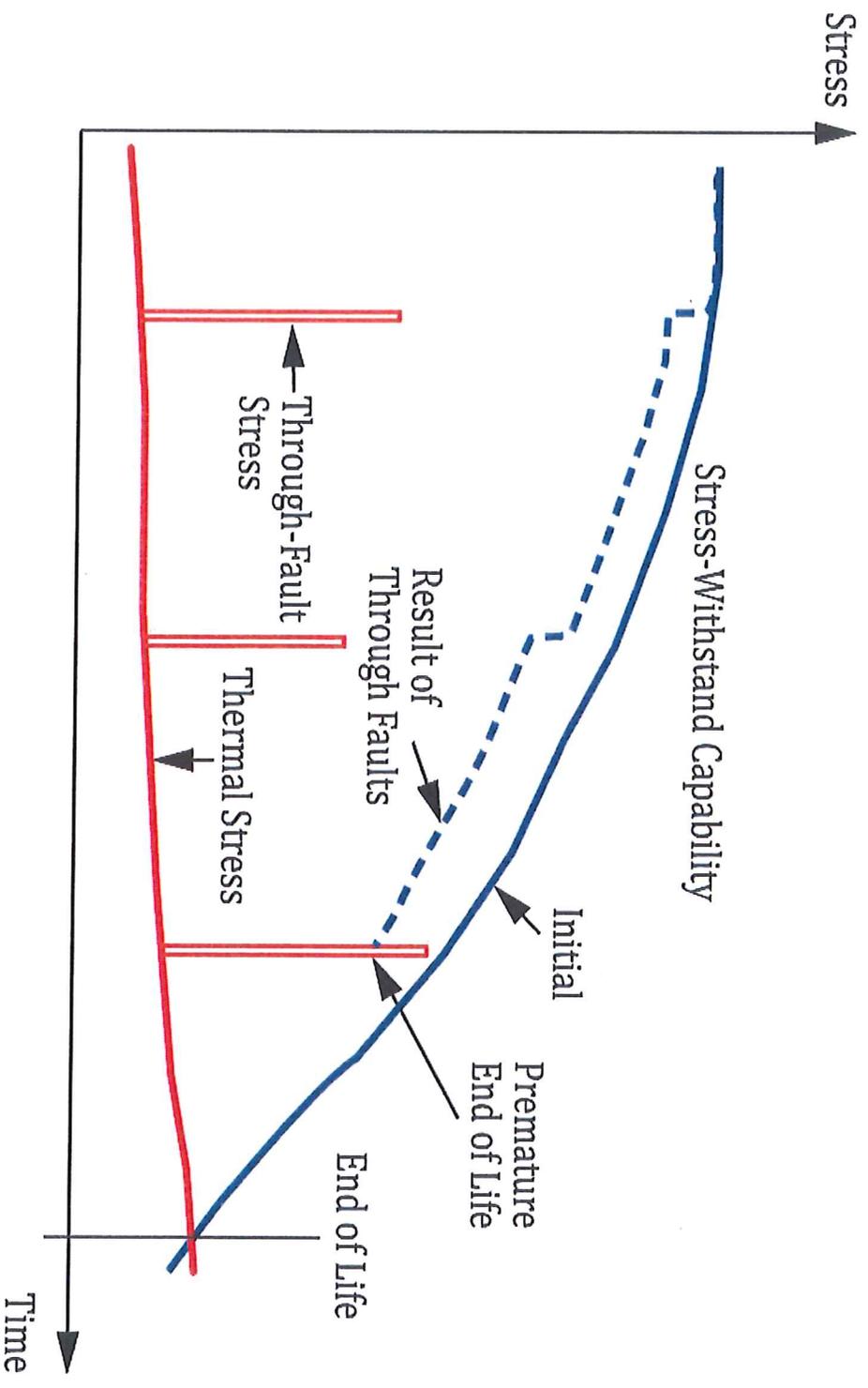
- Use model to calculate

aging / loss of life (accumulated)

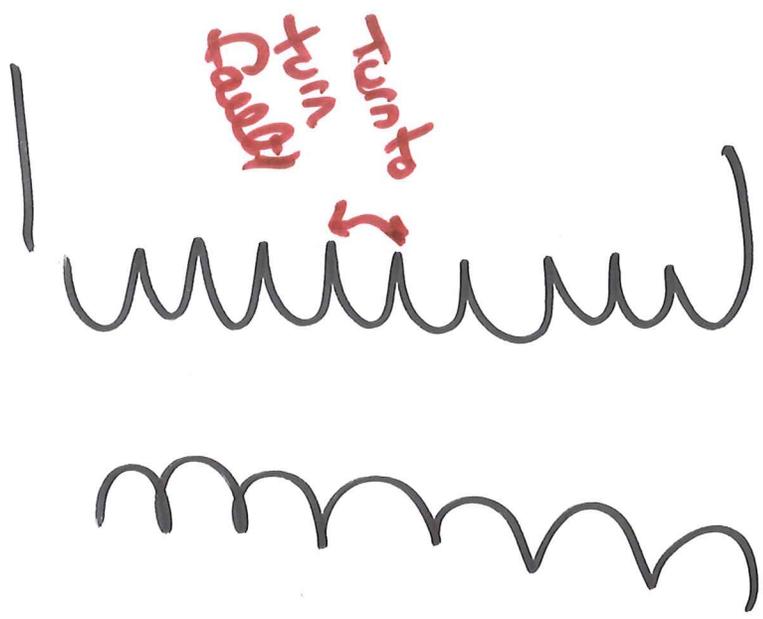
I^2t → more for through faults also overload

L2 2/22

Combined Effect of Thermal and Through-Fault Stresses



Internal Turn-to-Turn Faults



- Looks a bit like an auto-tuning form

- Small change in currents at terminals **fault**

- Starting 5% of turns

- 1000A at ~~point~~ point

- 50A change in terminal currents

Phase Differentiated
 doesn't
 might see this

Alternate protection

- Sudden pressure relays
- Negative sequence differential