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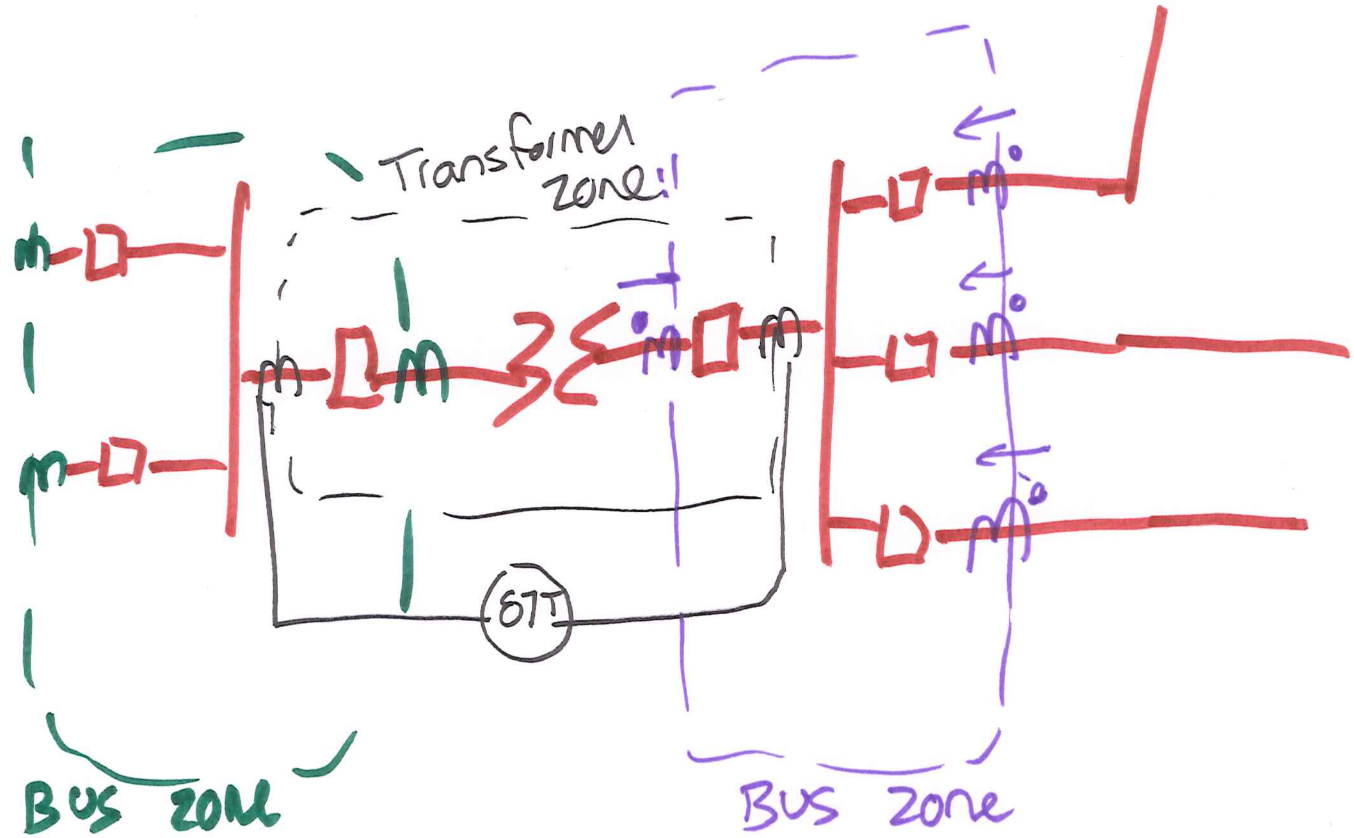
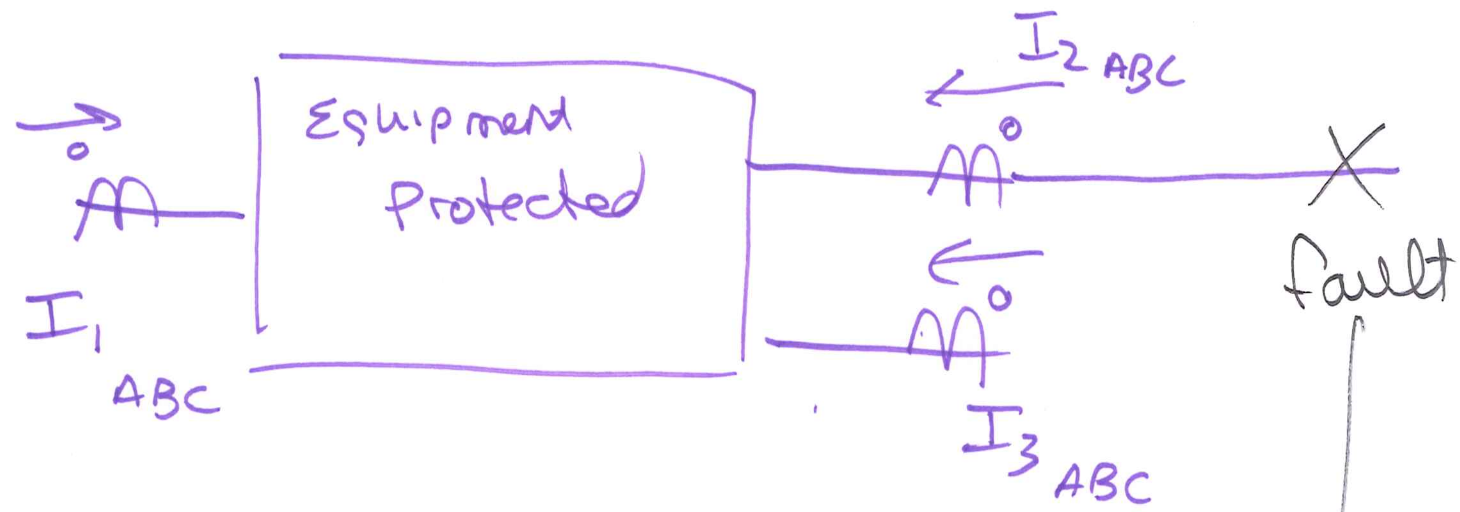
# ECE 525

# POWER SYSTEM PROTECTION AND RELAYING

SESSION no. 24




- Simplest scheme - Bus Differential 87B




Normal Load conditions

$$\bar{I}_{1A} + \bar{I}_{2A} \; \bar{I}_{3A} = 0$$

$$\bar{I}_{1B} + \bar{I}_{2B} + \bar{I}_{3B} = 0$$

$$\bar{I}_{1C} + \bar{I}_{2C} + \bar{I}_{3C} = 0$$

} also holds for external faults

# Internal fault

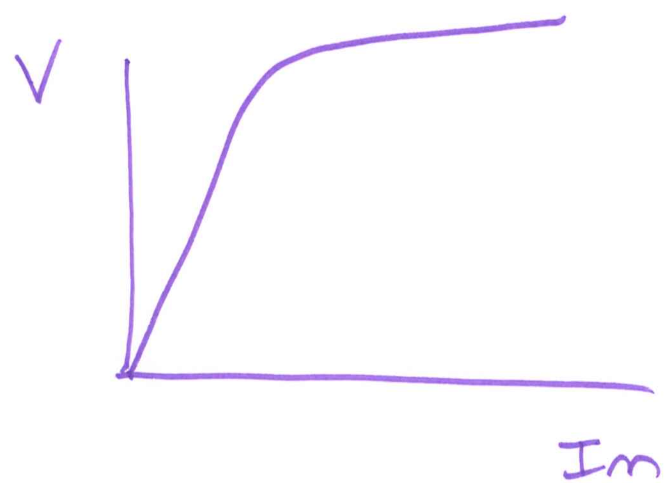
- Between the CTs

$$\bar{I}_{1A} + \bar{I}_{2A} + \bar{I}_{3A} = \bar{I}_{Af}$$

- setting a threshold to differentiate a fault from external fault or load
  (internal)

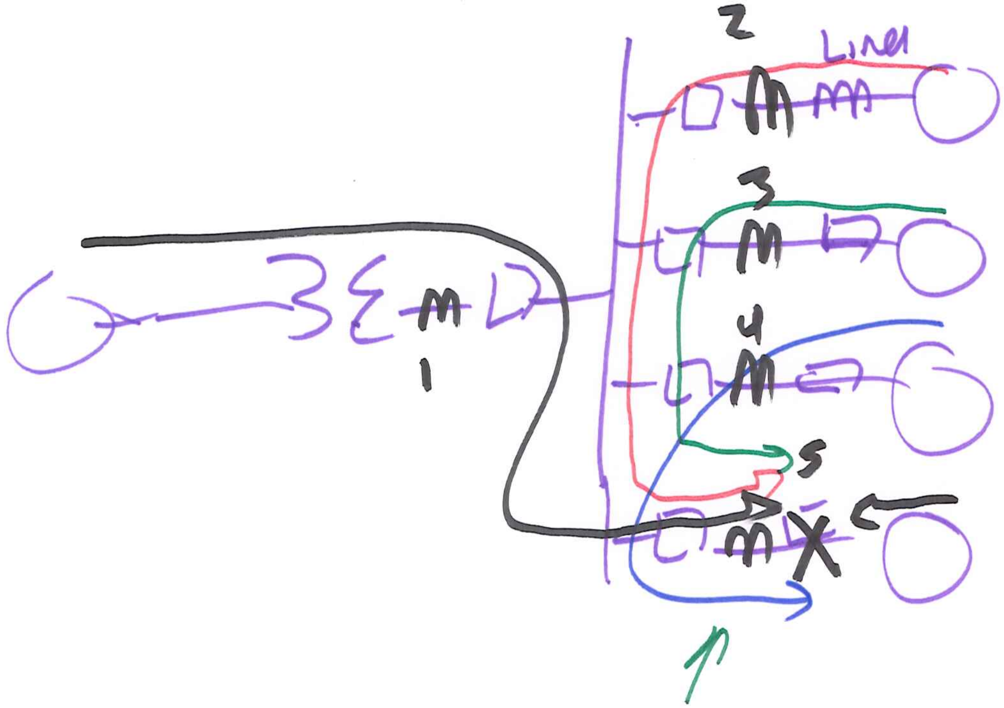
→ Relay operates on secondary currents

- For bus scheme
  - matched CTs
  - all same C-class



- CT saturation concerns

  - Big concern is external faults




$$\bar{I}_{1A} + \bar{I}_{2A} + \bar{I}_{3A} + \bar{I}_{4A} + 0.5 \cdot \bar{I}_{5A} e^{j\theta} \neq 0$$

due to saturation

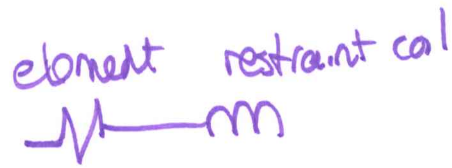
CT sees fault current contribution from 4 sources

# Possible fixes

1. Linear CTs (no iron core)
   - Linear couplers
   - Optical CTs

2. Restrained Differential Element

Low impedance differential element




→ we'll discuss micropressor implementation next

(3) High impedance differential

→ you know the CT on external faulted circuit will saturate

- force it to saturate deeply & use that in detection scheme

→ voltage based detection

Low impedance Bus differential

$$I_{opA} = \left| \bar{I}_{1A} + \bar{I}_{2A} + \bar{I}_{3A} + \cdots + \bar{I}_{nA} \right|$$

$$I_{RTA} = |I_{1A}| + |I_{2A}| + |I_{3A}| + \cdots + |I_{nA}|$$

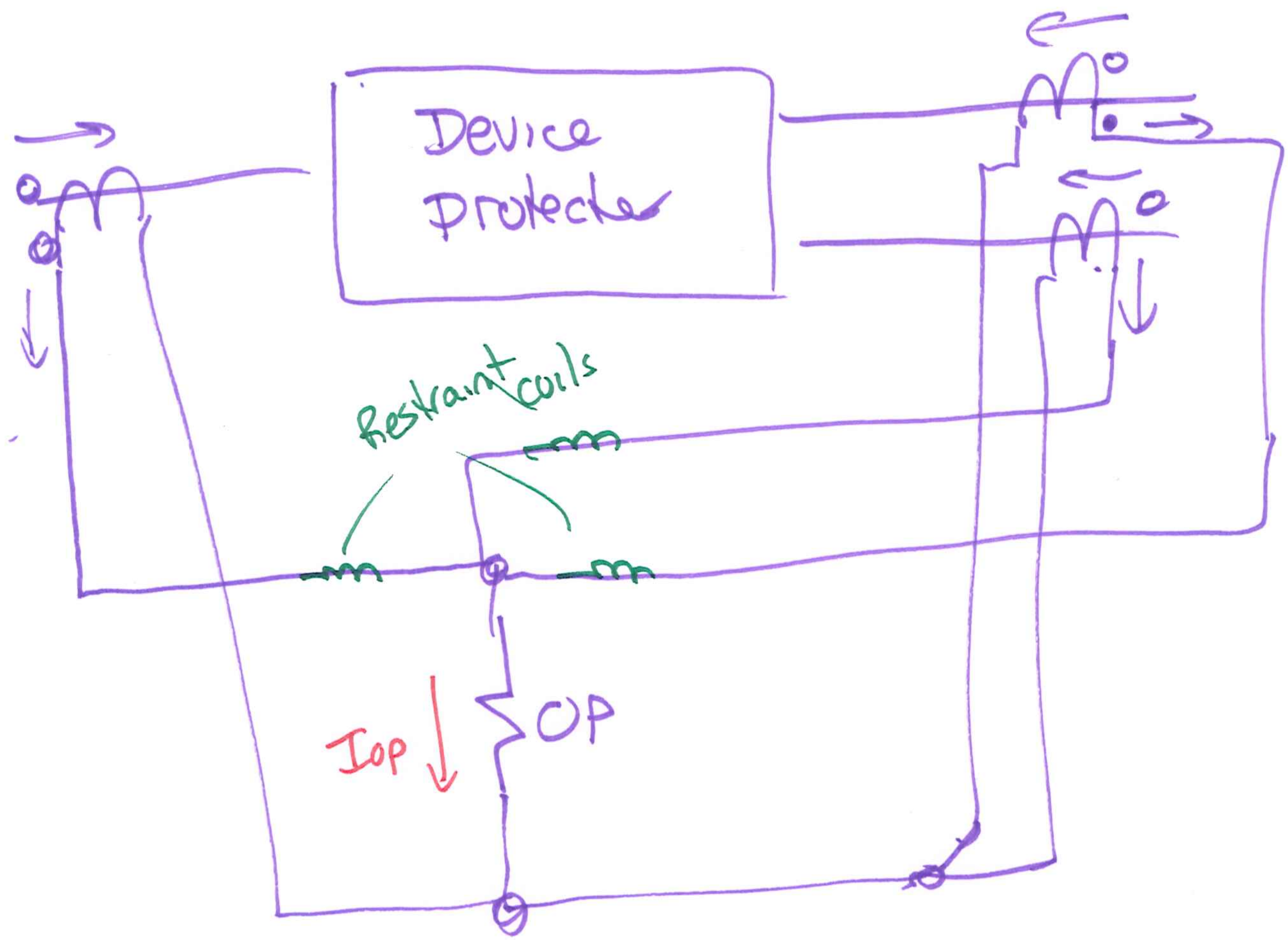
→ for load or external fault (not saturation)

$I_{opA}$ → small

$I_{RTA}$ → large

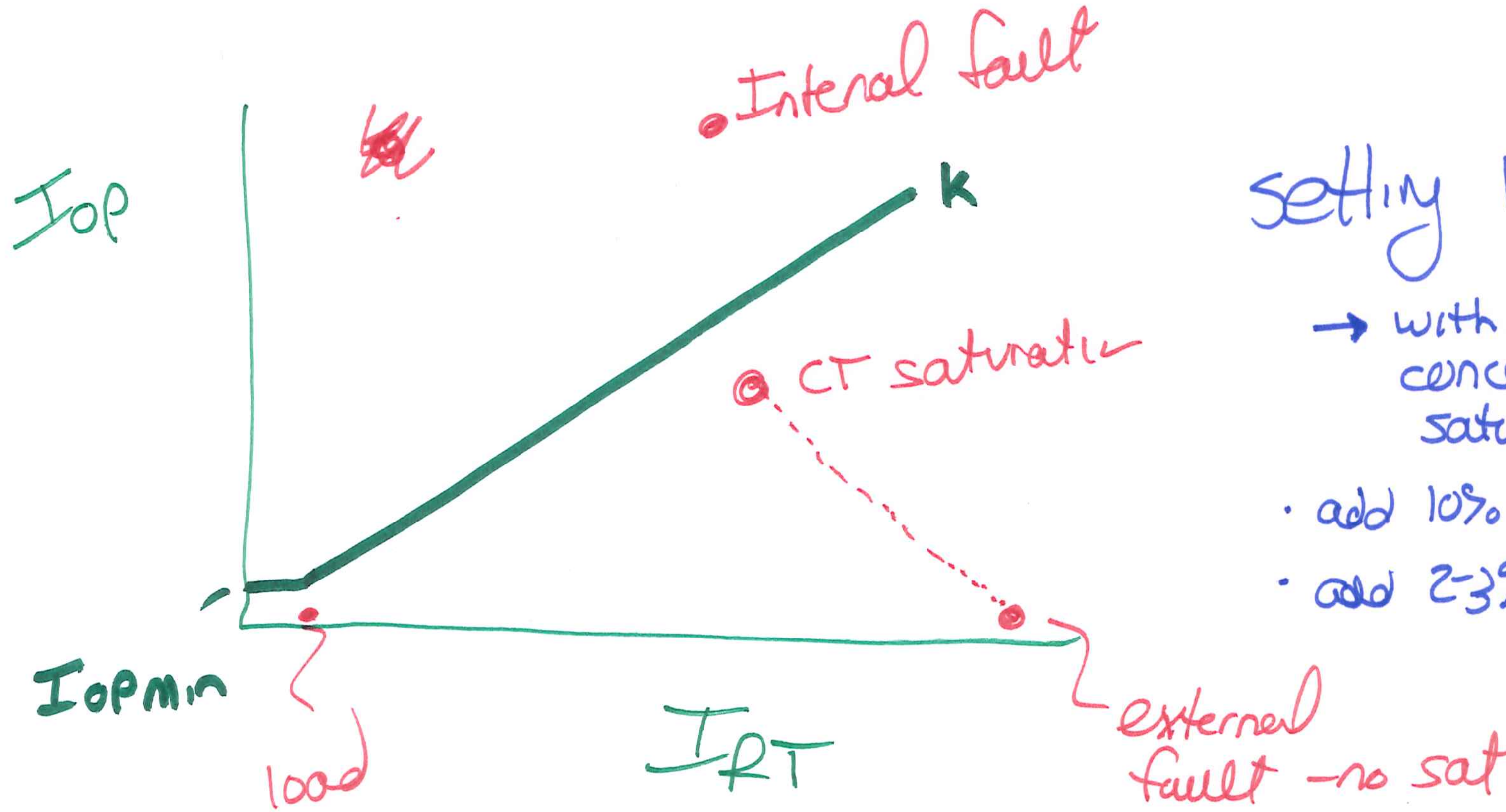
Internal fault $I_{opA}$ large

$I_{RTA}$ large


Device
Protected
Restraint coils
OP
Iop

TRIP if $I_{op} > k \cdot I_{RT}$

$k \cdot |I_{1A}| + k \cdot |I_{2A}| + k \cdot |I_{3A}|$




setting k (slope)

→ with minimal concern for saturation

- add 10% for each CT
- add 2-3% for filter transient

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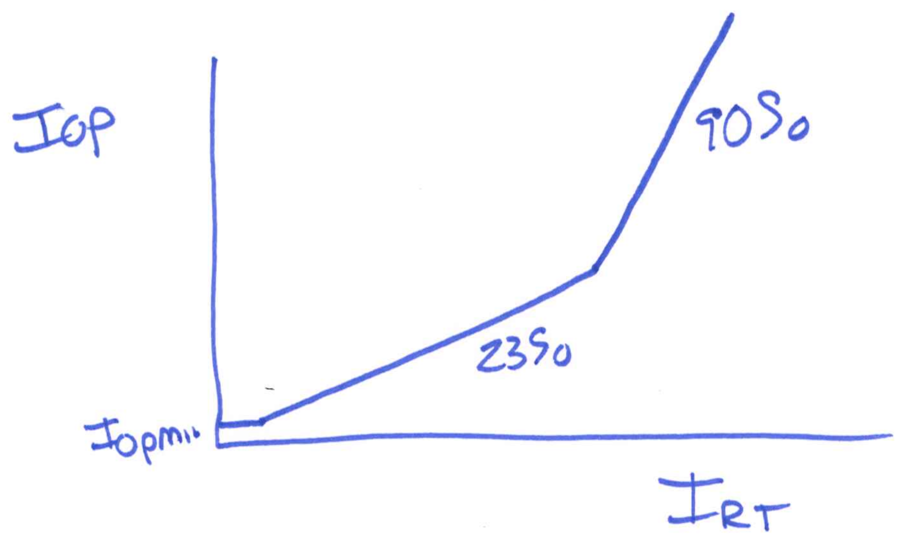
# How do you handle CT saturation

① Dual slope characteristic

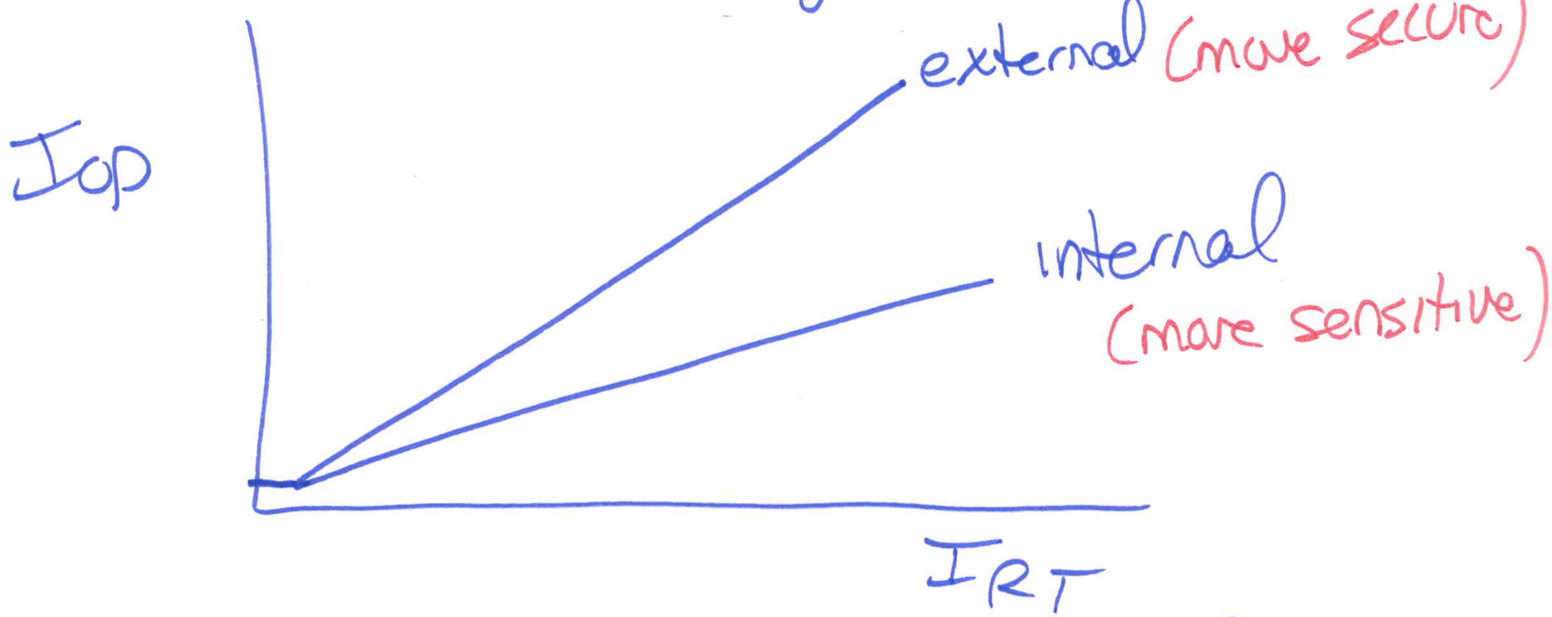



steeper slope for big currents

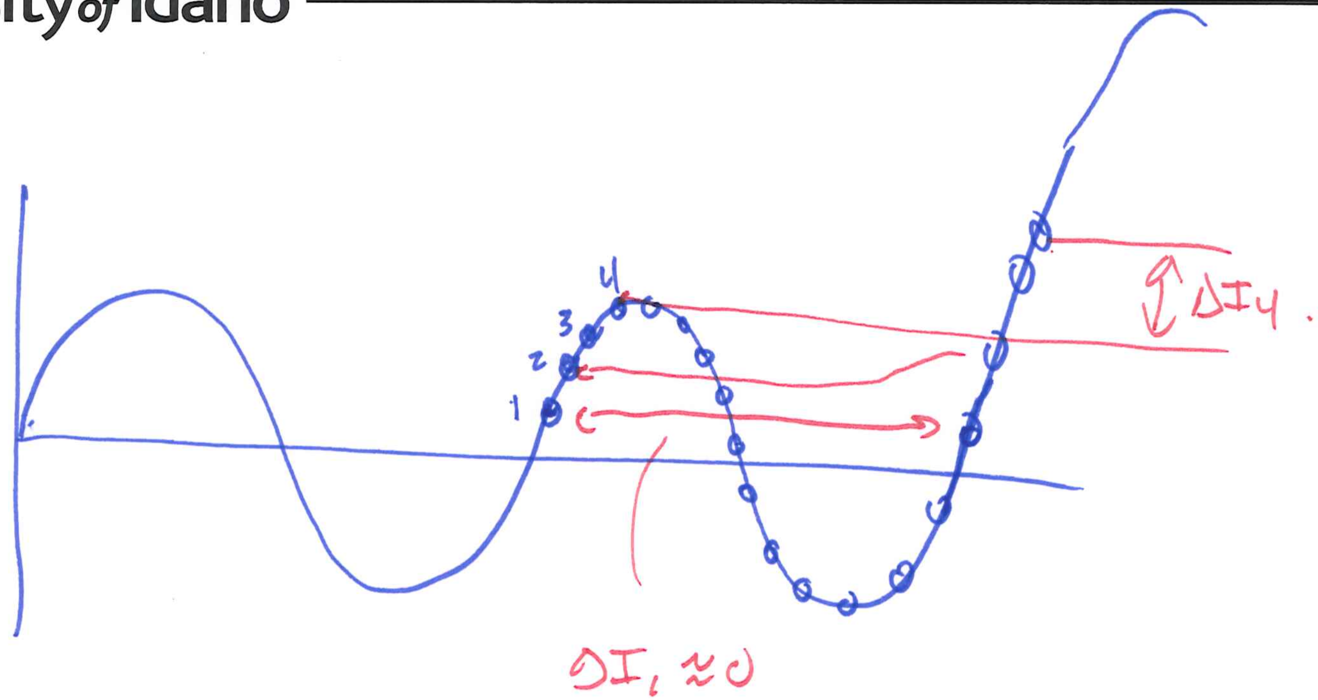
(not great or DC offset)

2 saturates more slowly - other protection should act first

② Dynamic slope setting



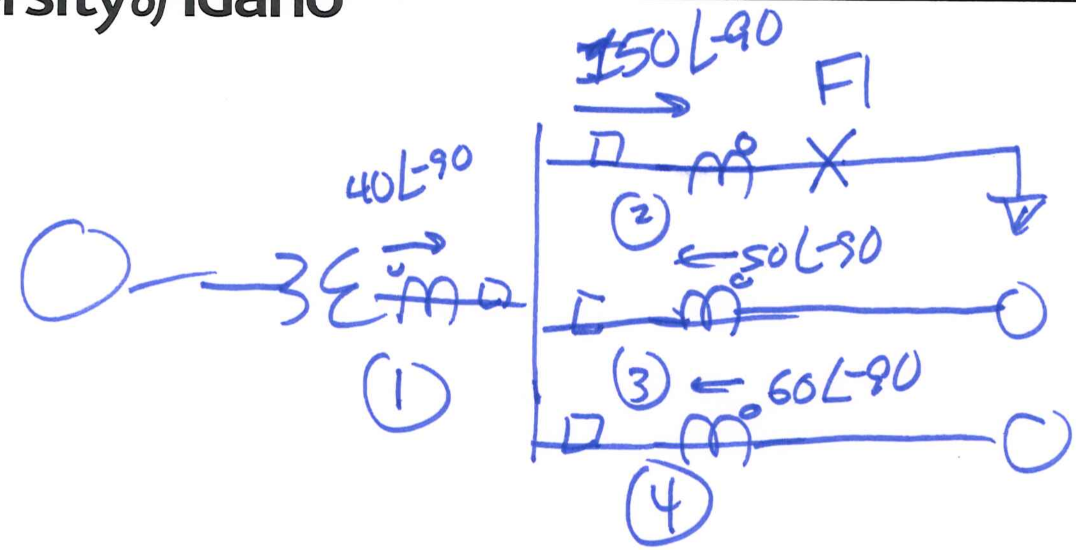

→ Make a fast determination if fault is internal or external
- Before saturates
- use unfiltered quantities (RAW)
  → superimposed quantities




$\Delta I_k = I_k - I_{k-RS}$

1 cycle old

- Produce operate current based on these ~~delta~~ quantities
- $\Delta I_{op}$ > Threshold declare external




No saturation

$$\bar{I}_{op} = \left| \bar{I}_1 + \bar{I}_2 + \bar{I}_3 + \bar{I}_4 \right|$$

$$= \left| 40\angle{-90^\circ} + 150\angle{+90^\circ} + 50\angle{-90^\circ} + 60\angle{-90} \right|$$

$$= 0 \text{ A}$$

$$I_{RT} = 300 \text{ A}$$

Fault current causes CT2 to saturate

→ relay sees 2/3 of current (no phase shift)

$$I_{op} = |40\angle{-90^\circ} + 100\angle{+90} + 50\angle{-90} + 60\angle{-90}|$$

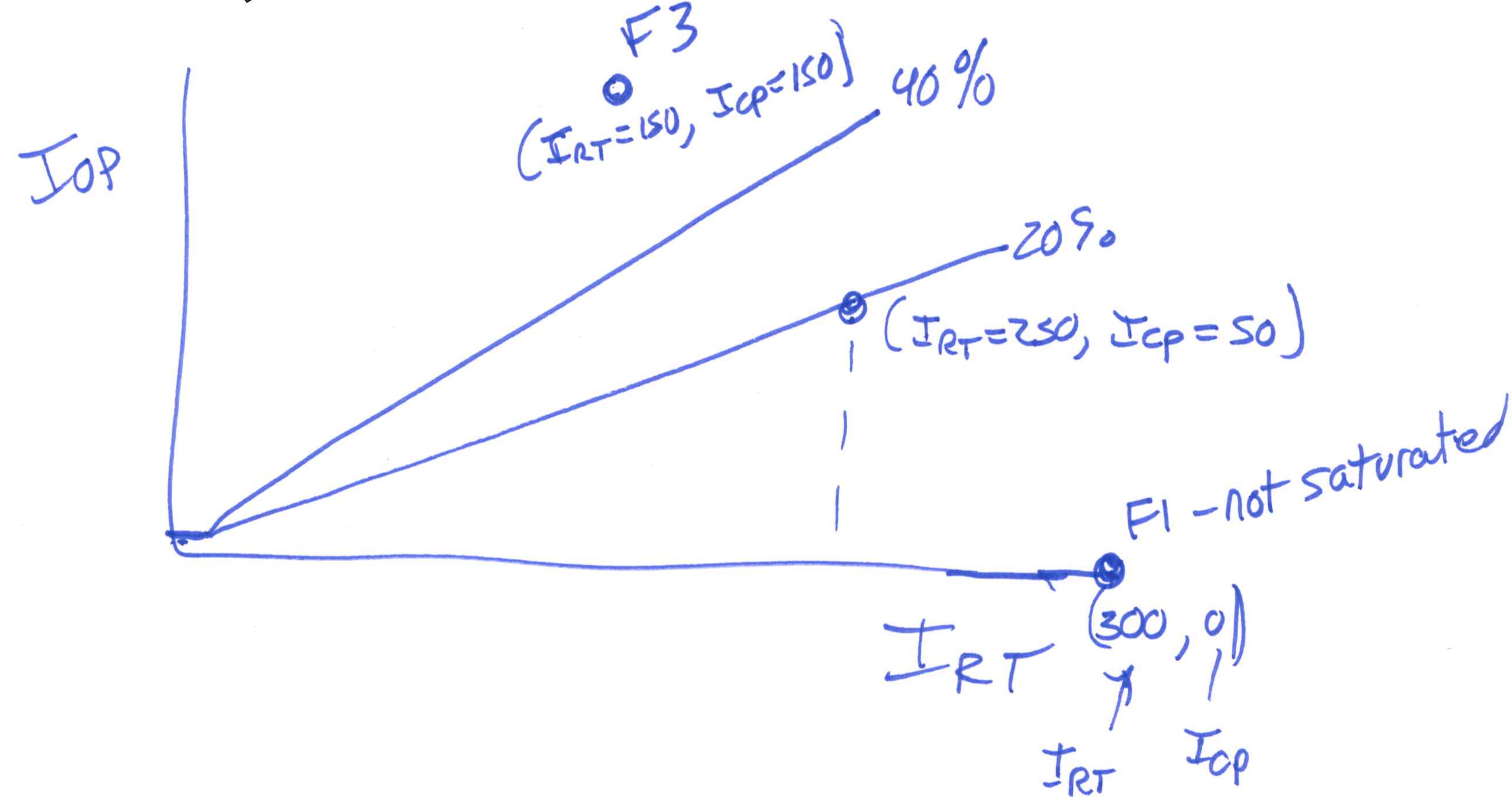
2/3

$$= |50\angle{-90^\circ}| = 50$$

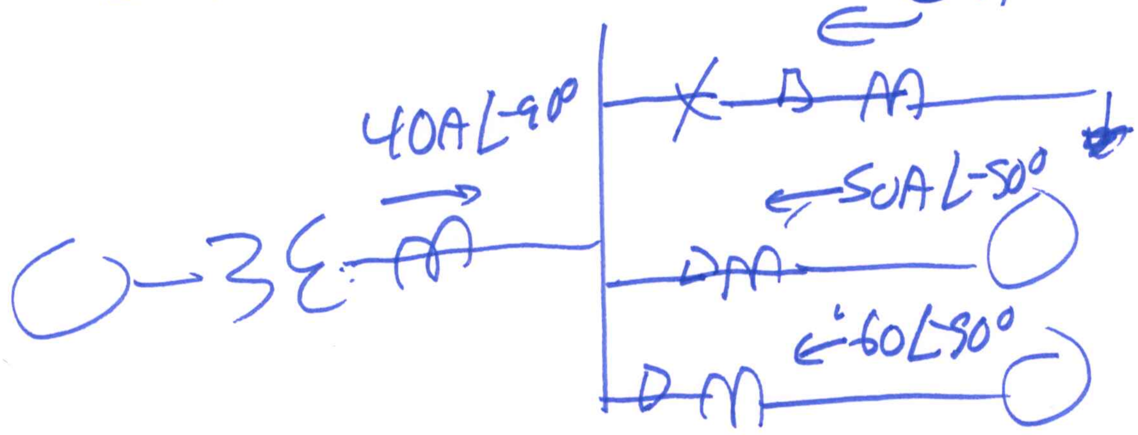
$$I_{RT} = 250$$

$$\frac{I_{op}}{I_{RT}} = 0.2 \ (20\%)$$

- would trip if slope < 20%


IOP
F3
(IRT=150, ICP=150)
40%
20%
(IRT=250, ICP=50)
F1 - not saturated
(300, 0)
IRT
IRT
ICP

Internal fault




$$I_{op} = |40\angle -90^\circ + 0 + 50\angle -90^\circ + 60\angle -90|$$

$$= 150A$$

$$I_{RT} = 150$$

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