ECE 525

POWER SYSTEM PROTECTION AND RELAYING

SESSION no. 28

- Threshold is set <u>above</u> any possible non fault condition

⇒ Determine worst possible inrush

- some vendors use instantaneous current (RAW) unfiltered
- some use a TRUE RMS

→ Some recommend 12 pu as threshold

→ The paper says over 16

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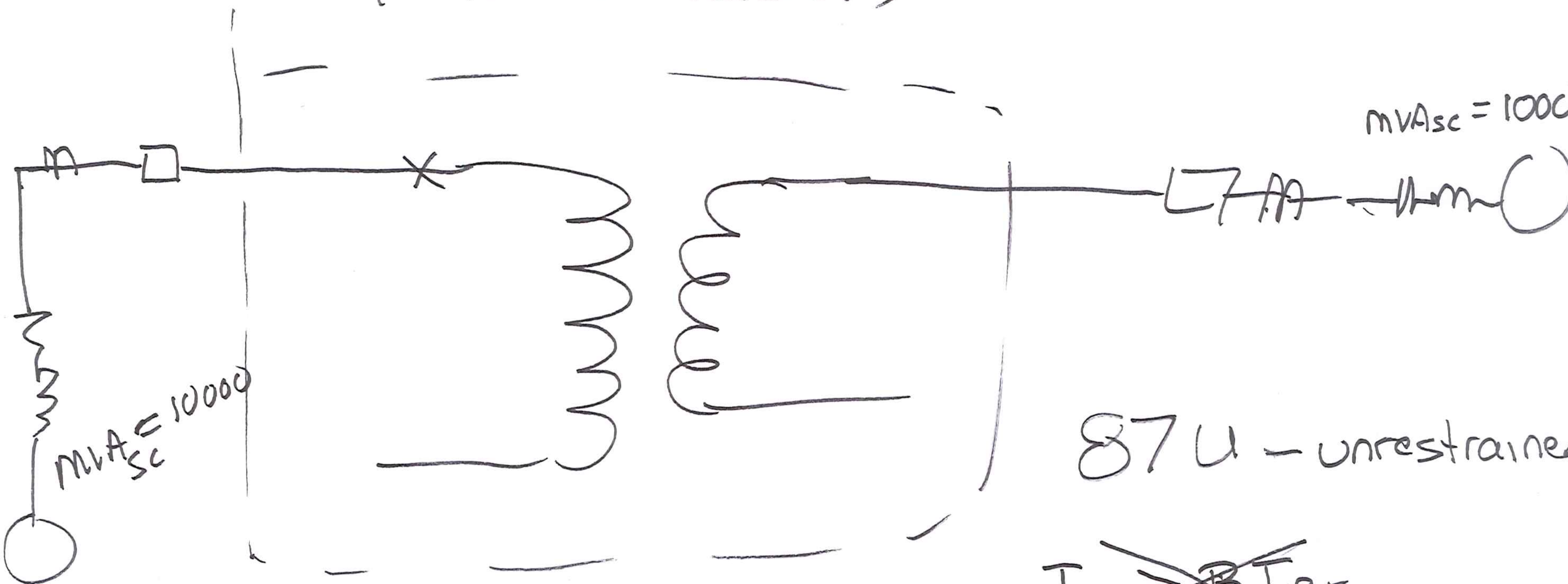
- Unrestrained Transformer Differential Element
  - Fast response for severe internal faults



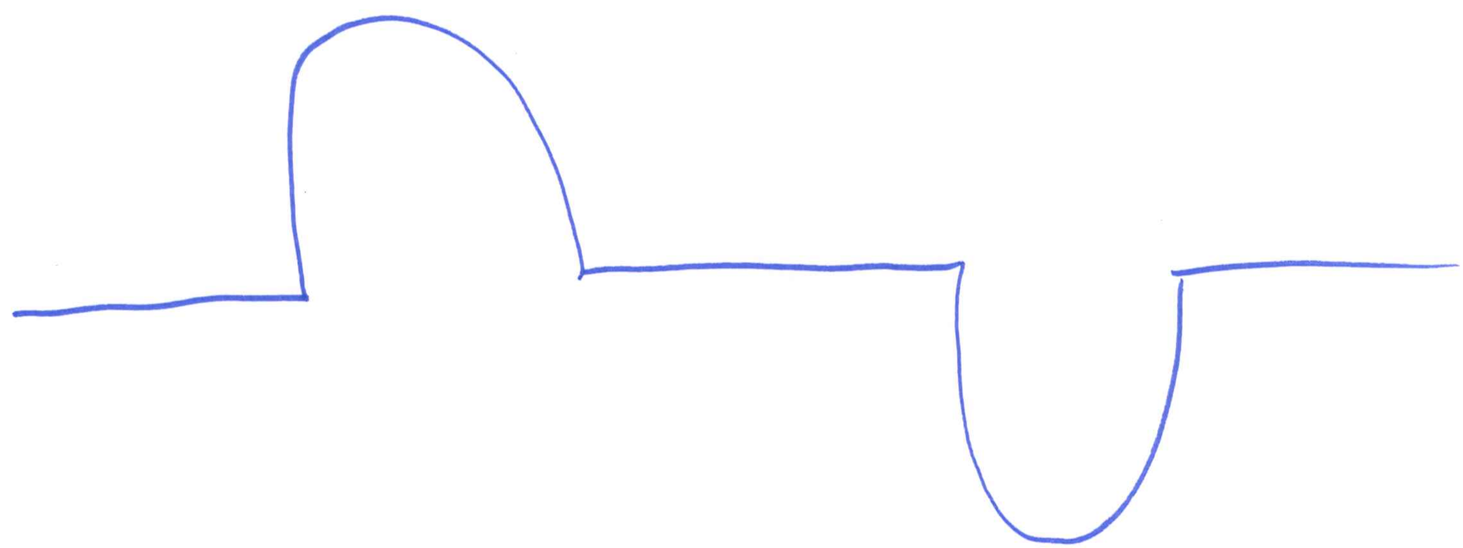
87U – unrestrained

~~$I_{op} > B I_{Rt}$~~

I_{op} > Threshold

University of Idaho

older computer power supply

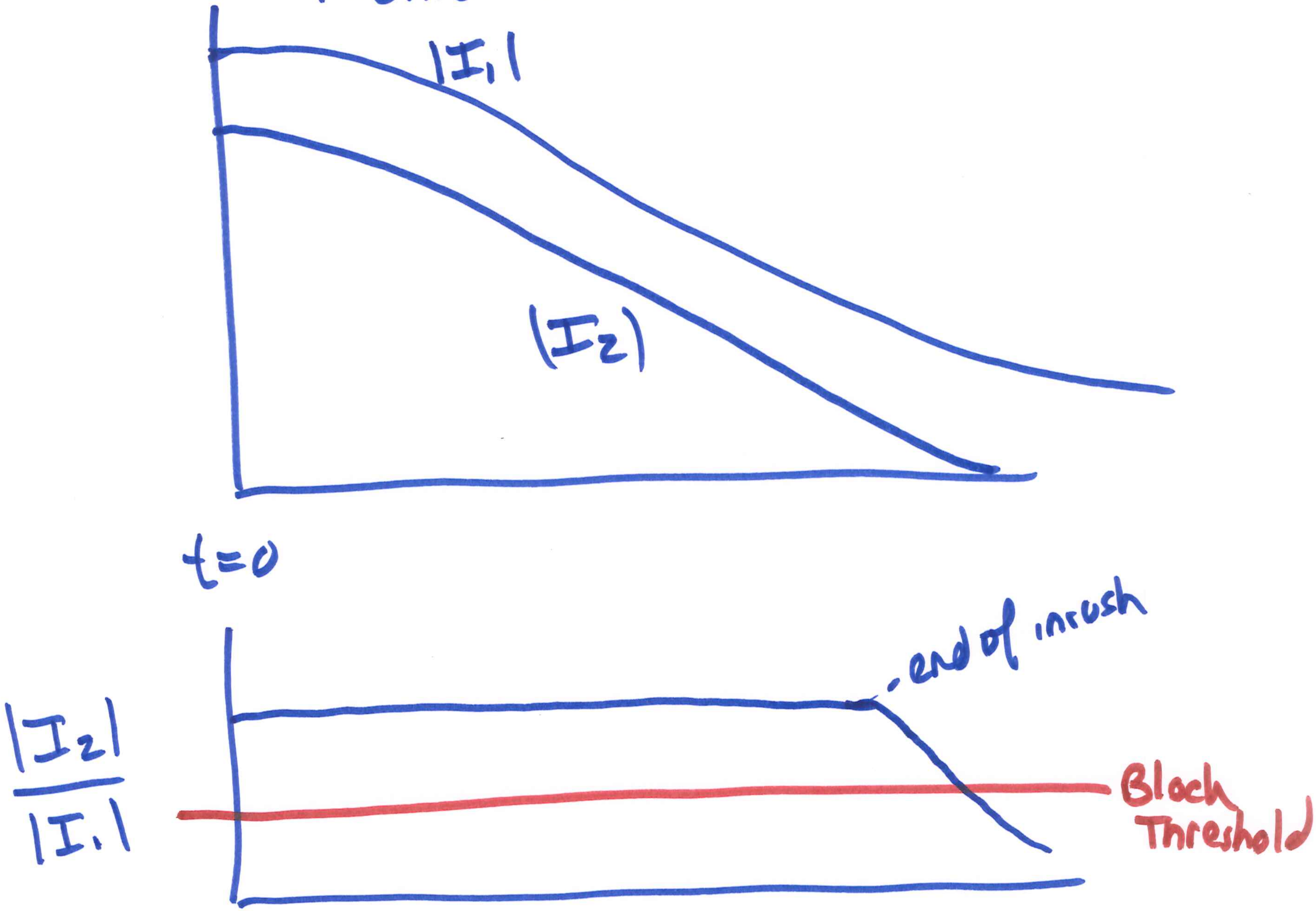


What if internal fault already present when energize or one occurs during energization?

- can pose problems with cross blocking -

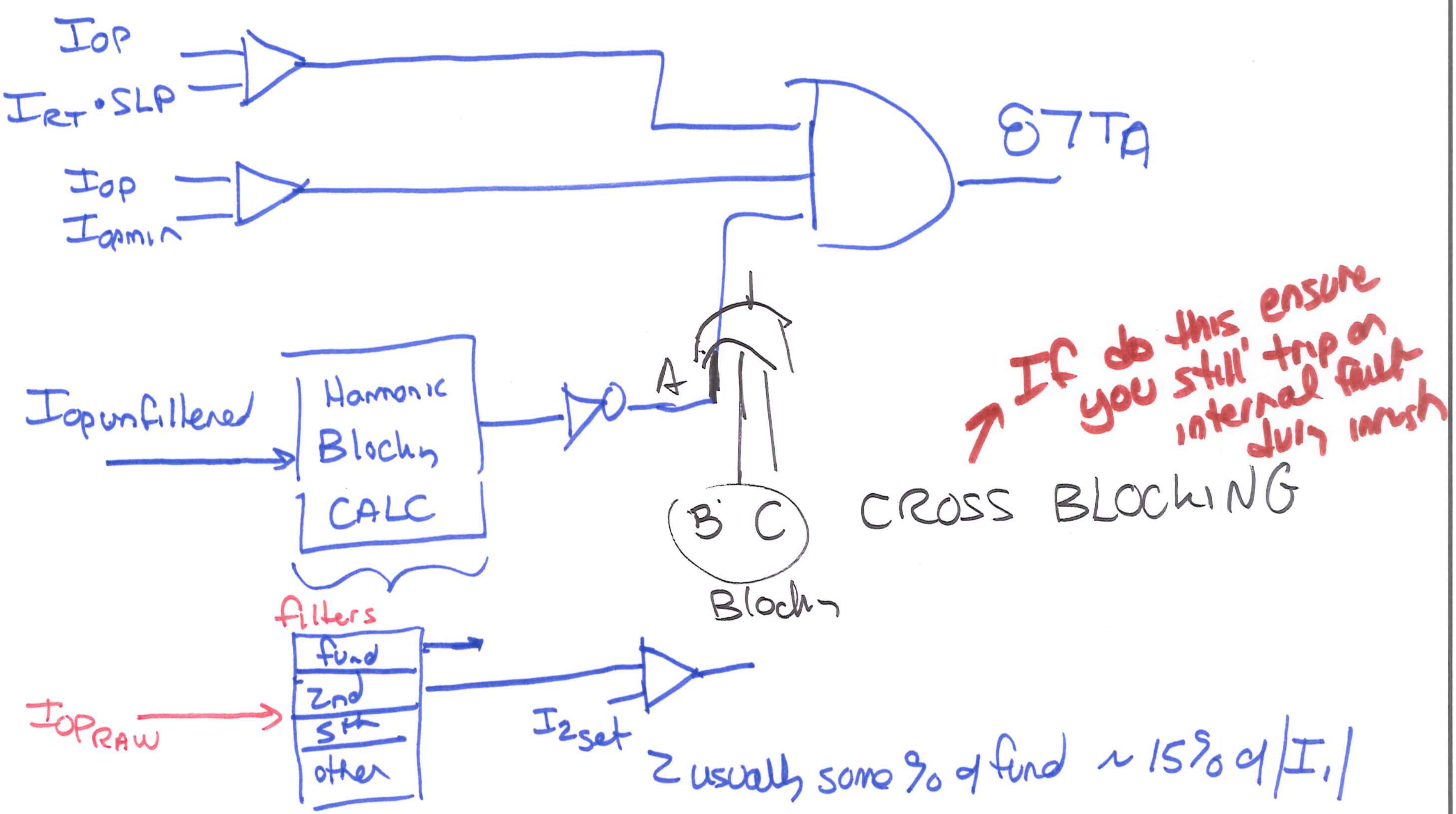
→ R_f – fault resistance impacts . . .

Normal Inrush



Back to restrained differential element

Harmonic Blocking



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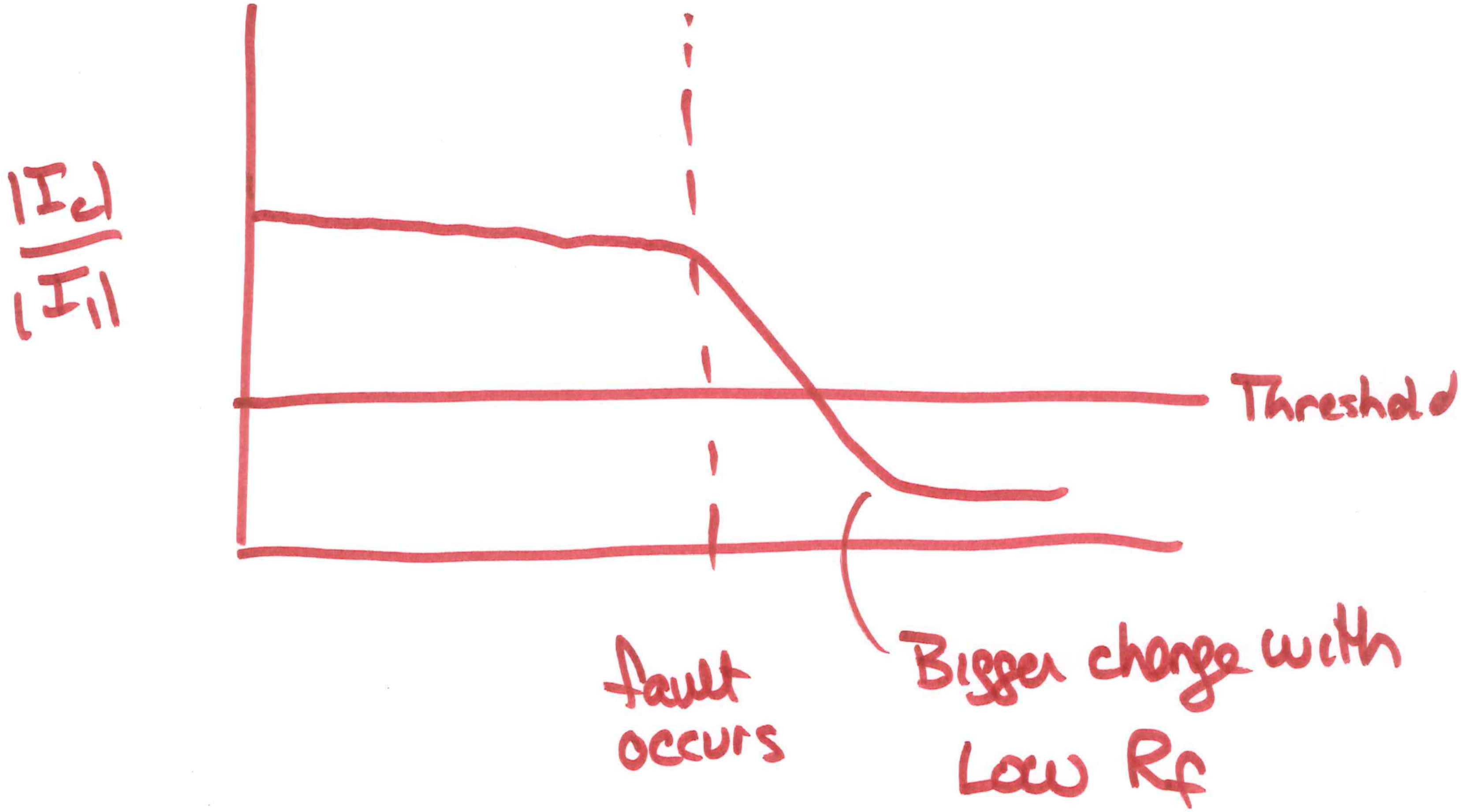
Internal fault



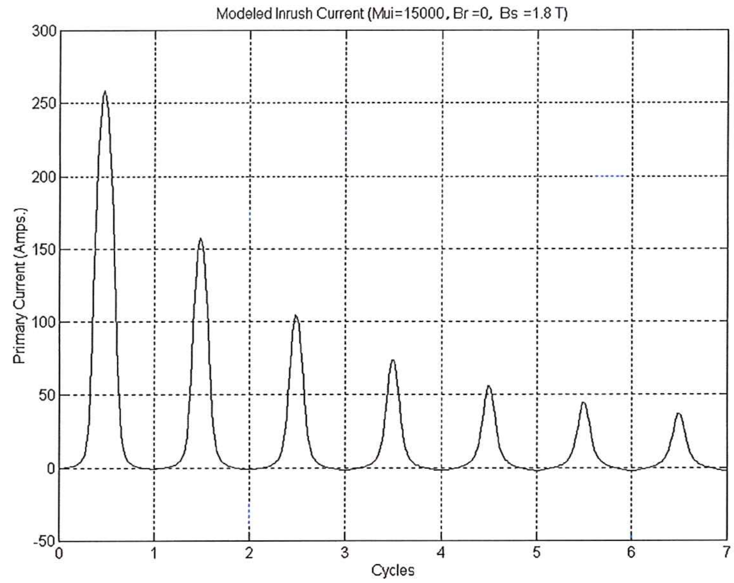


Figure 6: C-Phase Inrush Current Obtained from Transformer Modeling

Fundamental Frequency and Second-Harmonic Content of the Inrush Current

Figure 7 shows the fundamental frequency and second-harmonic content of the C-phase inrush current shown in Figure 6. The maximum fundamental frequency current magnitude is 71.9 amps, and the maximum second-harmonic magnitude is 48.0 amps. Both magnitudes decrease as the inrush current diminishes. Figure 7 also shows the second harmonic as percentage of the fundamental frequency current. This percentage is above 60% for this energization condition.

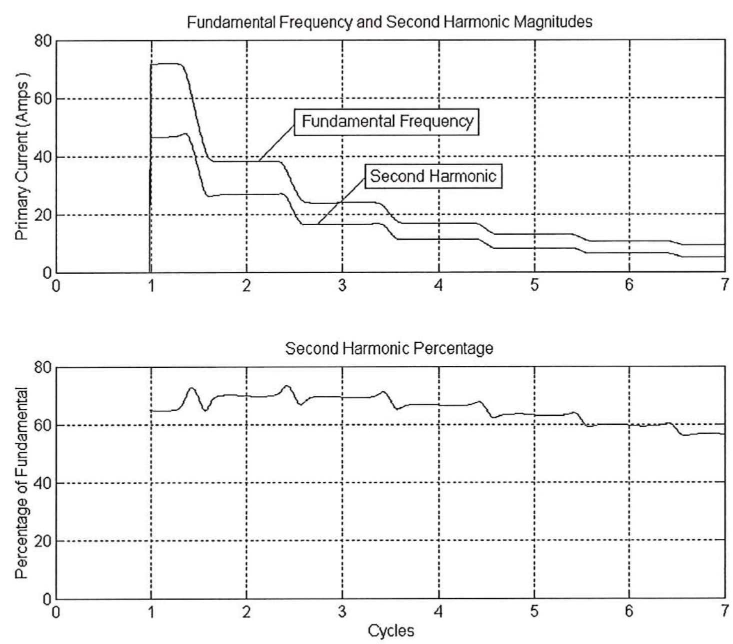


Figure 7: Fundamental Frequency and Second-Harmonic Content of the Inrush Current

Figure 9 shows the A-phase current obtained with the transformer model for the same overvoltage condition. The peak value of the excitation current is approximately 57 amps in the actual current and in the modeled current. The two current waves are similar in magnitude and in shape. To properly simulate the excitation current zero crossings, we modeled the hysteresis loops for this overexcitation condition.

Table 1 shows the odd-harmonic content of the current signal shown in Figure 9. The third and fifth harmonics provide reliable quantities to detect overexcitation conditions. The third harmonic is filtered out with the delta connection compensation of the differential relay or the delta connection of the CTs. A fifth-harmonic level detector can identify overexcitation conditions.

Table 1: Harmonic Content of the Excitation Current While Overexciting the Transformer Bank

Frequency Component	Magnitude (Primary Amps)	Percentage of Fundamental
Fundamental	22.5	100.0
Third	11.1	49.2
Fifth	4.9	21.7
Seventh	1.8	8.1

Current Differential Relay

The relay consists of three differential elements. Each differential element provides percentage restrained differential protection with harmonic blocking and unrestrained differential protection.

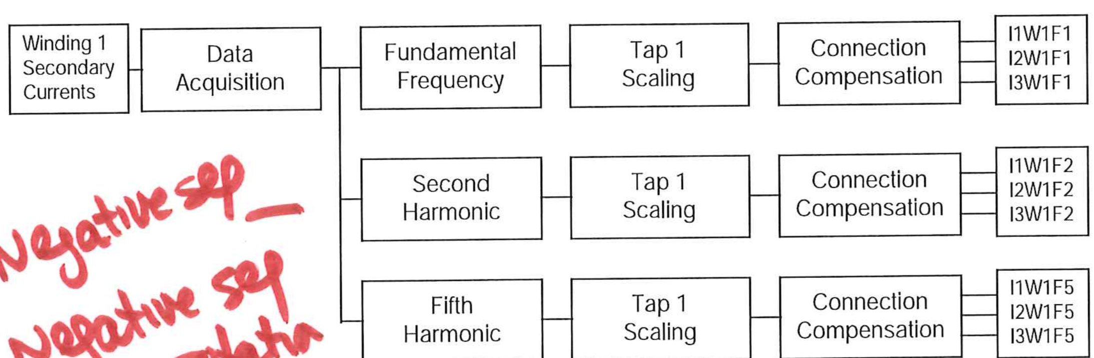


Figure 10: Data Acquisition and Filtering for Winding 1 Currents

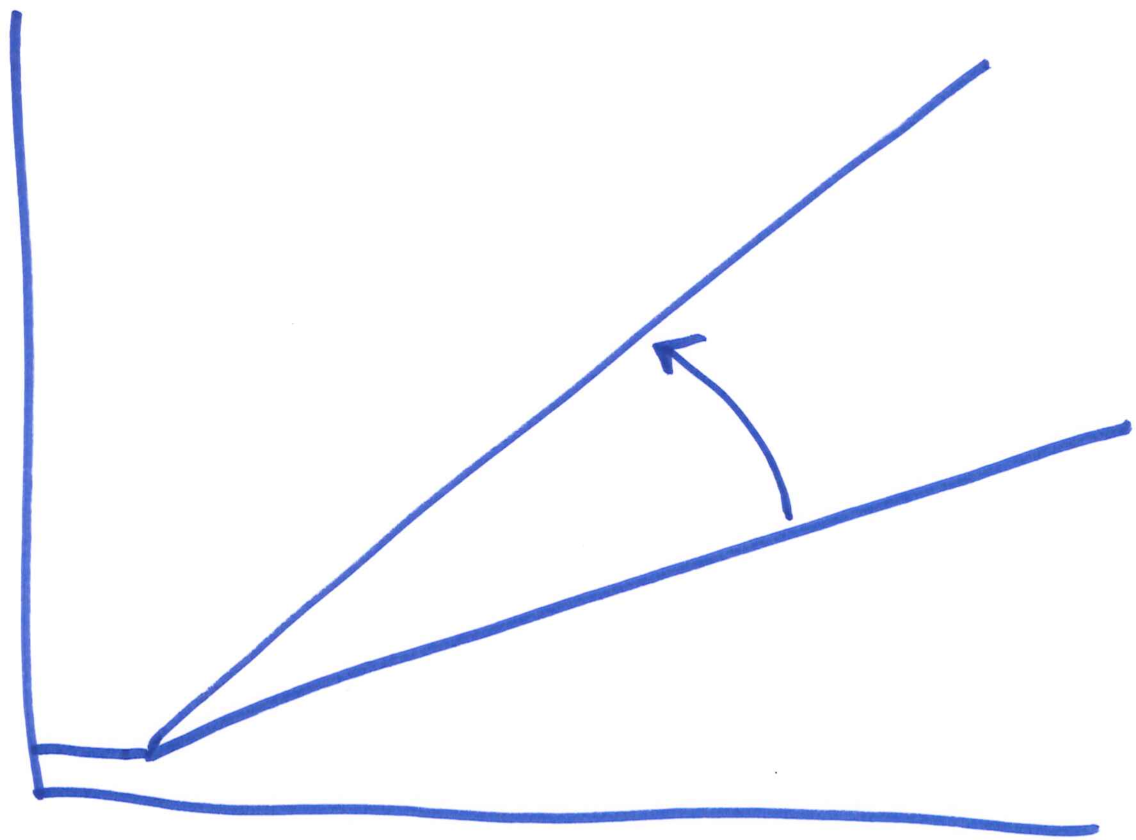
Figure 10 shows the block diagram of the data acquisition and filtering sections for Winding 1 currents. The input currents are the CT secondary currents from Winding 1. The relay reduces the magnitude of these currents and converts them to voltage signals. Low-pass filters remove high-frequency components from the voltage signals. Digital filters extract the fundamental, second-, and fifth-harmonic quantities from the digital signals. The Tap 1 setting scales the signals in magnitude. After signal scaling, the relay removes the zero-sequence component of

Harmonic Restraint

- Adding to the slope during inrush

$$I_{RTA} = |I_{RT\,fund_A}| \cdot SLP + |I_{RT2}| \cdot k_2 + |I_{RT4}| \cdot k_4 \cdots$$

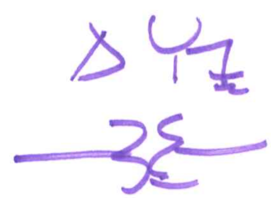
$$|I_{RT\,fund_A}| \rightarrow |I_{R_A}| + |I_{S_A}|$$



	Harmonic Blocking	Harmonic Restraint
External fault security	Good	Good
Inrush security	Good *	Good *
Dependable	Good	Good
Response speed internal fault (normal cond)	somewhat faster	fast
fault on energization	~~fast~~ fast	faster (esp low R_f fault)

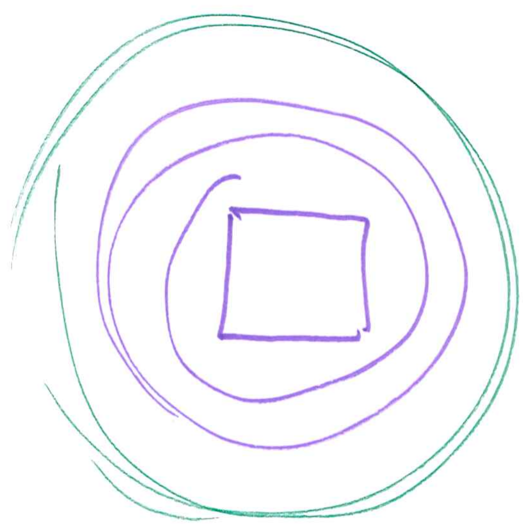
* modern steels w/ lower I_2

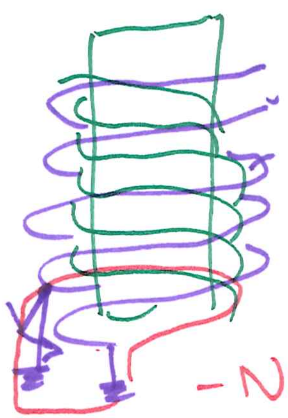
Restricted Earth Fault Protection



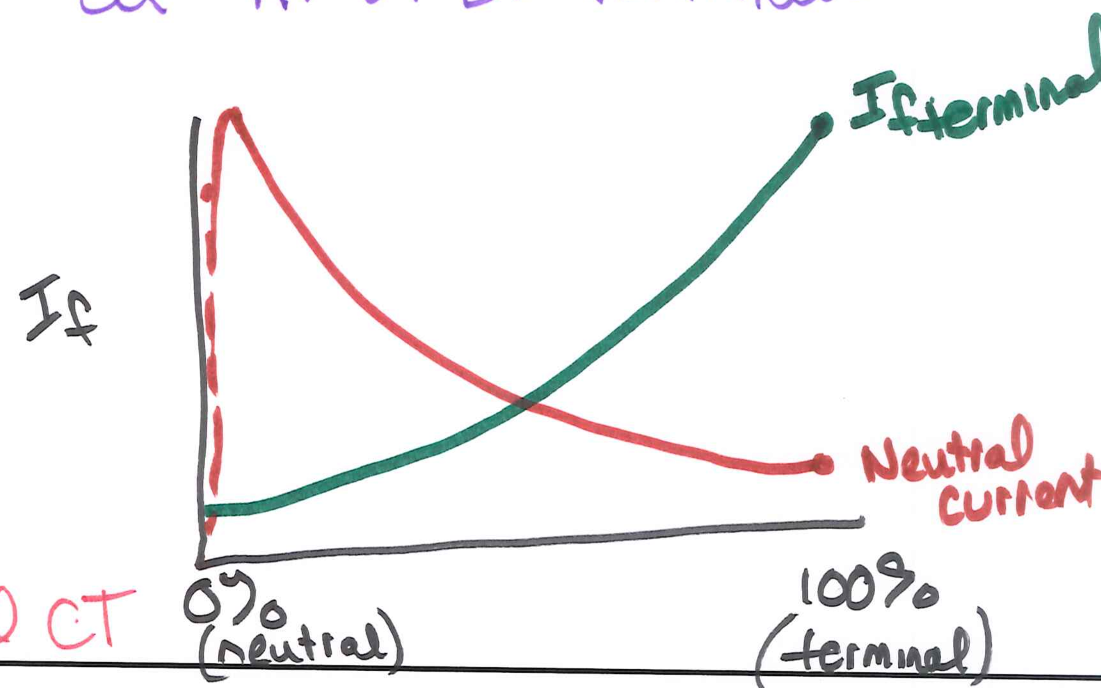
→ Y-G side, an internal fault close to neutral can see high I_f

– Not much current at HV or LV terminals



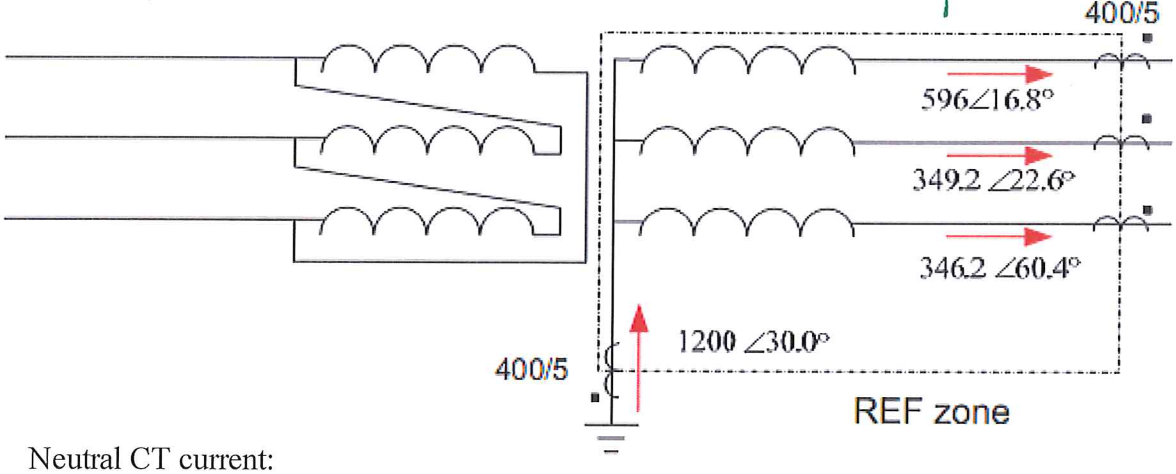


– Needs a neutral CT



b) Consider the restricted earth fault protection scheme shown below. Determine whether the earth fault is inside or outside the protected zone, give reasons for your answer.

load currents & a fault



Neutral CT current:

$I_N := 1200 \cdot e^{j \cdot 30deg}$ $\qquad CTR_{Neutral} := \frac{400}{5}$

LV CT currents (note negative sign due to polarity of CT comparted to labelled current)

$I_{A\_LV} := -596 \cdot e^{j \cdot 16.8deg}$ $\qquad CTR_{phase} := \frac{400}{5}$

$I_{B\_LV} := -349.2 \cdot e^{j \cdot 22.6 \cdot deg}$

$I_{C\_LV} := -346.2 \cdot e^{j \cdot 60.4deg}$

$I_R := I_{A\_LV} + I_{B\_LV} + I_{C\_LV}$ $\qquad |I_R| = 1225.161$ $\qquad arg(I_R) = -150.275 \cdot deg$

Residual current

$I_{N\_sec} := \frac{I_N}{CTR_{Neutral}}$ $\qquad I_{R\_sec} := \frac{I_R}{CTR_{phase}}$

$Torque_{REF} := Re\left(I_{N\_sec} \cdot \overline{I_{R\_sec}}\right)$ $\qquad Torque_{REF} = -229.715$

- Negative torque implies fault is out of zone.

- ground fault on system

[illegible] =

$$\frac{d\phi}{dt} = \frac{V_1}{N_1} = \frac{V_2}{N_2} = \frac{V_f}{N_f}$$