EIT Engineering Institute of Technology. | ECT Engineering College of Technology. | ECST Engineering College of Science and Technology. | IDC Technologies

# The Relay That Refused to See a Short

09 July 2026


## Emeritus Professor Akhtar Kalam

EIT EMERITUS PROFESSOR


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# Introduction – Presenter

## Emeritus Professor Akhtar Kalam

Emeritus Professor at Victoria University and EIT.
Academic Director and Chair of the Academic Board - Texila College Australia.
Director of Al-Kalam Educational Solutions.
Editor-in-Chief of AJEEE
Distinguished Professor/Adjunct Faculty in Australia, India, Malaysia and Oman.
He has published over 610 publications in his area of expertise and has written over 29 books.
Supervised 51 postgraduate research students to graduation, including 39 PhD's and 12 MEngs. Currently, 10 postgraduate research students (four PhD students at VU and six DEng students at EIT) are being supervised.
Public, University, and Motivational Lecturer.
Consultant for the electricity supply industries in Australia and overseas.
Assisted in change management plans for Universities and the higher education sector.

### Education

The University of Bath, Bath, UK, D.Eng., Electrical Engineering
The University of Oklahoma, Norman, USA, MS, Electrical Engineering
Aligarh Muslim University, Aligarh, India, BSc. Eng., Electrical Engineering
St Xavier's College, Calcutta, India, Applied Science

### Professional Society Activities

Australian Institute of Energy – Fellow
Engineers Australia – Fellow
The Institution of Engineers and Technology, UK – Fellow.
The Institution of Electrical and Electronic Engineers, USA –Life Senior Member.

*"My vision is to provide exciting higher education science and engineering courses, research, consultancy and collaborate in development work of the industry and communities within Australia and beyond."*

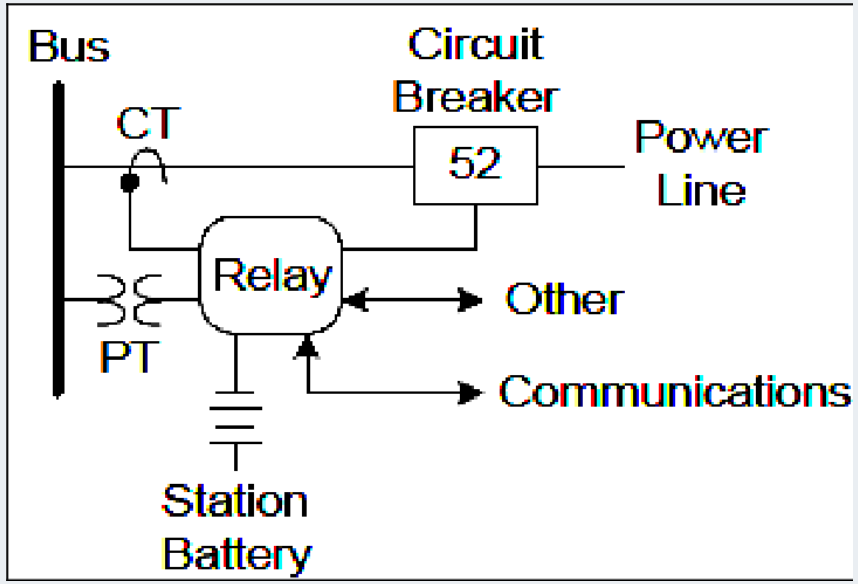
# Agenda

| | |
|---|---|
| 1 | Learning Outcomes |
| 2 | The Mystery |
| 3 | Protection System Overview |
| 4 | Standards Applied |
| 5 | Lessons Learned |
| 6 | Discussion Exercise |
| 7 | Q&A |

# Learning Outcomes

By the end, participants should:

- Explain how protective relays detect faults
- Analyse situations where relays may fail to operate
- Evaluate CT and VT influences on protection
- Diagnose hidden causes of relay maloperation
- Apply systematic engineering investigation methods
- Identify lessons for protection system design



# The Mystery

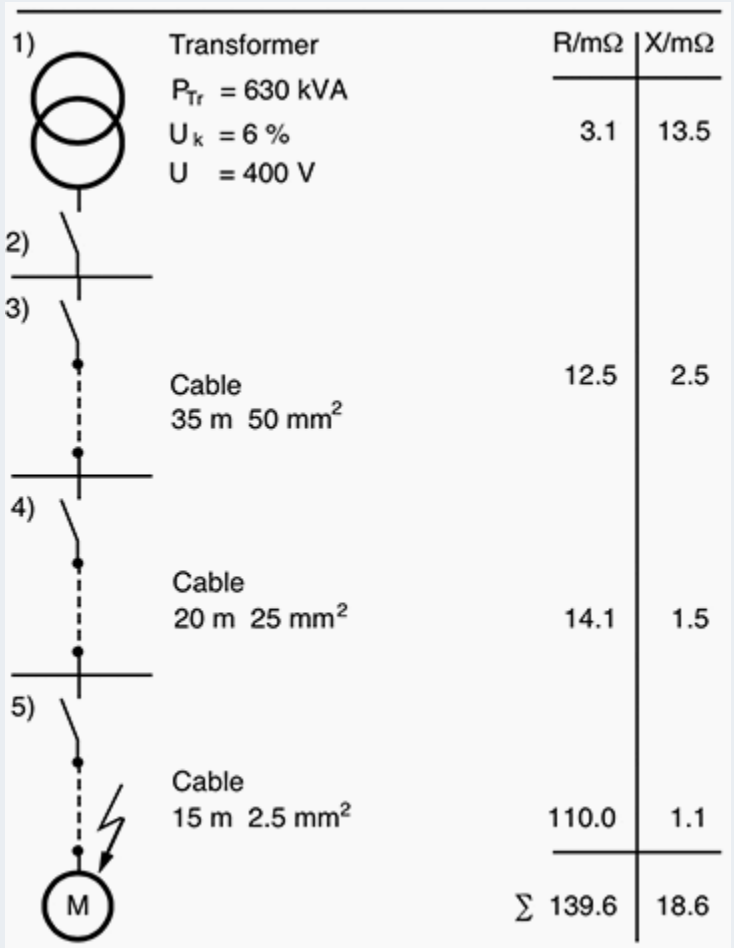
A feeder experienced a phase-to-phase short circuit.

Observed:

- ✓ Visible arc flash
- ✓ Circuit conductor damage
- ✓ Customer outage
- ✓ Fault confirmed after inspection

Yet:

- ✗ Protection relay did not trip
- ✗ Breaker remained closed
- ✗ Backup protection operated 12 seconds later



# Initial Reactions

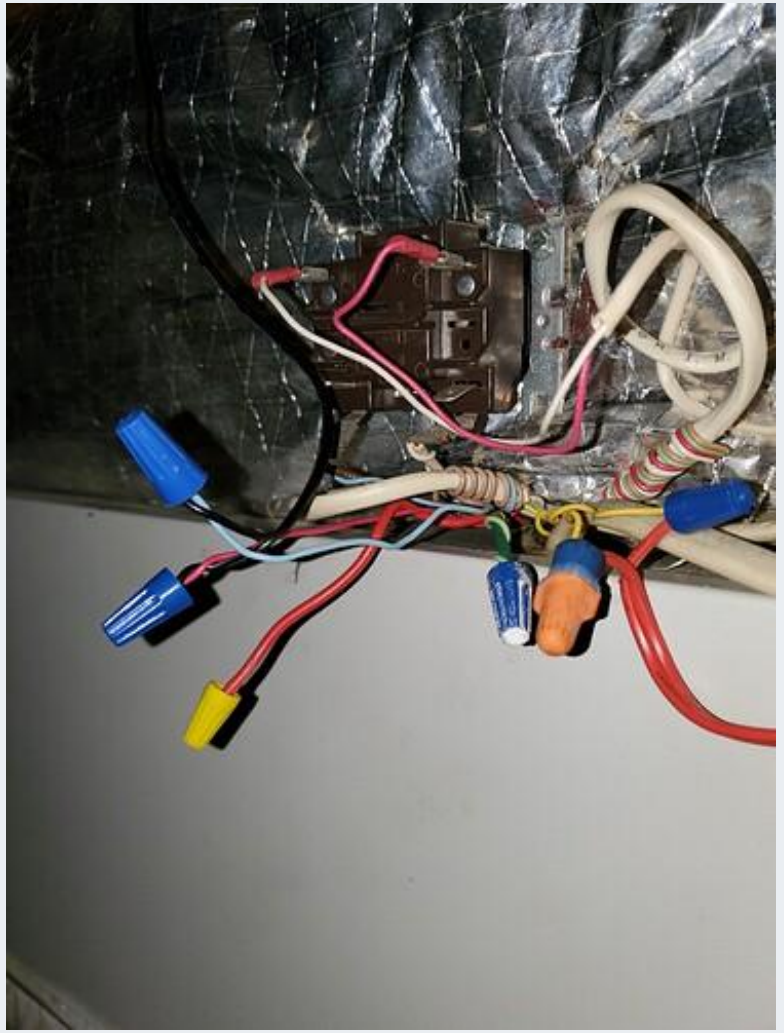
Common Assumptions

Most engineers initially conclude:

- Relay failure
- Software bug
- Wiring error
- Human error
- Fault recorder malfunction

Important Principle:

The obvious explanation is not always the correct explanation.



# Protection System Overview

## Typical Protection Chain

Fault Occurs

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Current Transformer (CT)

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Relay Inputs

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Protection Algorithm

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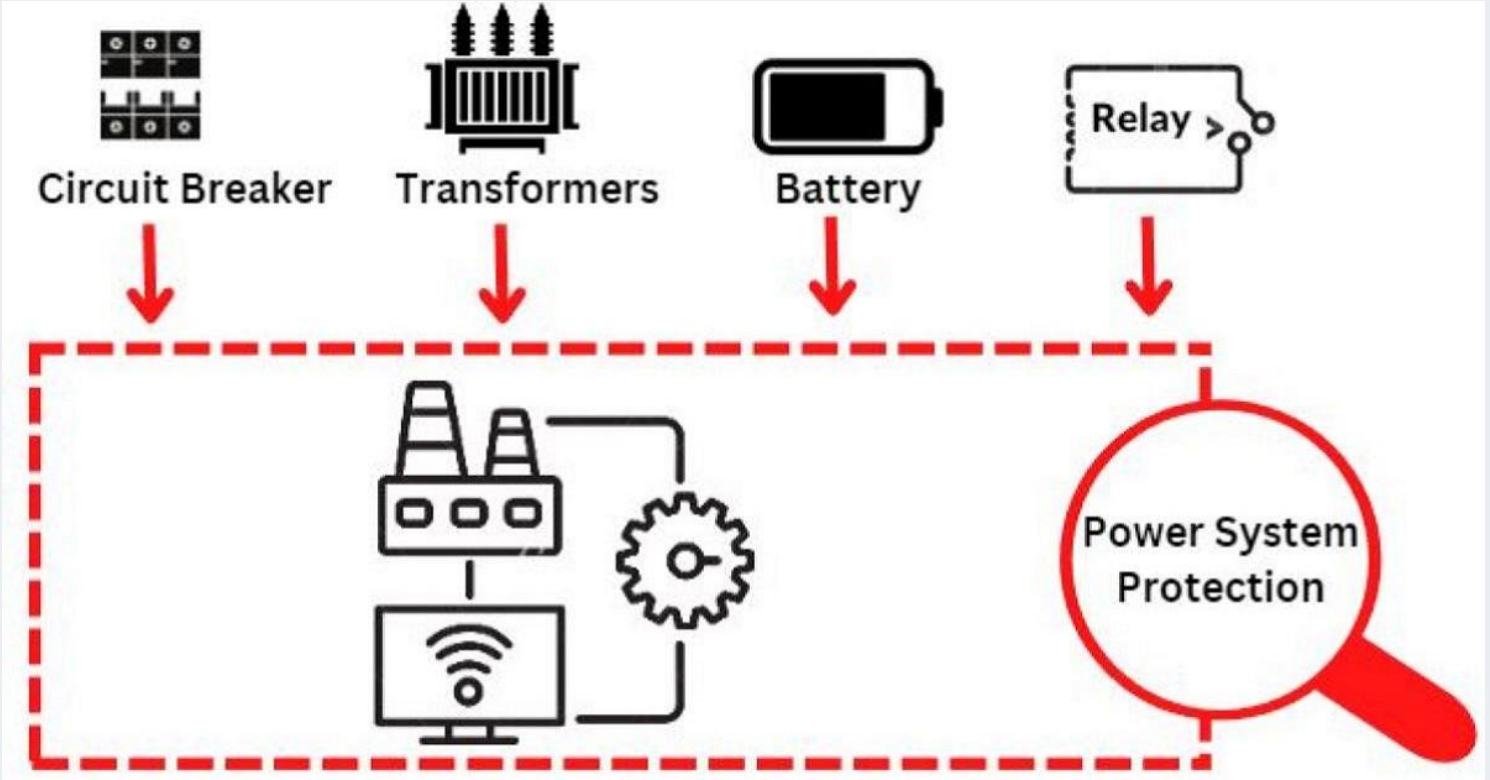
Trip Logic

↓

Circuit Breaker

↓

Fault Clearance



# How Overcurrent Relays Detect Faults

Basic Principle

Normal current:

- Within operating limits

Fault current:

- Exceeds the pickup threshold

The relay issues a trip command

Example

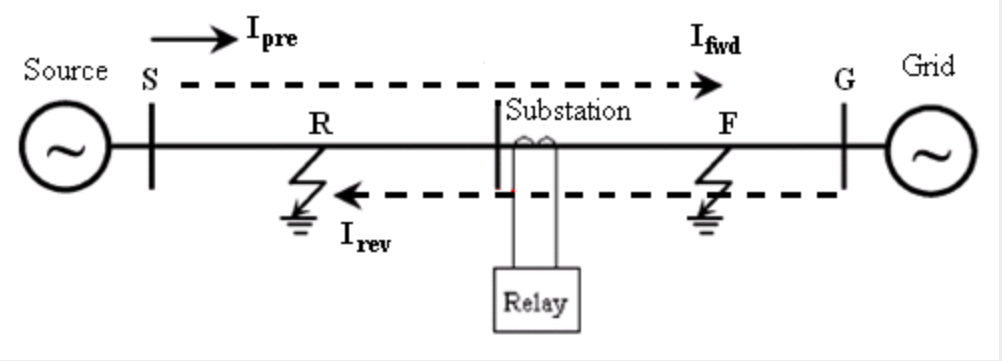
Normal load: 150 A

Relay pickup: 300 A

Fault current: 5000 A

Expected outcome:

Relay trips rapidly.



# The Fault Site

Investigation Findings

- Phase B and C conductors contacted
- Arc marks present
- Insulation destroyed
- Damage consistent with fault current

Evidence strongly confirmed:

A real short circuit occurred

# Event Records

Relay Event Log

Recorded Current:

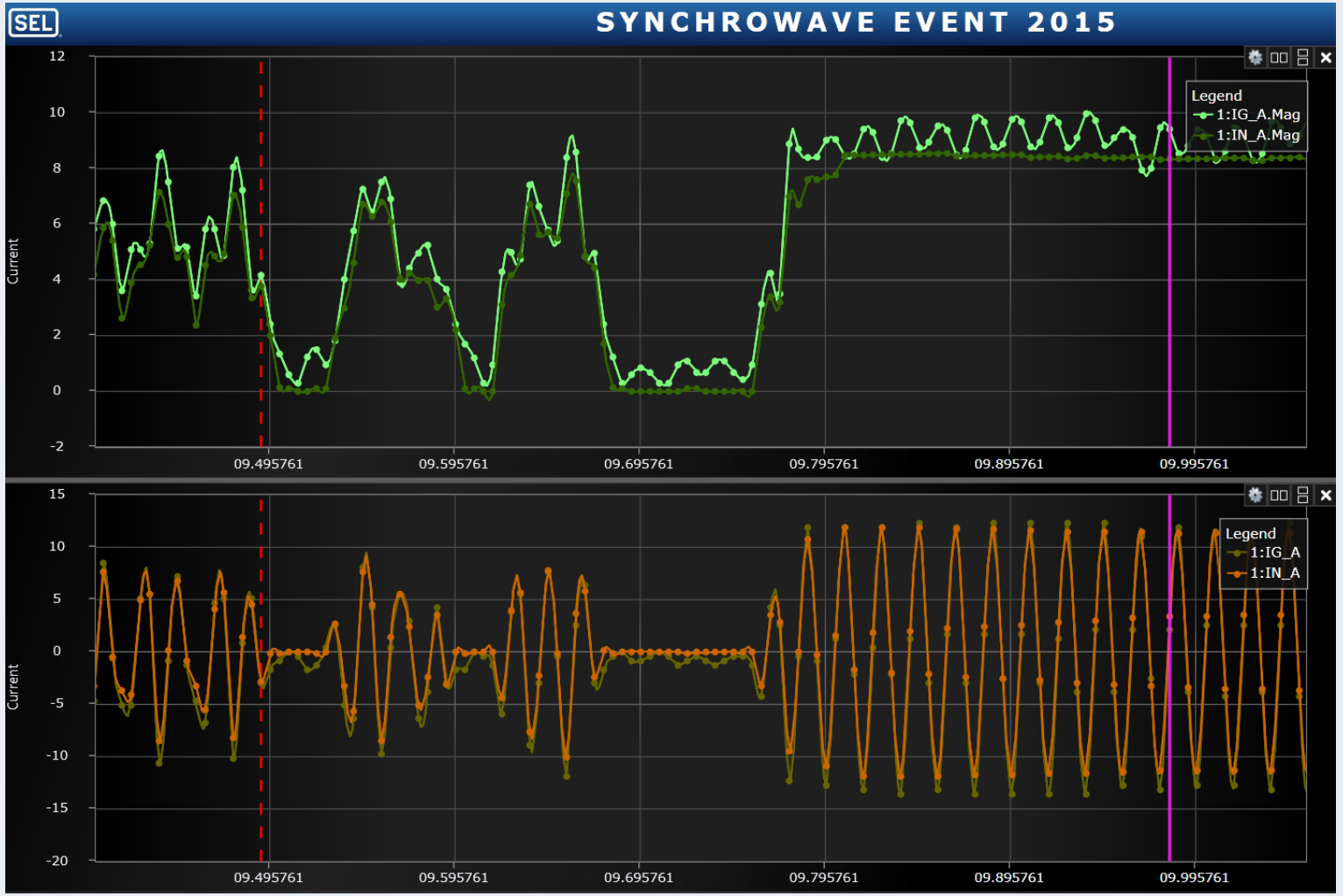
Phase A: 140 A

Phase B: 165 A

Phase C: 155 A

Trip Status:

- No operation
- No alarm
- No fault indication



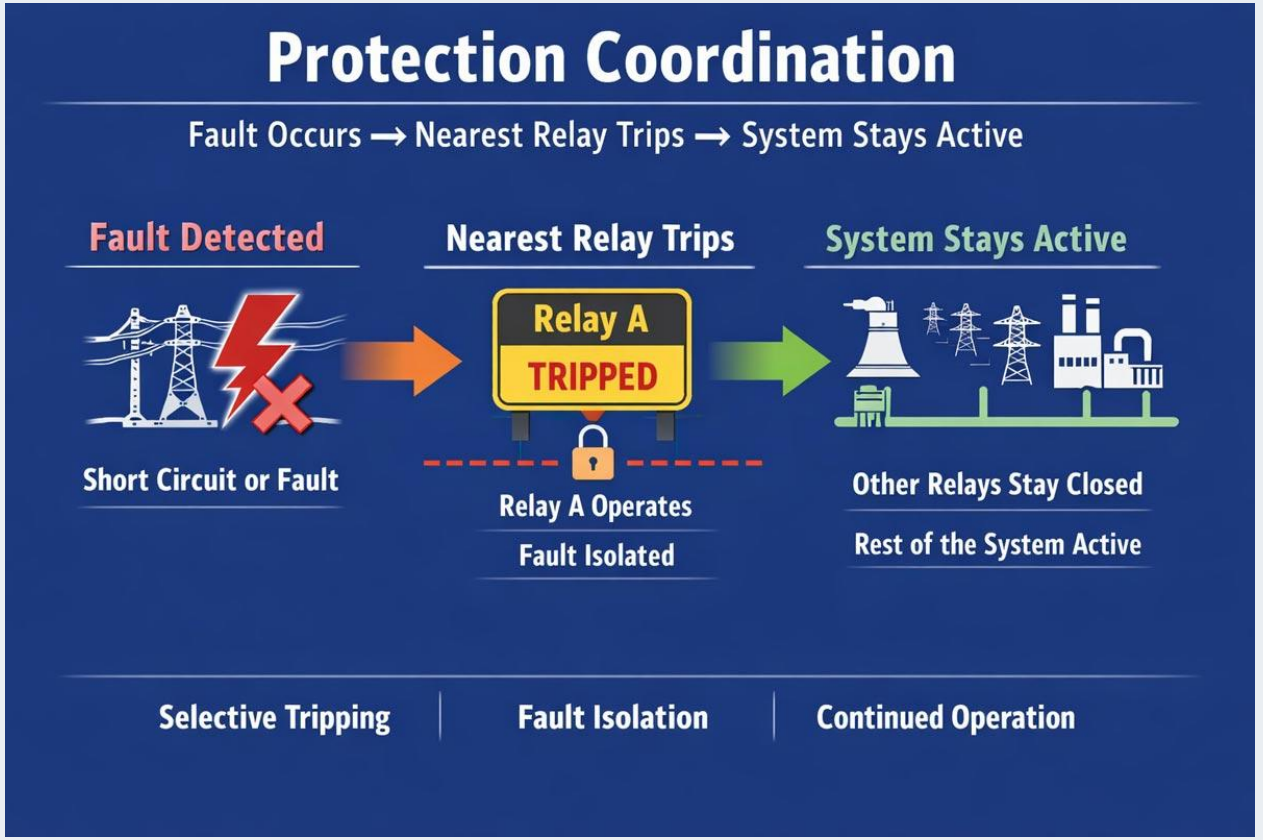
# Critical Question

Did the Relay See the Fault?

Two possibilities:

1. Relay saw the fault and chose not to trip
2. Relay never saw the fault

Which is more likely?



# Instrument Transformers

Current Transformers (CTs)

Purpose:

Convert large primary currents into manageable secondary currents.

Example:

1000 A / 1 A CT

1000 A primary

↓

1 A secondary

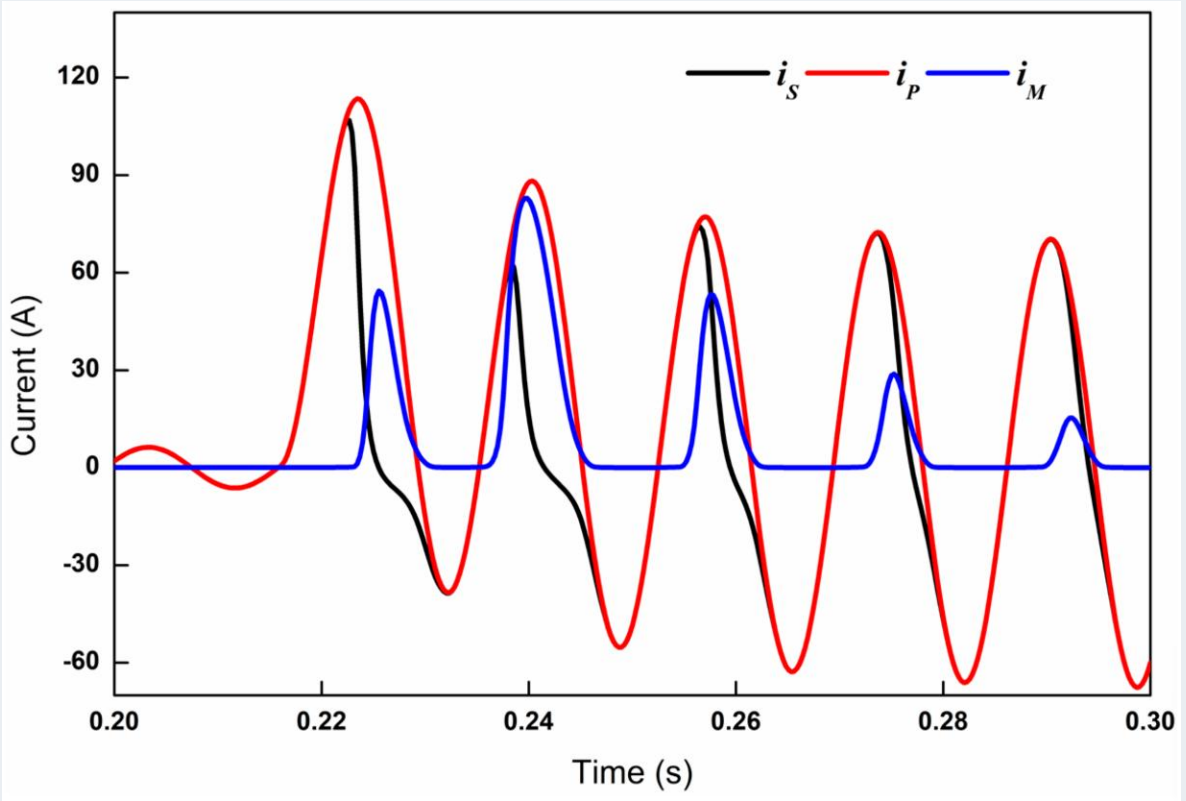
# CT Saturation

What Happens During Large Faults?

CT magnetic core may saturate.

Consequences:

- Distorted waveform
- Reduced output
- Measurement error
- Protection blindness



# Understanding CT Saturation

Normal Operation

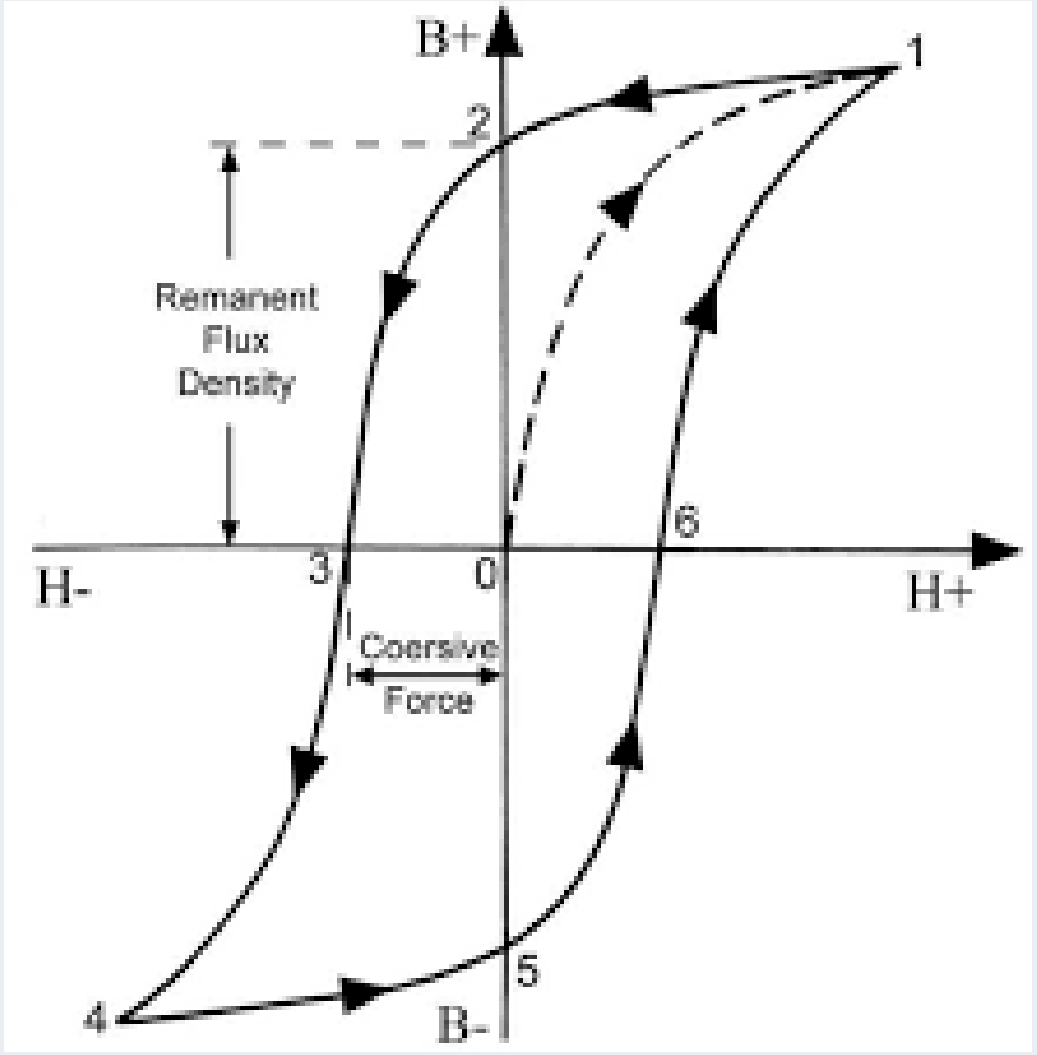
Primary Current → Accurate Secondary Current

Saturated Operation

Primary Current → Distorted Secondary Current

Relay sees:

Much smaller current



# Fault Current Analysis

**Calculated Fault Current**

Network study predicted:

**9.8 kA**

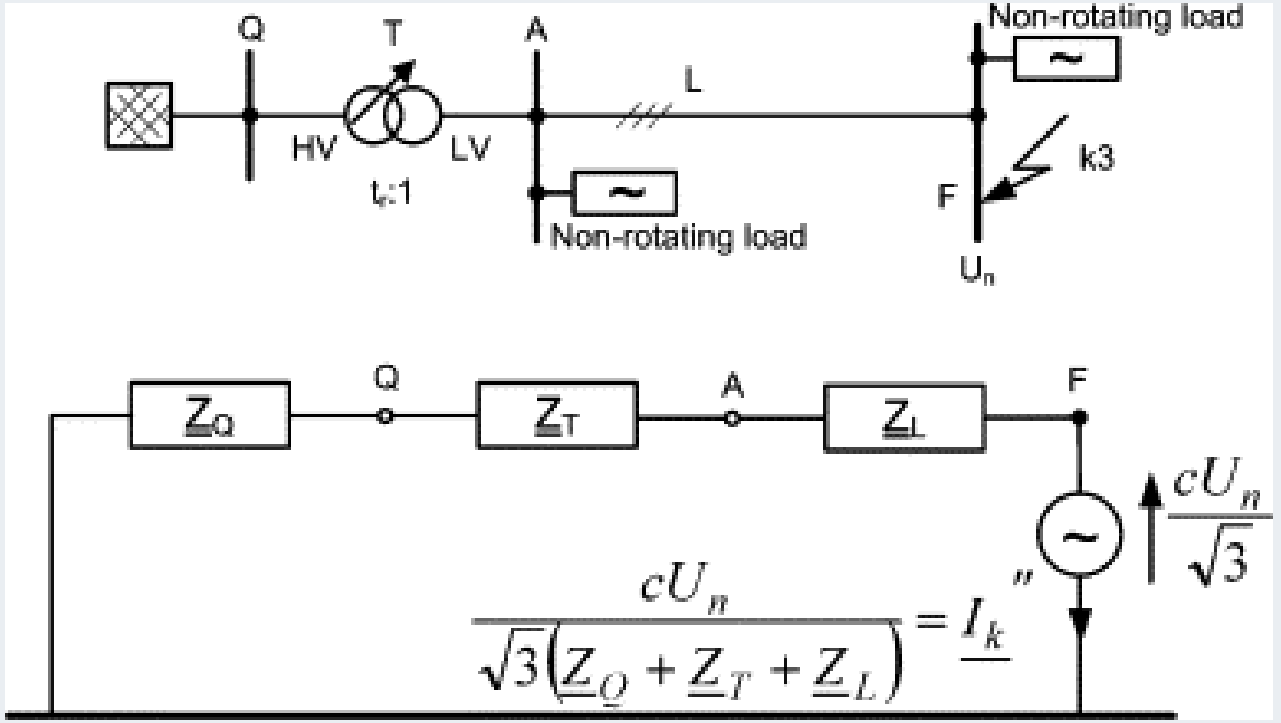
Relay pickup:

**600 A**

Large margin available.

Question:

Why wasn't the pickup reached?



# Oscillography Review

Disturbance Record Findings

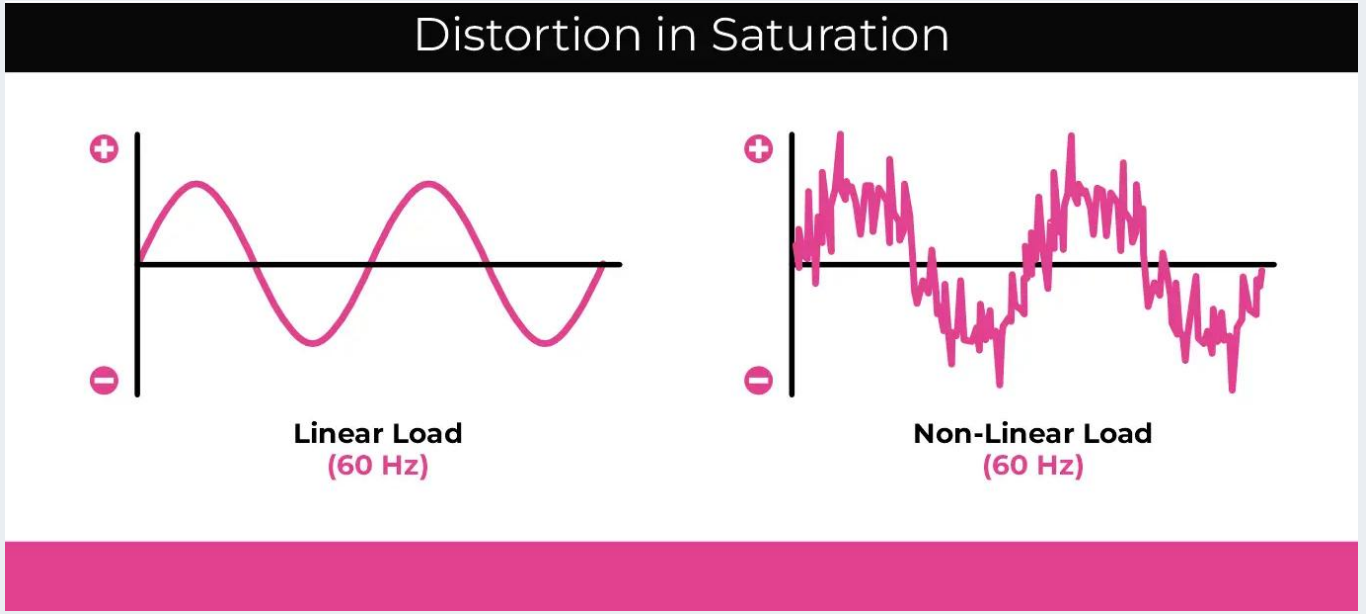
Fault inception visible

Current waveform heavily distorted

Flattened waveform peaks observed

Strong indication:

CT saturation



# The DC Offset Problem

Fault Current Components

AC Component

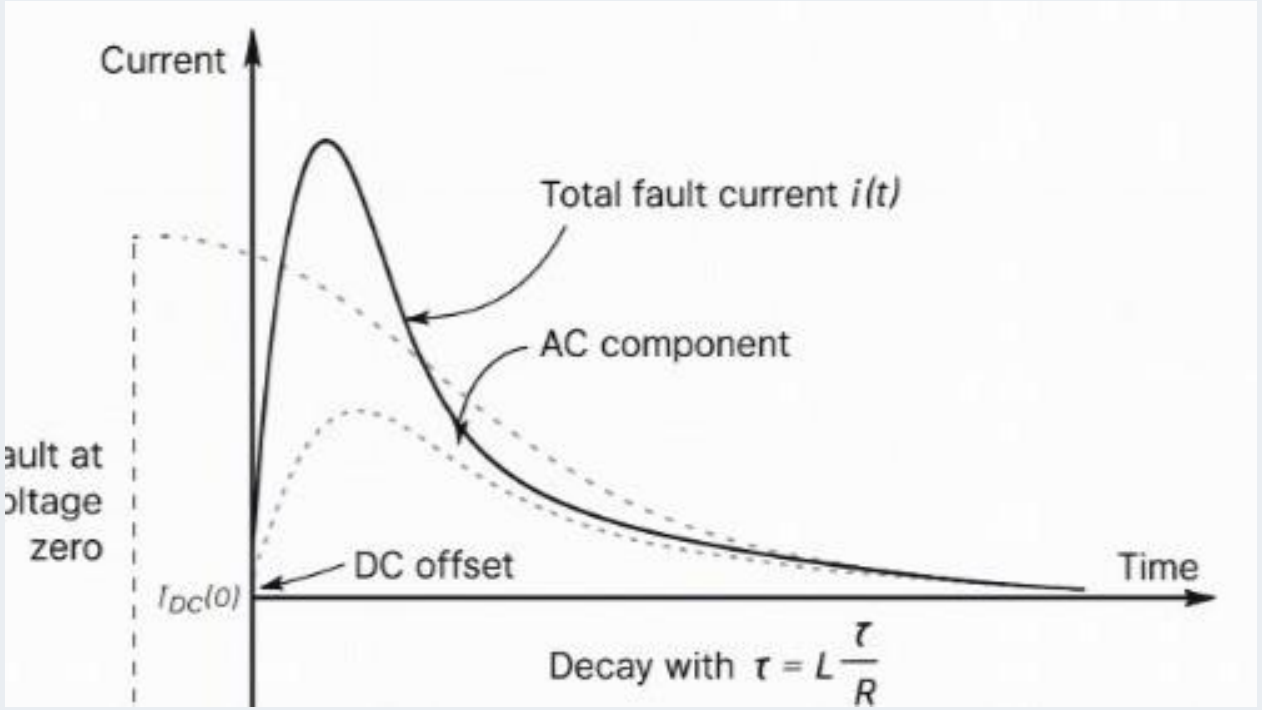
+

DC Offset Component

=

Asymmetrical Fault Current

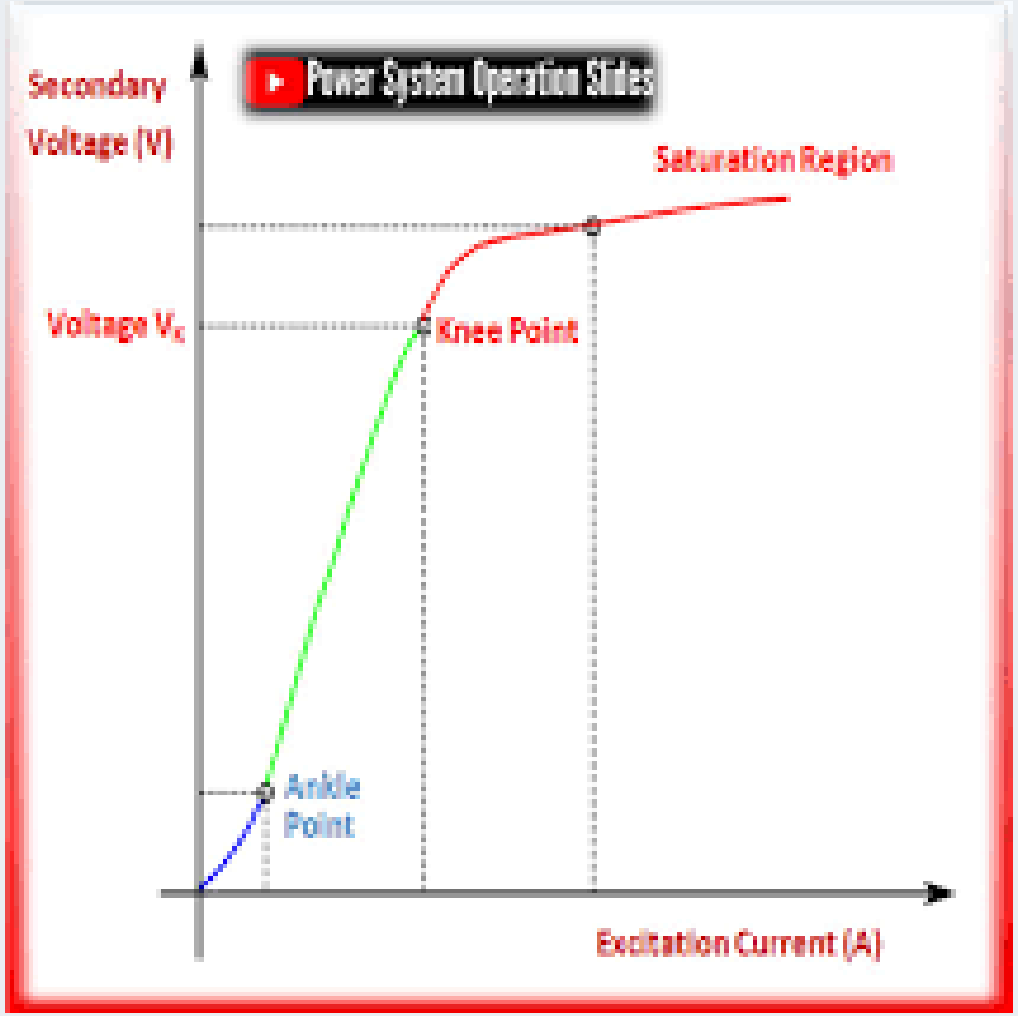
Large DC offset increases the risk of CT saturation.



# Why Saturation Occurred?

Contributing Factors

- High fault level
- Long CT secondary leads
- High burden
- Small CT knee-point voltage
- Significant DC offset



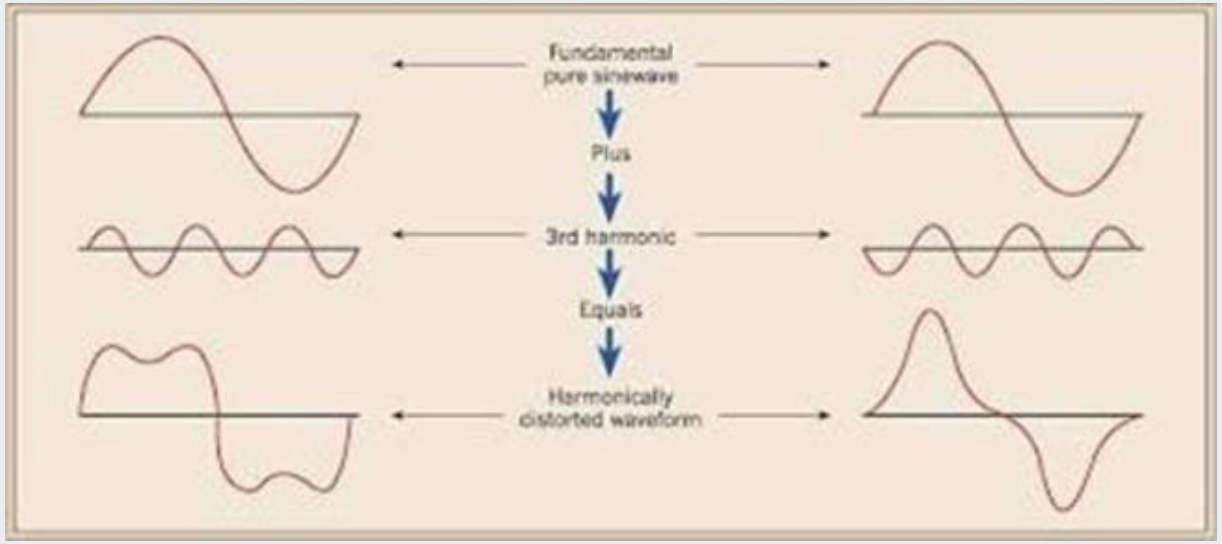
# Relay Algorithm Limitations

Modern Relays Use Filtering

Functions include:

- RMS estimation
- Harmonic filtering
- Noise rejection

Excessive waveform distortion can create unexpected behaviour.



# Secondary Injection Testing

**Workshop Testing**

Relay operated correctly.

Trip output functional.

Settings verified.

Conclusion:

**Relay hardware healthy**

# Primary Injection Testing

Site Testing

High current injected through CT circuit.

Results:

Abnormal CT performance observed.

# The Hidden Culprit

**CT Ratio Error**

Further investigation discovered:

Incorrect CT replacement during maintenance.

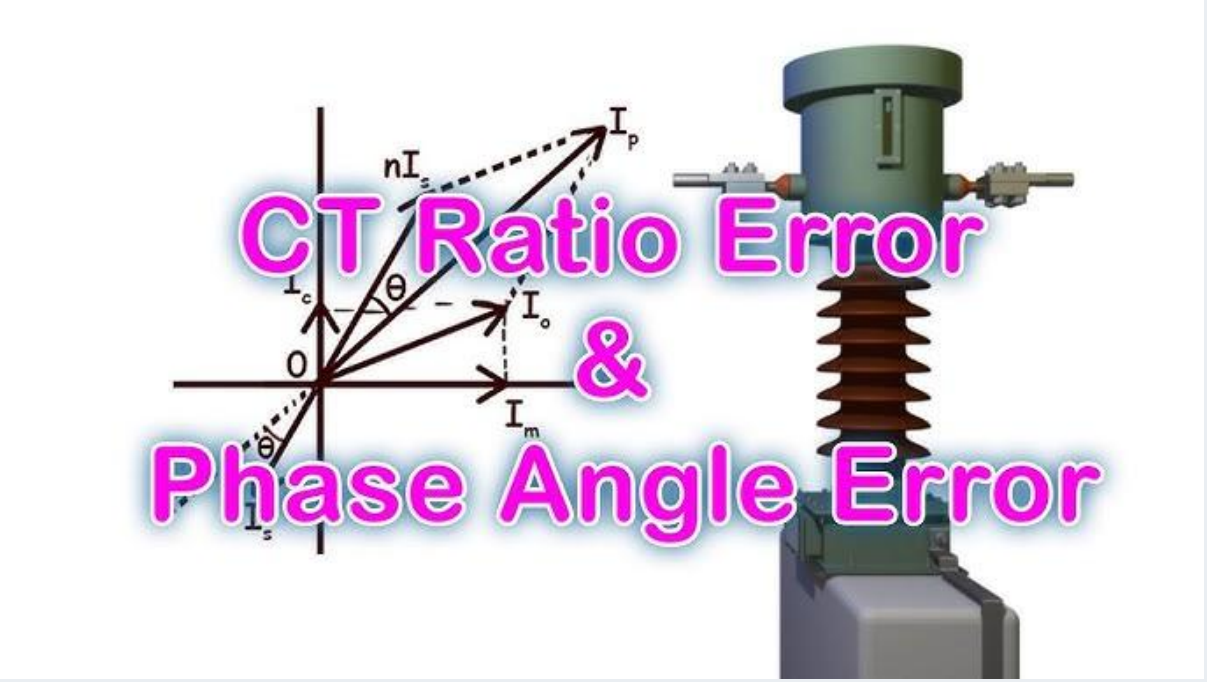
Installed CT:

600/1

Required CT:

1200/1

Relay settings not updated.



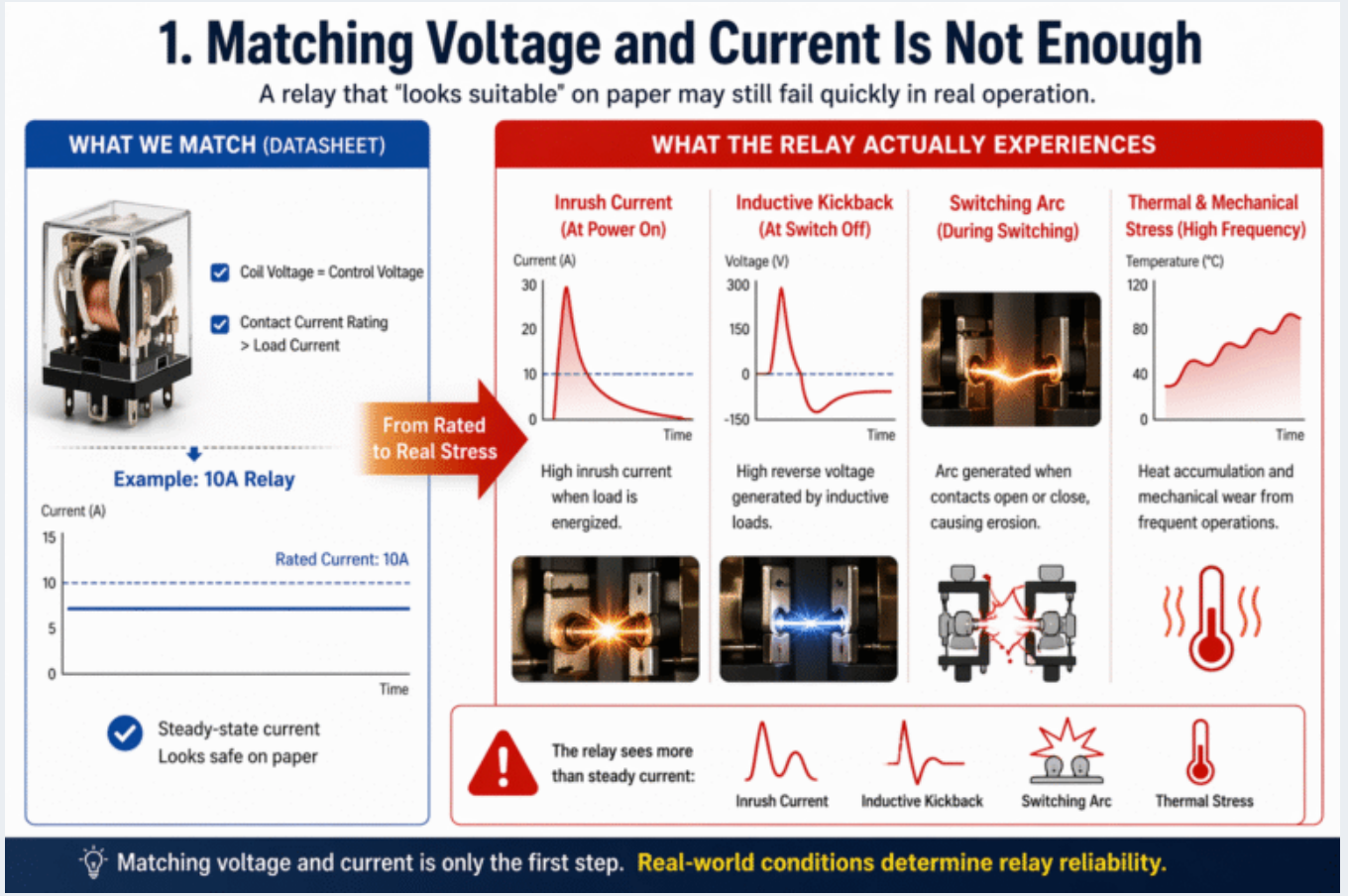
# Combined Failure Mechanism

Multiple Factors Aligned

1. Incorrect CT ratio
2. Severe saturation
3. High DC offset
4. Marginal relay settings

Result:

Relay underestimated fault current.



# Swiss Cheese Model

Protection Failure Layers

Design

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Installation

↓

Commissioning

↓

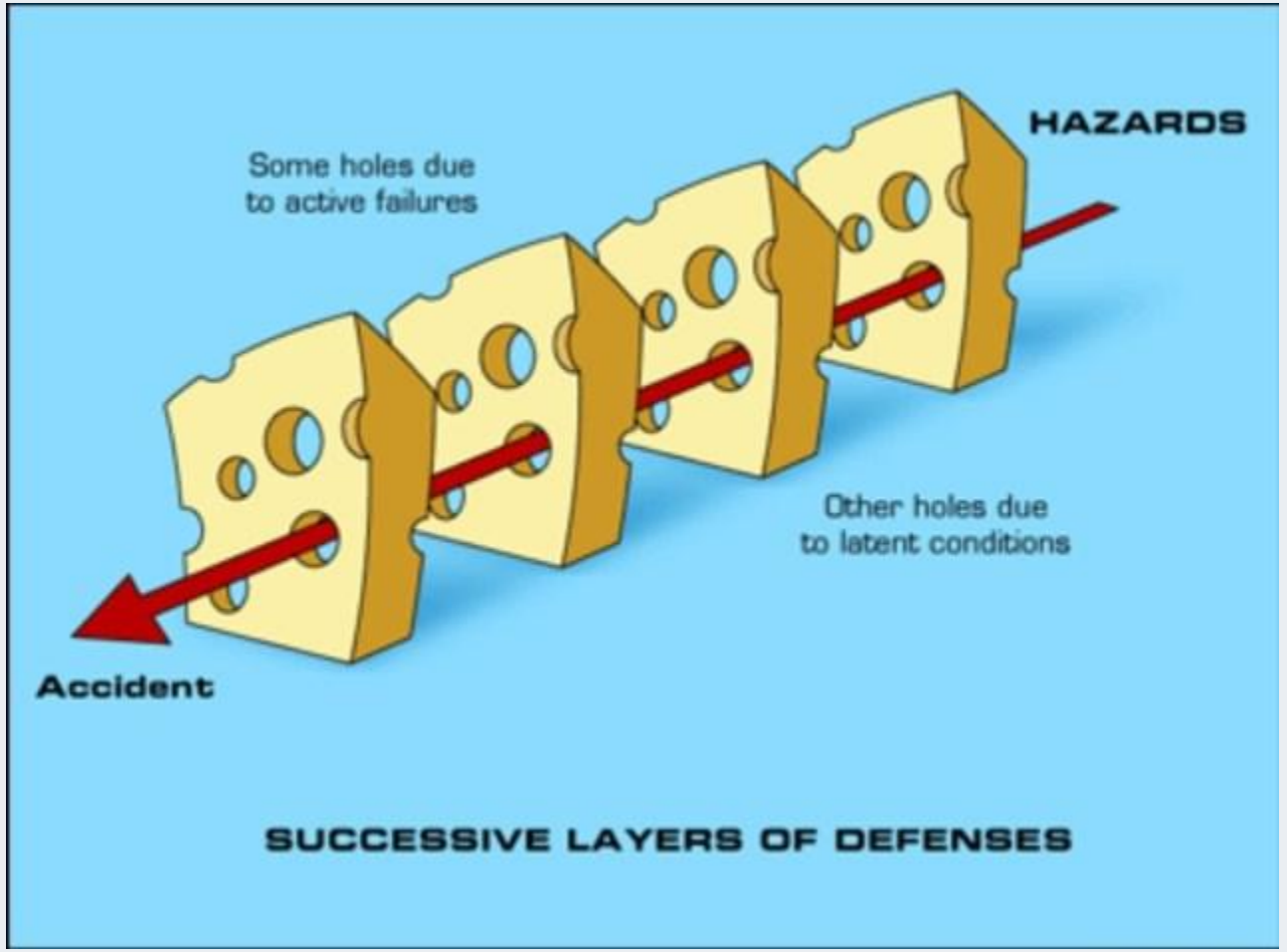
Maintenance

↓

Operation

Multiple holes aligned.

Fault escaped detection.



# Root Cause Analysis

## Technical Causes

- CT saturation
- Incorrect CT ratio

## Organisational Causes

- Inadequate maintenance control
- Missing commissioning verification
- Poor documentation

# Engineering Lessons

## Lesson 1

Never assume relay measurements are correct.

## Lesson 2

Always investigate CT performance.

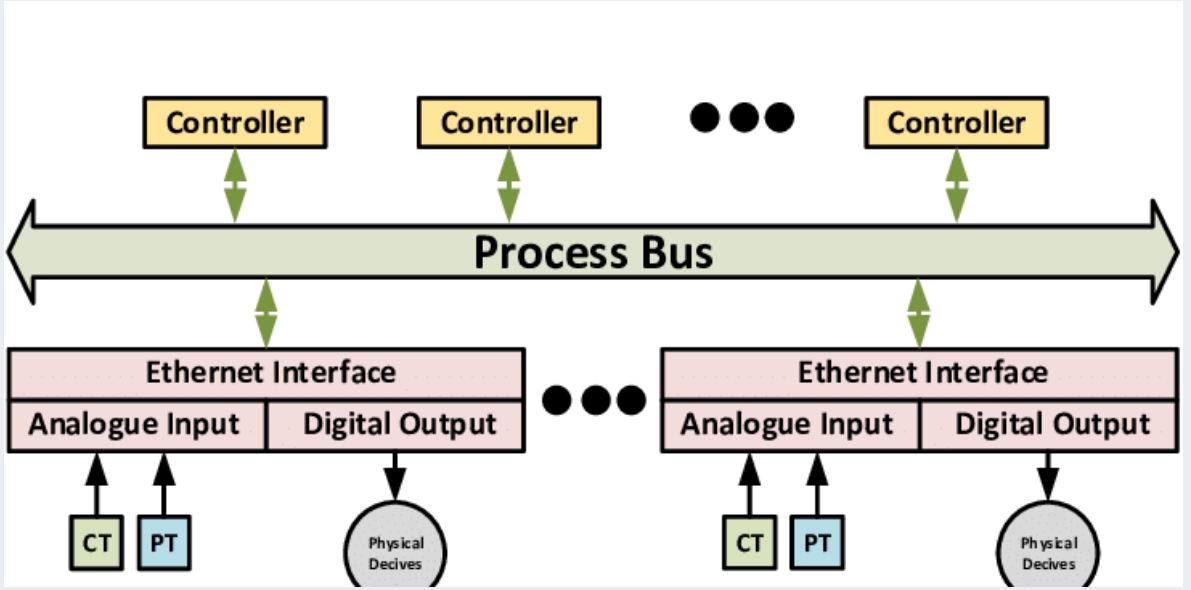
## Lesson 3

Verify settings after equipment replacement.

# Modern Solutions

Emerging Technologies

- Digital substations
- IEC 61850 process bus
- Optical current transformers
- Adaptive protection
- AI-assisted fault diagnostics



# Discussion Exercise

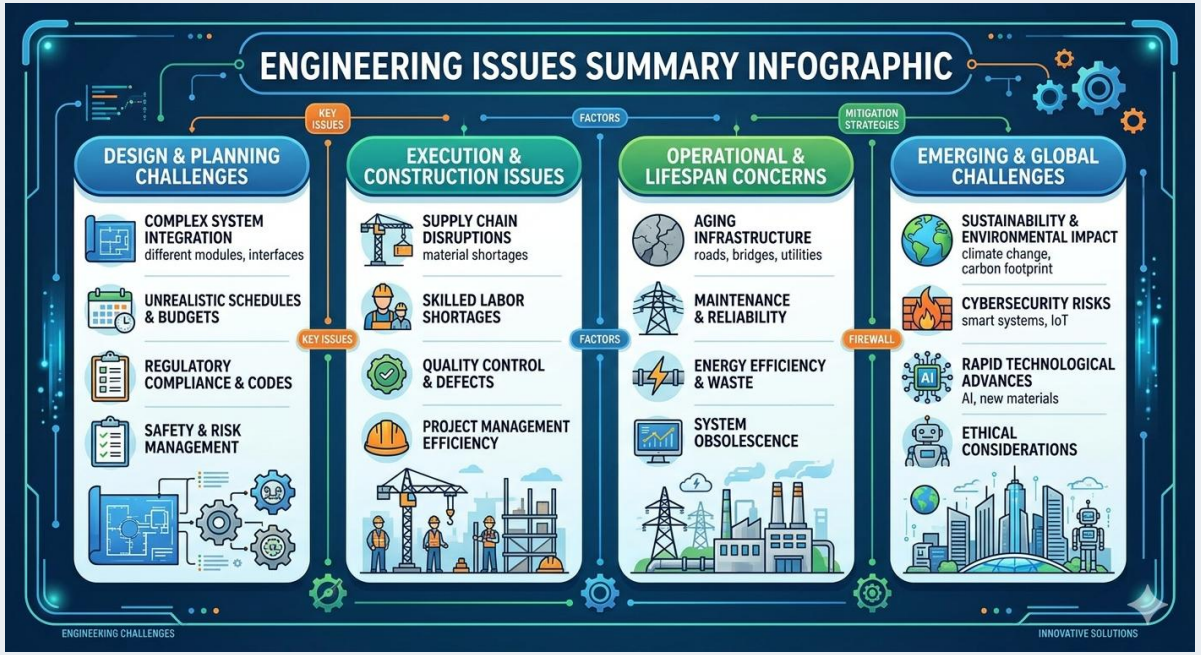
Group Question

What would you investigate first?

You arrive at a substation where:

- A physical fault exists
- Relay did not trip
- Event records appear normal

# Key Takeaways




## Remember

✓ Relays only act on what they measure

✓ CTs can lie

✓ Saturation can hide faults

✓ Settings matter

✓ Verification is essential

✓ Systematic investigation beats assumptions.

# Final Mystery Question

Was the Relay Actually Wrong?

Or

Was It Acting Correctly on Incorrect Information?

# Upcoming Mysteries Webinars

Register now!

16 July - The Capacitor Bank That Blew Itself Up Quietly
13 August – The Motor That Wouldn’t Start - Unless It Was Empty
20 August - The Neon Sign That Pulsed with Passing Trucks
10 September – The Battery Bank That Lost Capacity Overnight
17 September - The Streetlight That Kept Turning on at Noon
12 November – The Transformer That Changed Tap Position by Itself
19 November – The Circuit That Lost Half Its Phase Over the Years
10 December – The PLC That Spoke Back - A Control Loop with a Mind of Its Own
17 December - The Resonant Substation - Lights Flicker Without Load Change
27 January - The Induced Voltage That Woke the Cattle

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# Thank You!

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|---|---|
| 52888WA Advanced Diploma of Applied Electrical Engineering (Power Industry) | 1 September 2026 |
| 52892WA Advanced Diploma of Electrical and Instrumentation (E&I) Engineering in Mining | 1 September 2026 |
| Professional Certificate of Competency in Power Distribution | 3 November 2026 |
| Professional Certificate of Competency in Hazardous Areas & Intrinsic Safety For Engineers & Technicians | 11 August 2026 |
| Graduate Diploma of Engineering (Electrical Systems) | 4 January 2027 |
| Associate Degree in Electrical Engineering | 8 February 2027 |
| Bachelor of Science (Electrical Engineering) | 8 February 2027 |
| Master of Engineering (Electrical Systems) | 4 January 2027 |
| Master of Engineering – Applied Research (Electrical Systems) | 4 January 2027 |
| Doctor of Engineering | 8 February 2027 |

# Upcoming Courses

Please note: Courses listed below are offered by separate institutions in the UK and South Africa, each subject to their own regulatory requirements - refer to the relevant website for location-specific details.

| Engineering College of Technology (ECT)<br>*UK qualifications* | Start Date |
|---|---|
| Bachelor of Engineering (Honours) in Industrial Automation | 21 September 2026 |
| Bachelor of Engineering (Honours) in Electrical Engineering | 21 September 2026 |
| Master of Science (Power System Analysis and Renewable Integration) | 5 October 2026 |
| Master of Science (Industrial Automation and Instrumentation Control) | 5 October 2026 |

| Engineering College of Science and Technology (ECST)<br>*South African accredited qualification & ECSA-endorsed* | Start Date |
|---|---|
| Bachelor of Engineering Technology in Electrical Engineering | 3 August 2026 |

# Q&A

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