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MYSTERIES: Earth Fault That Didn't Return to Earth

19 March 2026

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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

	Why study mysteries?
	Introducing the case
	The two hypothesis
	Fundamentals
	The resolution
	Key Technical Lessons
	Key Takeaways
	Q&A

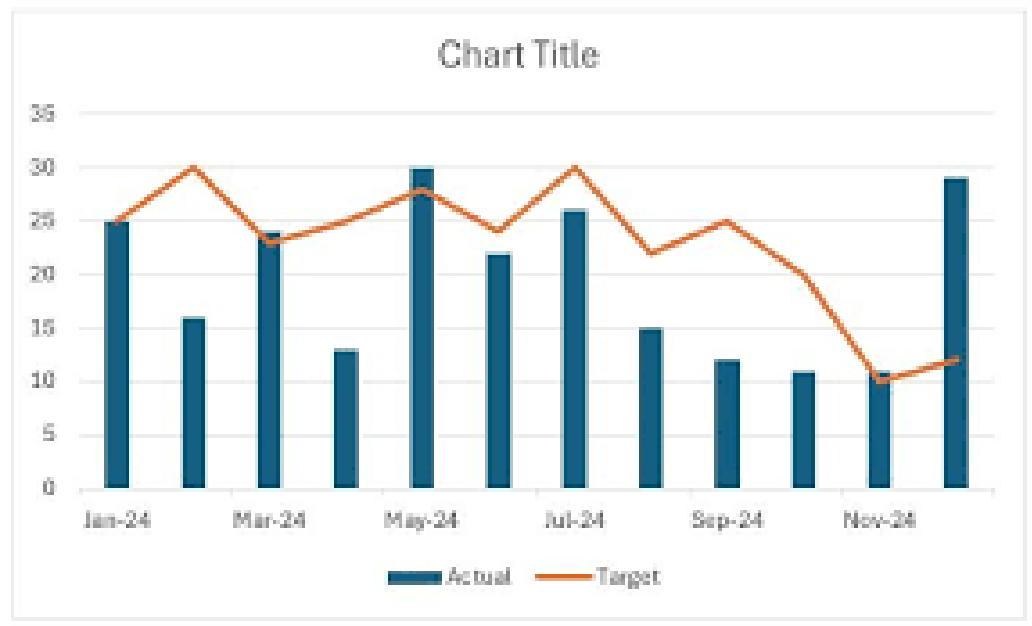
Why Study Engineering “Mysteries”?

- Many serious incidents begin as minor anomalies
- Real systems rarely fail cleanly
- Engineers are often called when the data is incomplete
- Experience = structured intuition

What Makes a “Mystery” in Engineering?

- Intermittent behaviour
- Time-dependent symptoms
- Non-electrical root causes
- Human assumptions masking

reality

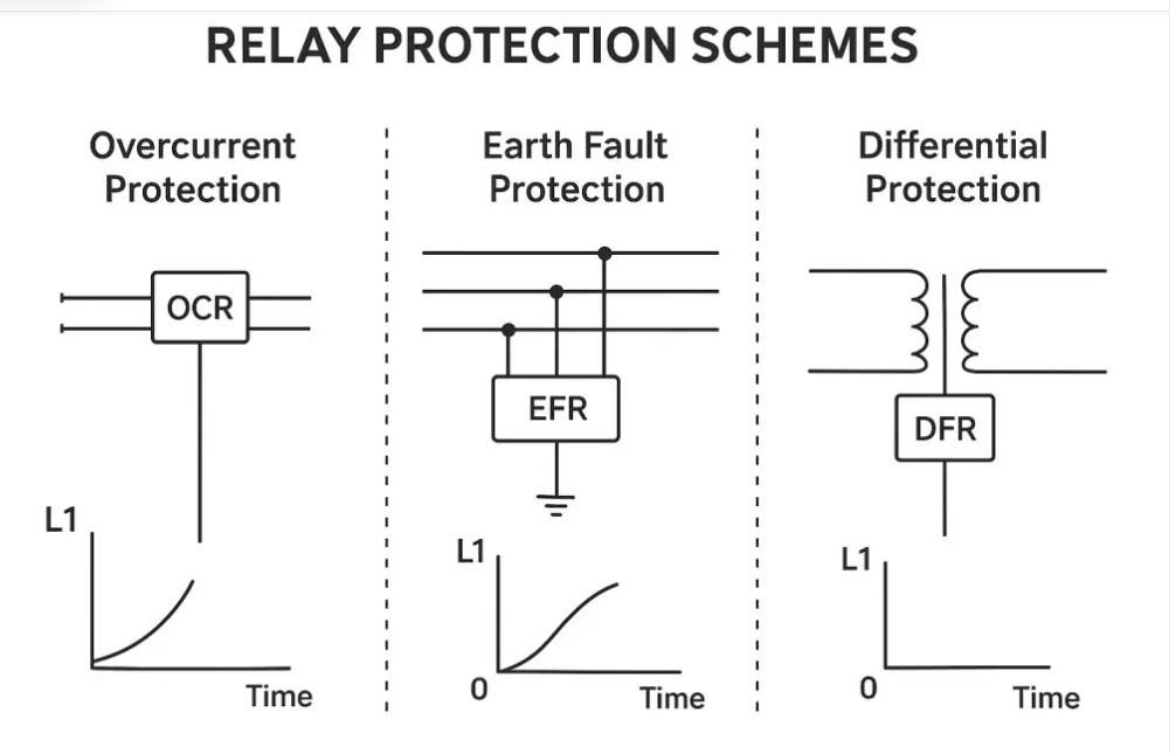


What Defines an Engineering Mystery?

- Symptoms without alarms
- Intermittent or time-dependent behaviour
- Conflicting data
- Multiple plausible explanations

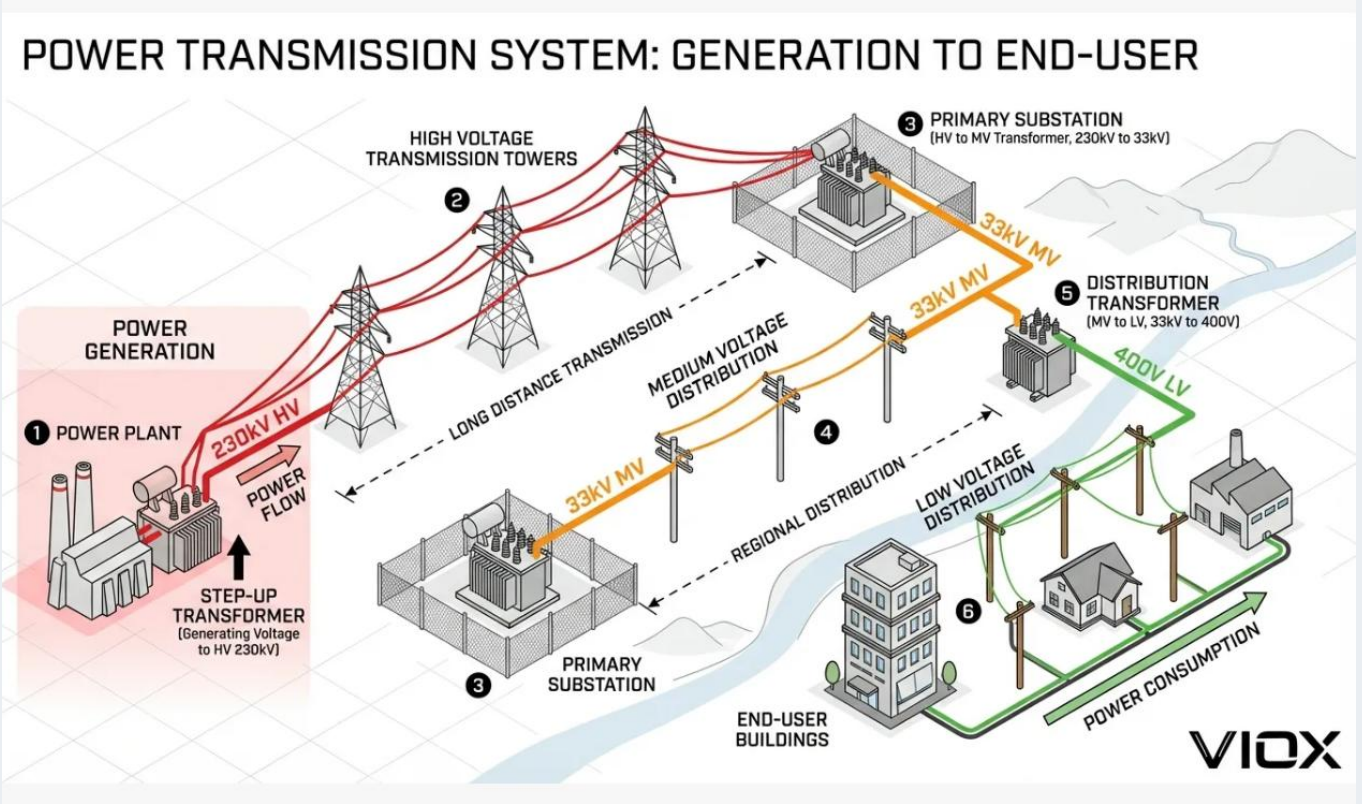
Why This Is a True Mystery?

- Earth faults are considered “simple”
- Protection schemes are well established
- Yet relays failed to operate
- Measurements contradicted expectations



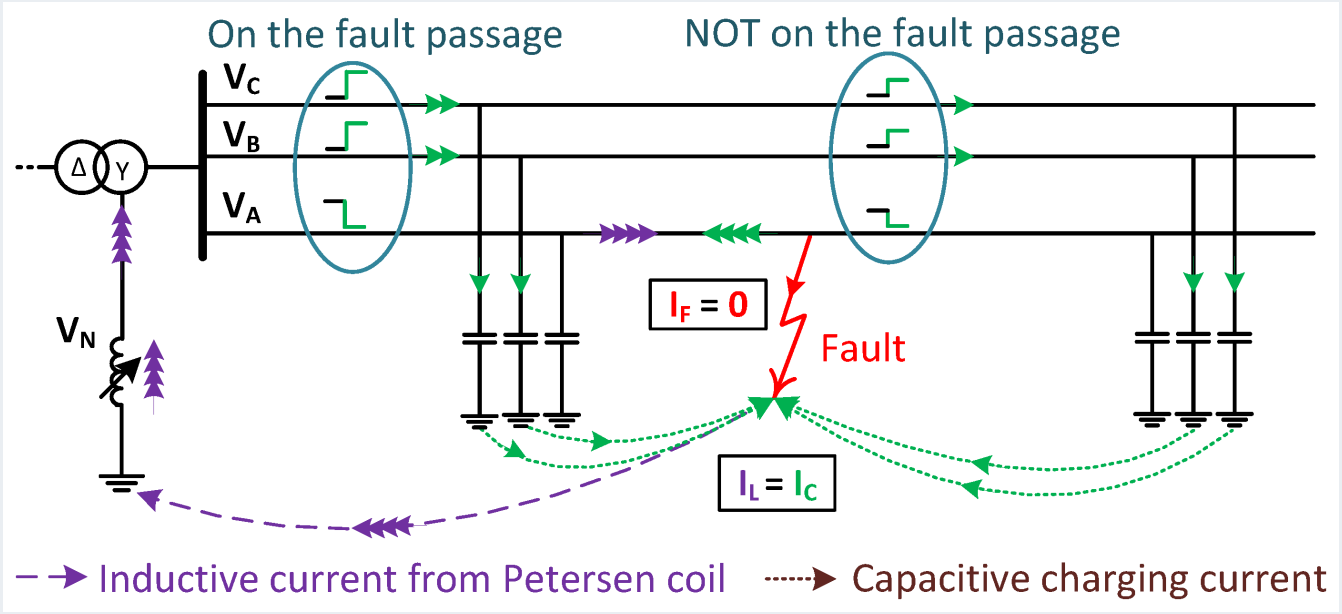
The System Under Study

- Medium-voltage industrial distribution system
- Multiple feeders
- Solidly earthed equipment frames
- Modern numerical protection relays



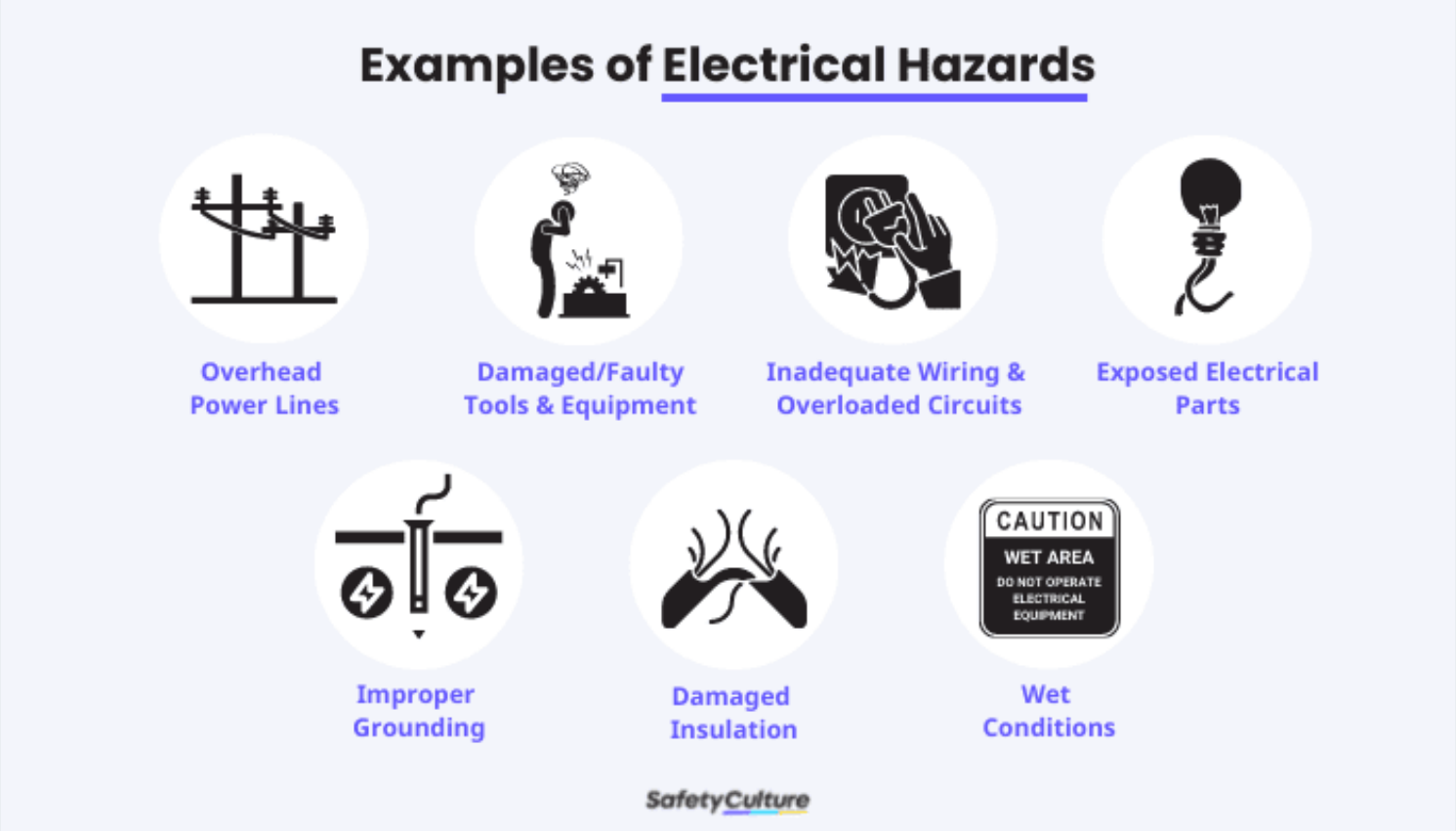
The Reported Problem

- Phase-to-earth fault occurred
- Visible arc damage
- No earth fault relay trip
- System continued operating



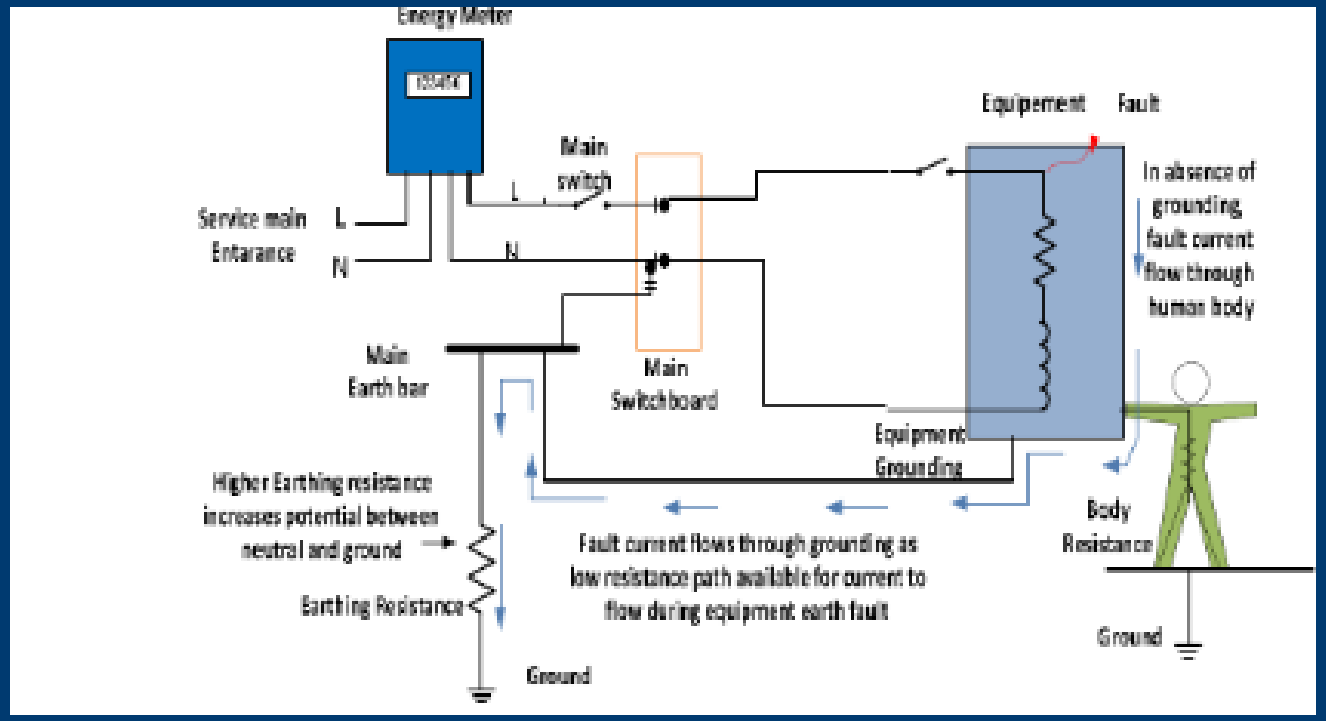
Immediate Safety Concerns

- Touch voltage risk
- Equipment damage
- Fire hazard
- Loss of protection credibility



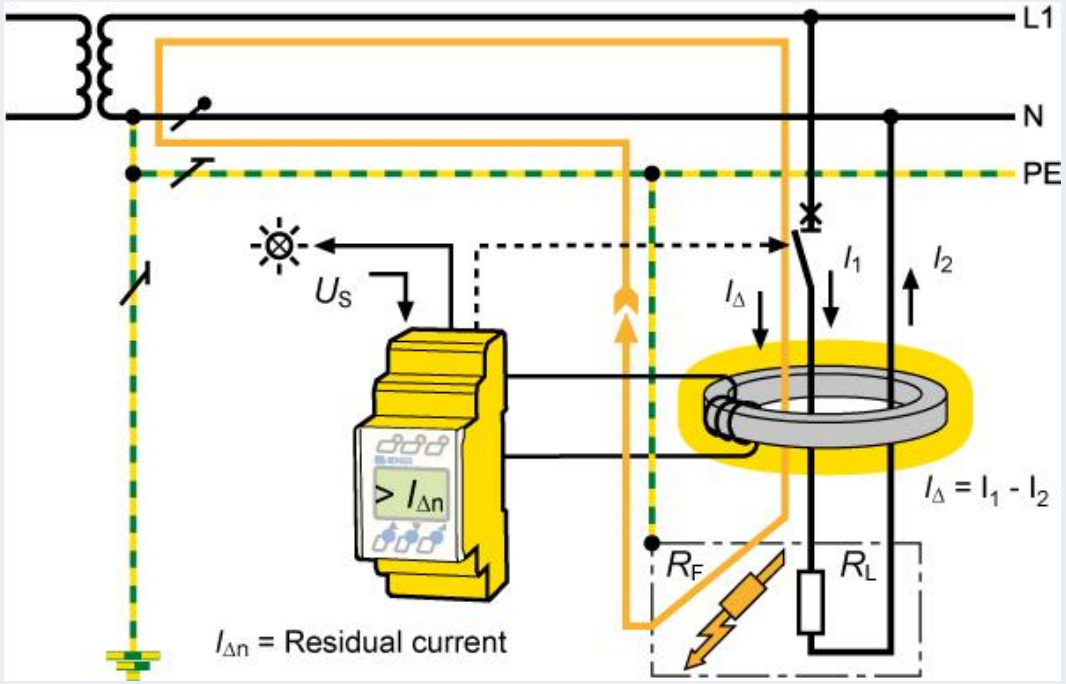
What Engineers Expected to See?

- Fault current flows into earth
- Returns via ground grid / soil
- Residual current detected
- Relay trips feeder



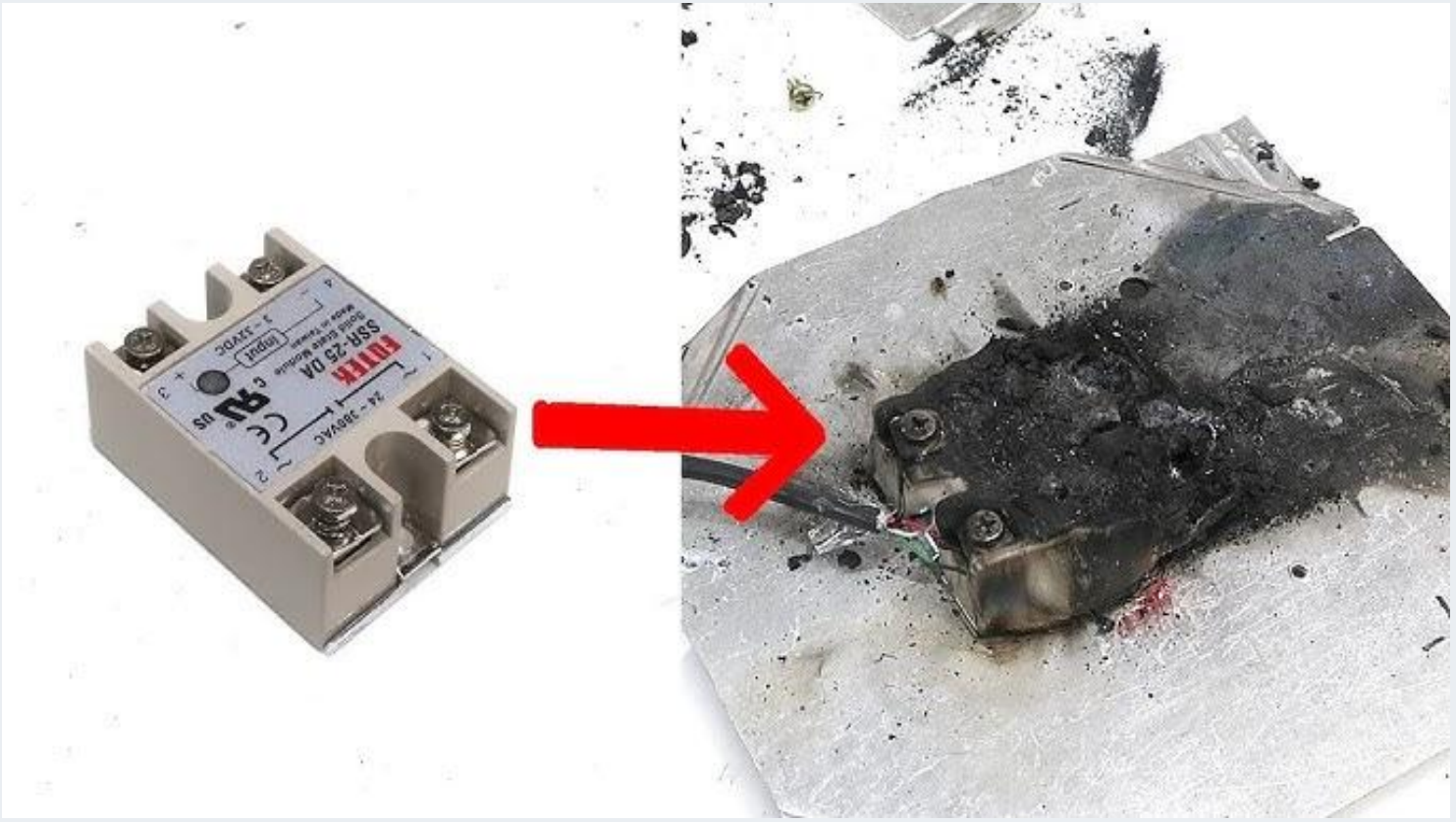
What Measurements Actually Showed?

- Minimal residual current
- No significant neutral displacement
- No relay pickup
- Yet visible fault evidence



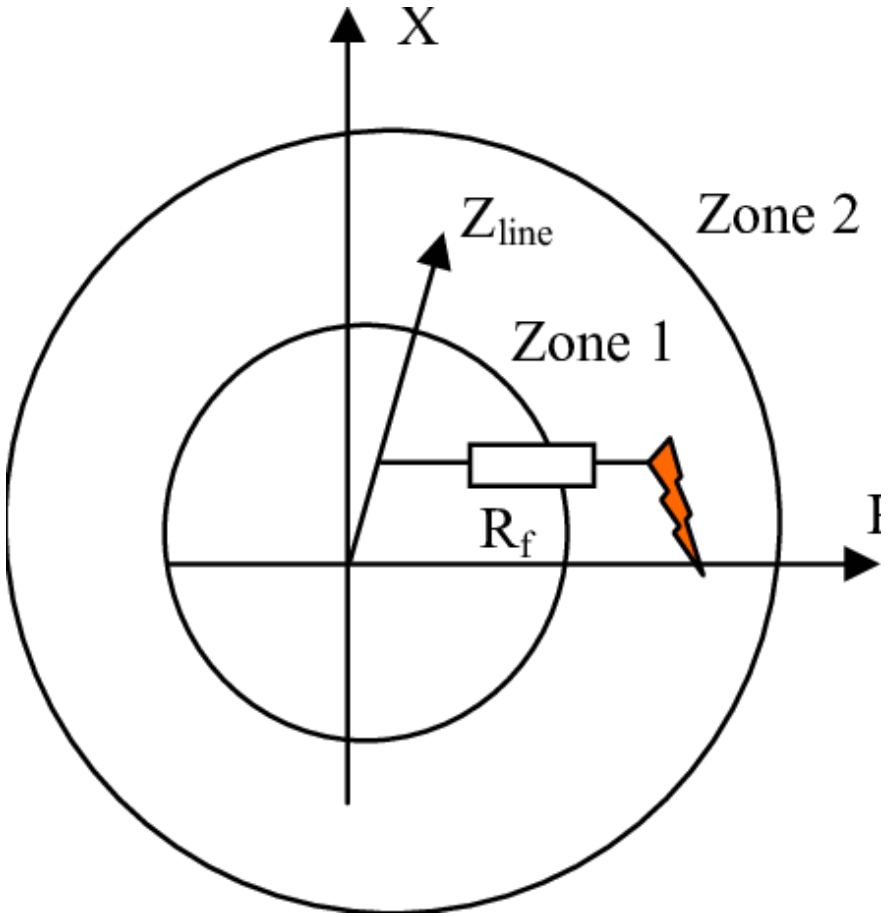
First Hypothesis: Relay Failure

- Relay settings checked
- CT polarity verified
- Injection tests passed
- Relay functioning correctly



Second Hypothesis: High-Resistance Fault

- Fault resistance suspected
- Surface contamination examined
- Arc marks indicated low impedance
- Hypothesis rejected

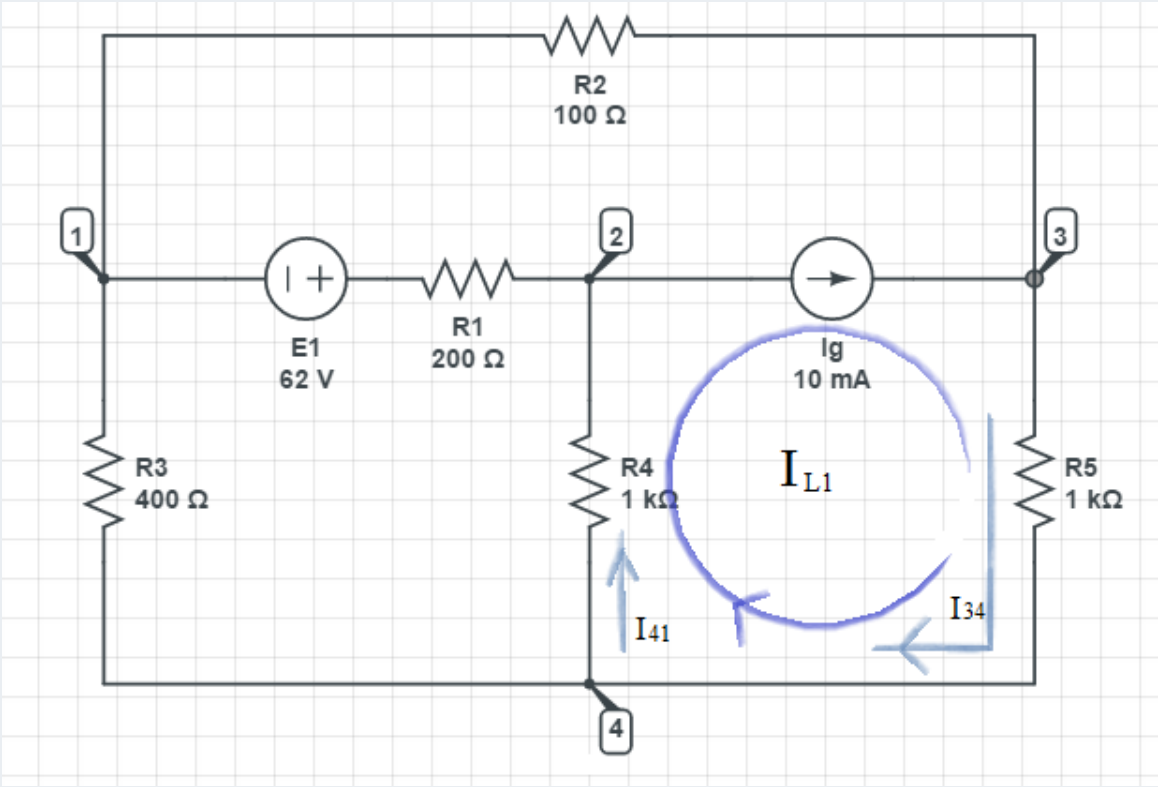


Revisiting a Fundamental Question

- What *is* “earth” electrically?
- Is earth always part of the circuit?
- Does current require soil?
- Where does current close its loop?

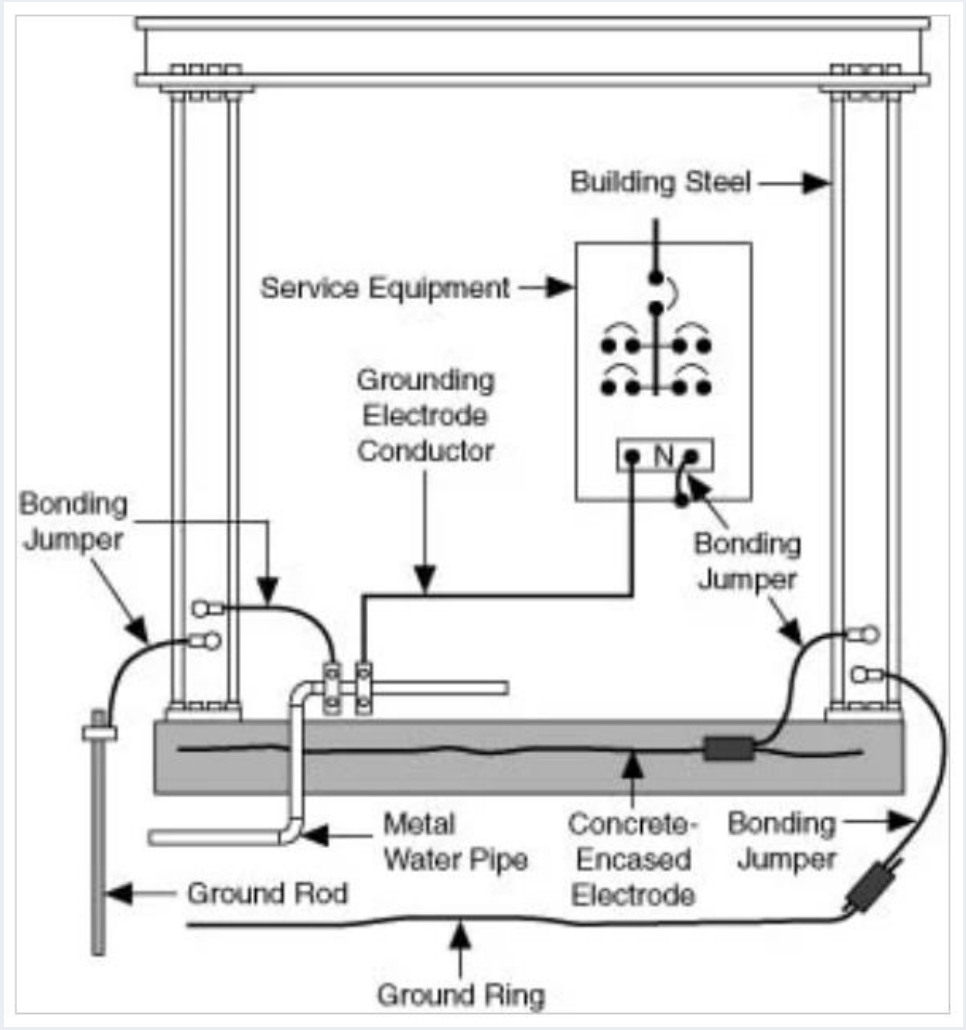
A Key Insight: Current Needs a Loop

- Current must return to its source
- Earth is not a source
- Earth is not magic
- Earth is just another conductor



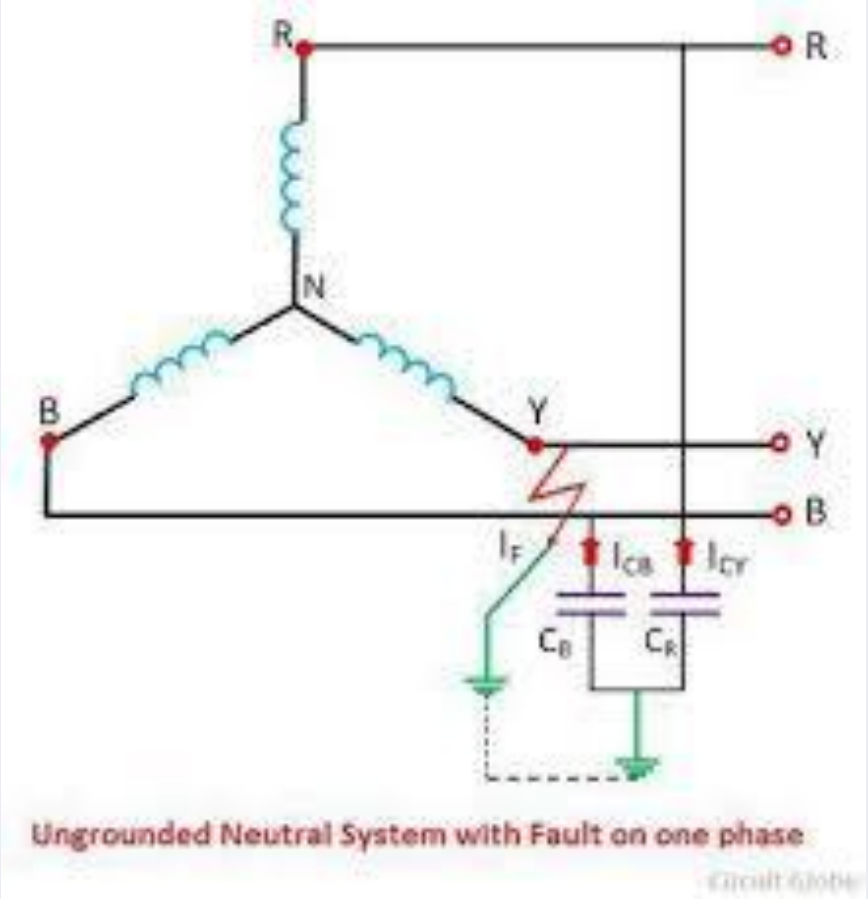
The System Grounding Method

- System neutral isolated from earth
- No neutral earthing resistor
- No grounding transformer
- “Floating” system by design



What Happens in an Ungrounded System?

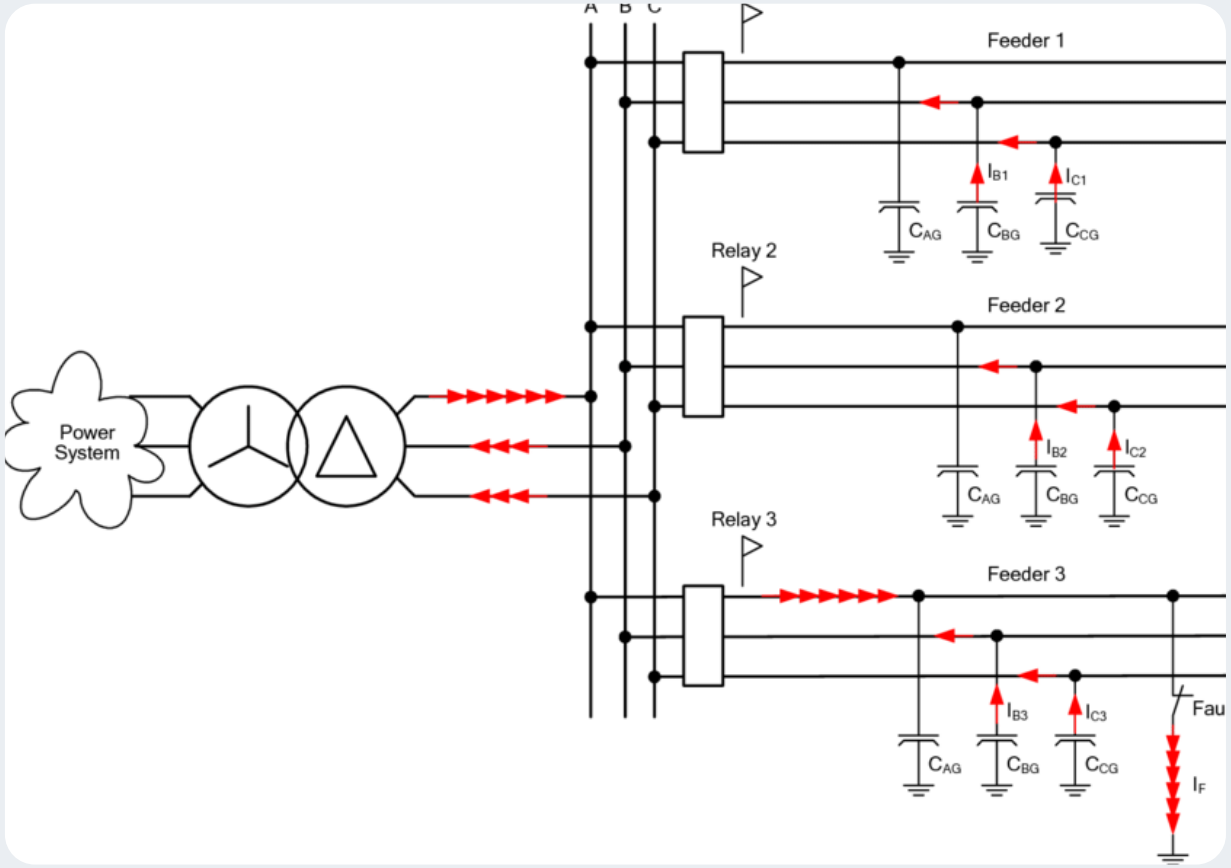
- Single earth fault produces minimal current
- Fault current flows via capacitances
- No solid return path
- System continues operating



Ungrounded Neutral System with Fault on one phase

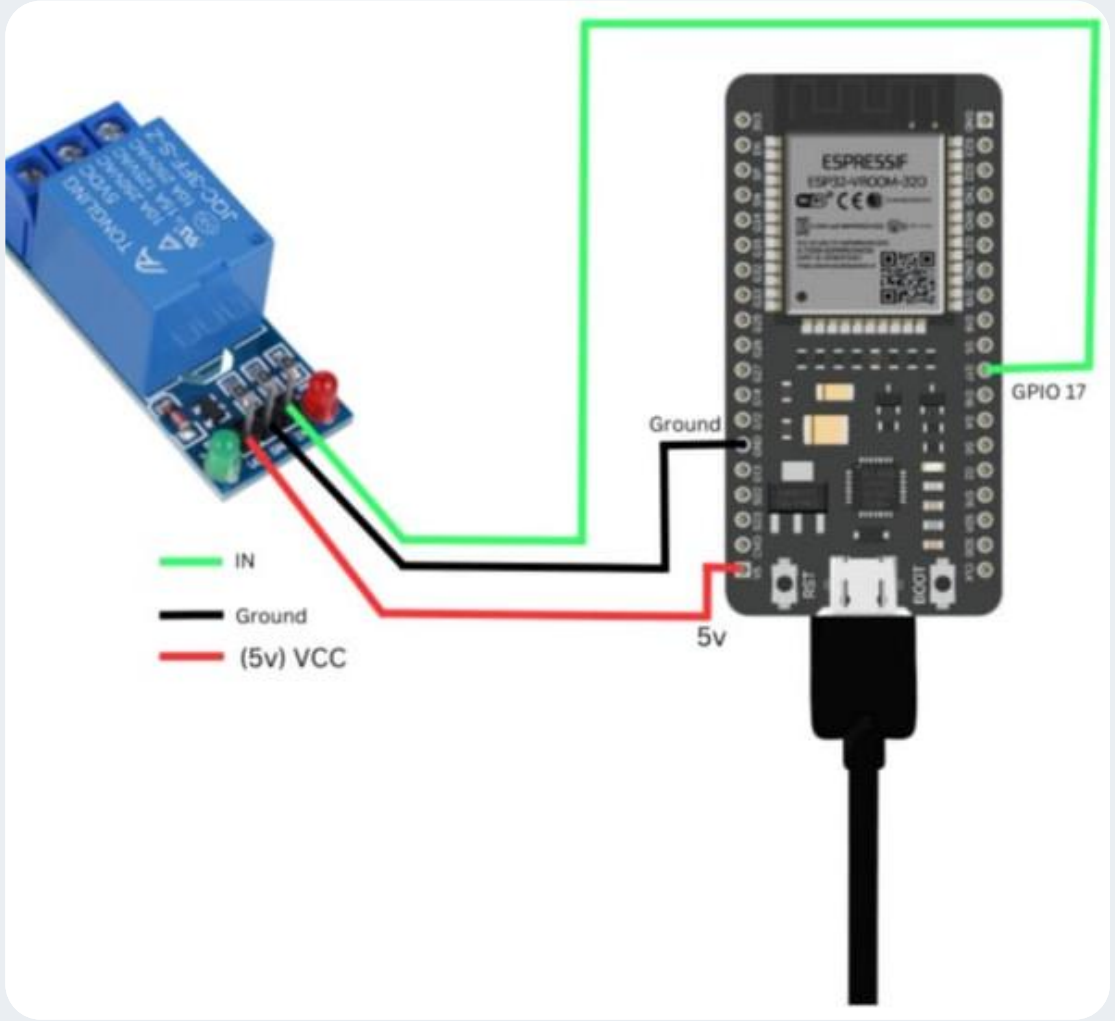
The Hidden Return Path

- Phase-to-earth capacitances
- Cable capacitance
- Motor winding capacitance
- Distributed, not concentrated



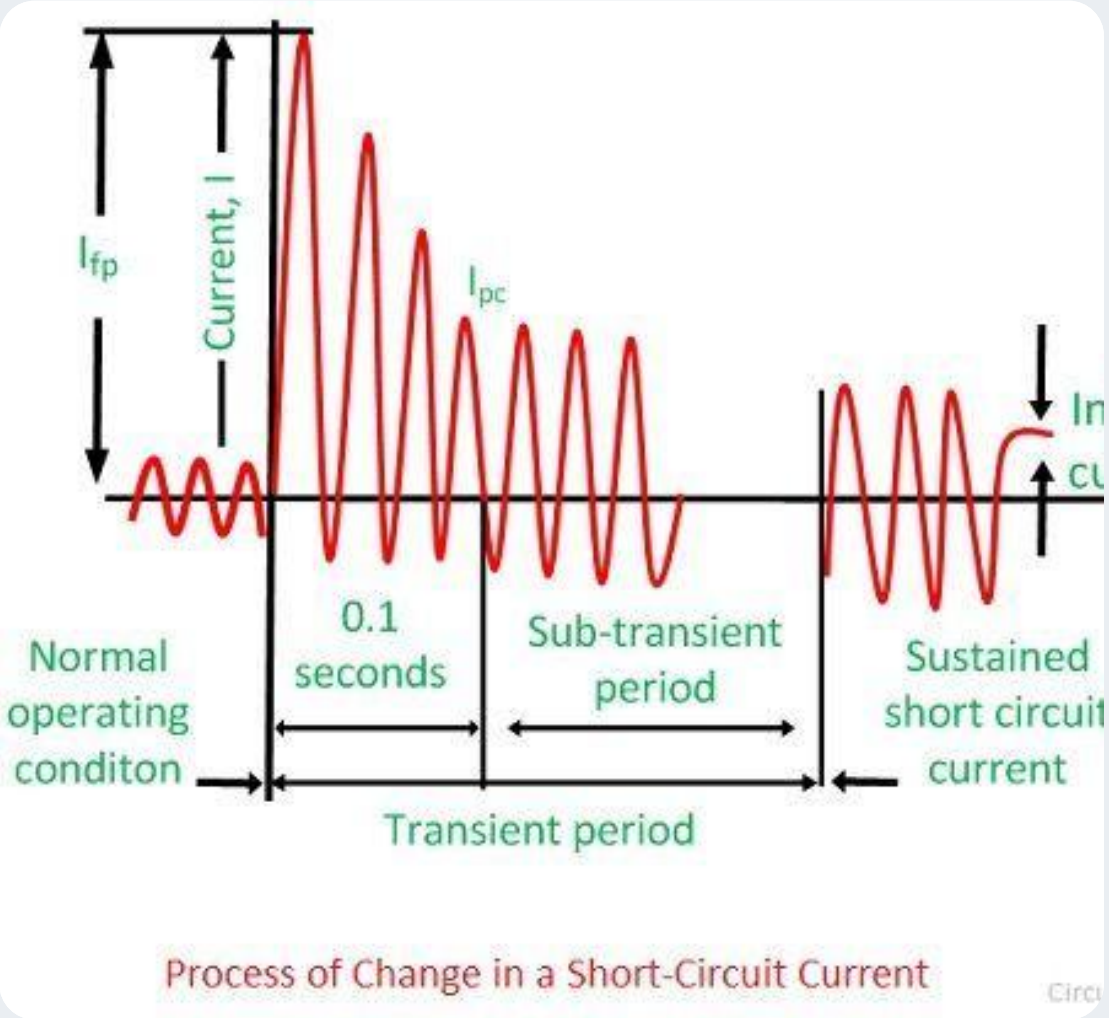
Why the Relay Saw Nothing?

- Capacitive currents very small
- Balanced across phases
- Residual sum near zero
- Below relay sensitivity



Why Damage Still Occurred?

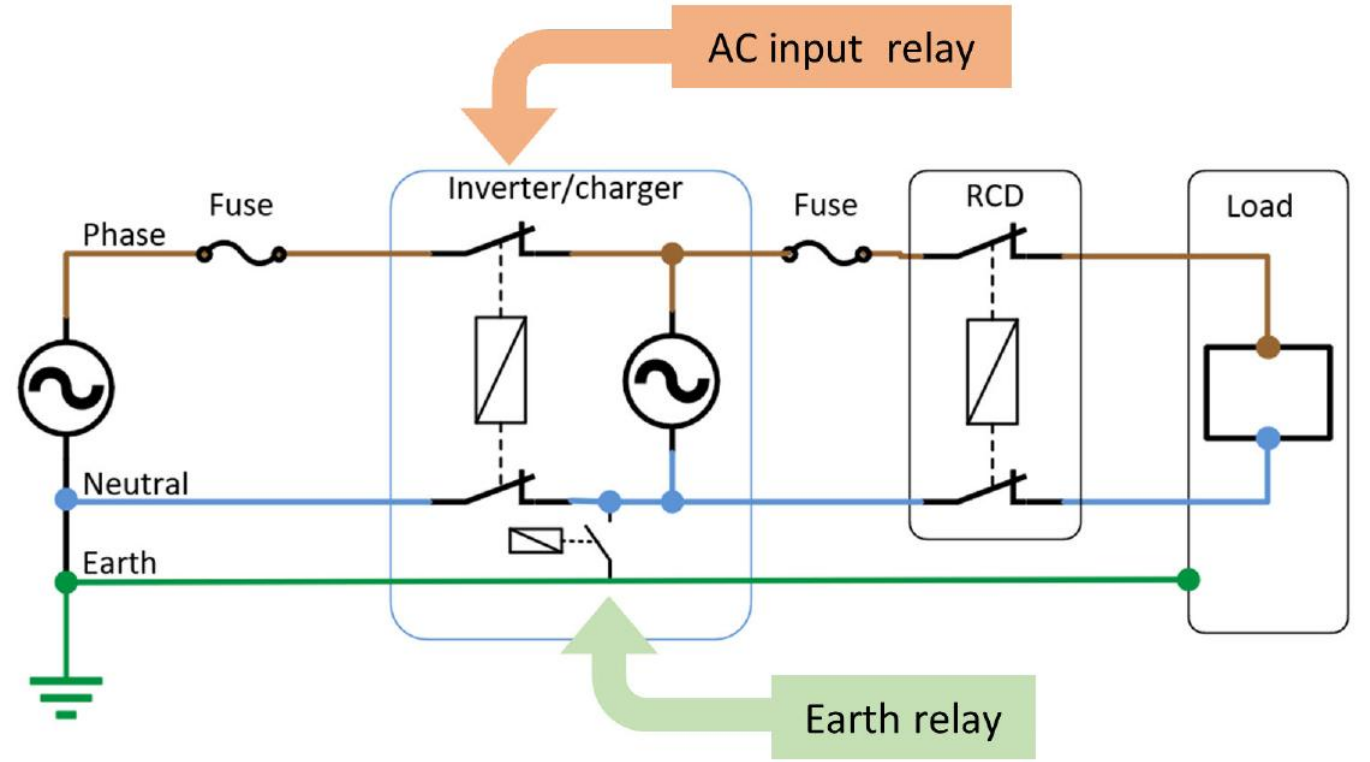
- Initial transient current high
- Local arc energy sufficient
- Mechanical and thermal damage
- Steady-state current small



Process of Change in a Short-Circuit Current

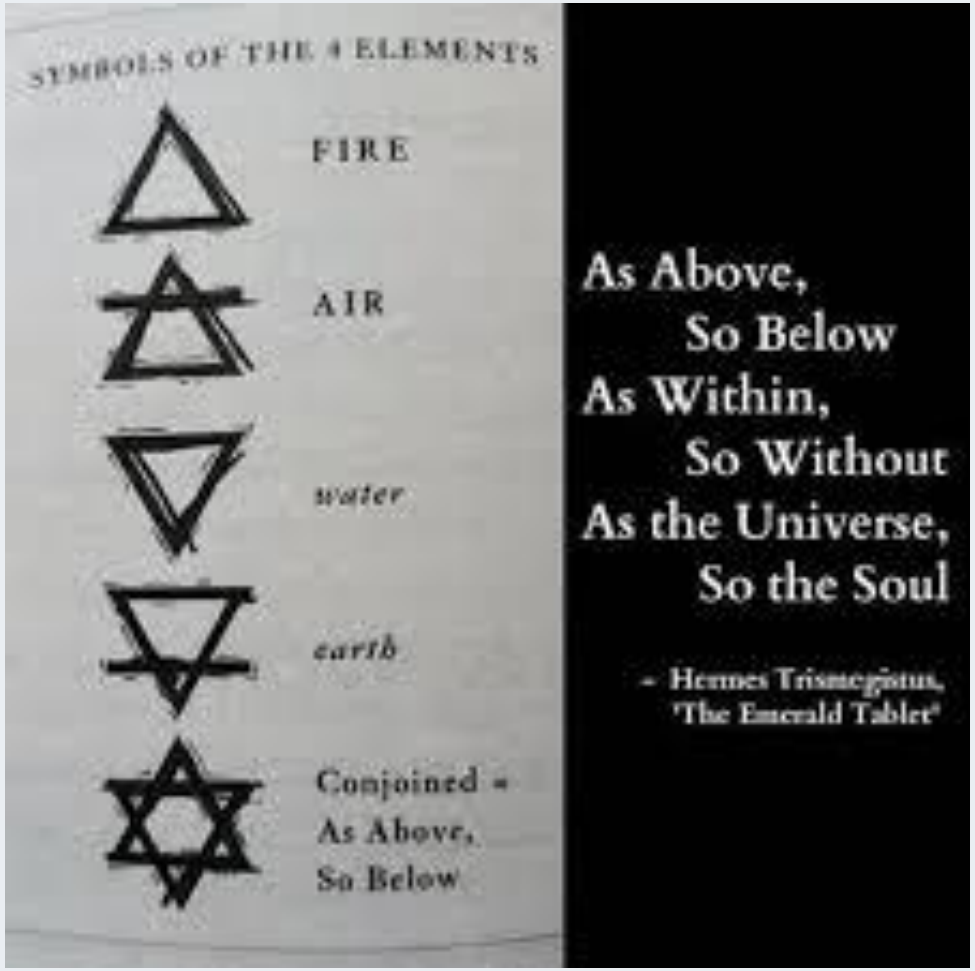
The Moment of Realization

- Fault did not “return to earth”
- It returned to the source
- Earth merely hosted the contact
- Mental model corrected



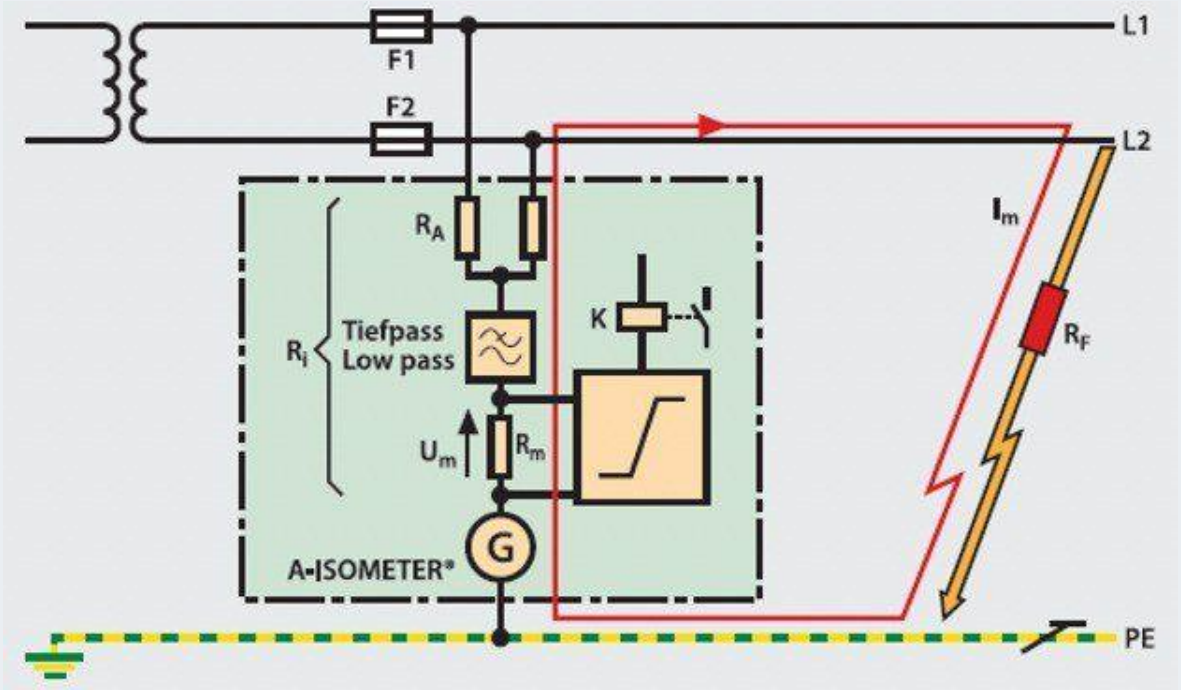
Why This Is Often Misunderstood?

- Earth symbol implies sink
- Language reinforces misconception
- Simplified teaching models
- Rare exposure to ungrounded systems



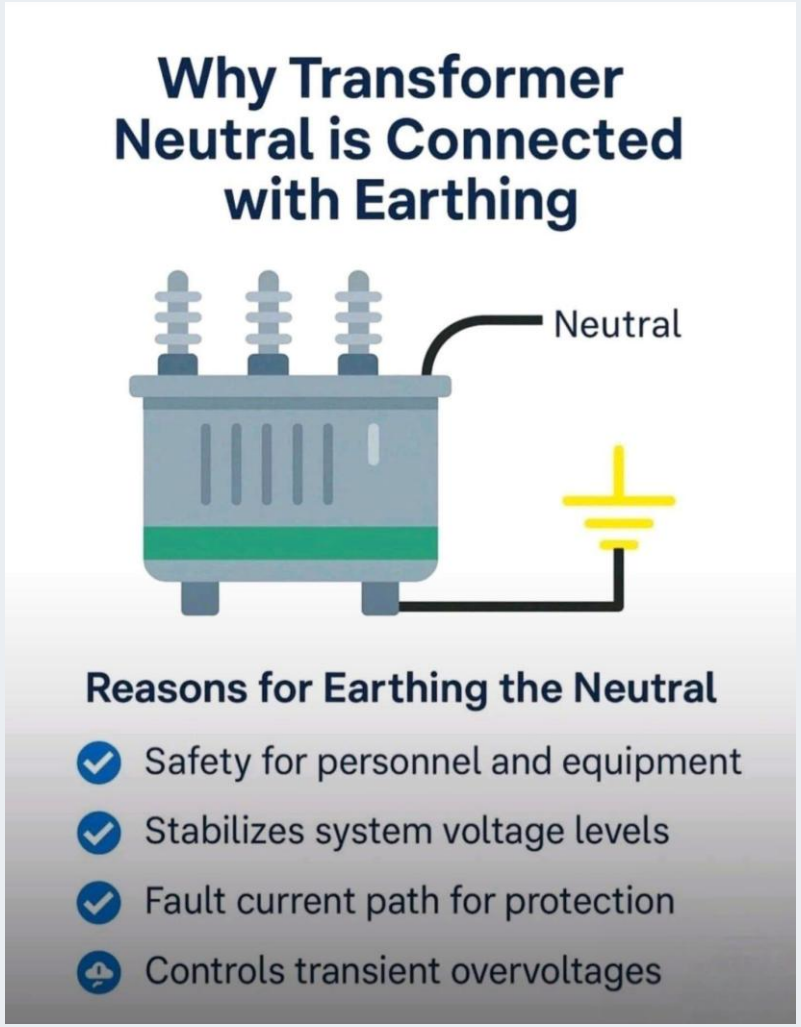
Correct Protection Philosophy

- Insulation monitoring devices
- Neutral displacement detection
- Grounding transformers
- Clear system grounding strategy



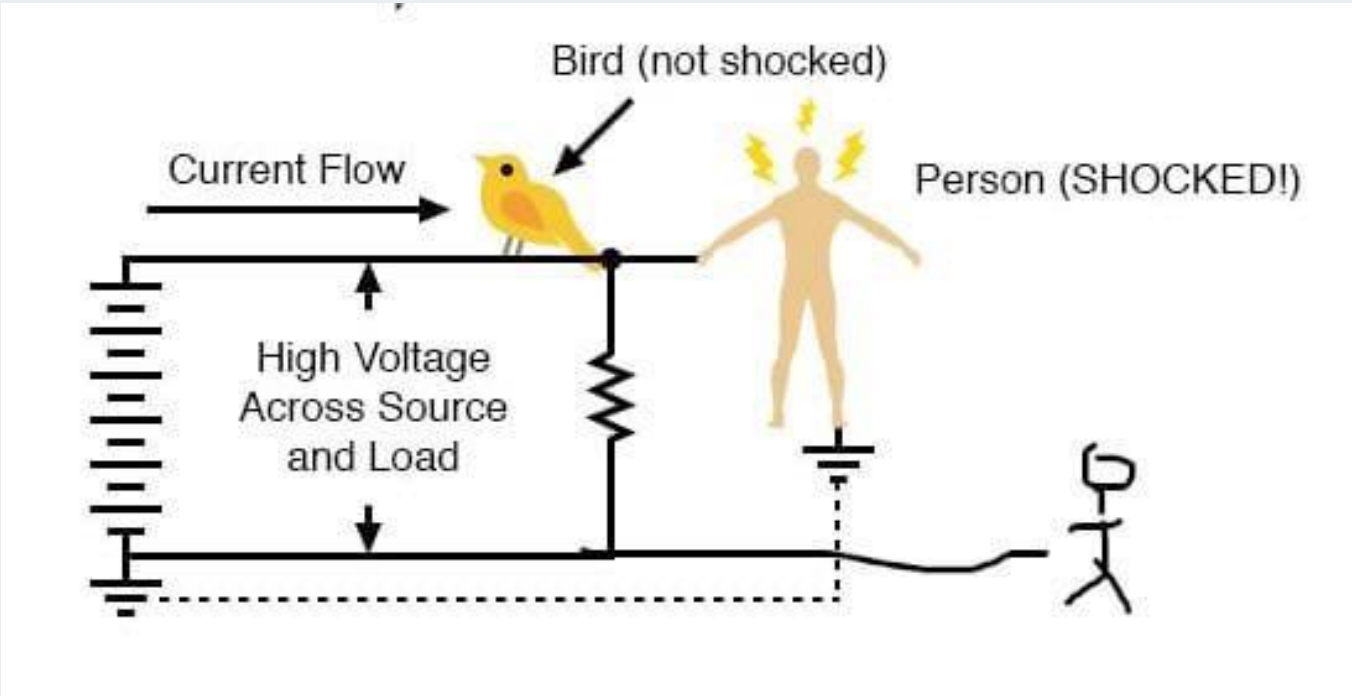
How the Issue Was Resolved?

- Grounding transformer installed
- Defined neutral-earth reference
- Earth fault current increased (intentionally)
- Reliable detection achieved



A Dangerous Half-Truth

- “Earth faults are safer in ungrounded systems”
- True for continuity
- False for insulation stress
- False for fault location

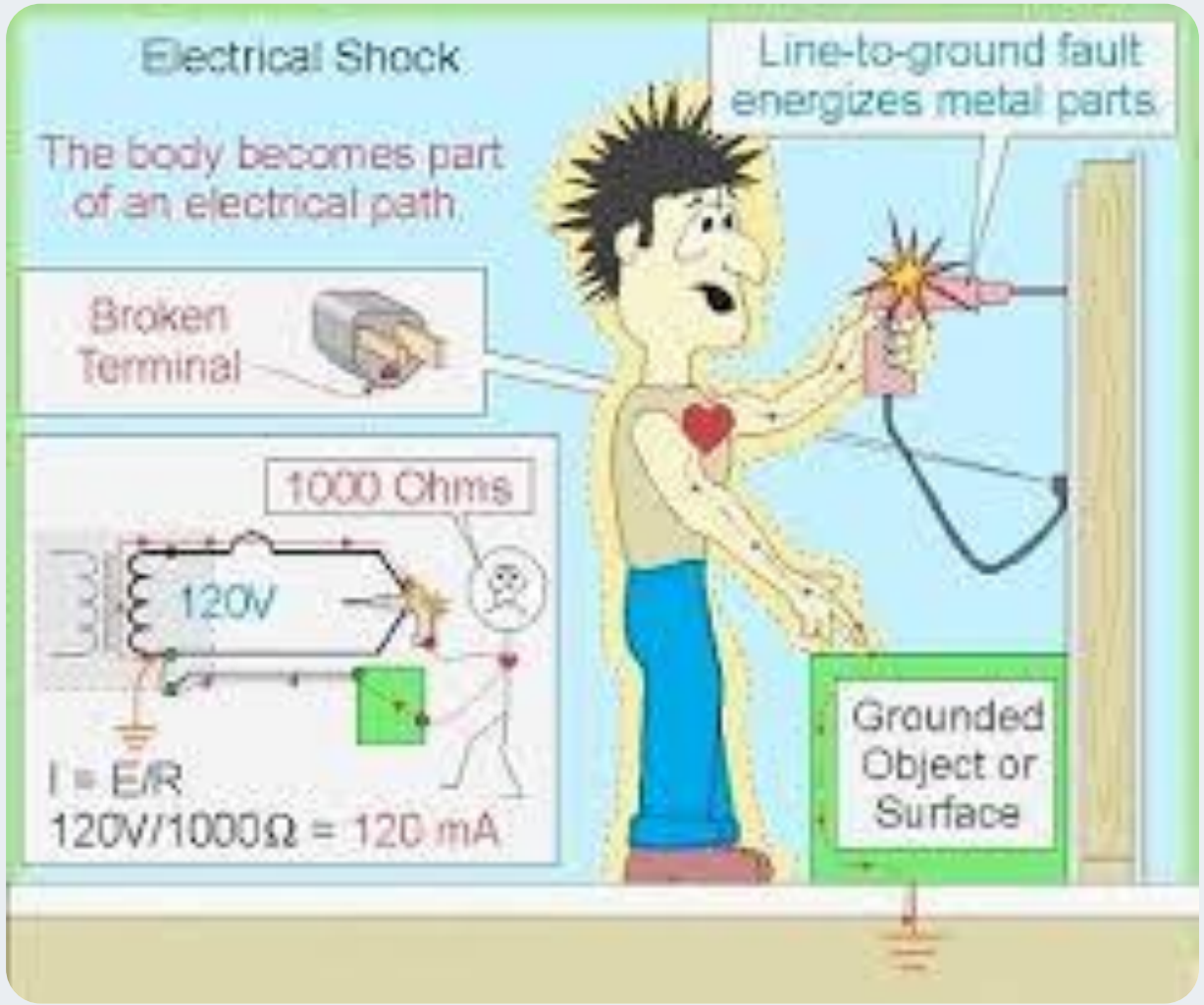


Similar Real-World Incidents

- Mines with floating networks
- Ships and offshore platforms
- Data centres with IT systems
- Hospitals with isolated supplies

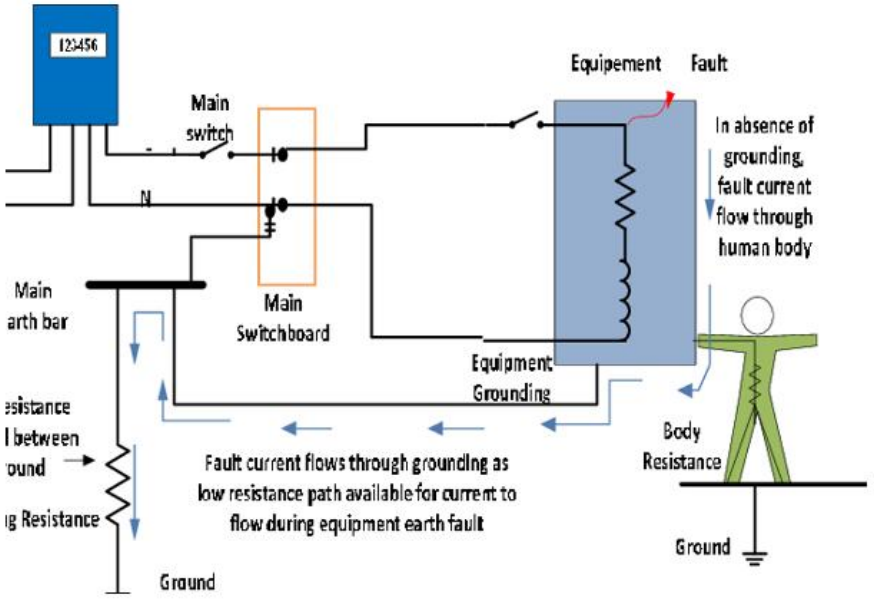
Student Thought Experiment

- What happens on the *second* earth fault?
- Where does current flow then?
- Which protection operates?
- How fast must it act?



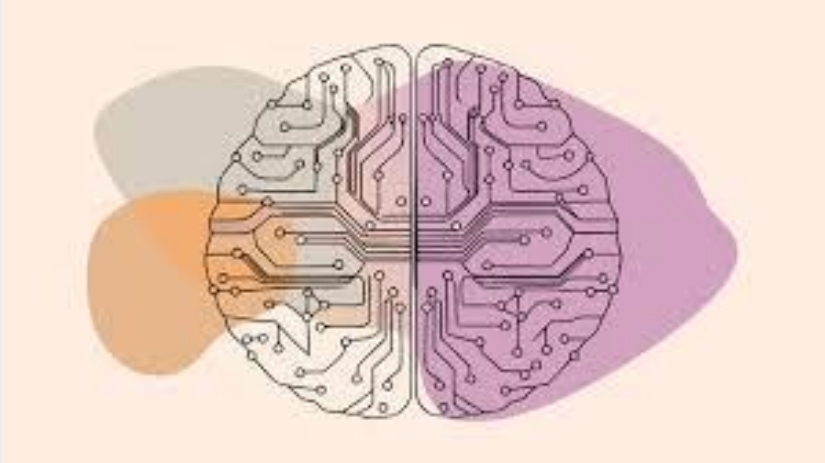
Core Lessons for Engineers

- Earth is not a current sink
- Grounding defines fault behaviour
- Protection follows physics, not symbols
- Always trace the return path



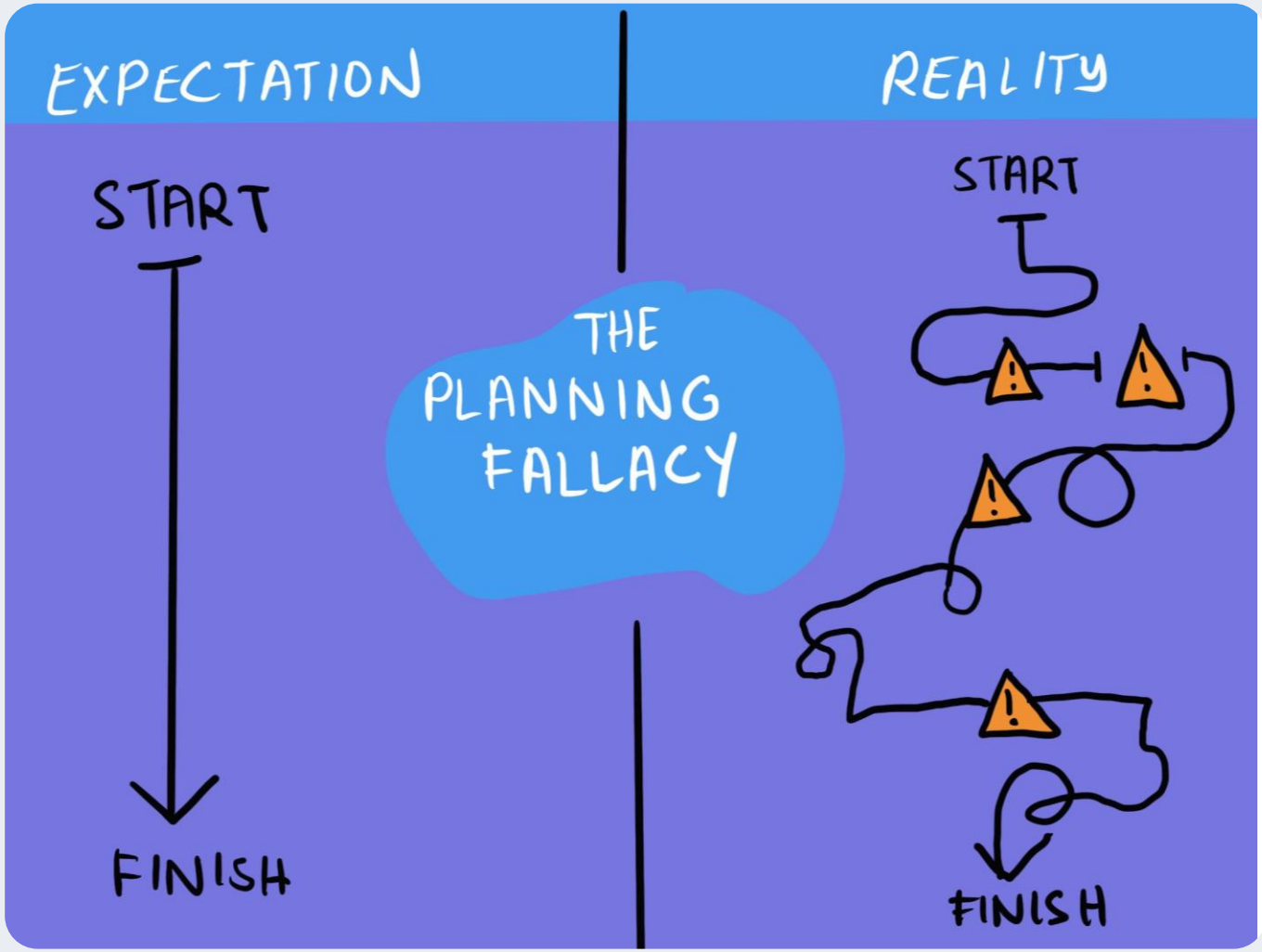
Why This Mystery Persists?

- Rarely demonstrated experimentally
- Counter-intuitive behaviour
- Overconfidence in assumptions
- Poor documentation of grounding



The Deeper Engineering Truth

- Systems behave exactly as built
- Not as imagined
- Not as labelled
- Not as assumed



Reflection

- Would a junior engineer solve this?
- What experience was critical?
- How could procedures improve detection?

Closing Thought

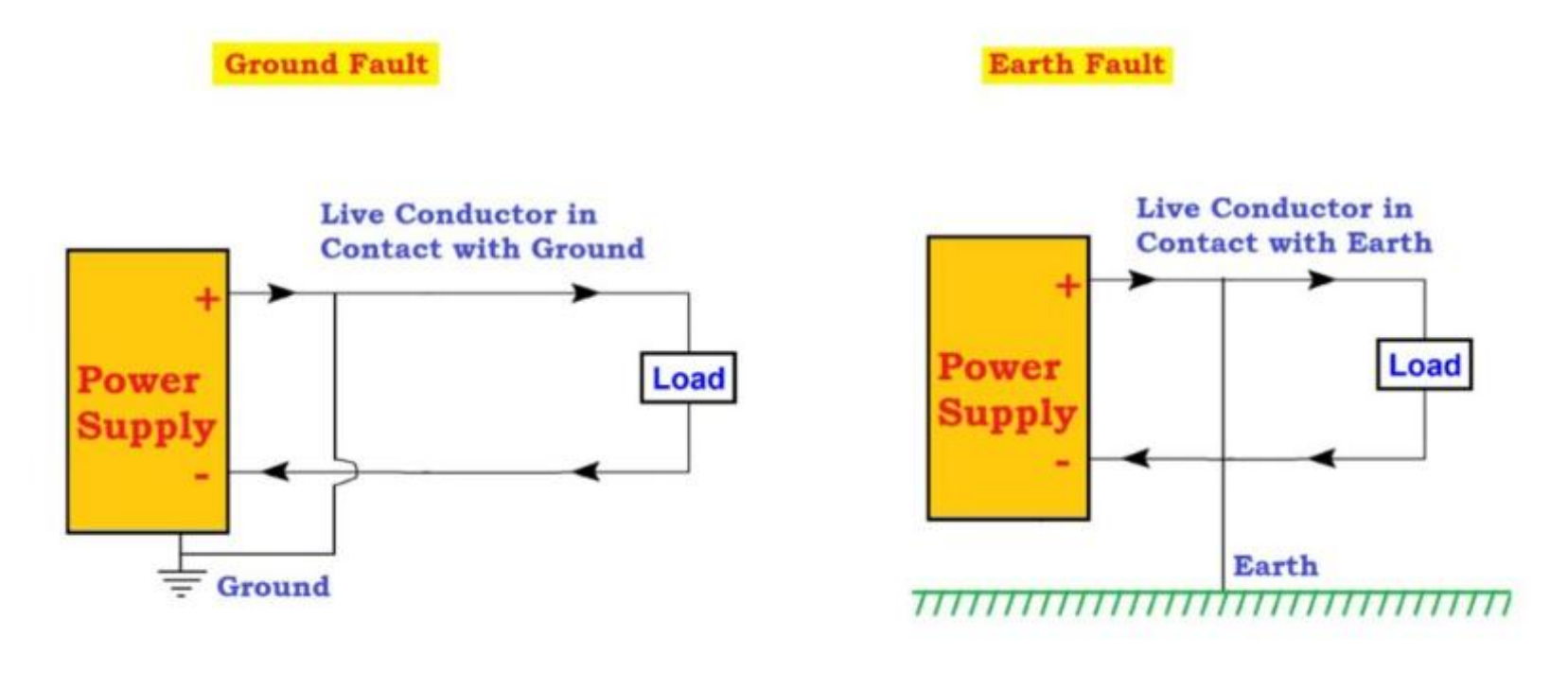
“Not all problems announce themselves electrically.
Some speak through sound, time, and behaviour.”

Key Takeaways

- Not all faults are failures
- Time patterns matter
- Network behaviour matters
- Investigation beats assumption

Final Thought

"Earth Faults Don't Care About Symbols - They Care About Circuits"



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Q&A

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Master of Science (Power System Analysis and Renewable Integration)	1 June 2026
Master of Science (Industrial Automation and Instrumentation Control)	1 June 2026

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Bachelor of Engineering Technology in Electrical Engineering	3 August 2026

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Contact Us:

Website
www.eit.edu.au

Head Office
6 & 8 Thelma Street, West Perth,
Perth, WA 6005

Phone
Inside Australia: 1300 138 522
Outside Australia: +61 8 9321 1702

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