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

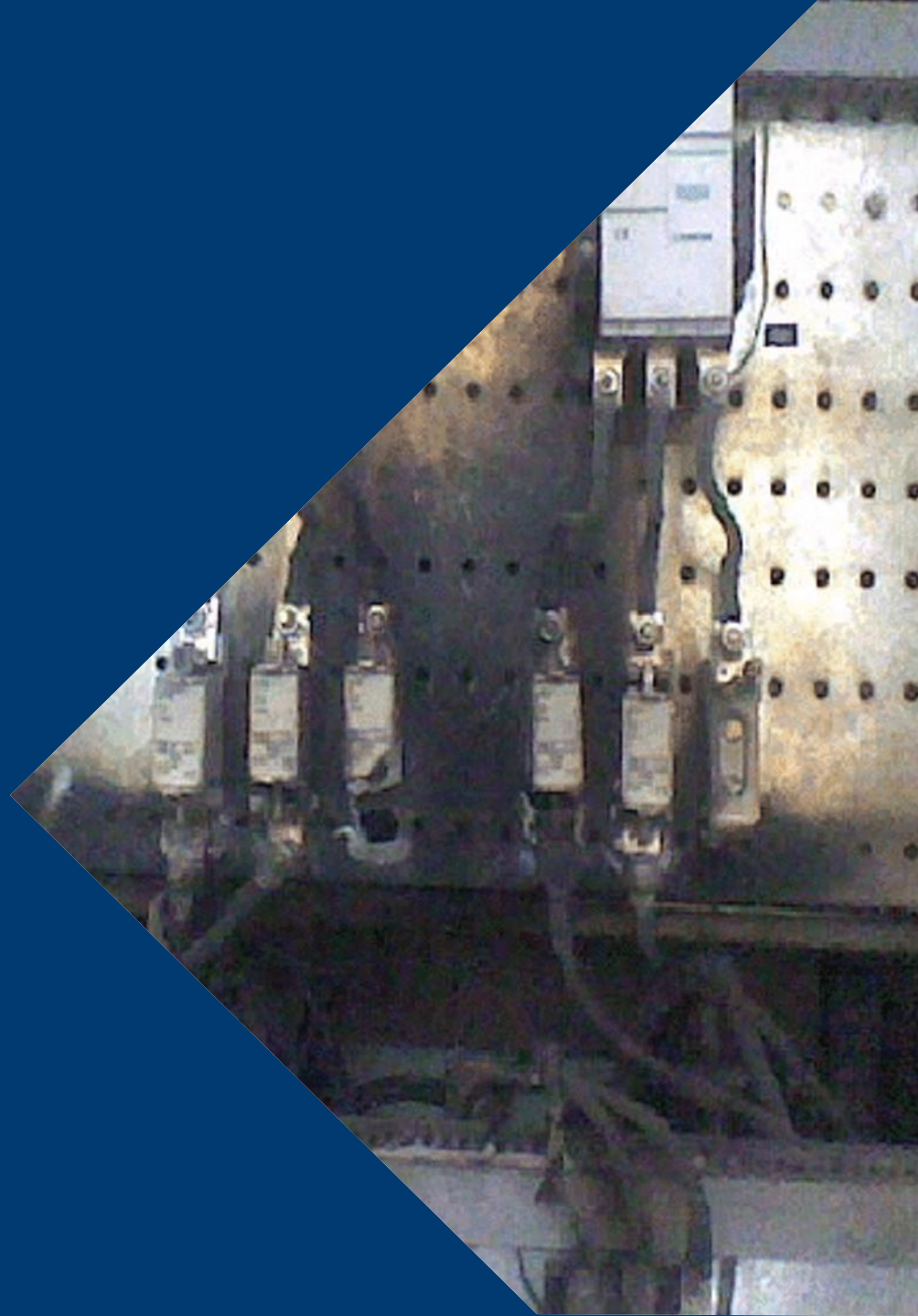
The Capacitor Bank That Blew Itself Up Quietly

Date: 16 July 2026

Emeritus Professor Akhtar Kalam

EIT EMERITUS PROFESSOR

Watch Webinar Recording Here



About EIT

We are dedicated to ensuring that you receive a world-class education and gain skills that you can immediately implement in the workforce.

Engineering Specialists

EIT is one of the only institutes in the world specializing in Engineering. We deliver professional certificates, diplomas, advanced diplomas, undergraduate and graduate certificates, graduate diplomas, bachelor's and master's degrees, and a Doctorate of Engineering.

Industry Oriented Programs

Our programs are designed by industry experts, ensuring you graduate with cutting-edge skills that are valued by employers. Our program content remains current with rapidly changing technology and industry developments.

World-Class Australia Accredited Education

Our vocational programs and higher education degrees are registered and accredited by the Australian Government. We have programs that are also recognized under three international engineering accords.

Industry Experienced Lecturers

Our lecturers are highly experienced engineers and subject specialists with applied knowledge. The technologies employed by EIT, both online and on-campus, enable us to source our lecturers from a large, global pool of expertise.

Unique Delivery Model

We deliver our programs via a unique delivery methodology that makes use of live and interactive webinars, an international pool of expert lecturers, dedicated learning support officers, and state-of-the-art such as hands-on workshops, remote laboratories, and simulation software.

ECT delivers interactive and online **UK qualifications**. ECT is committed to providing students with a world-class education, where they acquire the knowledge and skills that are applicable and valued in industry.

- Bachelor of Engineering (Honours) in Industrial Automation
- Bachelor of Engineering (Honours) in Electrical Engineering
- Master of Science (Power System Analysis and Renewable Integration)
- Master of Science (Industrial Automation and Instrumentation Control)

Learn more here.

Registered UK Higher Education Provider | UKPRN: 10089771

ECST delivers a **South African accredited qualification** on-campus. ECST is committed to providing students with a world-class education, where they acquire the knowledge and skills that are applicable and valued in industry.

- Bachelor of Engineering Technology in Electrical Engineering (SAQA 123645)

Learn more here.

The Engineering College of Science and Technology (Pty) Ltd is provisionally registered with the Department of Higher Education and Training until 31/12/2028 as a private higher education institution under the Higher Education Act, 1997. Registration certificate no. 2025/HE07/007.

IDC Technologies – Practical Engineering & Technical Training

Founded in 1992 to deliver engineering and technical training that supports industry needs.

Specializes in professional development across:

- Electrical Engineering
- Instrumentation & Process Control
- Information Technology
- Mechanical Systems
- Project Management

Focuses on practical, real-world learning with skills that can be applied immediately in the workplace. Courses, workshops, and conferences are developed in consultation with industry to ensure relevance and impact. Supports engineers, technicians, and technical professionals in building job-ready expertise. Over 30 years of training experience with a strong presence across Australia and international markets. Continues to play a key role in upskilling the engineering workforce and strengthening technical capability across industries

Disclaimer

The courses and qualifications mentioned in this presentation are offered by separate legal entities operating in different jurisdictions – one in Australia, one in South Africa and one in the United Kingdom. Each entity is subject to its own local regulatory requirements and accreditation standards.

Prospective students should refer to the relevant institution's official website for accurate, up-to-date information specific to their location, including course availability, fees, regulatory status, and enrolment conditions.

- For the Engineering Institute of Technology (EIT) visit: https://www.eit.edu.au/
- For the Engineering College of Technology (ECT) visit: https://www.ect.ac.uk/
- For the Engineering College of Science and Technology (ECST) visit: https://www.ecst.ac.za/

Event Conduct

Please keep discussion lawful and respectful; follow the moderator’s directions.
Do not share illegal or abusive content. Recording is not permitted unless authorised.
Breaches may lead to removal.

To protect intellectual property, confidential information, and the privacy of presenters and attendees, the use of AI note-taking bots, recording bots, or automated meeting assistants is not permitted during this webinar. Any unauthorized AI agents may be removed from the session at the organizer's discretion.

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."

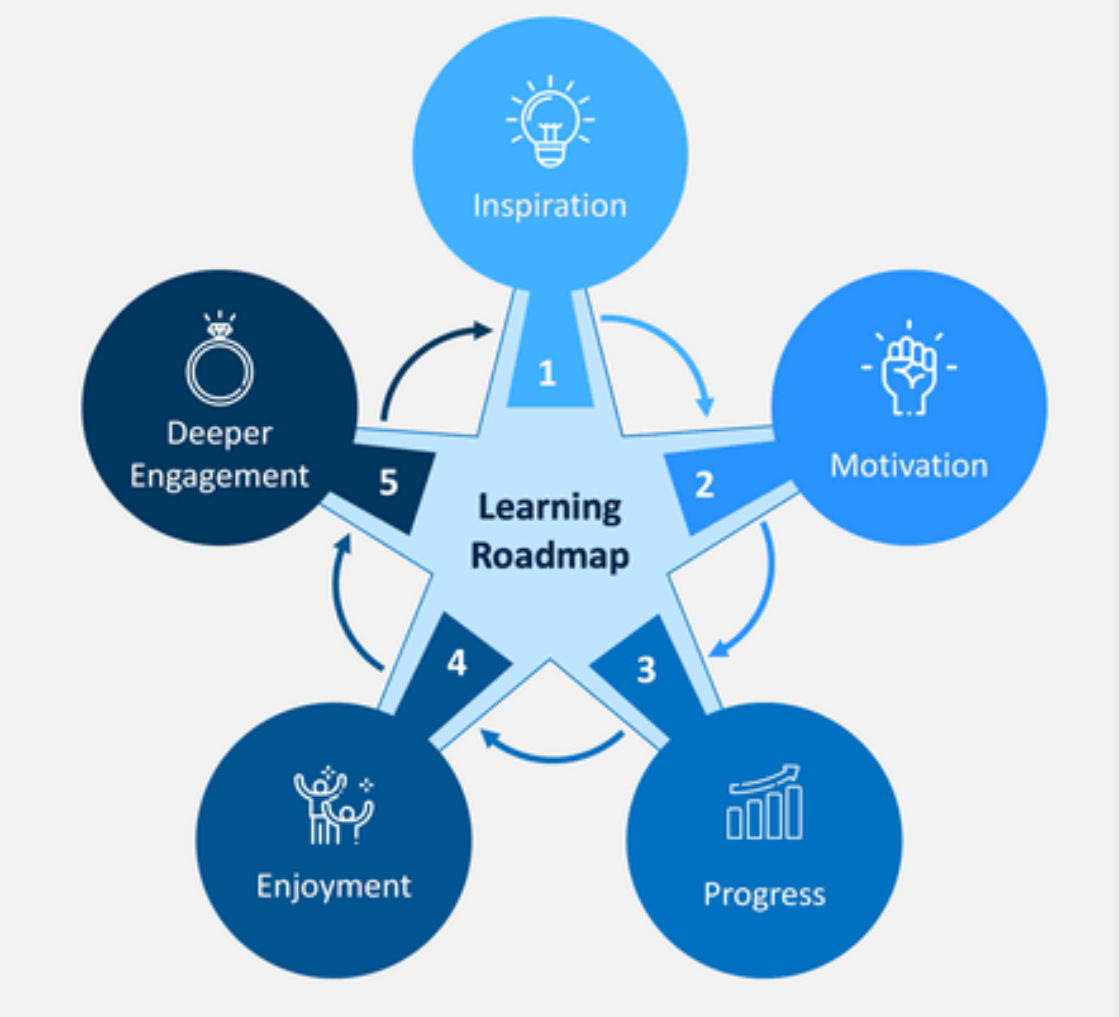
Agenda

1	Learning Objectives
2	The Mystery Begins
3	The Protection Puzzle
4	Asset Management Lessons
5	Modern Power Systems Challenge
6	Broader Engineering Lessons
7	Final Reflection

Learning Objectives

By the End of This Session Participants will be able to:

- Explain the purpose of capacitor banks
- Understand common capacitor bank failure modes
- Identify harmonic-related risks
- Explain resonance phenomena
- Investigate unusual asset failures
- Develop mitigation strategies



The Mystery Begins

What Happened?

An 11 kV capacitor bank suddenly failed inspection.

Observations:

- ✓ No protection trip
- ✓ No explosion heard
- ✓ No fire
- ✓ No visible external damage

Yet:

- ✗ Several capacitor units were internally destroyed.

Initial Clues

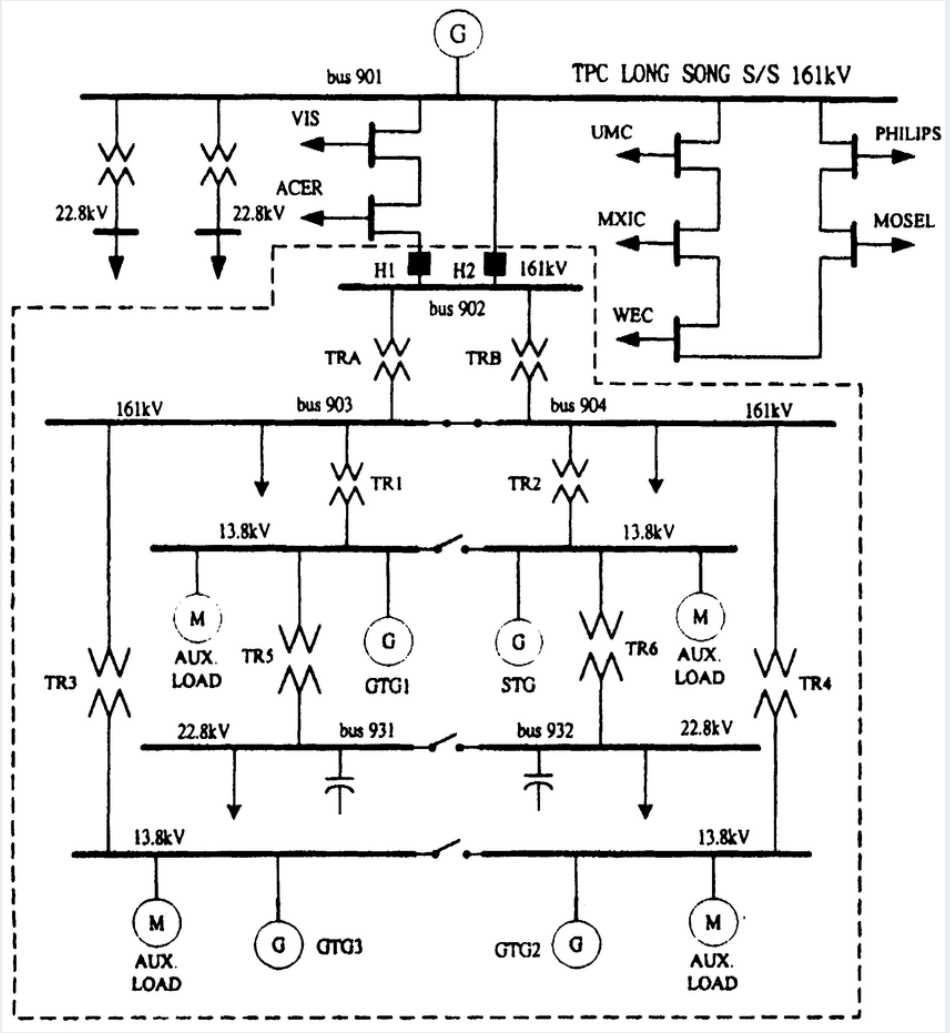
Site Conditions

Industrial facility

- Large VSD installations
- Arc furnaces
- Non-linear loads
- Significant harmonic distortion

Capacitor bank:

- Installed 7 years earlier
- Rated for expected reactive demand
- No major modifications reported

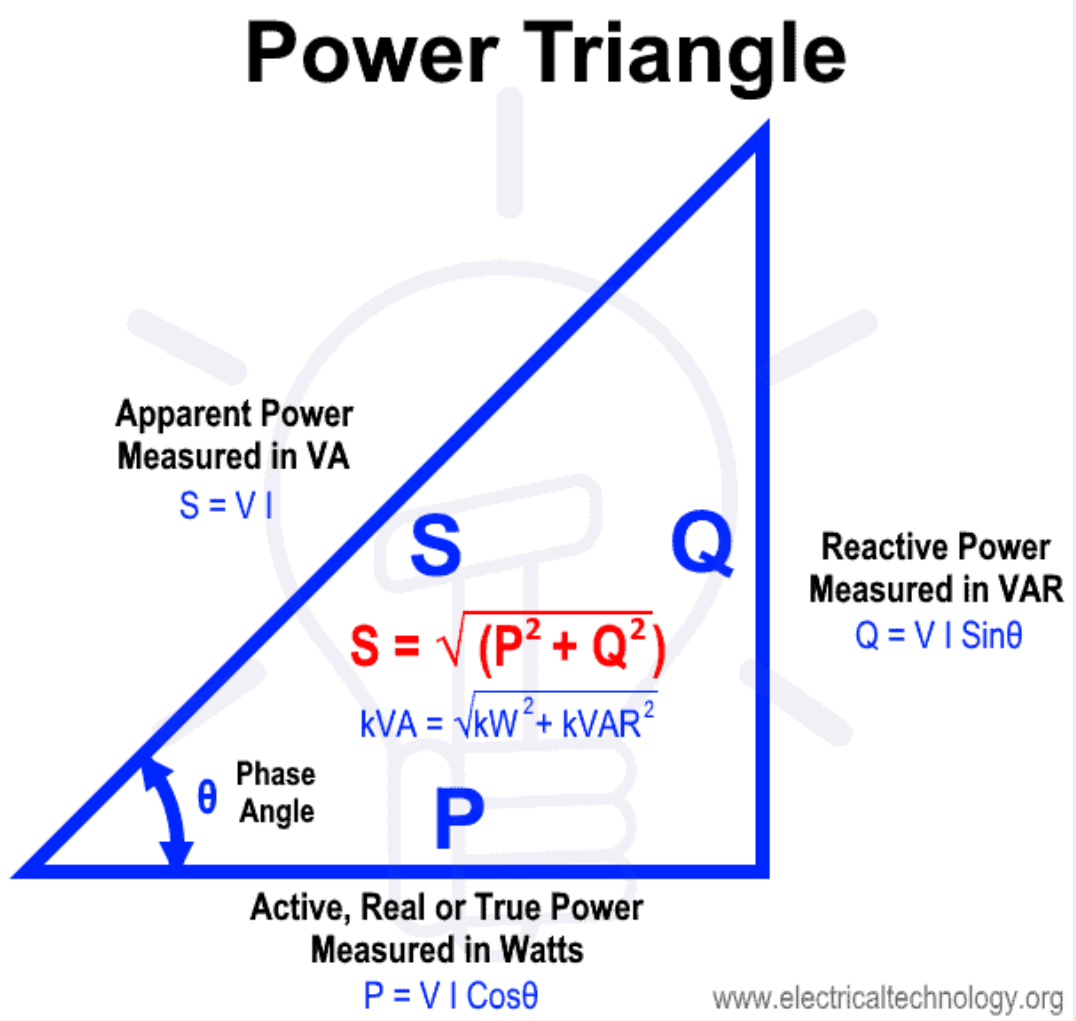


Why do capacitor banks exist?

Primary Functions

Capacitor banks:

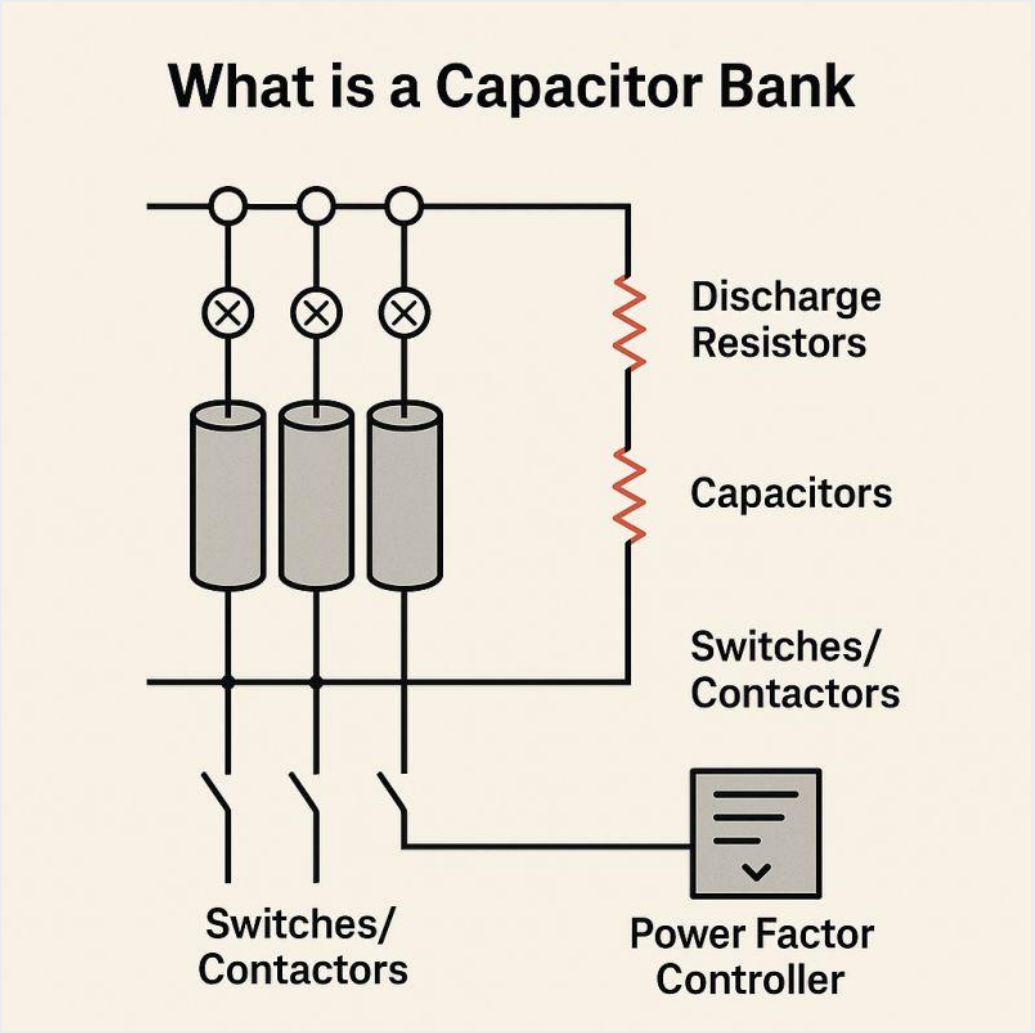
- Improve power factor
- Reduce network losses
- Increase voltage support
- Release transformer capacity
- Reduce demand penalties



Typical Capacitor Bank Construction

Main Components:

- Capacitor units
- Fuses
- Switching devices
- Protection relays
- Current transformers
- Voltage transformers
- Discharge resistors



Normal Failure Modes

Common Causes:

- Dielectric breakdown
- Overvoltage
- Overcurrent
- Ageing
- Moisture ingress
- Manufacturing defects
- Switching transients

Inspection Findings

Internal Examination

Engineers discovered:

- Bulging capacitor cans
- Ruptured dielectric layers
- Discoloured internal components
- Elevated temperatures

No evidence of:

- Lightning
- Major switching surge
- External short circuit

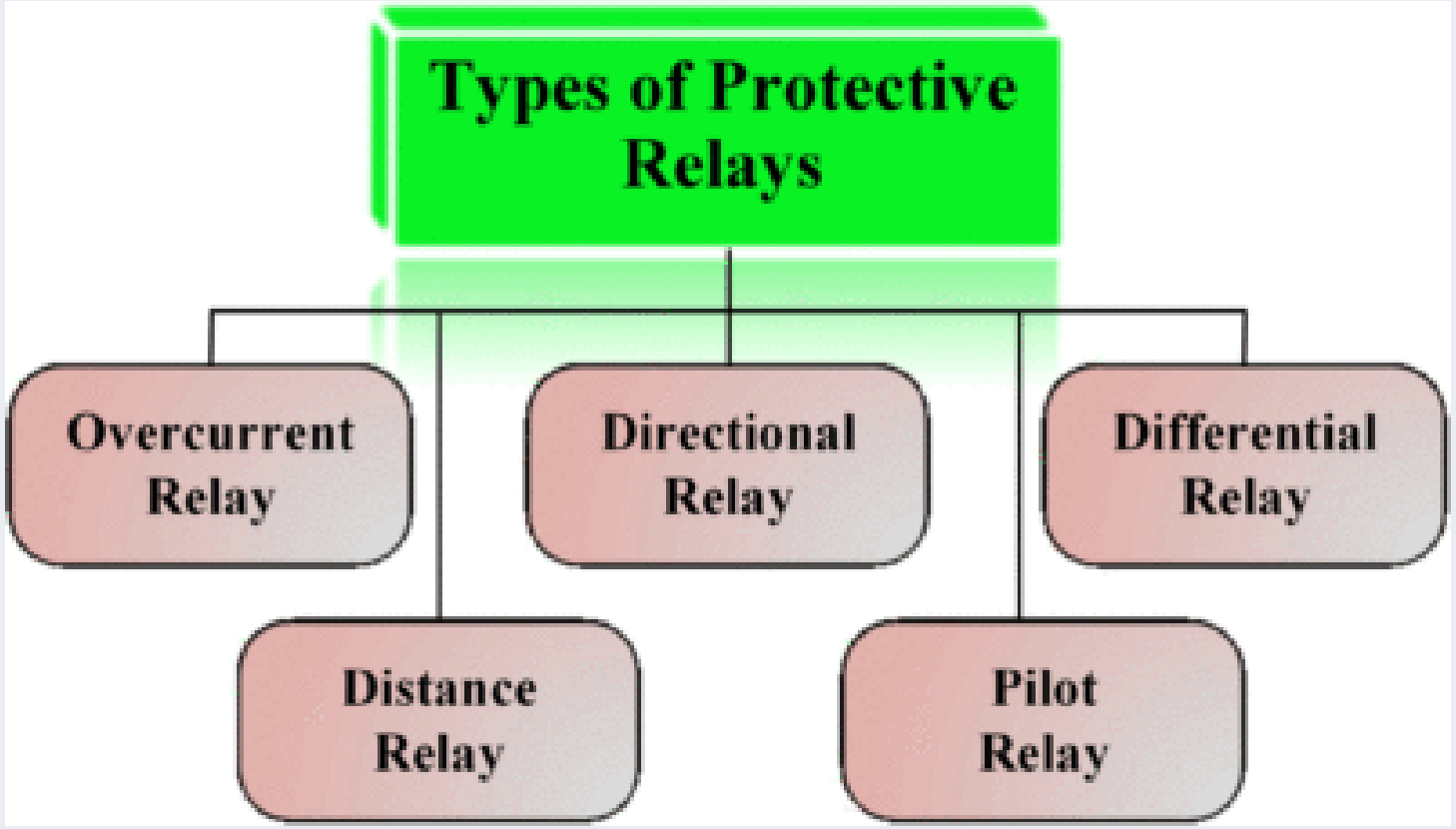
The Protection Puzzle

Why Didn't Protection Operate?

Protection included:

- Overcurrent
- Earth fault
- Unbalance detection

No recorded trip events.



First Investigation Hypothesis

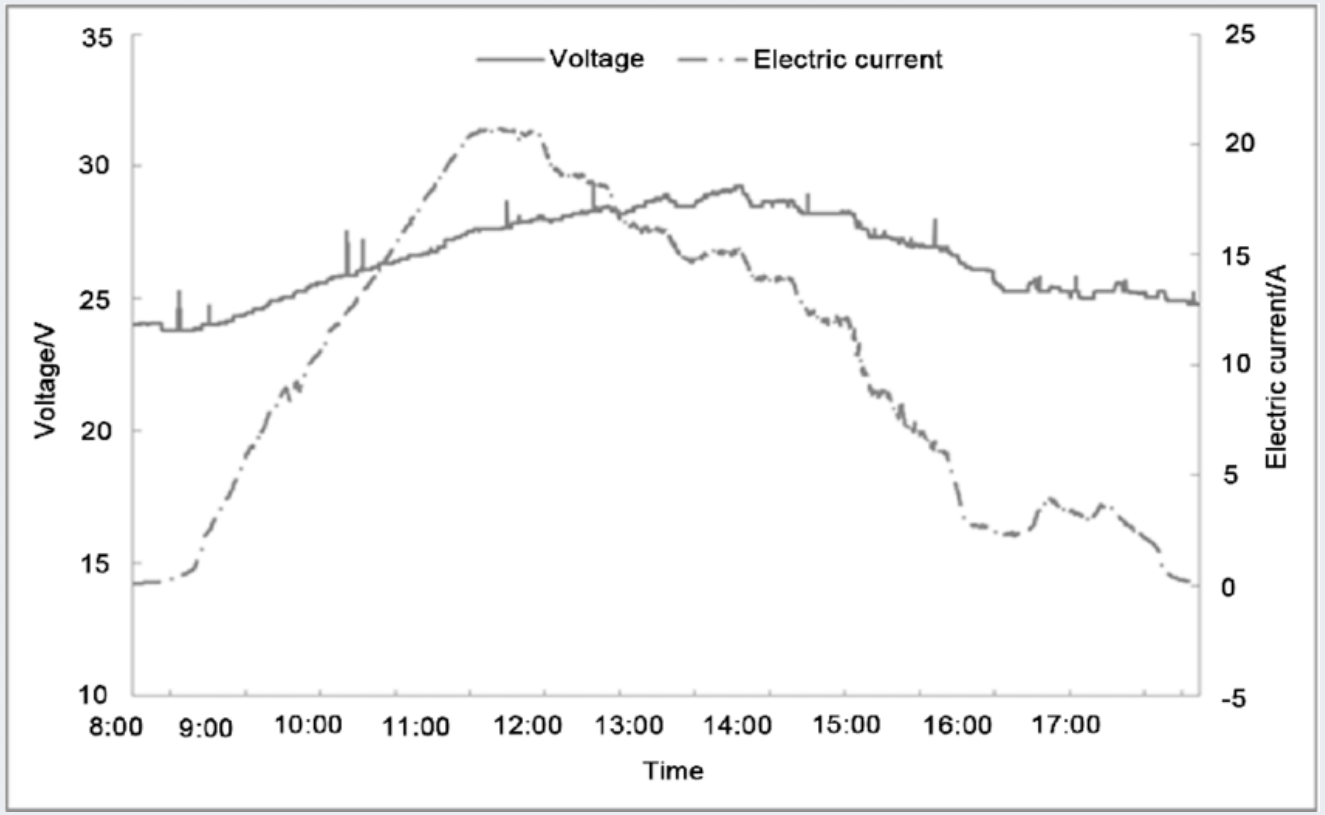
Was It Overvoltage?

Measurements showed:

- System voltage within limits
- No significant utility disturbances
- No recorded voltage excursions

Conclusion:

Overvoltage unlikely.

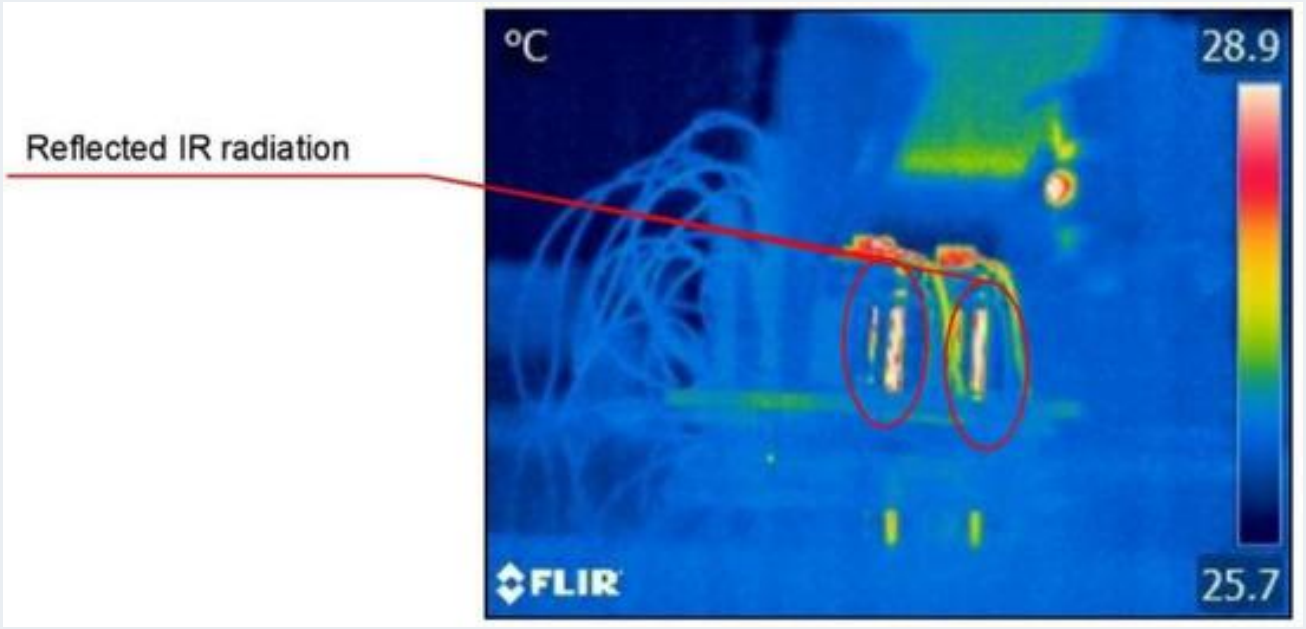


Thermal Investigation

Temperature History

Infrared inspection records showed:

- Slight temperature increase
- Progressive worsening
- No alarm thresholds exceeded

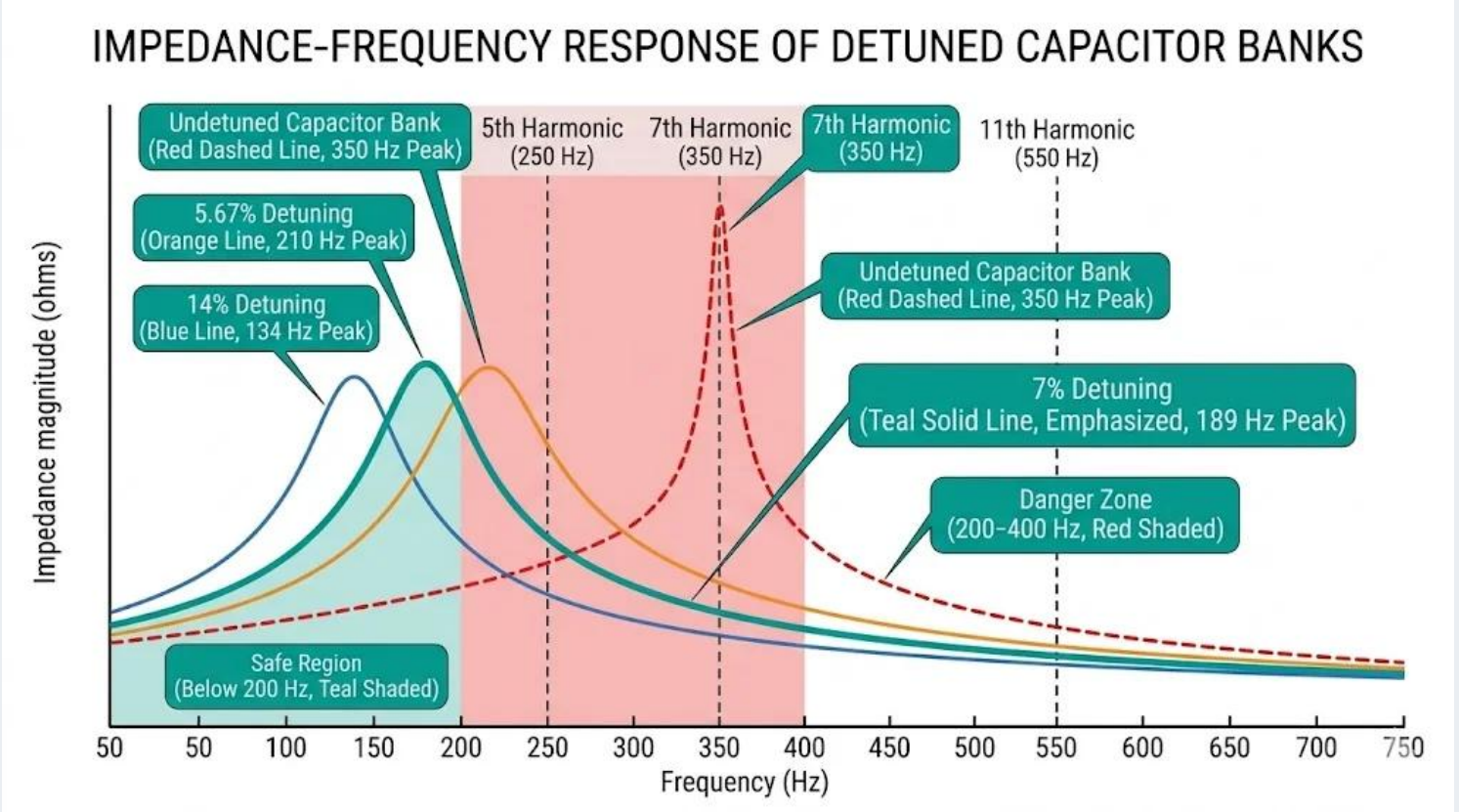


Looking at Harmonics

Harmonic Measurements

Power quality survey revealed:

- High 5th harmonic
- Significant 7th harmonic
- Elevated THD



Sources of Harmonics

Harmonic-Producing Equipment

- Variable speed drives
- UPS systems
- Arc furnaces
- Rectifiers
- Switching power supplies

Capacitor Reactance

Capacitors and Frequency

Capacitive reactance decreases with frequency.

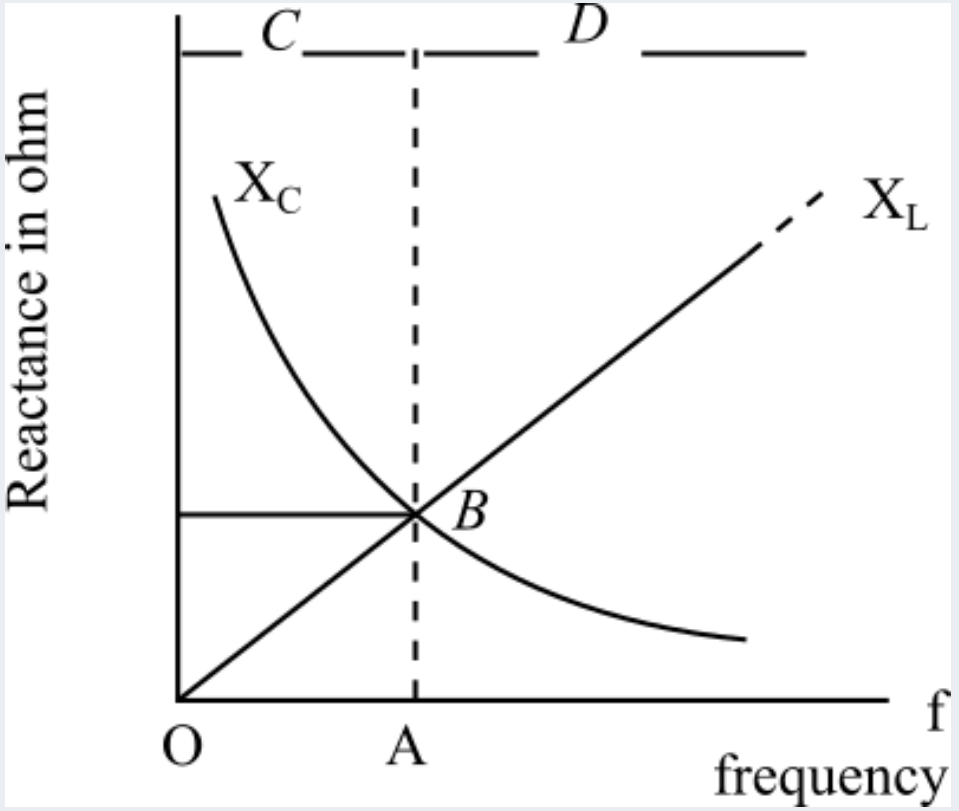
The Reactance Formula

This inverse relationship is governed by the standard mathematical formula for capacitive reactance (X_C):

$$X_C = \frac{1}{2\pi fC}$$

Where:

- X_C is the **capacitive reactance** measured in Ohms (Ω)
- f is the **frequency** of the signal in Hertz (Hz)
- C is the **capacitance** in Farads (F)



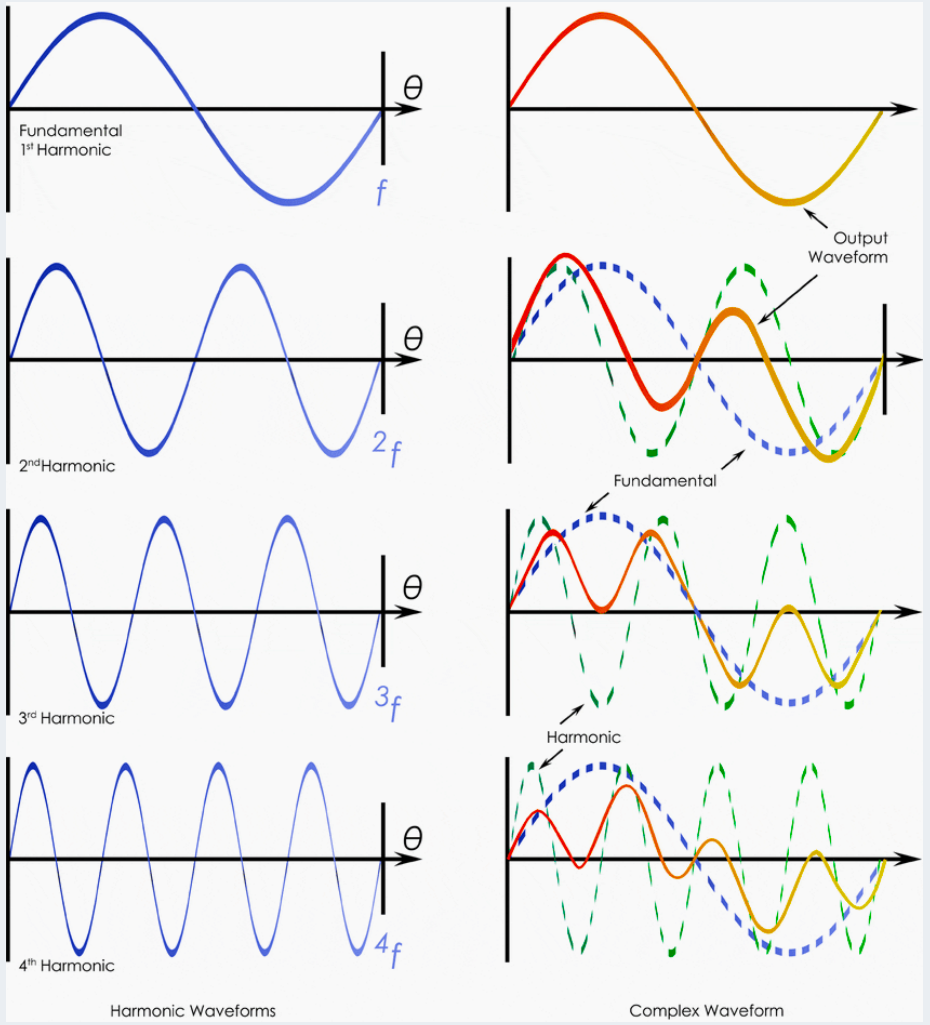
Harmonic Current Amplification

A Hidden Problem

Higher harmonic frequencies can produce:

- Excessive current
- Excessive heating
- Accelerated ageing

Even when fundamental current remains normal.



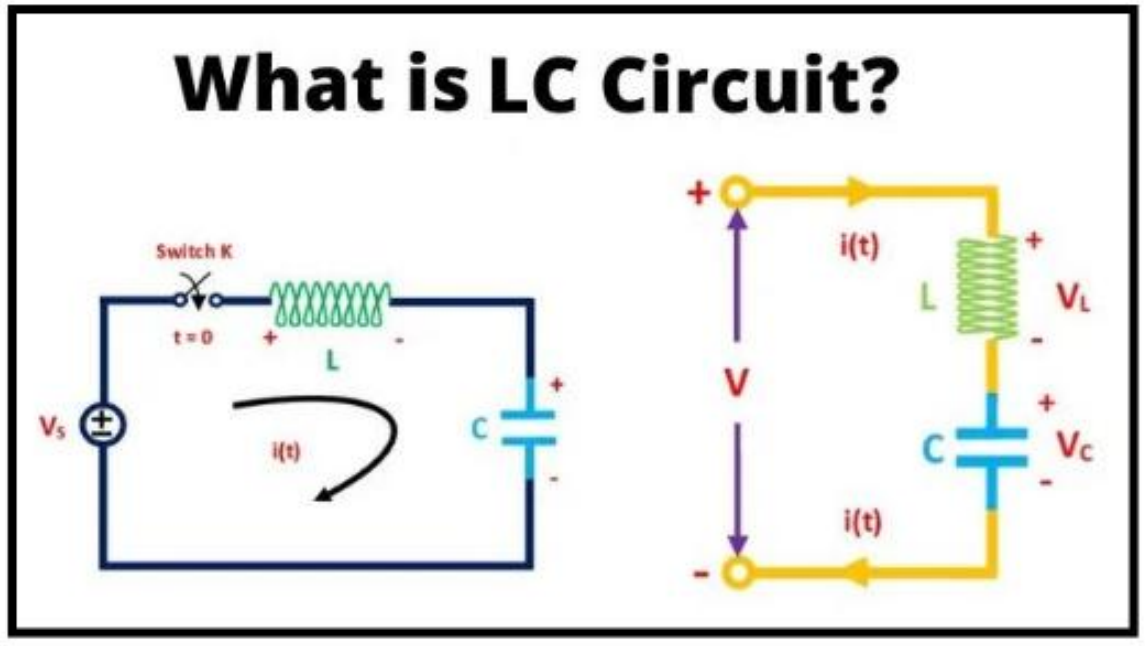
The Resonance Concept

Electrical Resonance

Power systems contain:

- Inductance
- Capacitance

Together, they can form resonant circuits.



Resonant Frequency

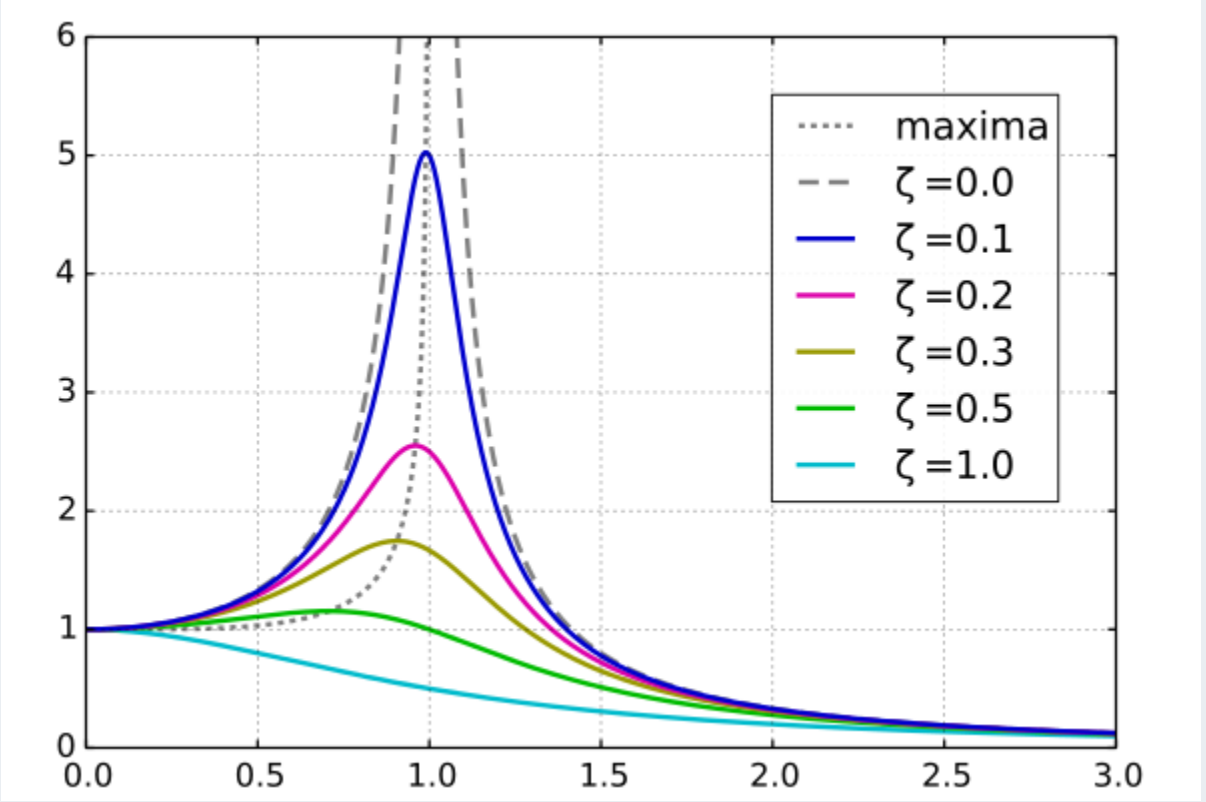
The Critical Frequency

When inductive and capacitive reactance balance:

Resonance occurs.

Consequences:

- High currents
- High voltages
- Equipment stress



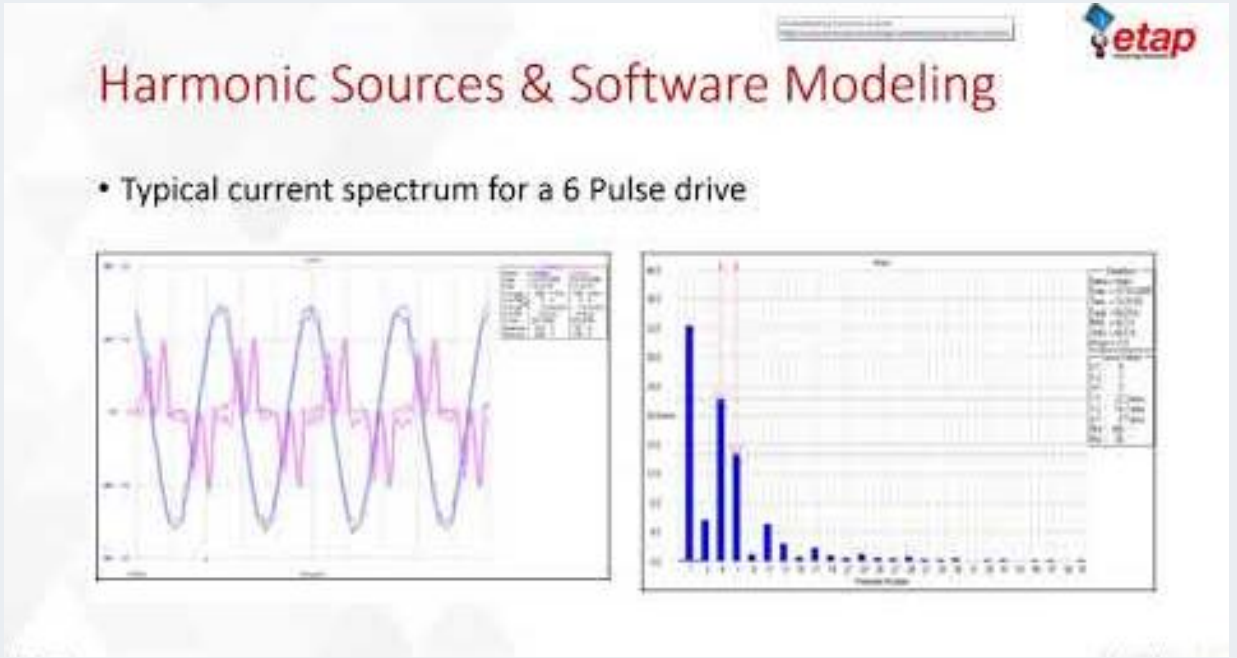
System Modelling

Detailed Simulation

Engineers created:

- Network model
- Harmonic model
- Capacitor bank model

Results indicated resonance near the 5th harmonic.



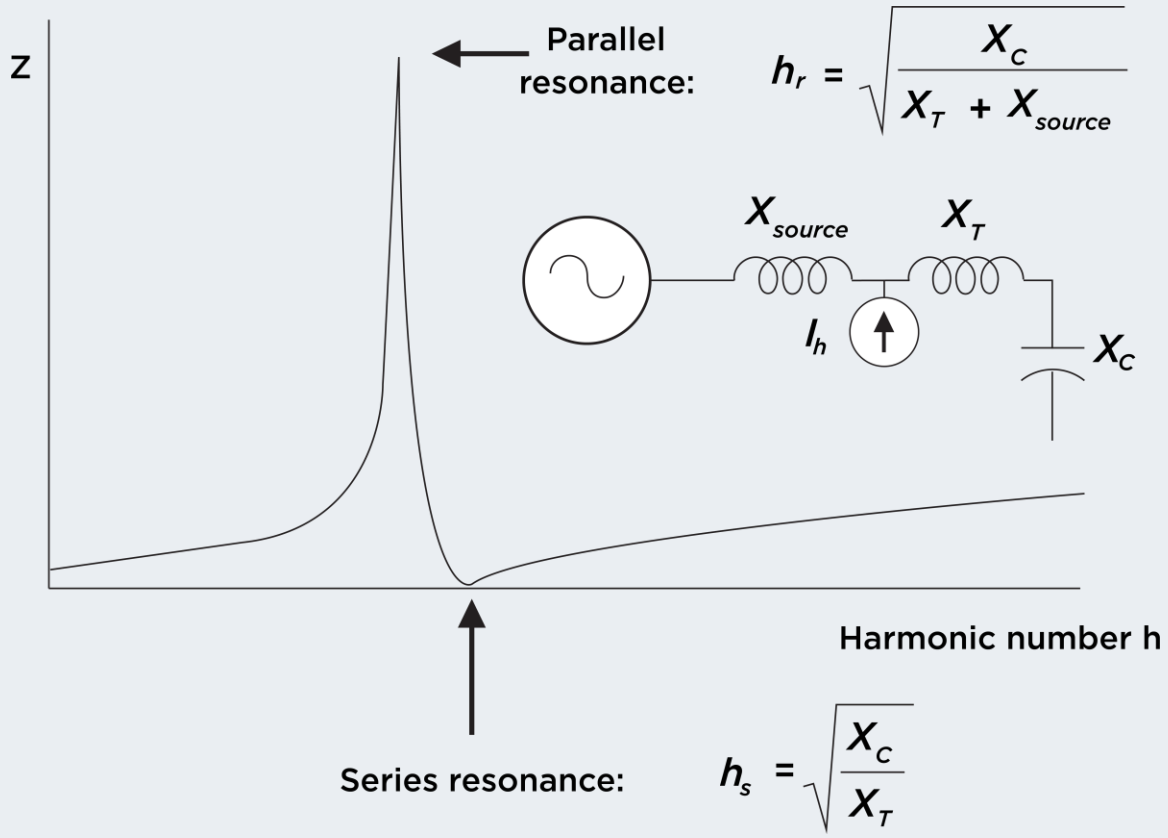
What Resonance Did?

Harmonic Magnification

The capacitor bank became a sink for amplified harmonic currents.

Consequences:

- Increased dielectric stress
- Internal heating
- Progressive degradation



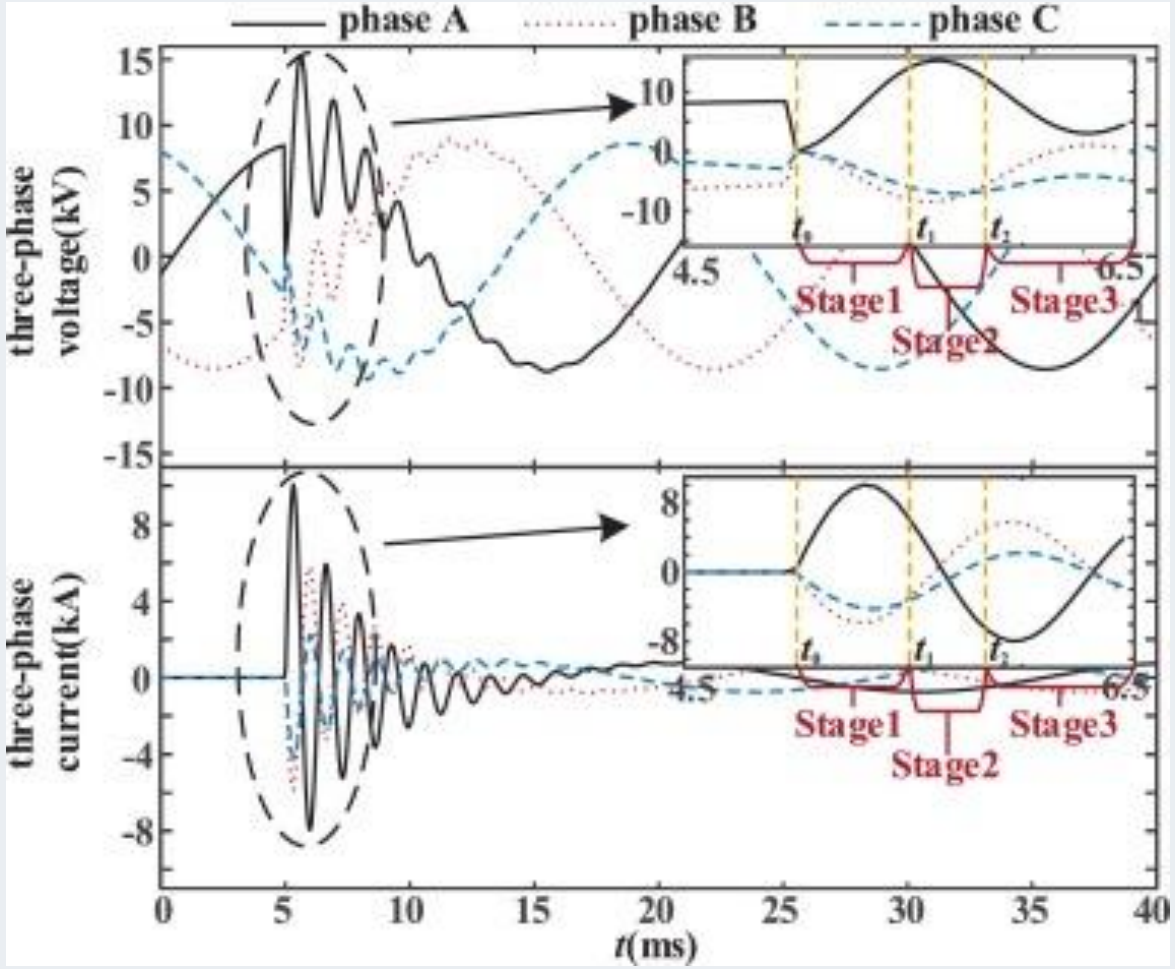
Why Failure Was Quiet?

Gradual Damage Process

Damage accumulated through:

- Continuous overheating
- Dielectric ageing
- Internal pressure increase

No dramatic event occurred.

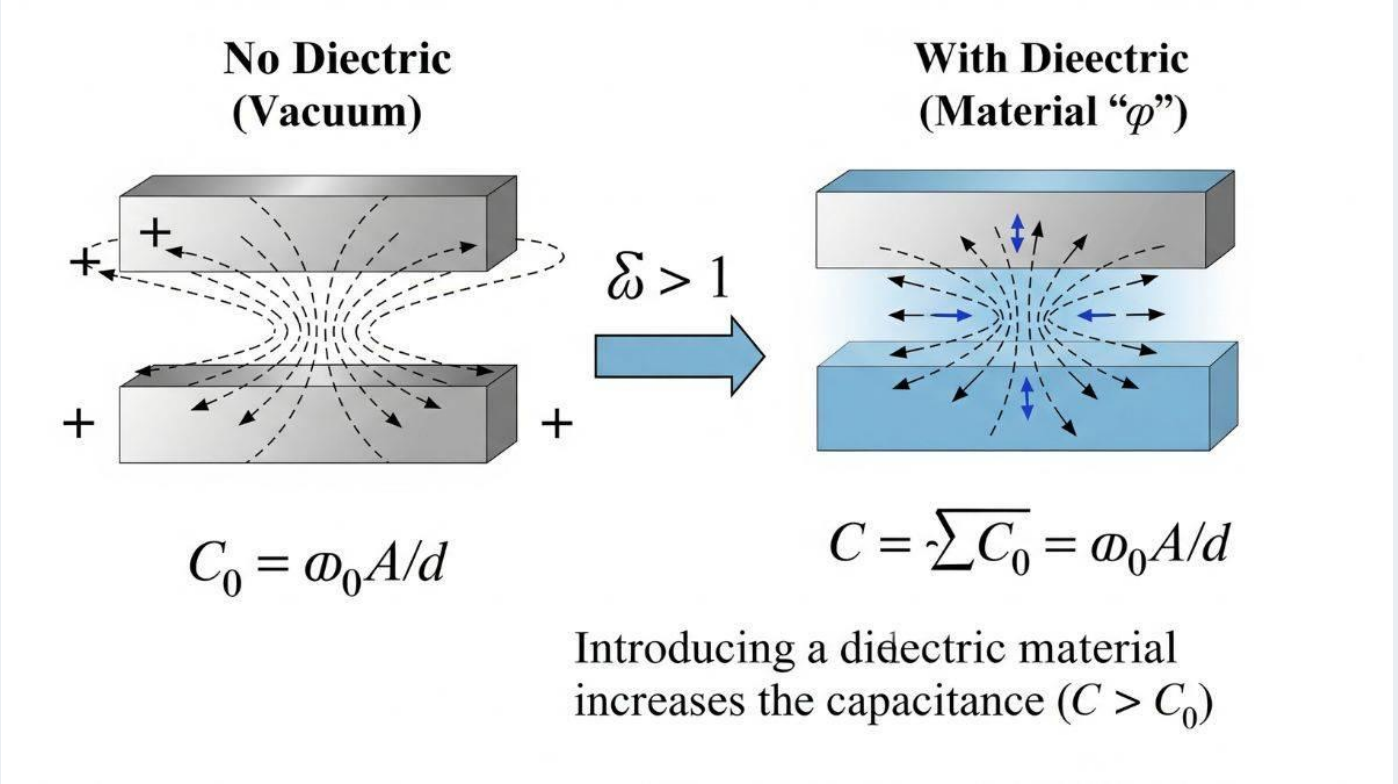


Capacitor Internal Physics

Inside the Capacitor

Failure mechanisms:

- Dielectric deterioration
- Partial discharge
- Gas generation
- Pressure build-up

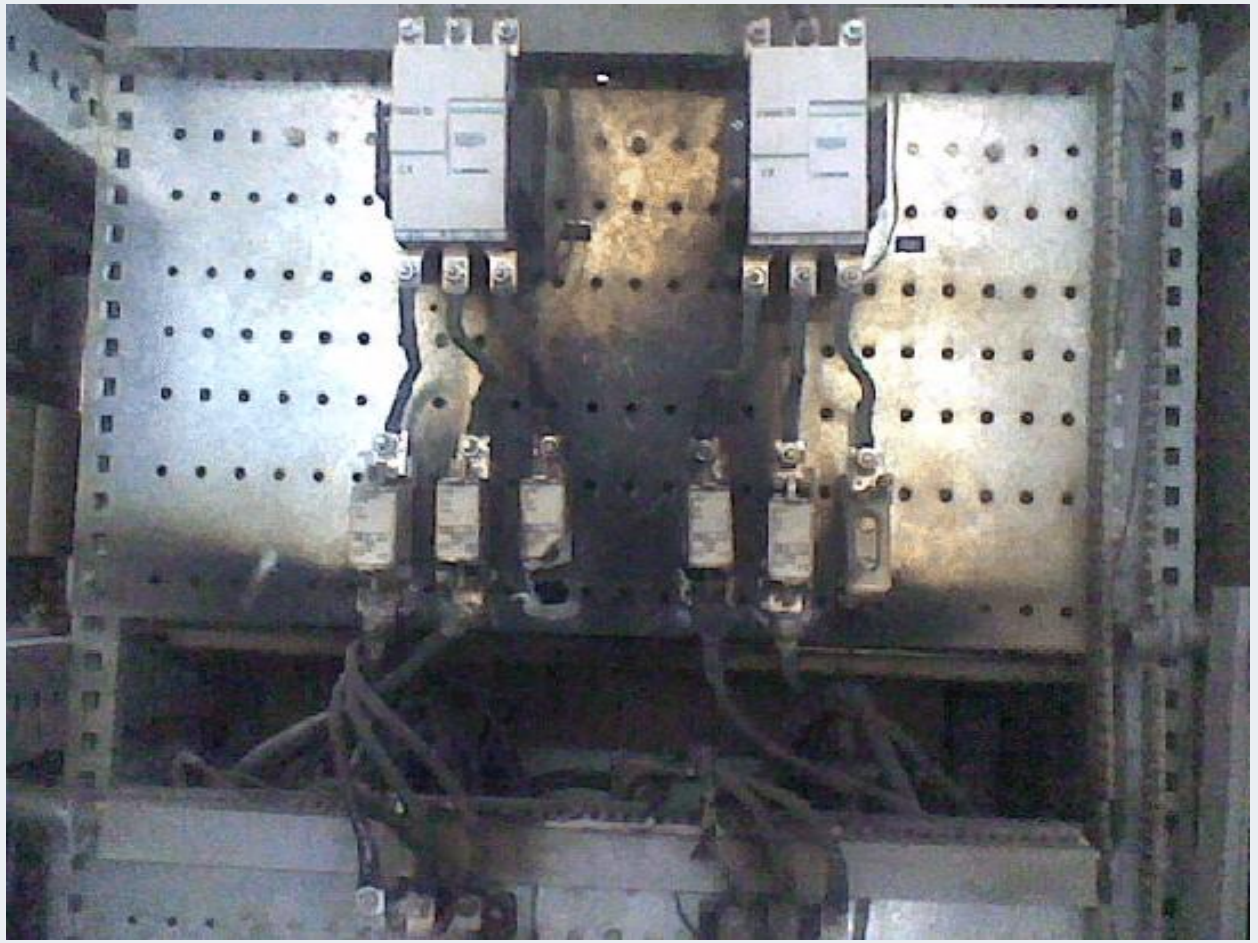


Partial Discharge Evidence

Laboratory Findings

Testing revealed:

- Local insulation breakdown
- Carbonisation tracks
- Dielectric erosion



Why Protection Missed It?

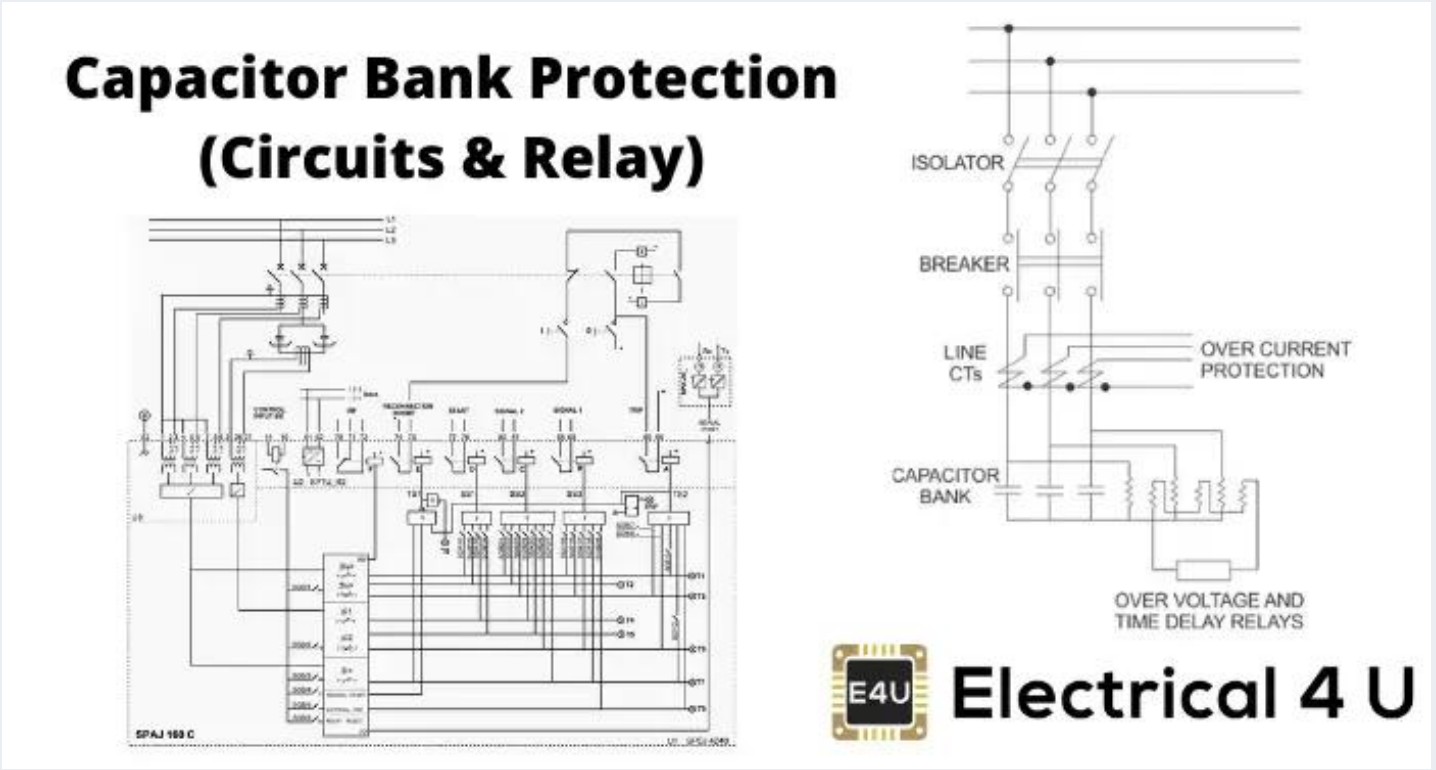
Protection Blind Spots

Protection monitored:

- ✓ Faults
- ✓ Short circuits
- ✓ Unbalance

But not:

- ✗ Progressive harmonic heating

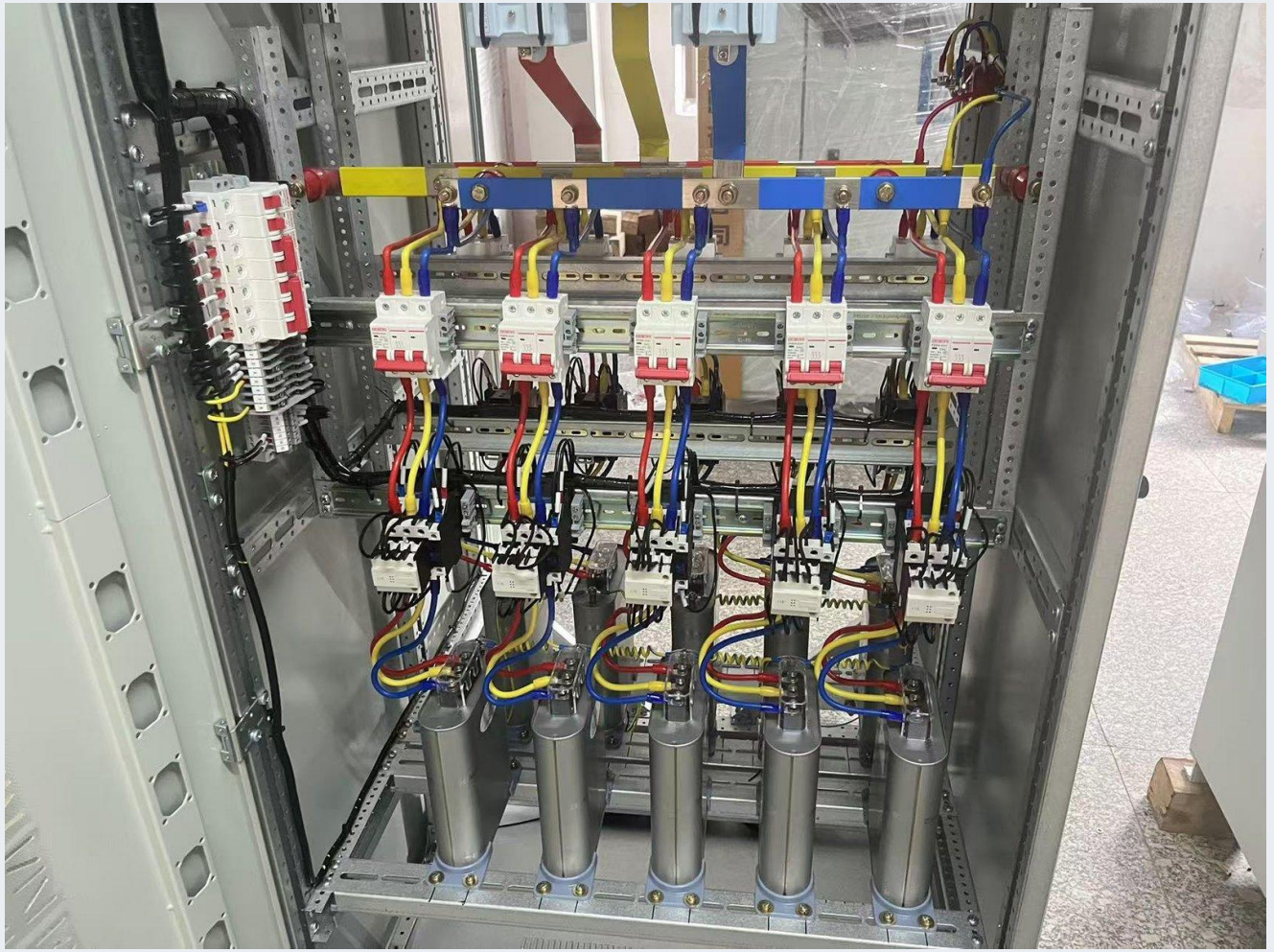


Asset Management Lessons

Monitoring Requirements

Monitor:

- Harmonic levels
- Temperature trends
- Capacitor current
- THD
- Unbalance



Modern Power Systems Challenge

More Electronics = More Harmonics

Growth drivers:

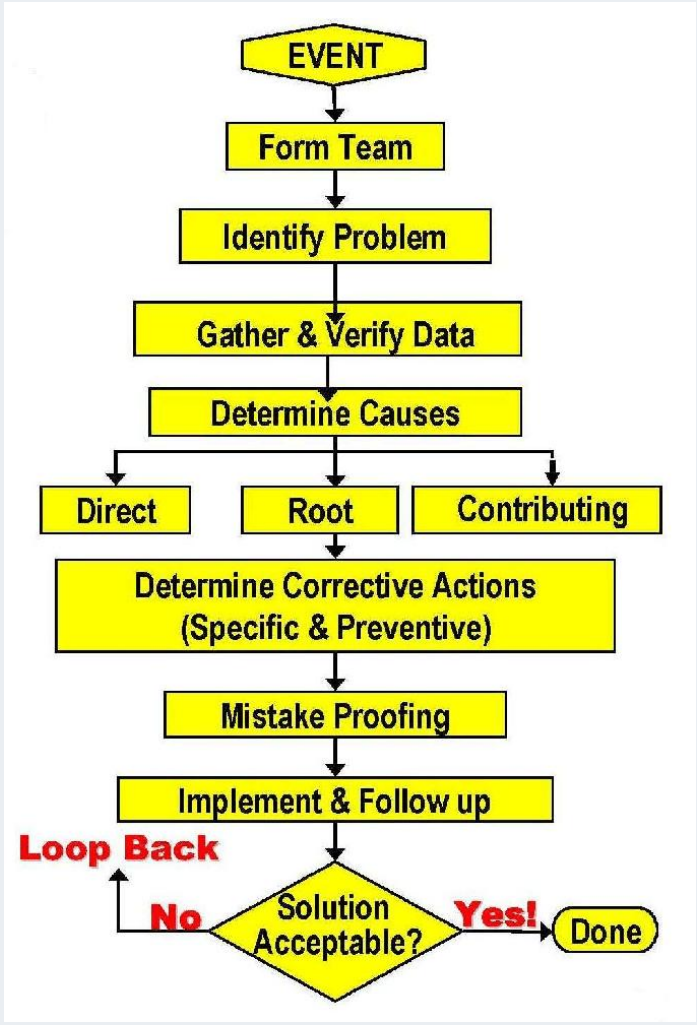
- Renewable energy
- EV charging
- VSDs
- Data centres

Engineering Investigation Process

Structured Root Cause Analysis

1. Gather evidence
2. Eliminate assumptions
3. Examine trends
4. Model system

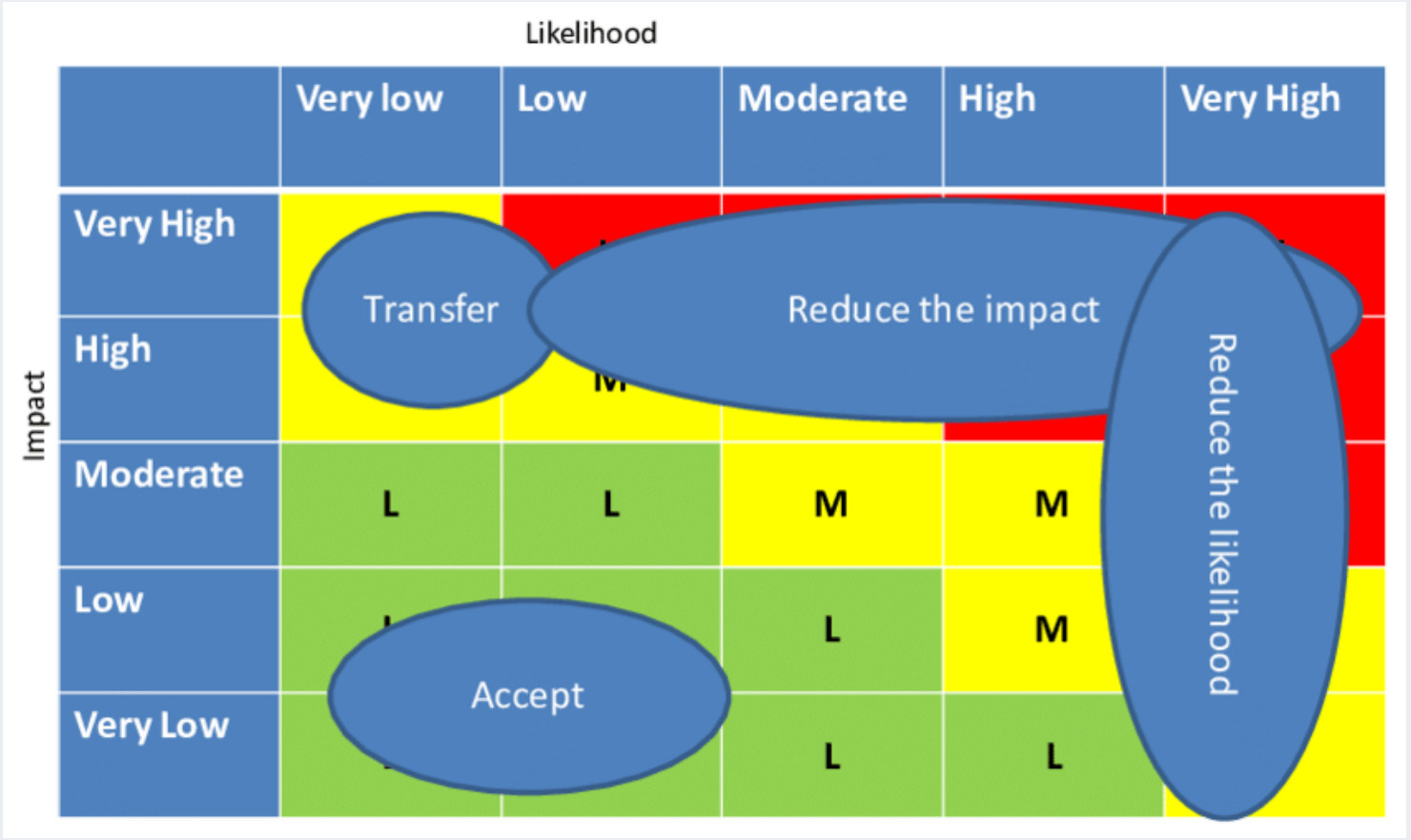
Validate findings



Possible Mitigation Options

Solutions

- Detuned capacitor banks
- Harmonic filters
- Active filtering
- Improved monitoring
- System redesign



Why Protection Missed It?

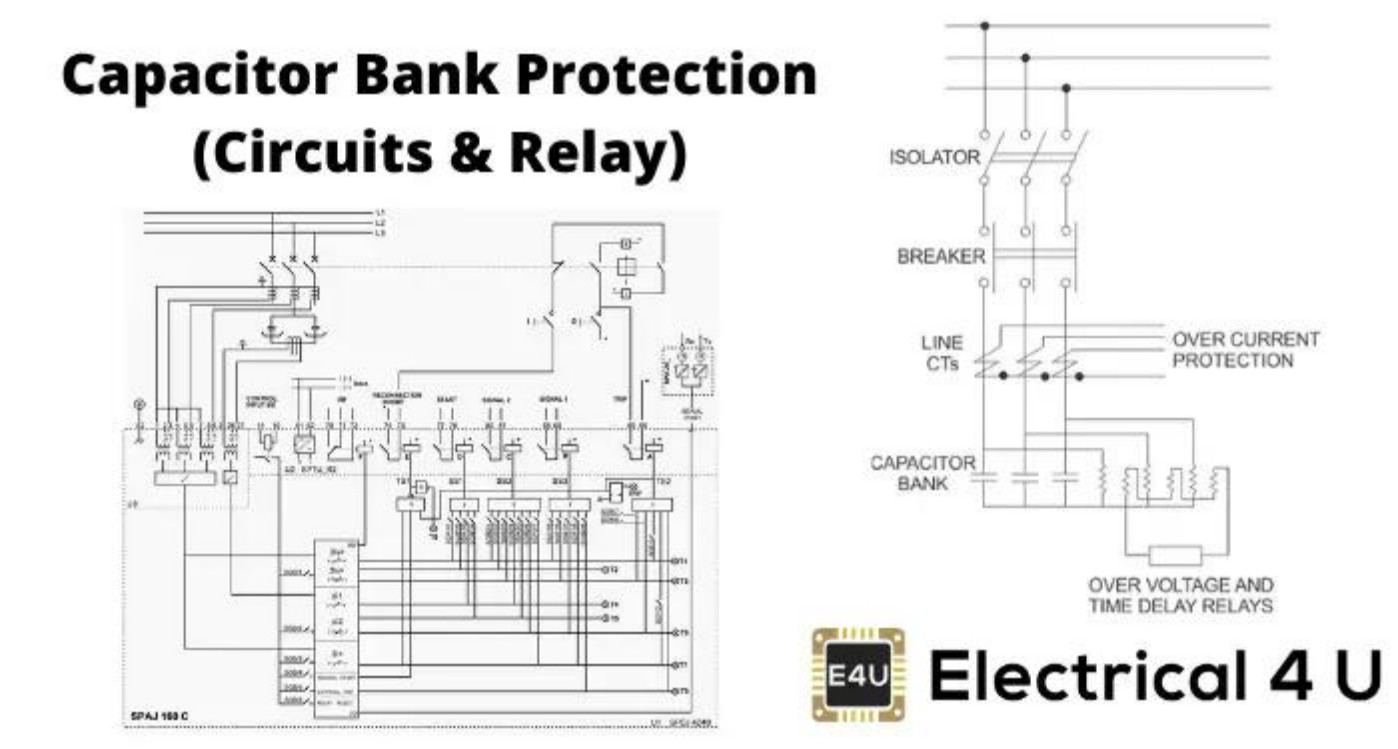
Protection Blind Spots

Protection monitored:

- ✓ Faults
- ✓ Short circuits
- ✓ Unbalance

But not:

- ✗ Progressive harmonic heating

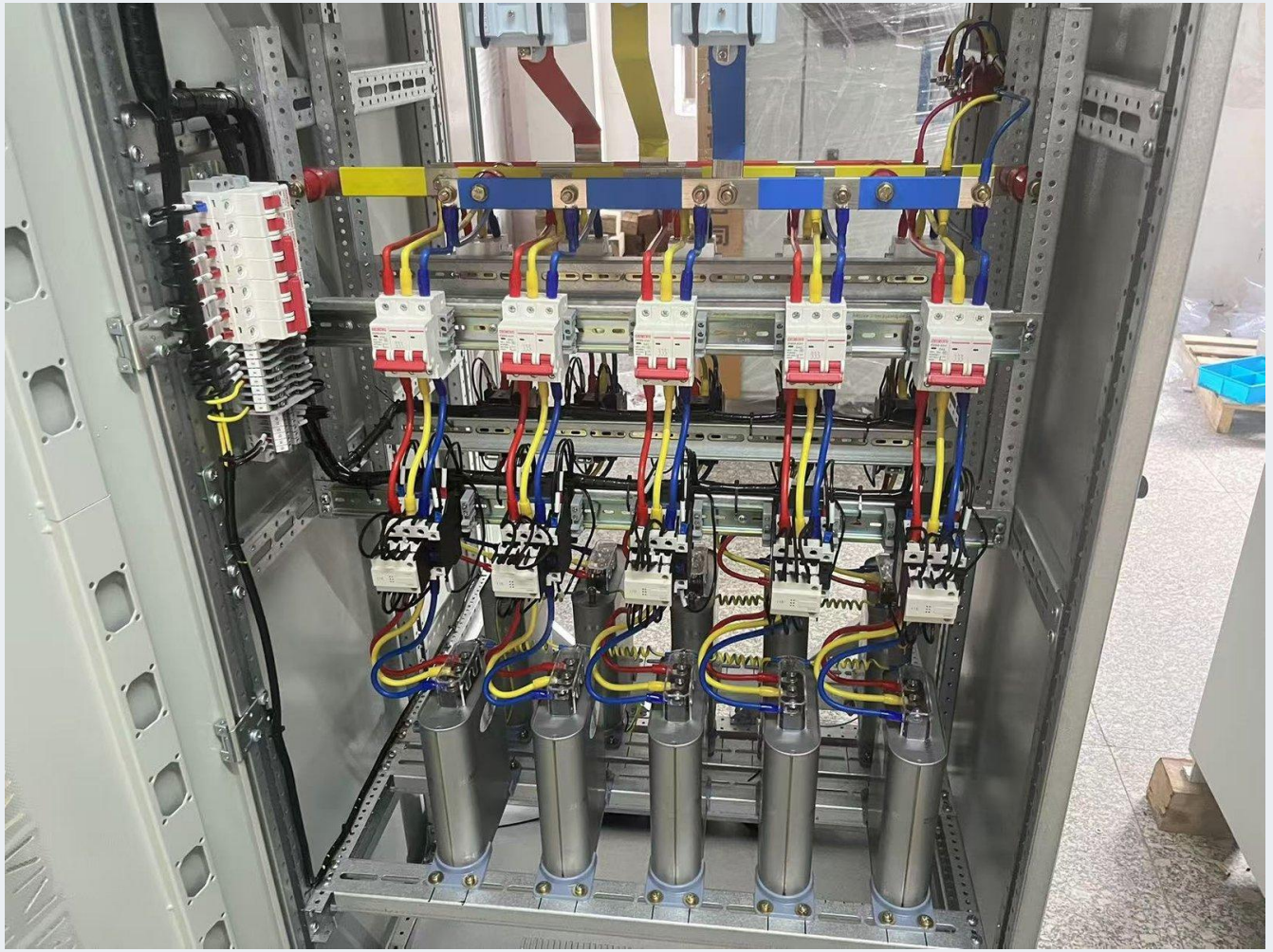


Asset Management Lessons

Monitoring Requirements

Monitor:

- Harmonic levels
- Temperature trends
- Capacitor current
- THD
- Unbalance



Modern Power Systems Challenge

More Electronics = More Harmonics

Growth drivers:

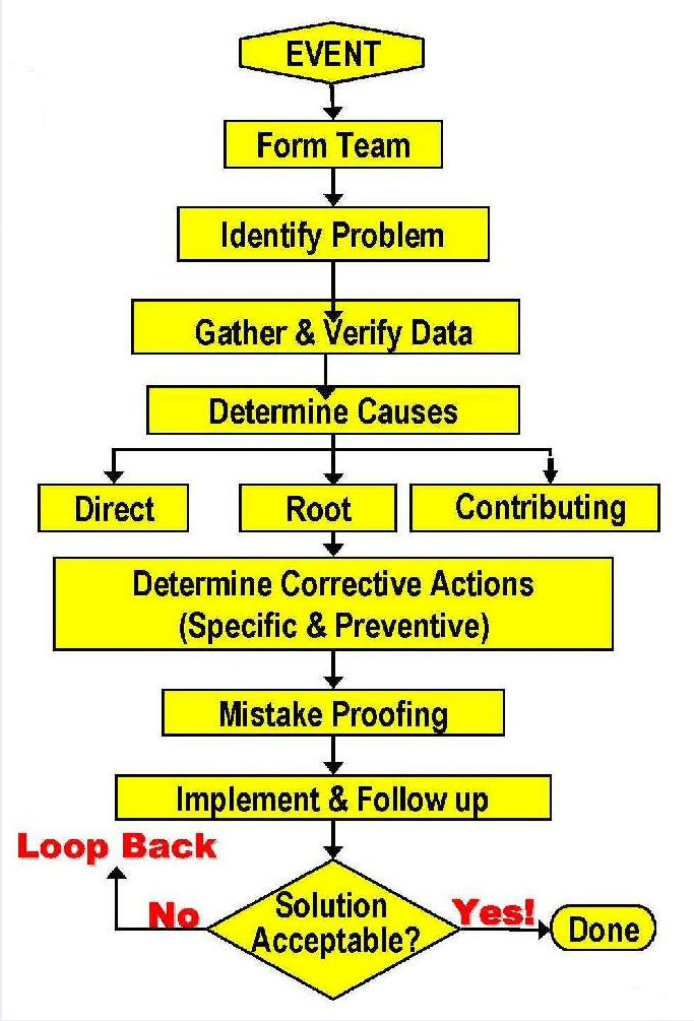
- Renewable energy
- EV charging
- VSDs
- Data centres

Engineering Investigation Process

Structured Root Cause Analysis

1. Gather evidence
2. Eliminate assumptions
3. Examine trends
4. Model system

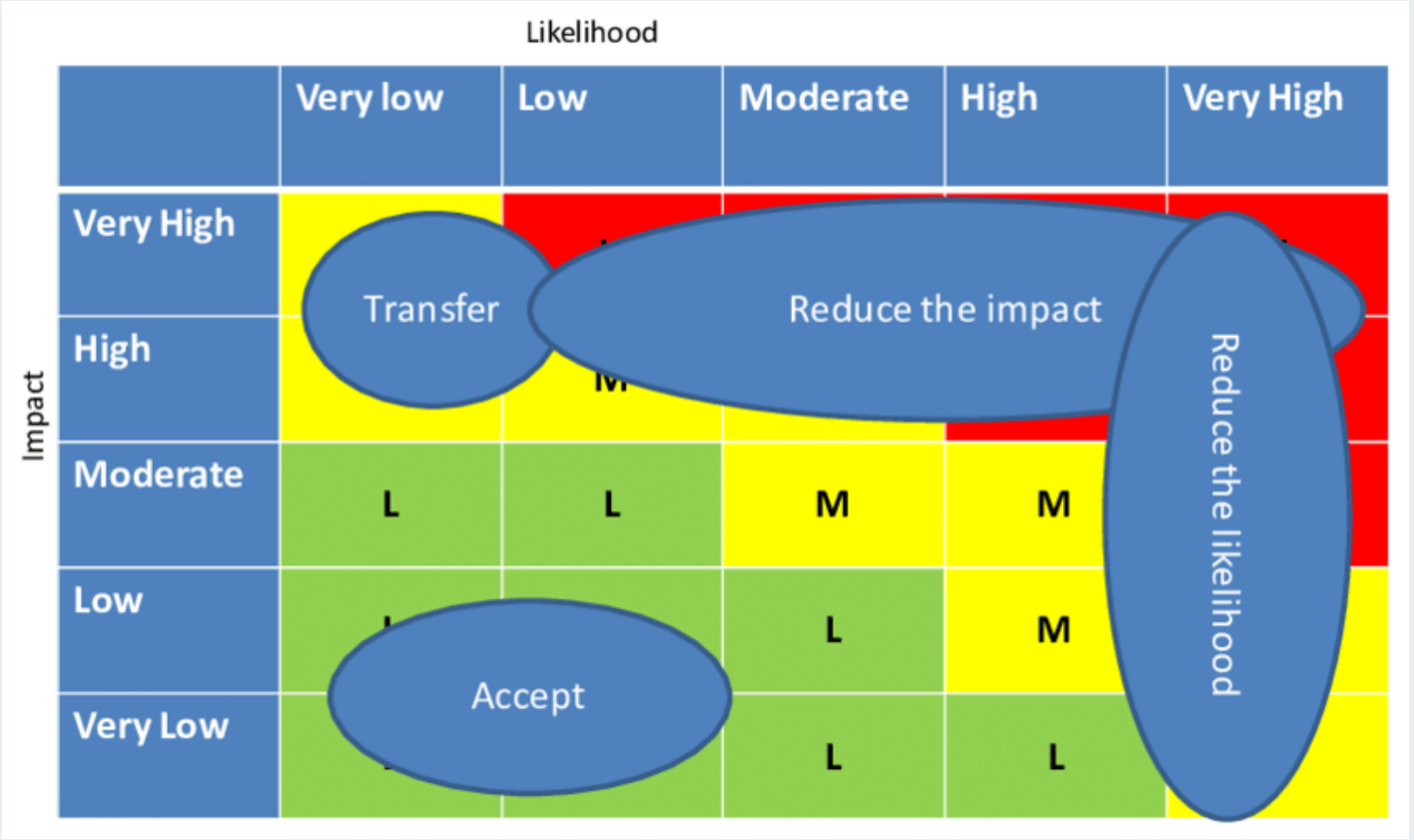
Validate findings



Possible Mitigation Options

Solutions

- Detuned capacitor banks
- Harmonic filters
- Active filtering
- Improved monitoring
- System redesign

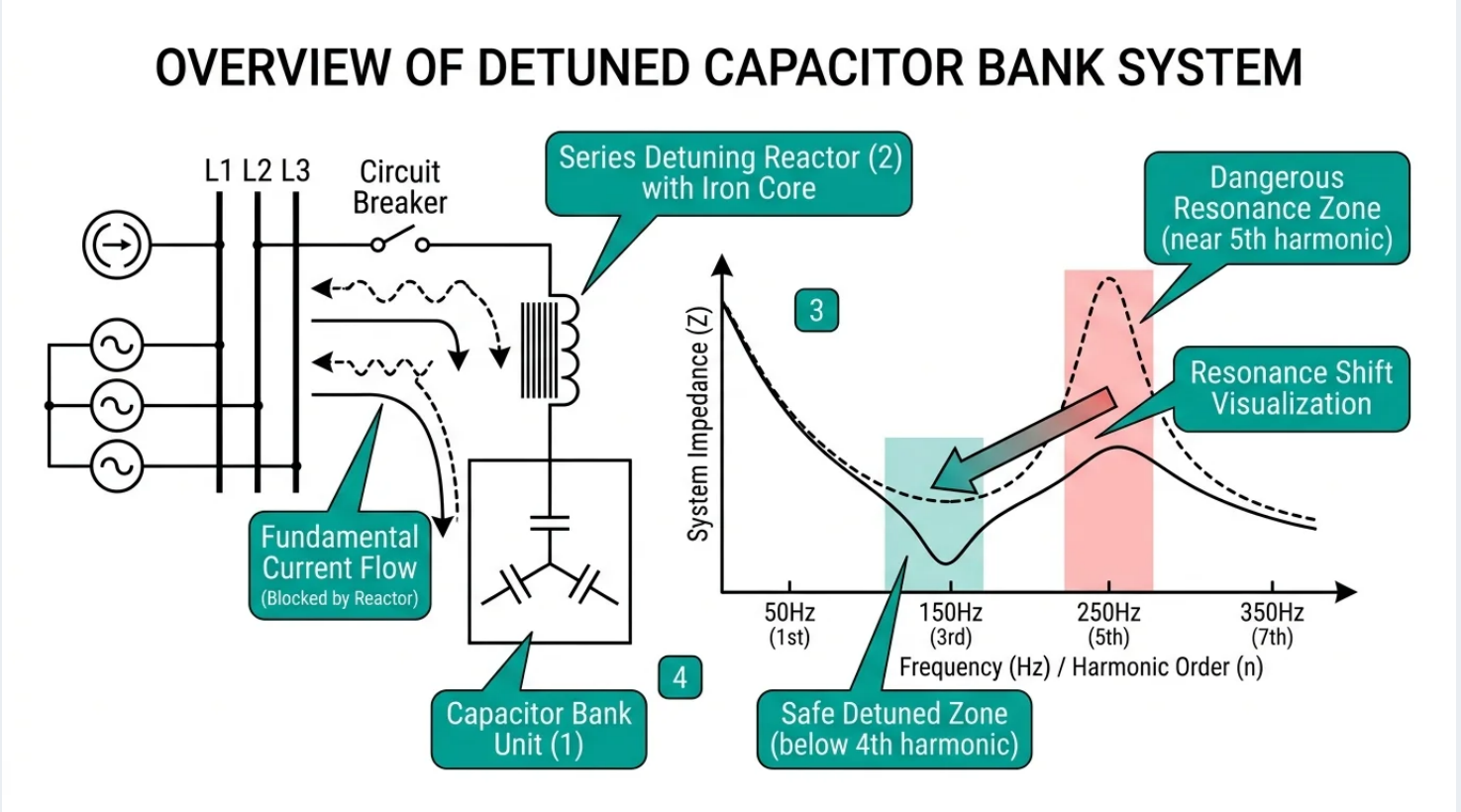


Detuned Capacitor Banks

The Most Common Fix

Series reactors:

- Shift resonance frequency
- Prevent harmonic amplification
- Improve reliability



Economic Impact

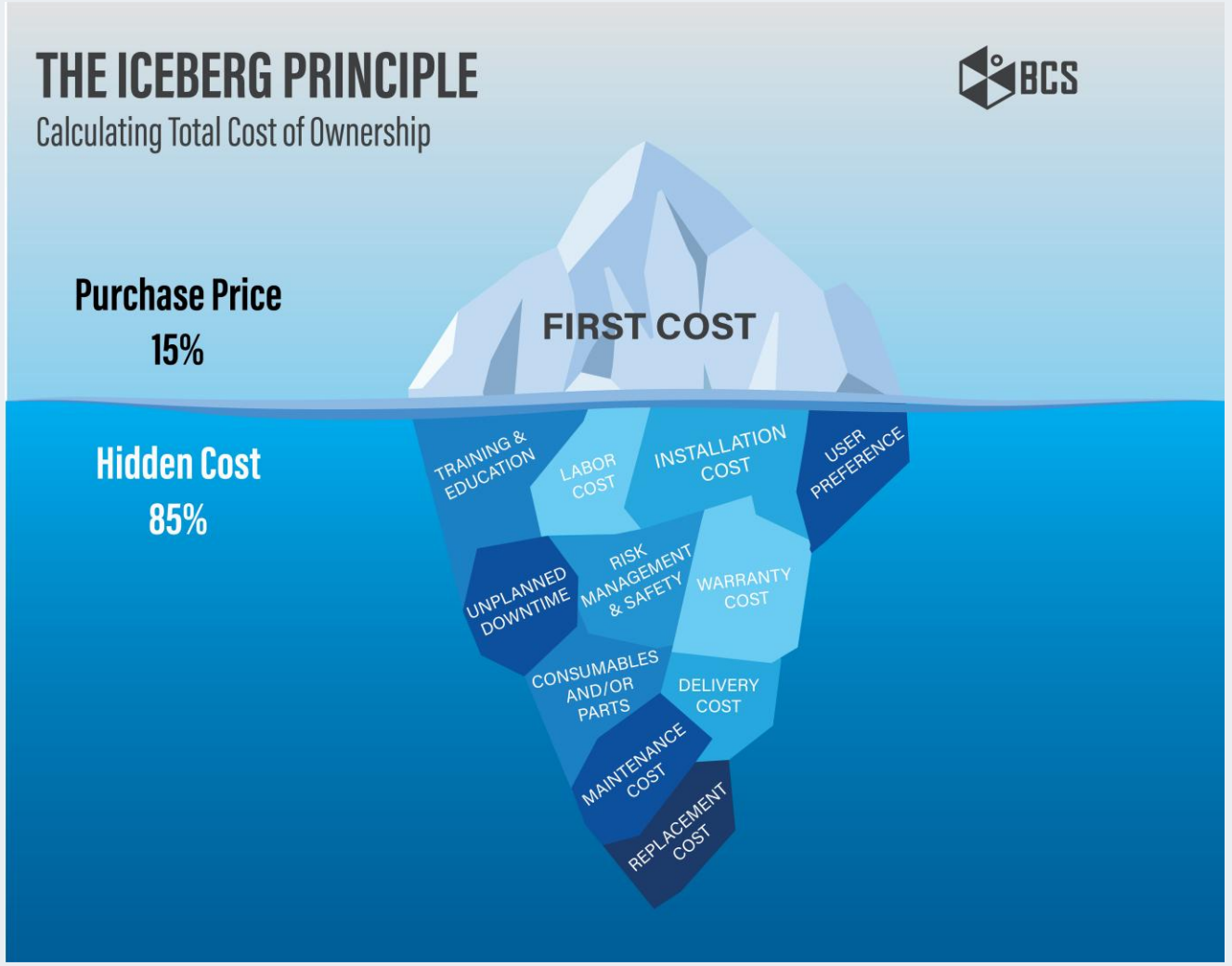
Hidden Cost of Failure

Direct costs:

- Equipment replacement
- Downtime
- Investigation

Indirect costs:

- Reduced efficiency
- Reliability concerns
- Production disruption



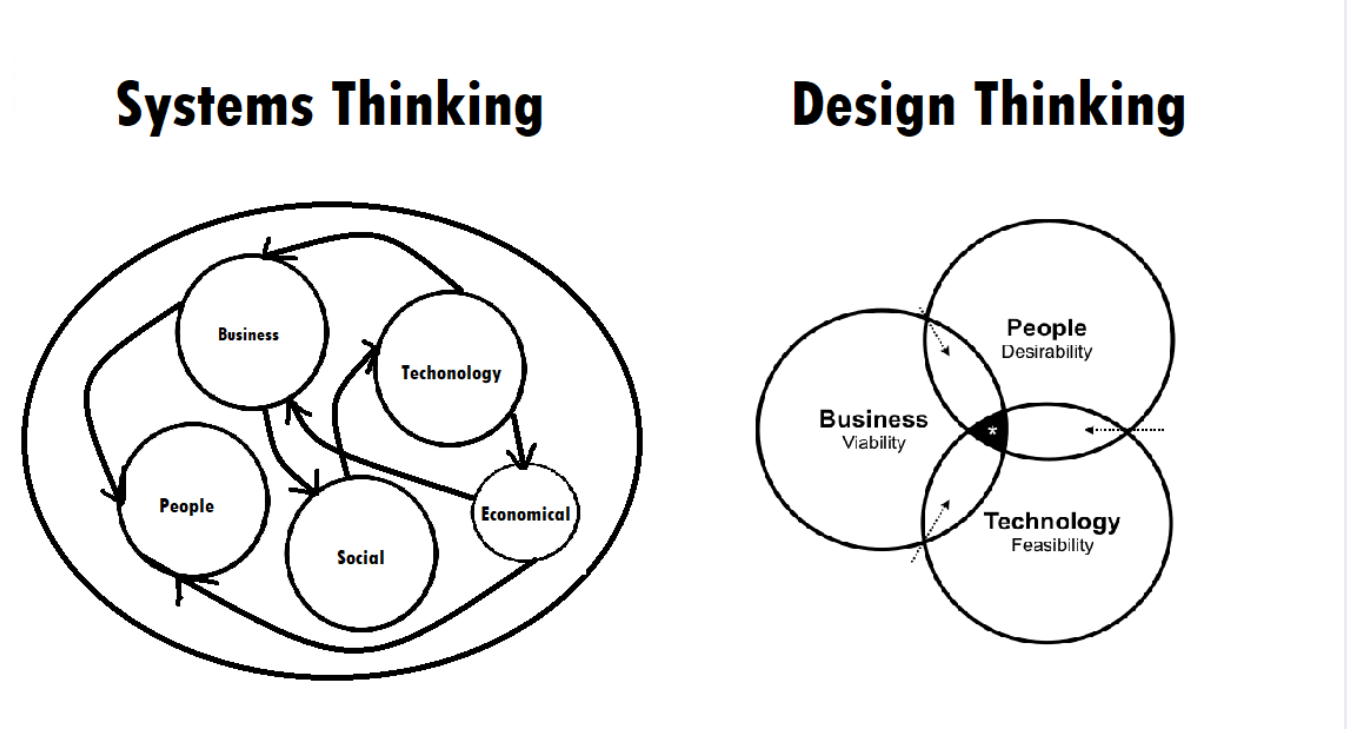
Broader Engineering Lessons

What Engineers Should Remember

Equipment rarely fails "without reason."

Look for:

- Interactions
- System effects
- Long-term trends
- Hidden operating conditions

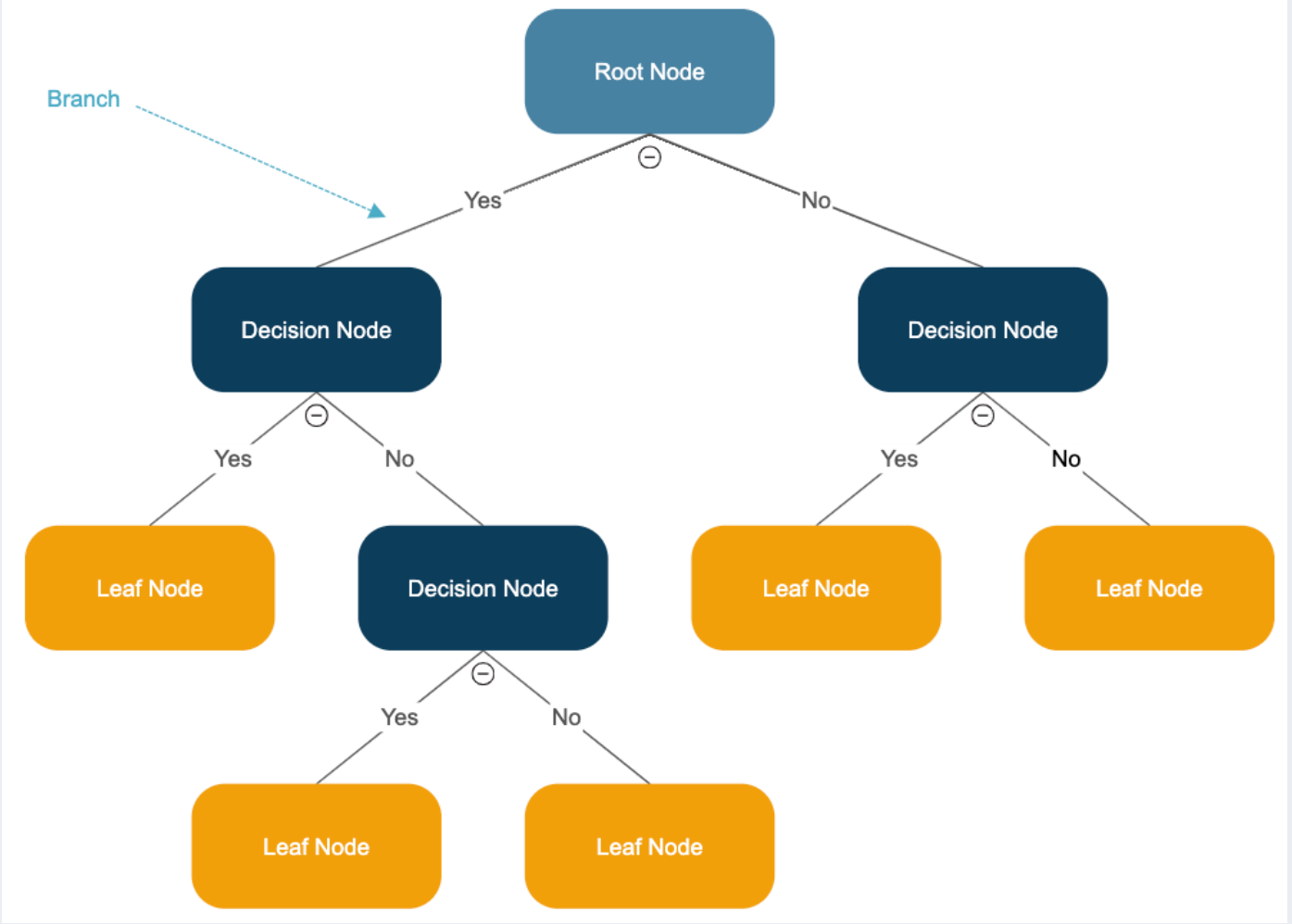


Discussion Question

If You Were the Lead Engineer

What would you investigate first?

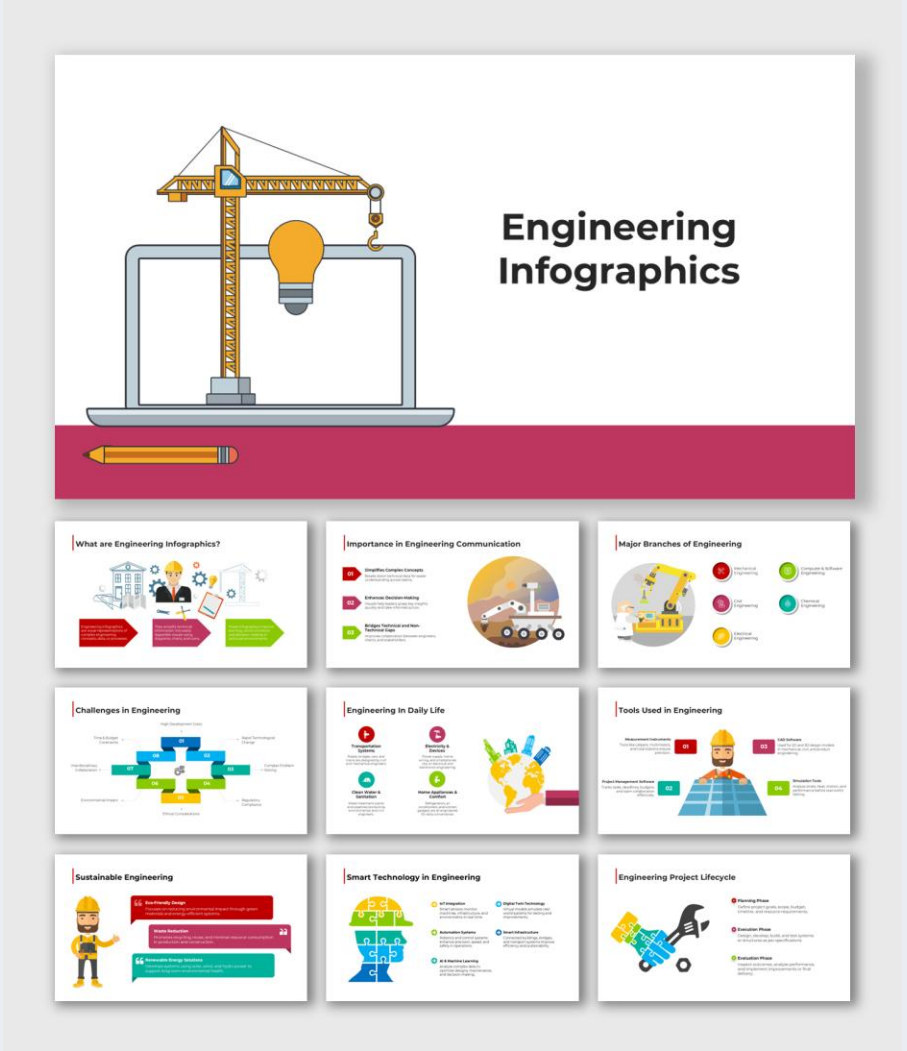
- Protection?
- Harmonics?
- Switching?
- Ageing?
- Manufacturer defect?



Key Takeaways

Main Messages:

- ✓ Capacitor banks can fail silently
- ✓ Harmonics are often underestimated
- ✓ Resonance can magnify small problems
- ✓ Protection may not detect progressive damage
- ✓ System studies are essential



Final Reflection

The Capacitor Bank That Blew Itself Up Quietly

Engineering Truth

"The most dangerous failures are often the ones that happen slowly, silently, and within normal operating limits."

Upcoming Mysteries Webinars

Register now!

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

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

Thank You!

Upcoming Courses

Please note: Courses listed below are subject to their own regulatory requirements, refer to the relevant website for further information.

Engineering Institute of Technology (EIT) *Australian Accredited Qualifications & Short Courses*	Start Date
52888WA Advanced Diploma of Applied Electrical Engineering (Power Industry)	1 September 2026
Professional Certificate of Competency in Battery Energy Storage and Applications	8 September 2026
52910WA Graduate Certificate in Hydrogen Engineering and Management	6 October 2026
Professional Certificate of Competency in Circuit Breakers, Switchgear and Power Transformers	13 October 2026
Graduate Certificate in Power System Analysis and Design	4 January 2027
Graduate Diploma of Engineering (Electrical Systems)	4 January 2027
Master of Engineering – Applied Research (Electrical Systems)	4 January 2027
Master of Engineering (Electrical Systems)	4 January 2027
Associate Degree in Electrical Engineering	8 February 2027
Bachelor of Science (Electrical Engineering)	8 February 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) *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) *South African accredited qualification & ECSA-endorsed*	Start Date
Bachelor of Engineering Technology in Electrical Engineering	3 August 2026

Q&A

EIT
Engineering Institute of Technology.

ECT
Engineering College of Technology.

ECST
Engineering College of Science and Technology.

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

Email
webinars@eit.edu.au

Courses
https://www.eit.edu.au/schedule/

Website
www.ect.ac.uk

Head Office
Whittle Way, Stevenage SG1 2FS,
United Kingdom

Phone
Inside UK: 0208 335 4014
Outside UK: +44 208 335 401

Programmes
https://www.ect.ac.uk/programmes/

Website
www. ecst.ac.za

Head Office
Unit 3, Elevation Gardens,
Elevation Close, Water fall
Office Park, Midrand, 1686

Phone
Within South Africa: 010 823 4497
Outside South Africa: +27 11 823 4497

Programmes
www.ecst.ac.za/course-types/bachelor-of-engineering/