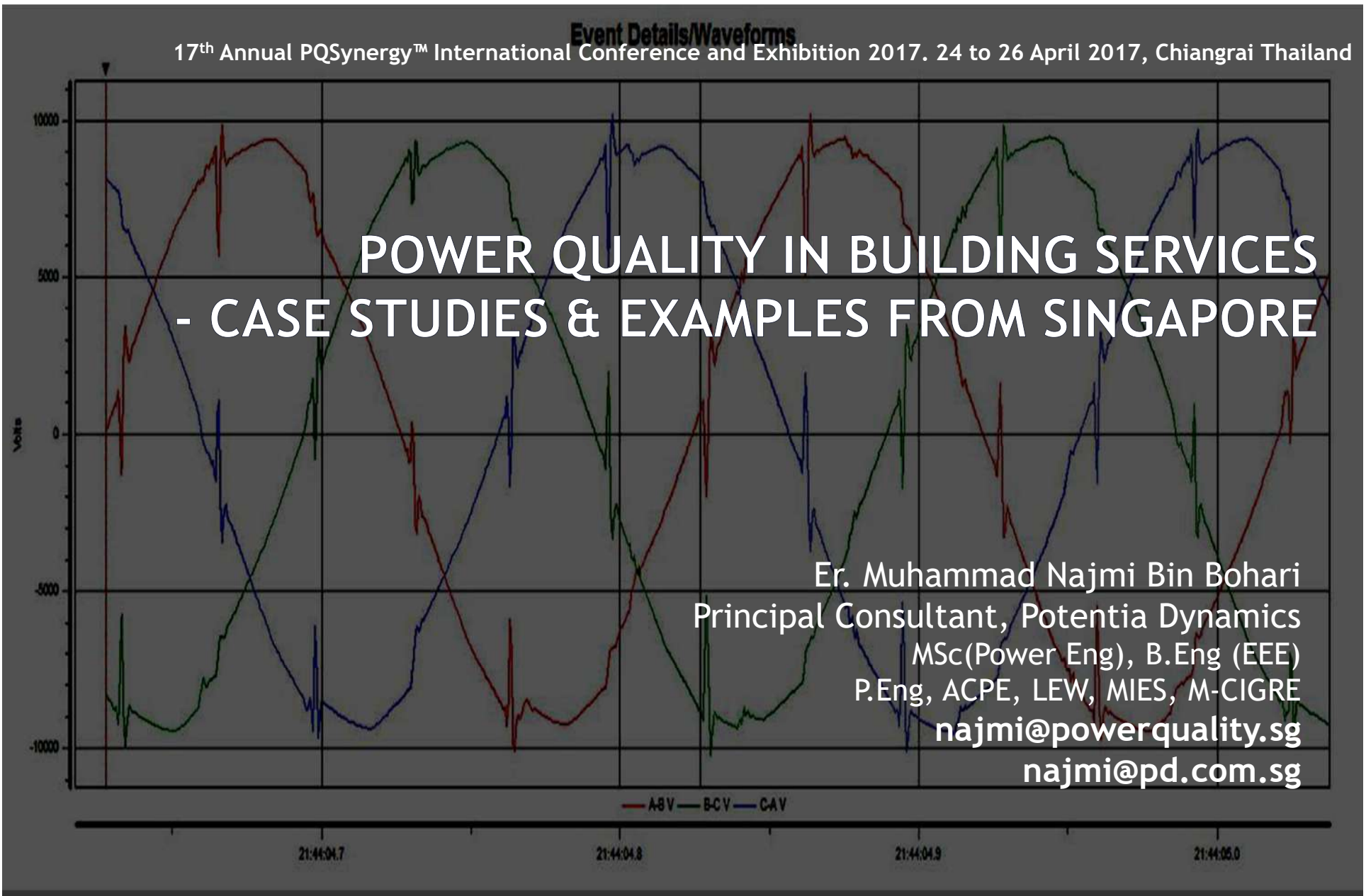
17th Annual PQSynergy™ International Conference and Exhibition 2017. 24 to 26 April 2017, Chiangrai Thailand



POWER QUALITY IN BUILDING SERVICES - CASE STUDIES & EXAMPLES FROM SINGAPORE

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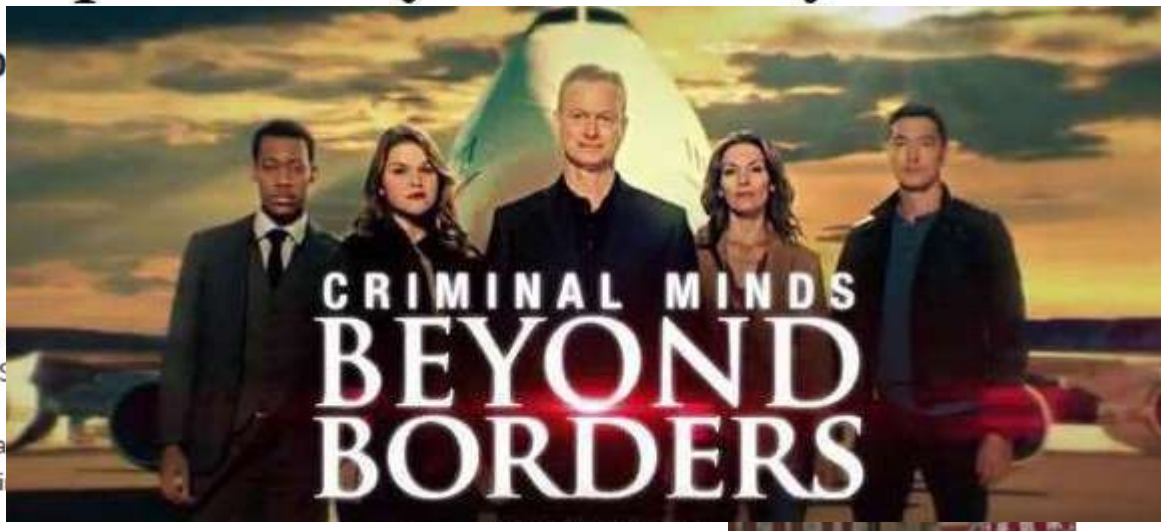
powerquality.sg the ABCs of power quality in Singapore

Criminal Minds misrepresents S'pore: Why can't Hollywood

After STB, Singapo Criminal Minds



Hot on the heels of a recent burn
episode featuring Singapore, the S

The response, albeit less sassy tha
which debunk claims of the Crimi
hidden underworld scene.

The Facebook post saw the SPF pointing out Singapore' ranking in the Gallup's Law and Order 2016 report, along with the hashtag #CriminalMindsBeyondBorders. This left little room for potential debate over the post being directed at the show.

Singapore Police Force
on Thursday

Singapore was ranked first in Gallup's Law and Order 2016 Report.
Remember, our statistics show that we are not like what TV shows say!
#CriminalMindsBeyondBorders

CRIME STATISTICS IN SINGAPO MES THAT REGISTERED A

an "overcrowded slum with a thriving underworld". Photo: Google Maps

SPEAKER BRIEFS

- Singapore-registered Professional Engineer (Electrical)
- ASEAN Chartered Professional Engineer
- Principal Consultant, Potentia Dynamics Pte Ltd
- Former Head, Power Quality & Engineering Analysis Unit, Quality Power Management Pte Ltd
- Former Executive Engineer from SP PowerGrid's Power Quality & Transient Management section.
- Writes on http://powerquality.sg, to share my views and experiences in this fascinating world of power quality.

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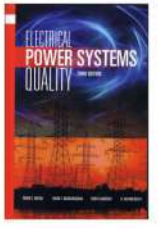
powerquality.sg the ABCs of power quality in Singapore

OUTLINE

- Typical Problems / Complaints
- 5 Common "Daily Encounters"
  - Problem
  - Findings
  - Lesson(s) Learnt

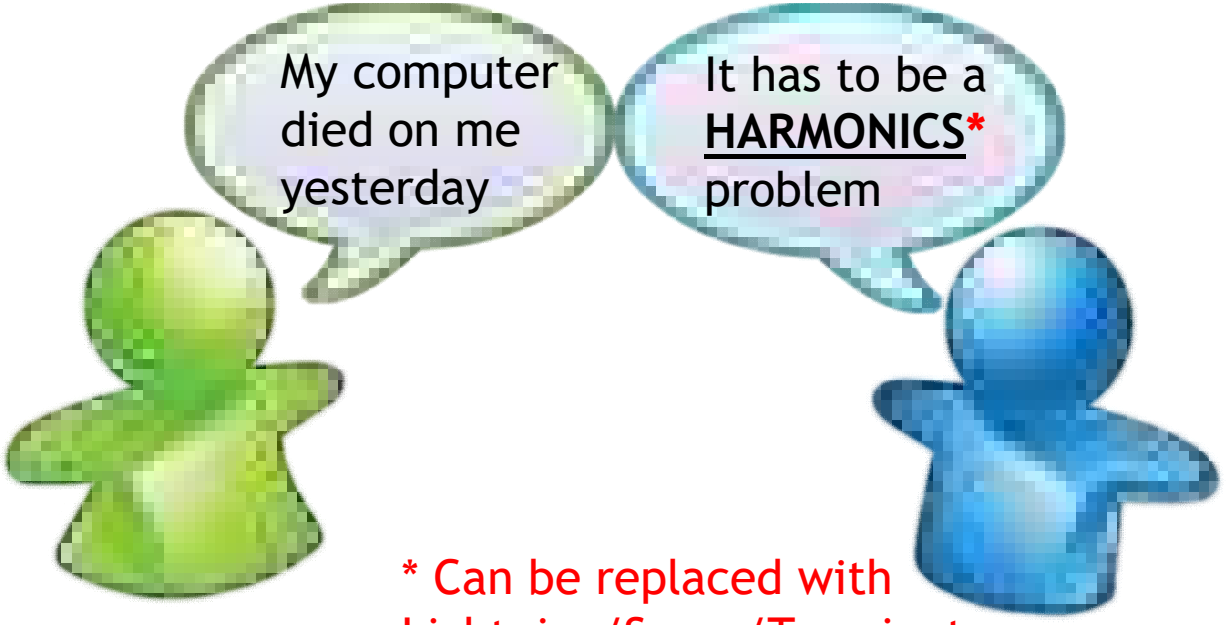
What is a PQ problem?



"Any power problem manifested in voltage, current or frequency deviations that result in failure or misoperation of customer equipment."

TYPICAL COMPLAINTS RECEIVED

- Harmonics
- Lightning
- Surge / Transients
- Non-specified power / power quality problem



* Can be replaced with Lightning/Surge/Transient

REAL NATURE OF PROBLEMS

- Earth fault – related (60%)
  - true downstream equipment/cable fault
  - misapplication
  - external events
- Malfunction of protective devices (15%)
- Lightning (5%)
- Harmonics / Waveform Distortion (5%)
- Overvoltage/Undervoltage (5%)
- Voltage Dip (5%)
- Others (eg. Human errors, unknown, environmental) (3%)
- Overload (2%)

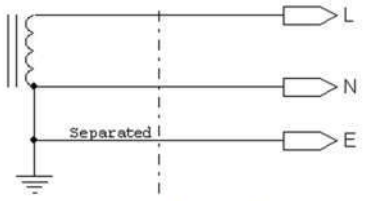
CASE STUDY 1

- Lift / Elevator in an under-construction residential cum commercial building keeps getting ‘stuck’
- Tripped on Residual Current Device (RCD) / RCCB frequently
- Affected workers’ movement up/down the building

TWO TYPES of Earthing Systems in Singapore

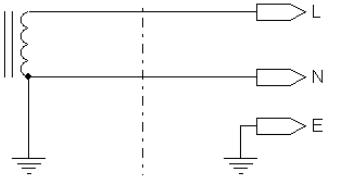
- TN-S
- TT

TNS



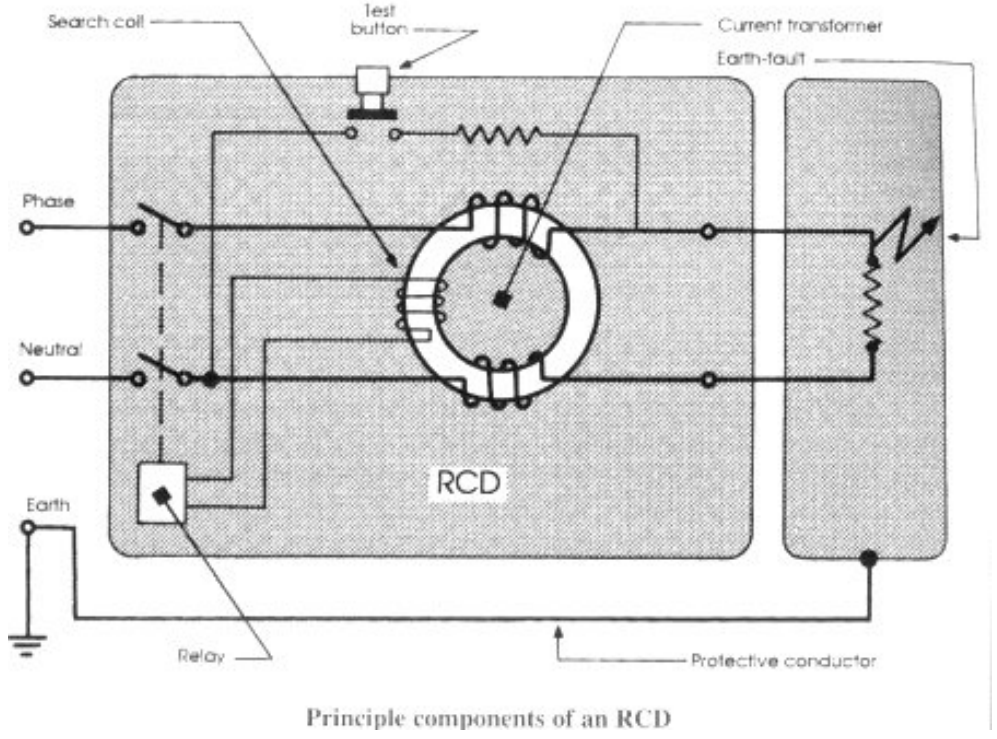
Ground supplied at source and Neutral and Protective Earth supplied to user separately.

T-T



Ground supplied at source for Source Earth and Neutral, but User's Protective Earth supplied by User.

WORKINGS OF AN RCD



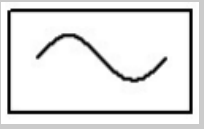
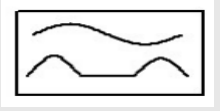
Principle components of an RCD

Main Uses

- Personnel protection (direct contact)
- Fault Protection (indirect contact)
- Fire

General Type vs Selective Type (With Delay)

TYPES OF RCD

Type of RCD	Uses
Type AC 	Can detect full wave AC residual currents only
Type A 	Can detect full wave AC and pulsating DC residual currents
Type B 	Can detect full wave AC, pulsating DC and pure DC residual currents

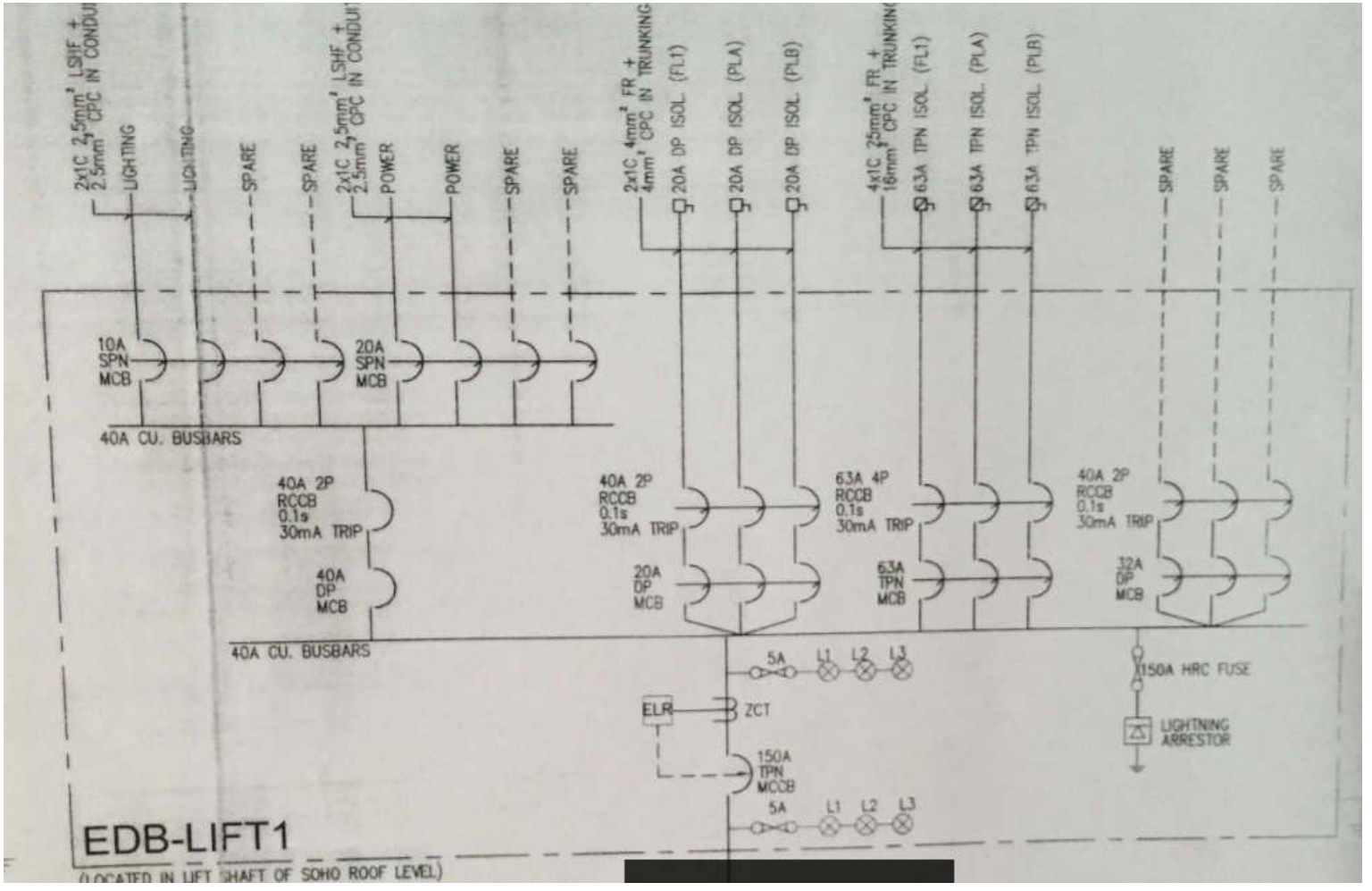
Typical Trip Ratings:
- 10mA, 30mA, 100mA, 300mA
- 500mA, 1000mA

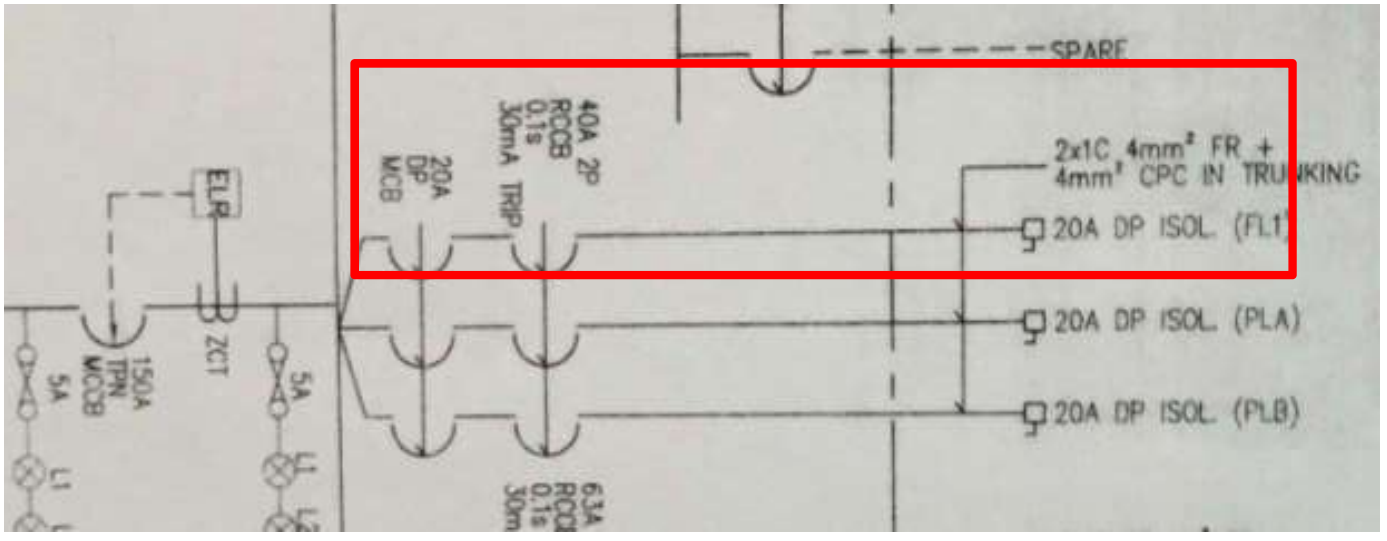
Can Trip anywhere above 50% of its trip rating

FINDINGS

- ‘Consultant’ had designed a 30mA RCD for the lift. Tripped every few minutes.
- Site operators changed it to 300mA.
- Frequency of trip decreased but still occurred several times per day

SINGLE LINE DIAGRAM





24HRS LEAKAGE TRENDING

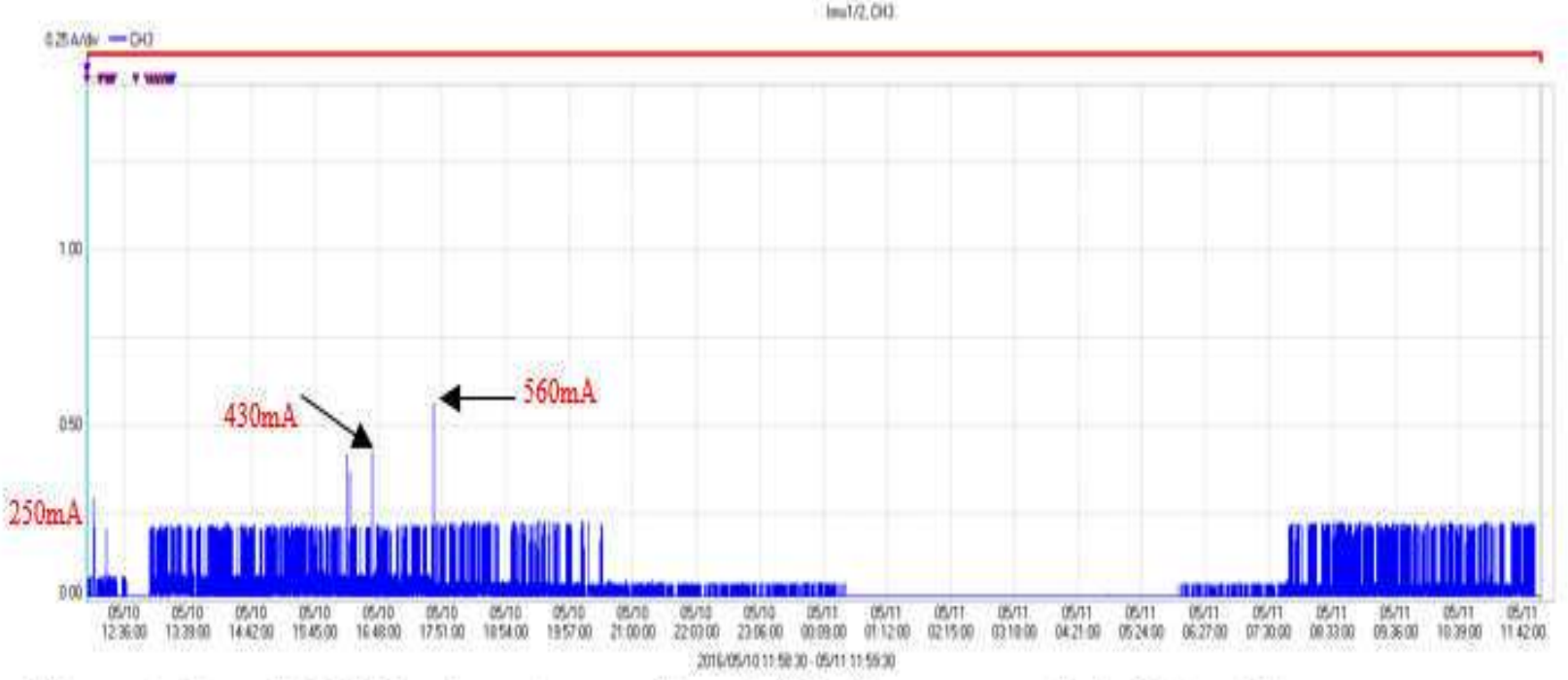


Figure 3: Overall RMS Leakage Current Trends (Maximum recorded = 560 mA)

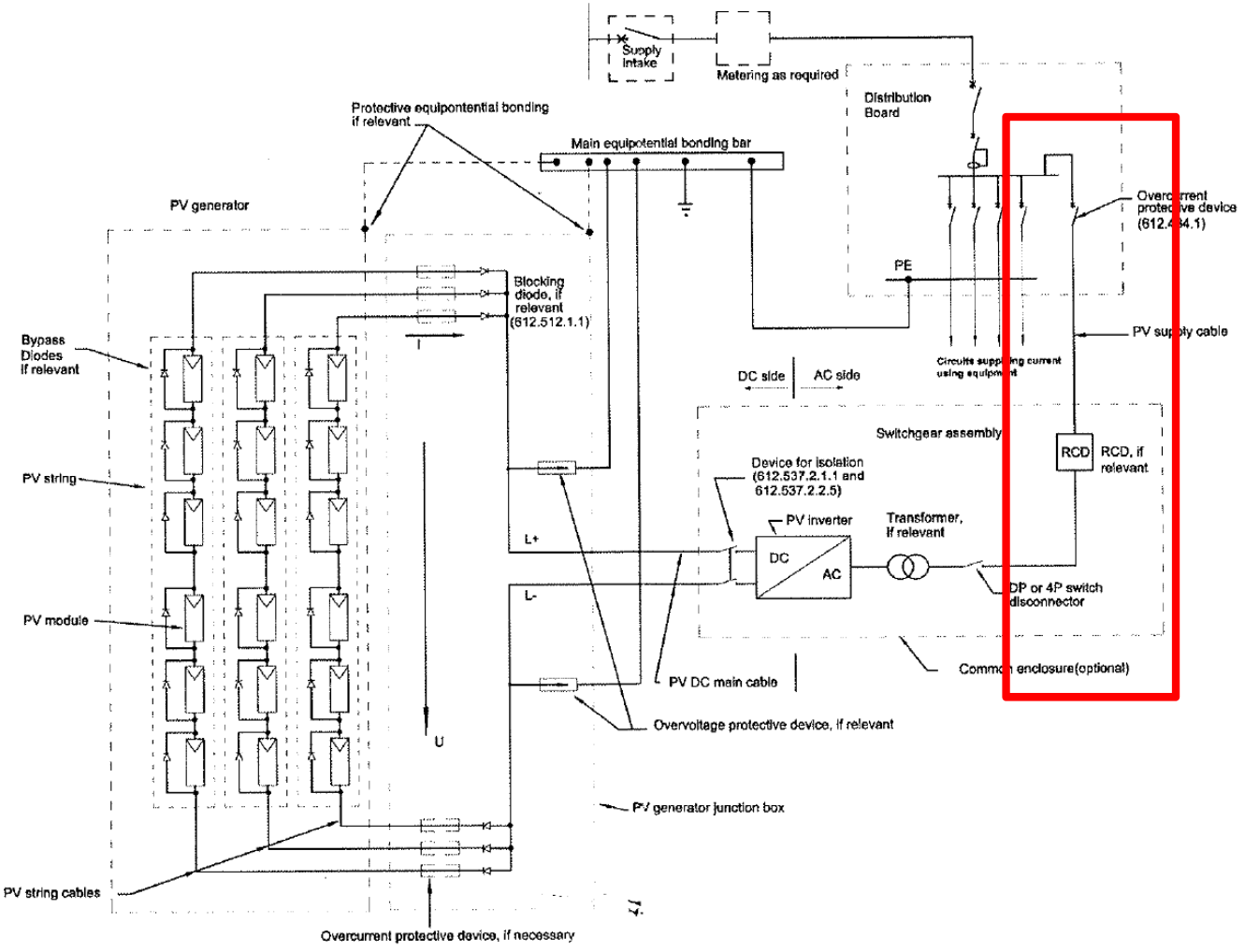
LESSON(S) LEARNT

- Misapplication of 30mA RCD protection (meant for personnel protection)
- Average leakage current recorded ~ 200mA
- 300mA RCD can trip anywhere above 150mA
- Standing leakage current of the equipment (lift) was not taken into consideration
- Type of load was also not taken into consideration (used a type AC instead of a type B RCD)

CASE STUDY 2

- PV System frequently trips the RCD
- Previously, the PV contractor's setup did not pose the same problems

TYPICAL PV SYSTEM SET-UP



USE OF RCD IN PV SYSTEMS

(IEC60364-7-712:2002)

If intended as fault protection (see Section 2.2 "Automatic Disconnection via Residual-Current Device" (page 6)), DIN VDE 0100-712 requires a type B residual-current device for transformerless inverters.

This requirement also applies to inverters with HF transformers, since there is no galvanic isolation between the AC current side and the DC voltage side.

This requirement does not apply to inverters with LF transformers.

One exception to this is if the manufacturer of the inverter can exclude the possibility of DC residual currents in the system. If necessary, type A residual-current devices can be used.

TEST WITH RCD ‘BYPASSED’

HIGHEST RECORDED: 165MILLIAMPS

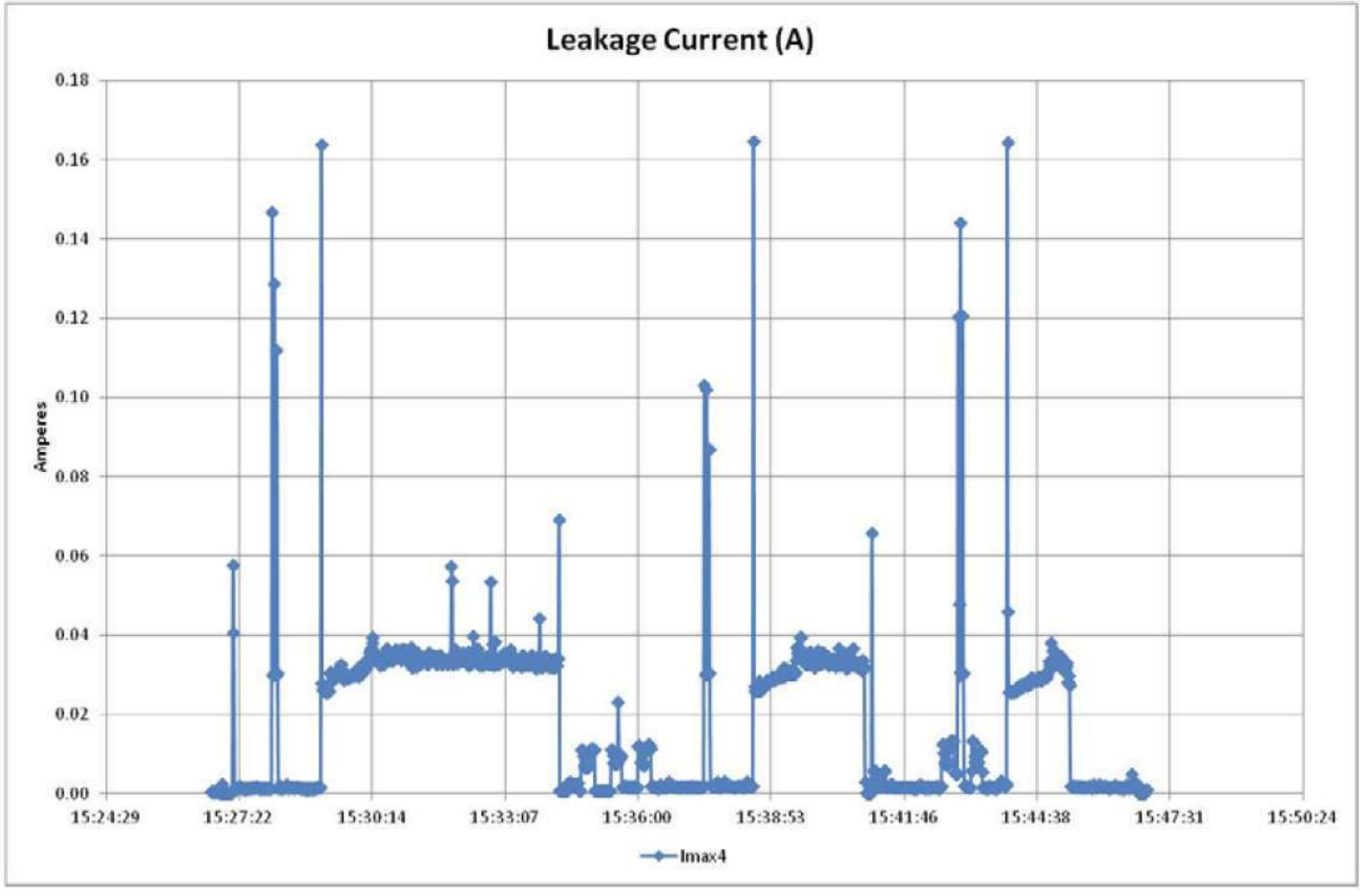


Fig3: Leakage current trends

FINDINGS

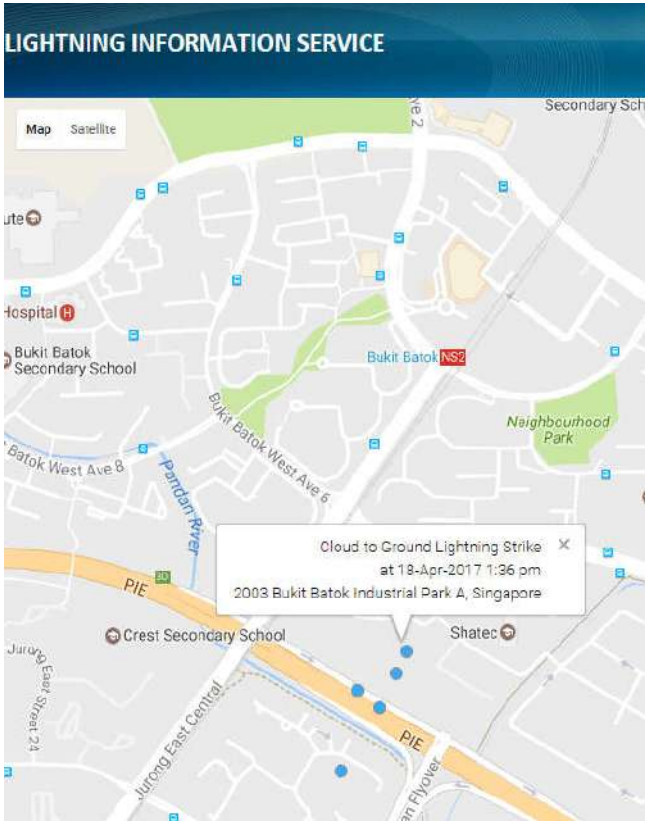
- 100mA RCD was used
- Differences was due to the different brand/make of the inverters used
- Hence different standing leakage current
- Test results showed 18 instances whereby leakage was above 50% of 100mA
- Highest leakage recorded was 165mA

LESSON(S) LEARNT

- Standing leakage current of equipment to be taken into consideration
- Not assume all equipment have same level of leakage current
- To use appropriate type of RCD
  - type B for transformerless inverters; which are able to inject DC during fault

CASE STUDY 3

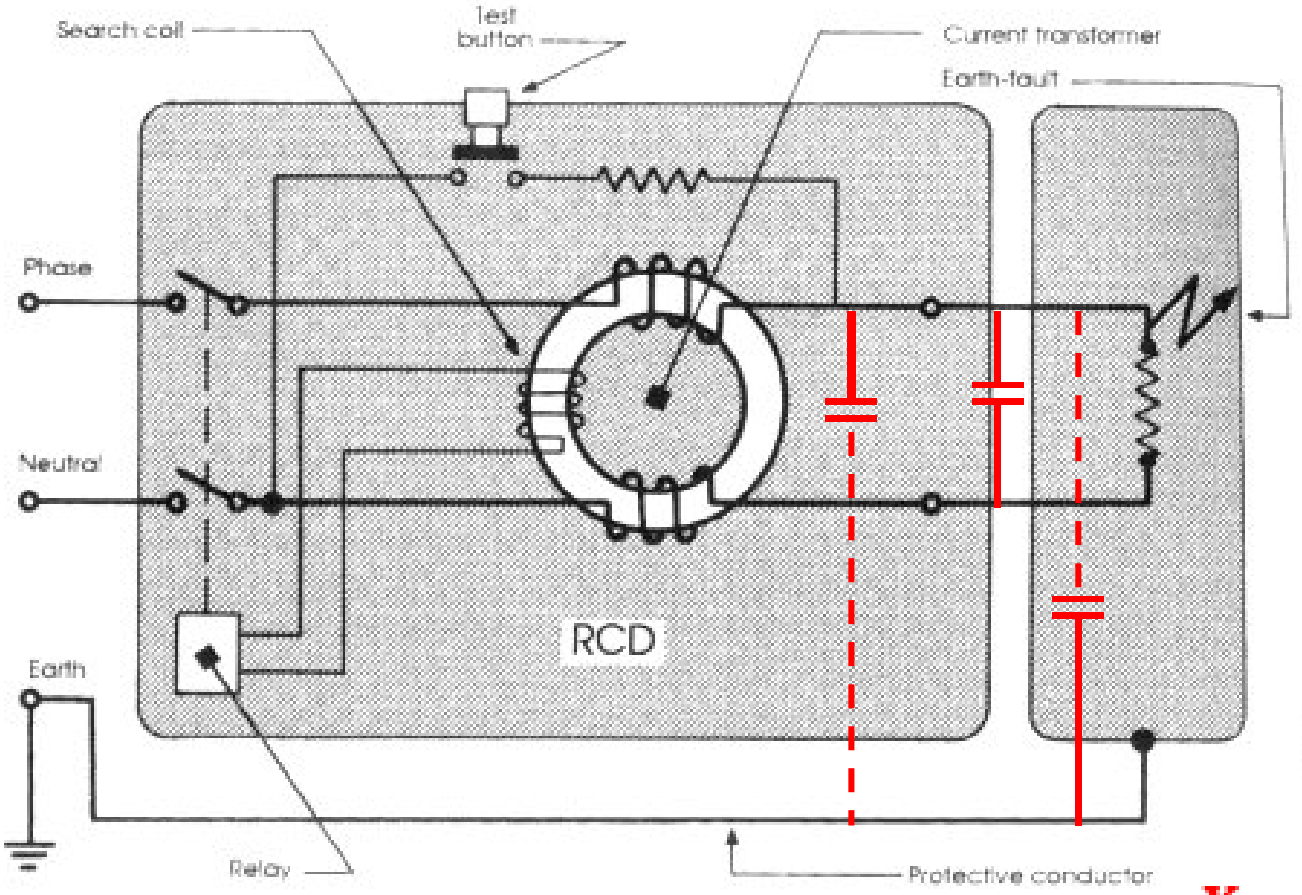
- External events tripping the RCDs
- Some experienced multiple concurrent trips of a no. of RCDs
- Trip Incidents coincided
  - heavy thunderstorms
  - voltage dip
  - switching events



FINDINGS

- Too many loads lumped under one single RCD
- RCDs “living on the edge”
- Nearing the 50% threshold
- An RCD can trip anywhere >50% of its trip rating
- Loads with mains filter
- Extension plug w “in-built” surge protection

WORKINGS OF AN RCD



Principle components of an RCD

$$Xc = \frac{1}{2\pi fc}$$

LESSON(S) LEARNT

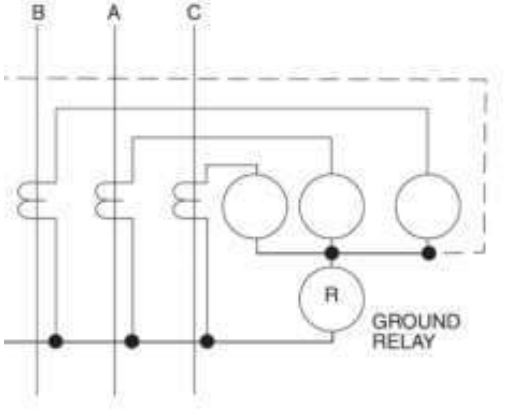
- Keep standing leakage current to about 20 to 25% of RCD trip value
- Less circuits per RCD
- Putting a surge protective device (before the RCD) reduce the frequency of tripping during thunderstorms
- “High Immunity” RCDs
- Choose right type of RCD

LESSON(S) LEARNT - OVERALL

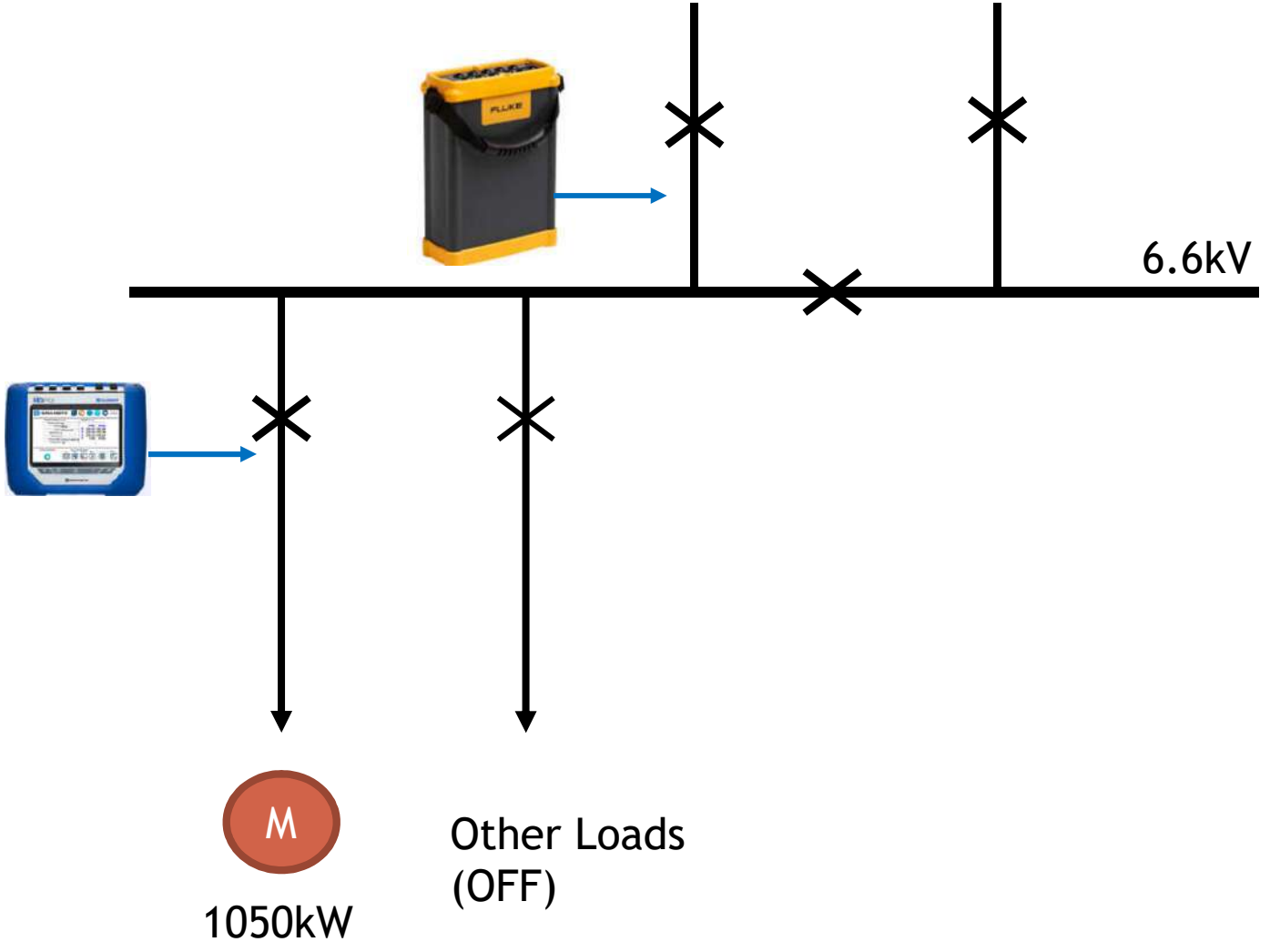
- Most cases down to misapplication of RCDs
- Know purpose of protection
- Consideration of standing leakage current
- Type of loads to be protected

CASE STUDY 4

- Starting a medium-voltage DOL motor frequently triggers the earth fault protection
- 3-CT configuration
- Conducted a simulation test at
- 1) Main Incoming panel
- 2) Outgoing to Motor panel
- 3) All other loads ‘OFF’



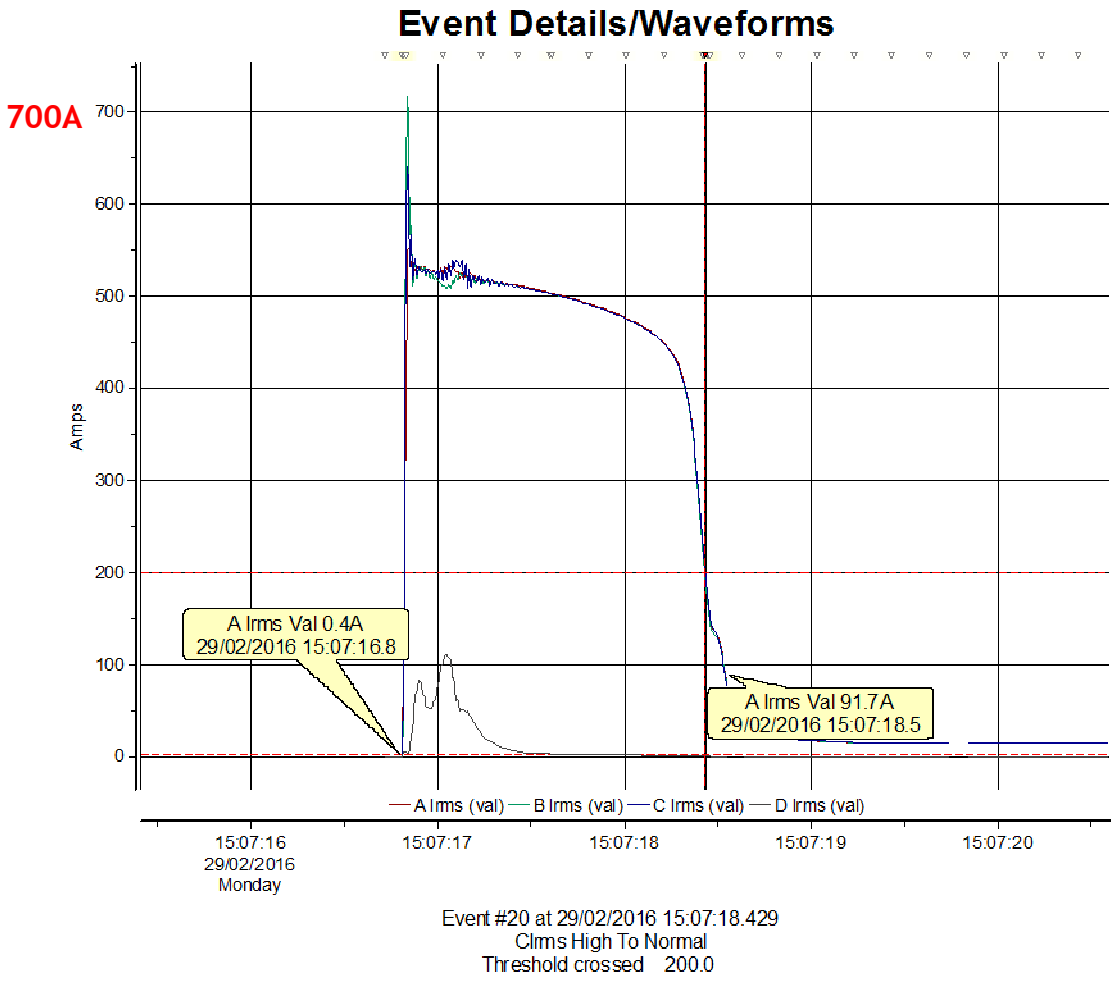
SIMPLIFIED SLD



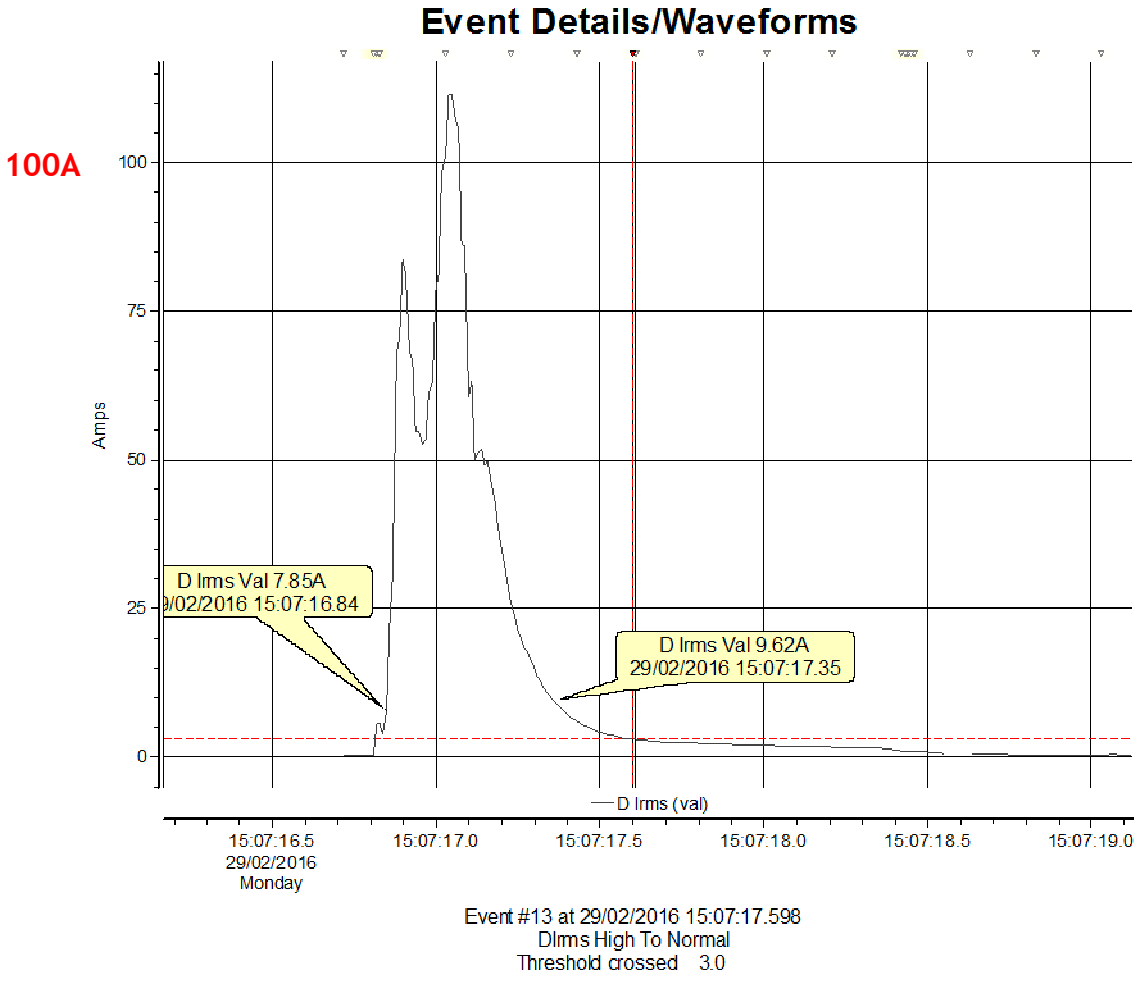
FINDINGS – FALSE EARTH FAULT

Circuit	Results – Approx. Duration	Results – Max. Current Recorded
Panel to Motor (250/5A) Overcurrent Element	Inrush duration: 1.7s	717A
Panel to Motor (250/5A) Earth Fault Element Setting = 10A (primary)	Duration above 10A: 0.51s	111.4A
Main Incoming Panel (1250/5A) Overcurrent Element	Inrush duration: 1.85s	719A
Main Incoming Panel(1250/5A) Earth Fault Element		2.556A

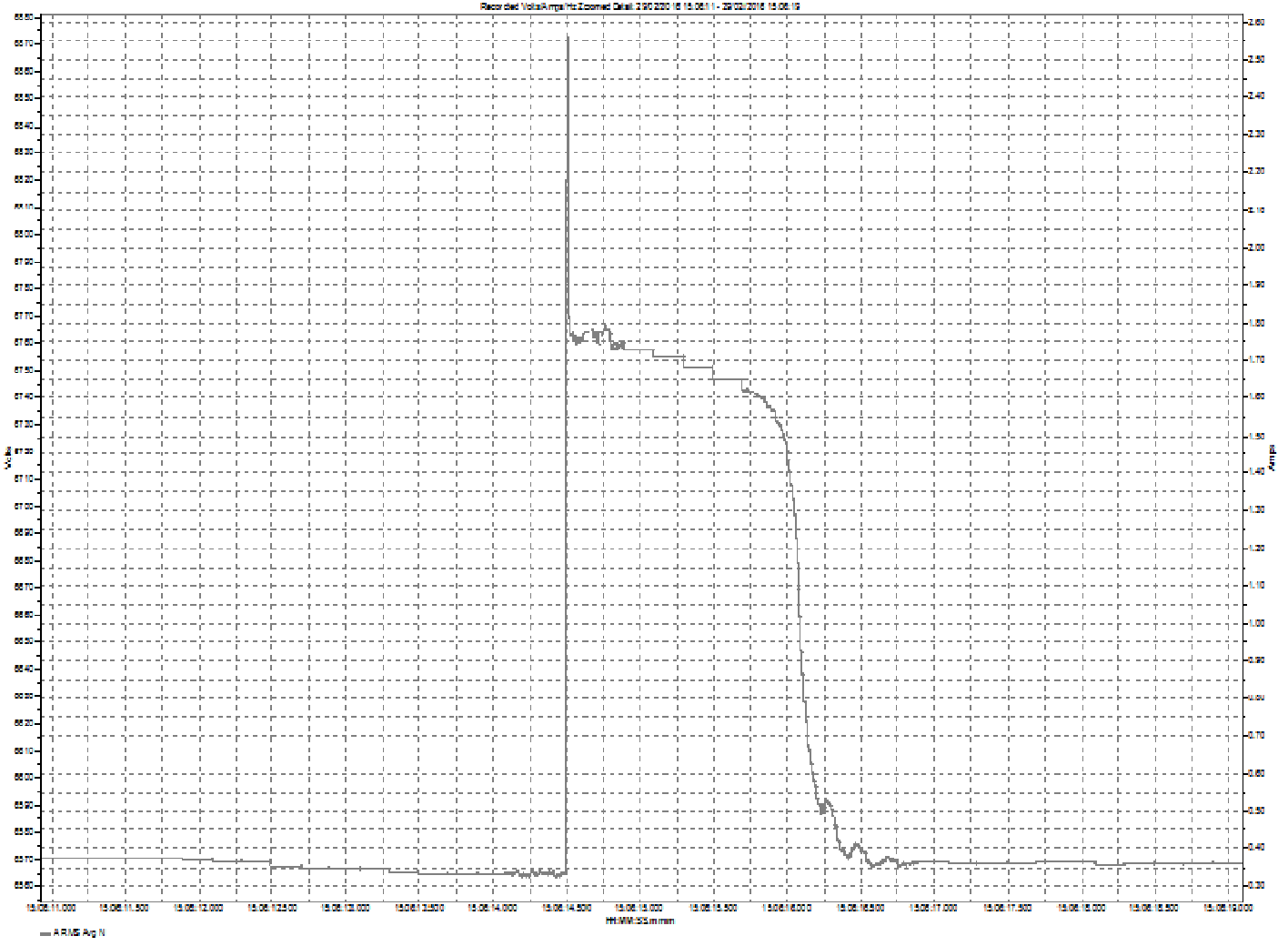
AT PANEL TO MOTOR



AT PANEL TO MOTOR

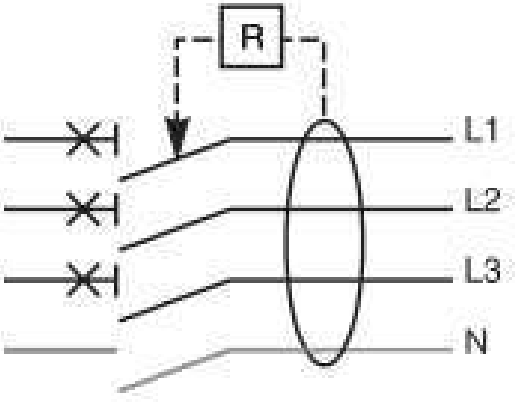


AT MAIN PANEL



LESSON(S) LEARNT

- During the ‘inrush’, the differences from produced a ‘seemingly’ high ‘earth-fault’
- Issue solved by using a core-balance CT
- 1 CT vs 3 CTs
- Introducing a ‘time delay’ is also possible provided protection coordination with other circuits are achievable



CASE STUDY 5: HARMONICS

- ‘Extreme’ Point of Views
- ‘Very Lax’ to ‘Very Stringent’

LIMITS BY UTILITY

- Too ‘lax’
- Only provided voltage-based limits
  - VTHD% at Point of Common Coupling (PCC)
  - Individual Vh% at PCC
- Code has provisions to request expected harmonic injection values from Customer (in practice, hardly ever practiced)

GRID LIMITS

6.7 Harmonics and Power Quality

6.7.1 All *connected persons* shall install equipment or devices to suppress harmonics and electrical noise produced by their electrical plant if the harmonics or electrical noise produced by such plants exceed the limits specified in Appendix F.

6.7.2 A *connected person* shall submit to the Transmission Licensee the expected noise and harmonics levels from their electrical plant upon request by the Transmission Licensee.

6.7.3 A *connection applicant* or *connected person* seeking *connection* at, or upgrading a connection at 66kV or higher voltages shall submit to the Transmission Licensee the following:

(a) the expected noise and harmonics levels from the electrical plant upon submission of the application for *connection* or for upgrading of the *connection*; and

(b) following *connection*, noise and harmonics levels annually or at such intervals as may be specified by the Transmission Licensee.

GRID LIMITS

F2.2 Harmonics

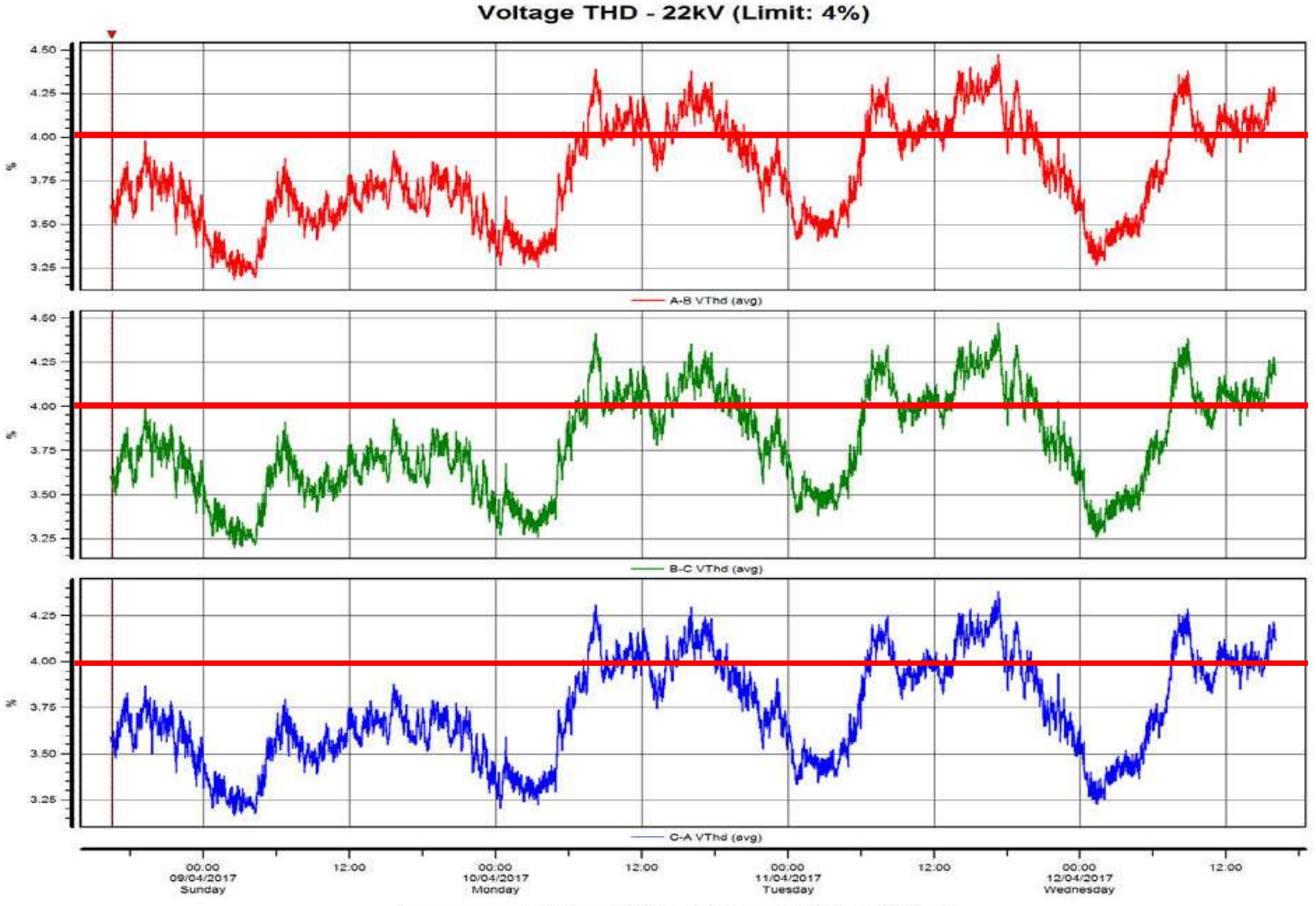
(a) The owner of an *installation* shall ensure that starting surges or harmonics generated by *connected persons*' and Transmission Licensee's equipment at the *installation* must not cause the maximum *total harmonic voltage distortion* at the point of common coupling to exceed the following:

(iv) At 22kV and 6.6 kV, a *total harmonic voltage distortion* of 4.0 percent with no individual odd harmonic greater than 3.0 percent and no individual even harmonic greater than 2.0 percent.

FINDINGS

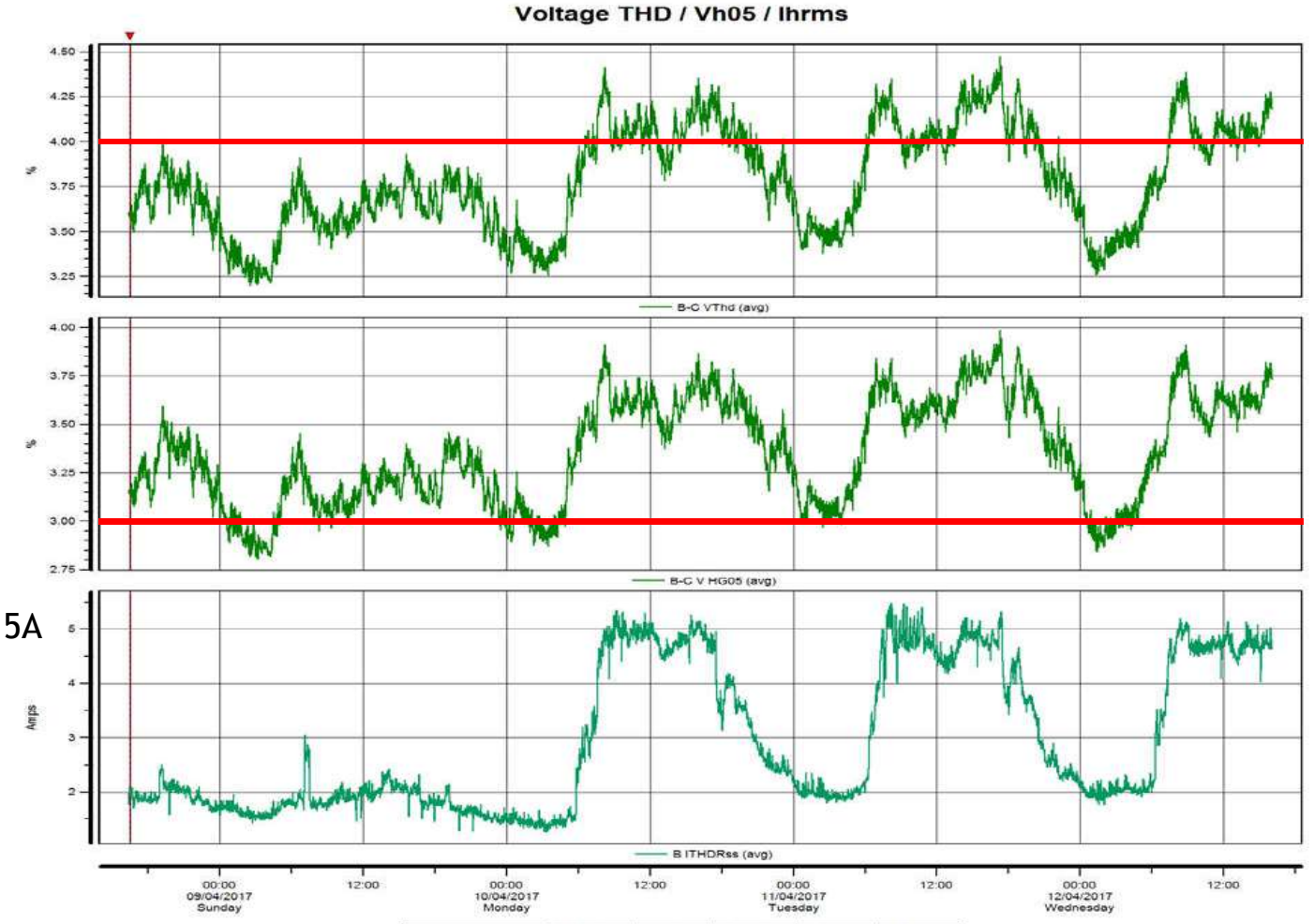
- Has led to parts of the medium voltage network (22kV) to see exceeding limits of the harmonic voltages
- Particularly the 5th order
- Then it becomes a challenge for the Grid Operator to find out & trace the ‘significant’ contributor

EXCEEDING GRID LIMITS



	Min	Max	Avg	95%	99%
A-BVThd	3.188	4.474	3.798	4.255	4.341
B-CVThd	3.203	4.474	3.797	4.242	4.334
C-AVThd	3.167	4.384	3.735	4.167	4.247

EXCEEDING GRID LIMITS



4% VTHD

3% Vh05

5A

	Min	Max	Avg	95%	99%
B-CVThd	3.203	4.474	3.797	4.242	4.334
BITHDRss	1.269	5.477	2.955	4.997	5.179
B-CV HG05	2.808	3.988	3.360	3.772	3.862

LIMITS BY BUILDINGS

- Some Grade ‘A’ Offices imposed harmonic limits per tenant
- Both voltage and current harmonic limits
- Tenant approved loads:
  Between 30A 1P/3P and 150A 3P
- Limits varies
- VTHD: ~ 5%
- ITHD: ~ 5 to 20%
- *At 5%; will certainly need a harmonic filter

SOME RECENT MEASUREMENTS

S/N	Intake	Loading (A)	Ihrms (A)
1	63A 3P	1.21 – 8.20A	2.04 (max)
2	80A 3P	1.69 – 21.42A	6.16A (max)
3	32A 3P	1.15A to 5.87A	1.34A (max)
4	40A 3P	0.36 – 9.2A	3.68A (max)

FINDINGS

- Poor understanding of harmonics from both tenants and the landlords' facility management agents
- ITHD% values taken 'at face value'
- May result in unnecessary installation of harmonic filters

TAKING ITHD ‘AT FACE VALUE’

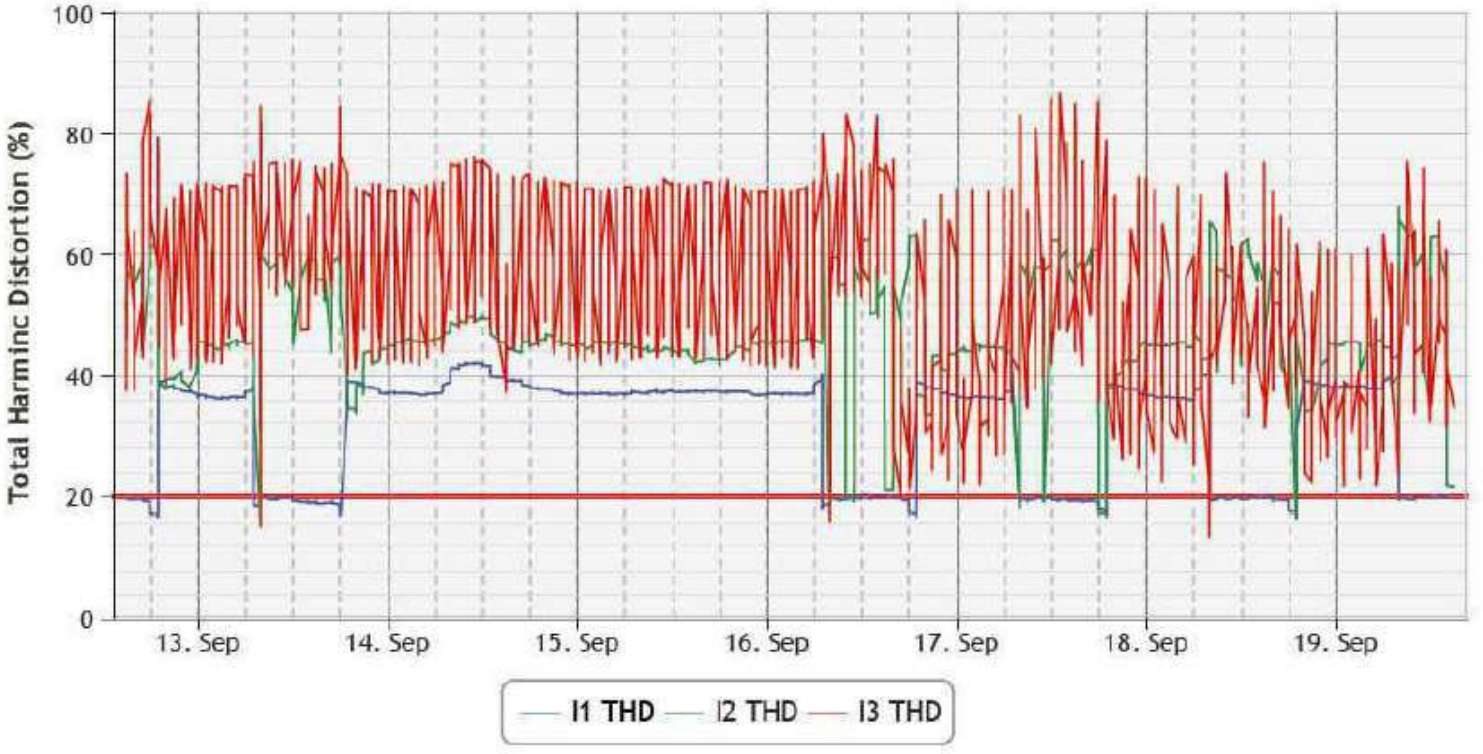
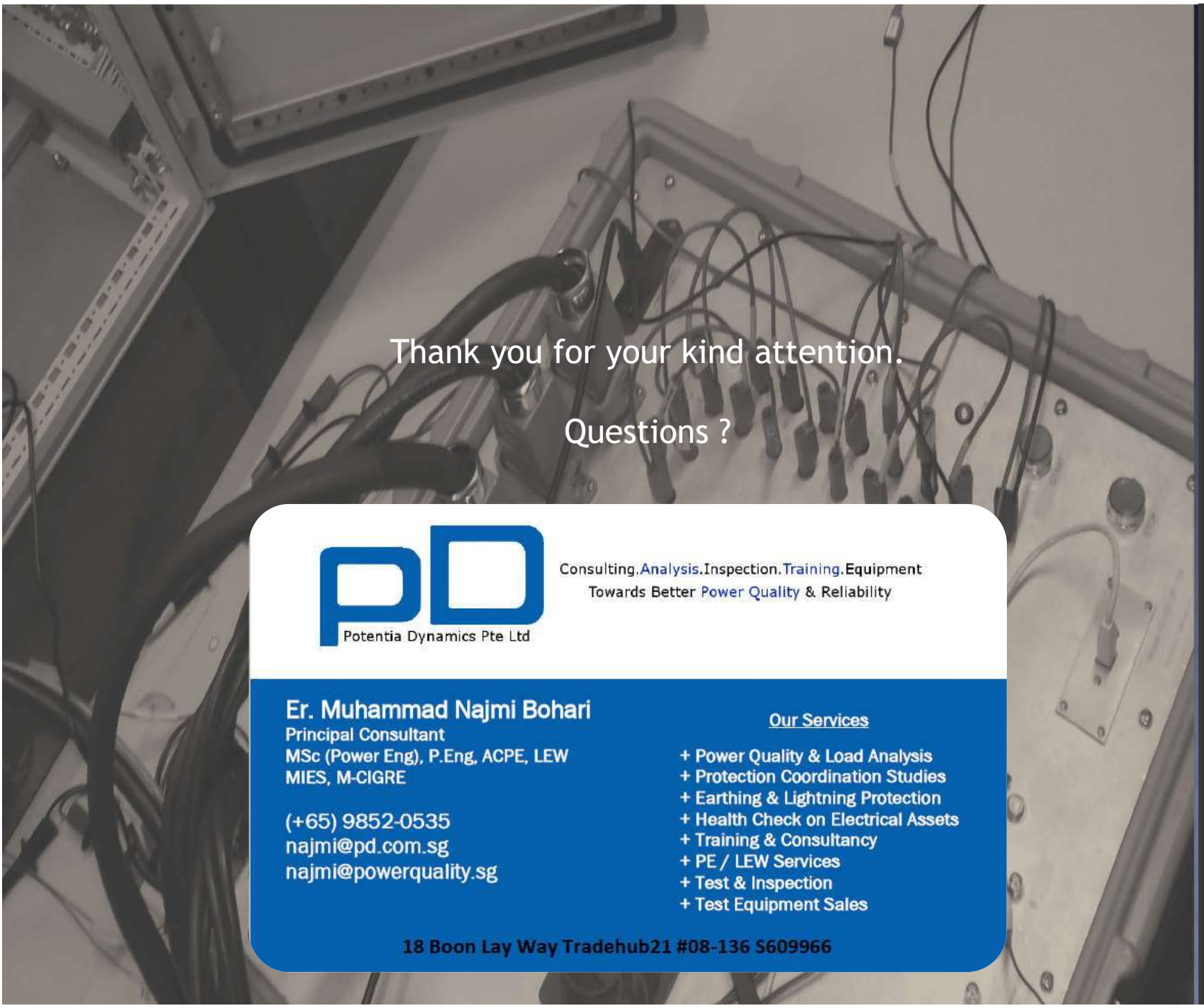


Fig 4: Current Total Harmonic Distortion

LESSON(S) LEARNT

- PQ Education is necessary (again!)
- A comprehensive power quality management programme is essential at all levels
  - Loads End
  - Customer LV & MV
  - Utility End
- Monitoring both voltage & current harmonics
- Setting limits for both



Thank you for your kind attention.

Questions ?

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Our Services

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+ Protection Coordination Studies
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