Study of nuisance tripping of residual current circuit breakers with electronic loads

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2. Detected phenomena
3. Tests performed
4. Equivalent circuit for theoretical explanation
5. Other cases of study
6. Conclusions

Introduction

- Nuisance tripping of residual current circuit breakers (RCCBs) is often related to the presence of electronic loads (computers, converters, etc.)
- The presence of harmonic currents are common cited as the causes
- The minimum tripping current varies with harmonic content and the phase angle of the harmonic component
  - RCCB tripping is determined by the peak value of the leakage current
  - Low order harmonic components with angles that increase the peak value of the current facilitate RCCB tripping
  - Desensitisation of the RCCB is produced by the presence of high-order harmonics and the minimum tripping current increases with increasing harmonic frequency

Introduction

- Thus, a leakage current containing a high component of harmonics, as in circuits that feed electronic loads is not a cause of nuisance tripping
- However, this type of circuit often suffers this problem
- For example, in computer rooms RCCBs sometimes trip when the computers are running, and even when they are turned off
- This study presents an investigation into the causes of RCCB nuisance tripping in circuits supplying electronic loads

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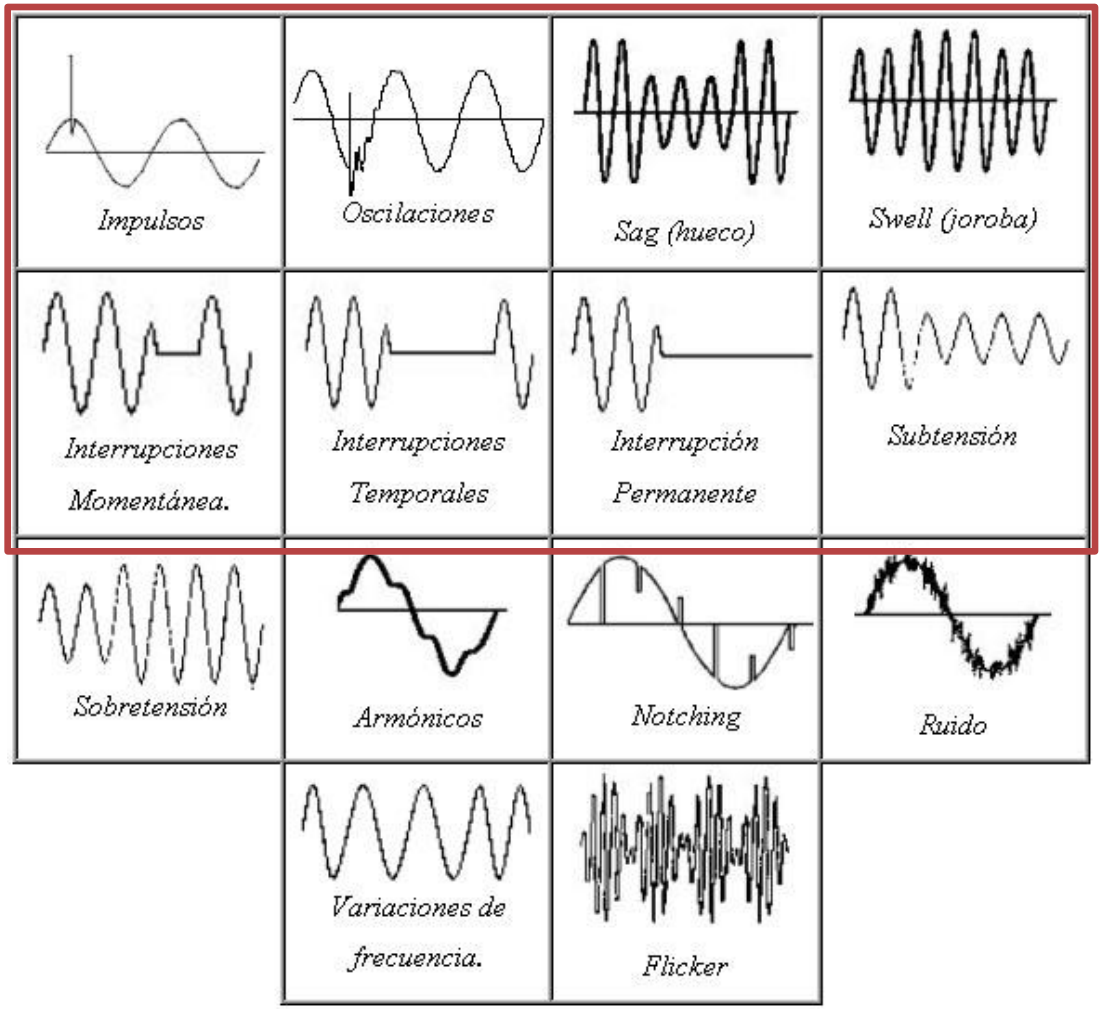
1. Introduction
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Detected phenomena

- The nuisance tripping of RCCBs occurred in a large hospital which became operational in February 2011
- The presence of strong disturbances in the grid voltage waveforms were detected. It appeared that these disturbances caused the high current discharges that sometimes caused the RCCBs to trip
- Detected phenomena
  - High peak voltages in some phases
  - High peak voltages in the neutral voltage to ground
  - Peak values in currents in some phases
  - Peaks of the same order in neutral current

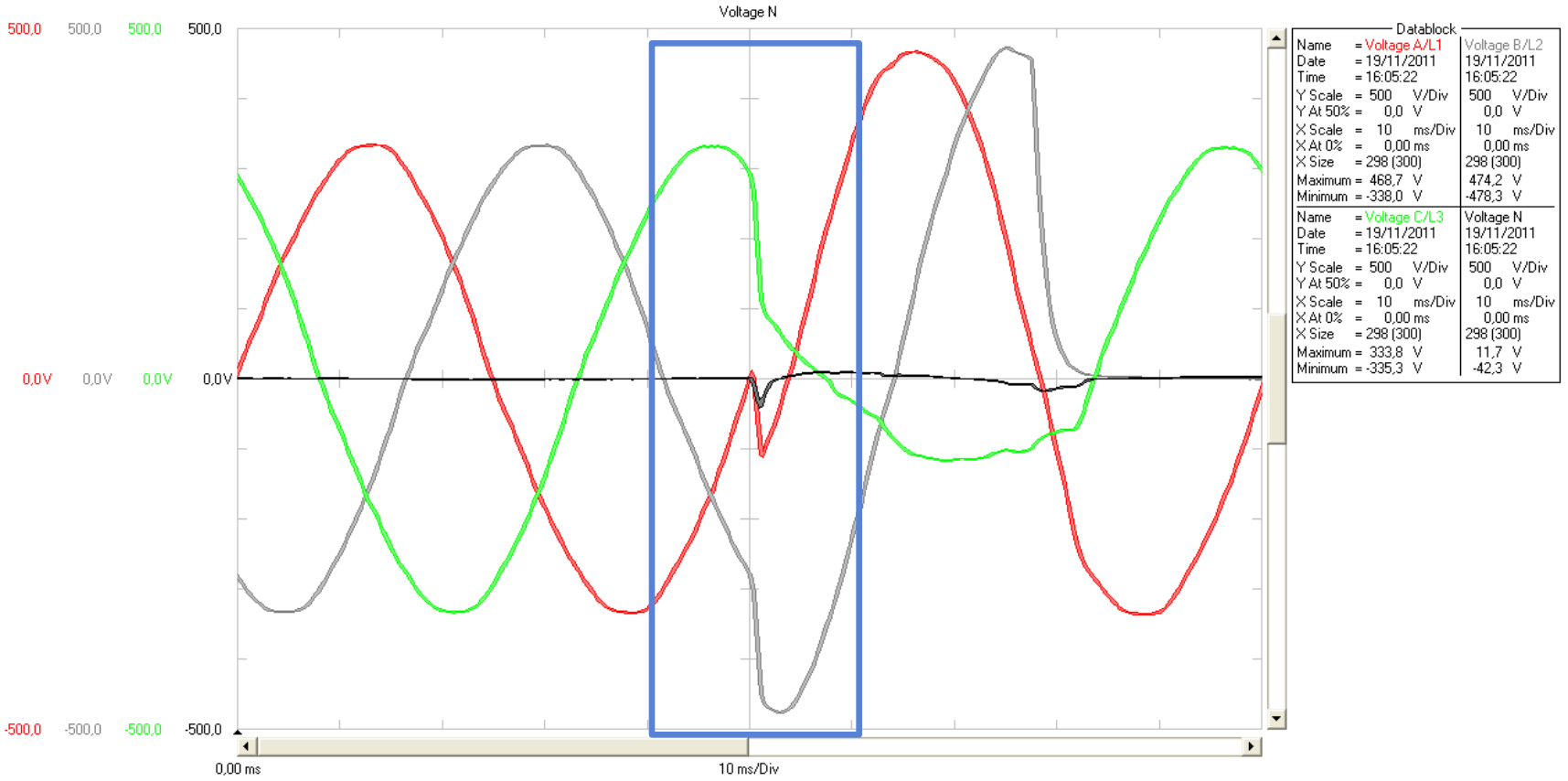
Introduction

- Power quality problems



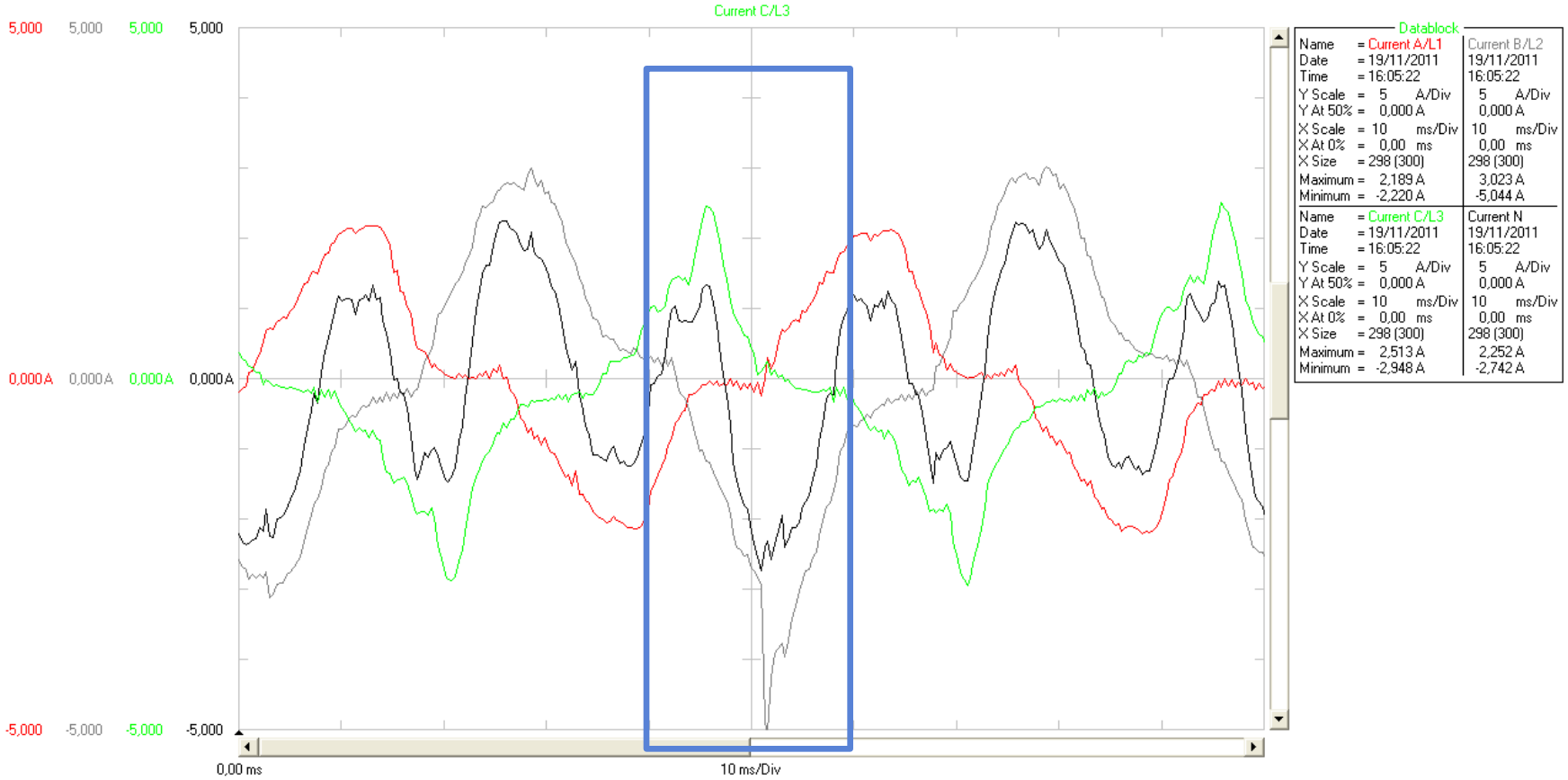
Detected phenomena

- Disturbance in the voltages produced during an RCCB tripping event on 19/11/2011 at 4,05 pm in a circuit feeding nine rooms in a hospital



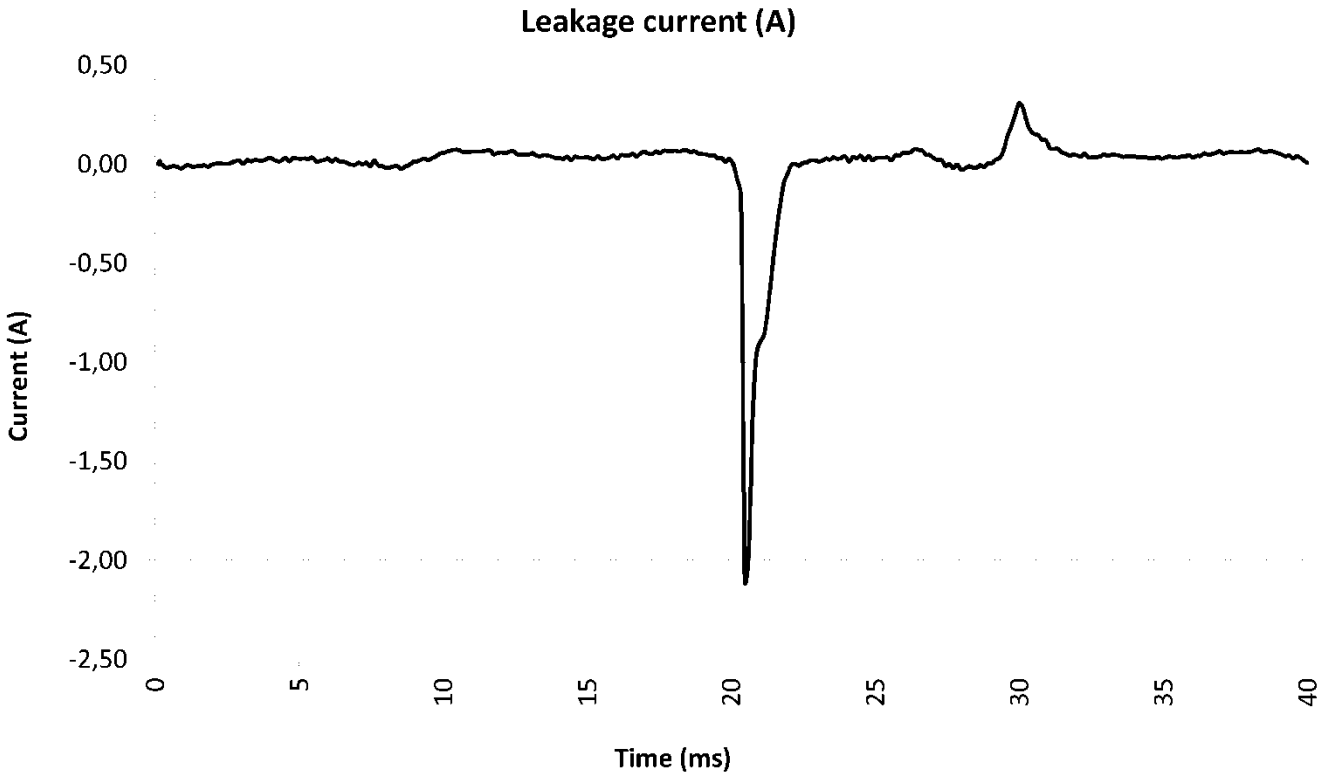
Detected phenomena

- Currents produced during an RCCB tripping event on 19/11/2011 at 4,05 pm in a circuit feeding nine rooms in a hospital



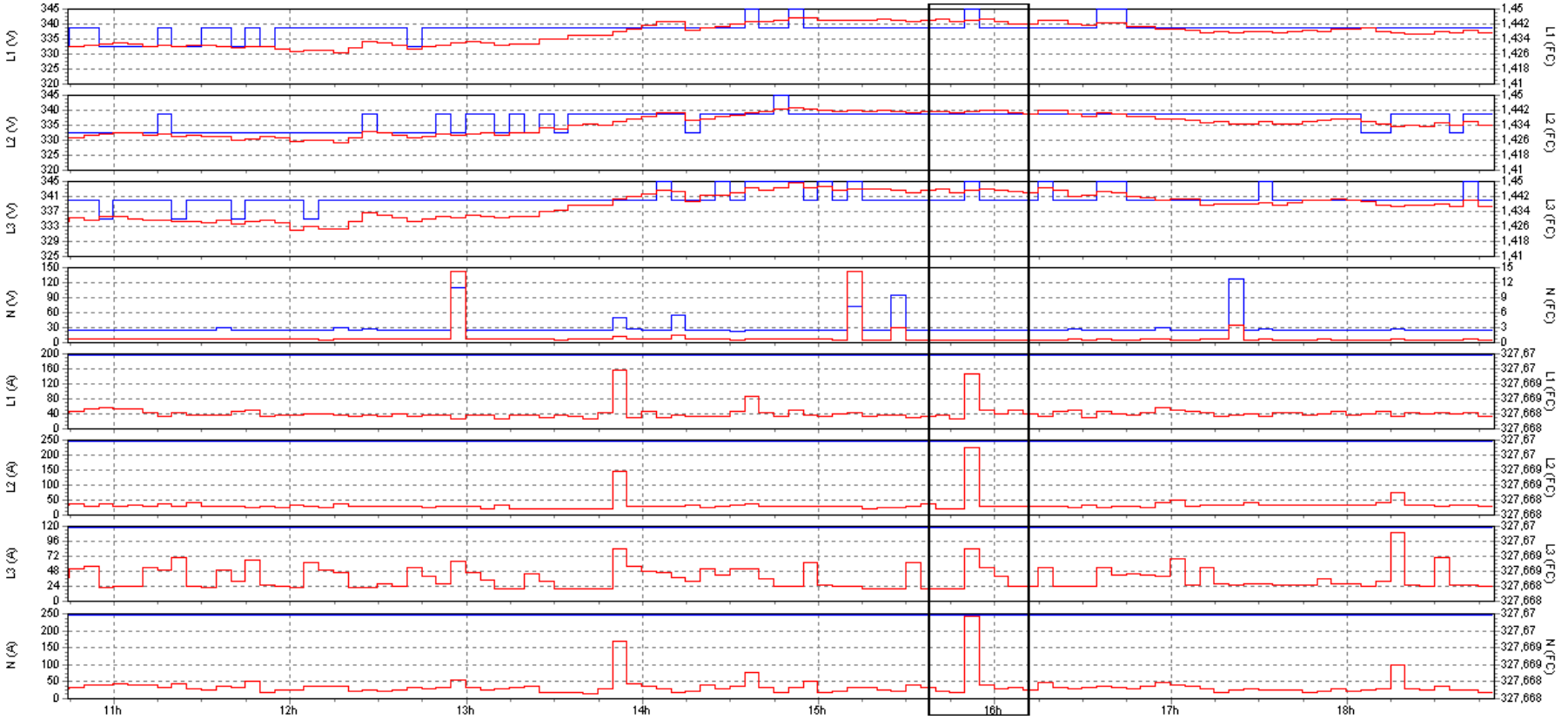
Detected phenomena

- Leakage current during an RCCB tripping event on 19/11/2011 at 4,05 pm in a circuit feeding nine rooms in a hospital



Introducción

- Voltage and current recording for 24/03 at 3,54 pm on a RCCB tripping event in a circuit feeding the main panel of a floor of a block of a hospital



Detected phenomena

- These disturbances produced leakage currents (by capacitive effect and varistor discharges in electronic equipment) and these leakage currents cause AC RCCBs to trip. Since these are short transients, they do not cause the SI RCCBs (an improved type A RCCB) to trip

- The type of loads present in the hospital (such as electronic loads, TV sets, electronic lights, and medical equipment with electronic power suppliers and batteries) contribute to increasing the transient currents which, in turn, raise the neutral-earth voltages and leakage currents, and so increase the frequency of tripping events

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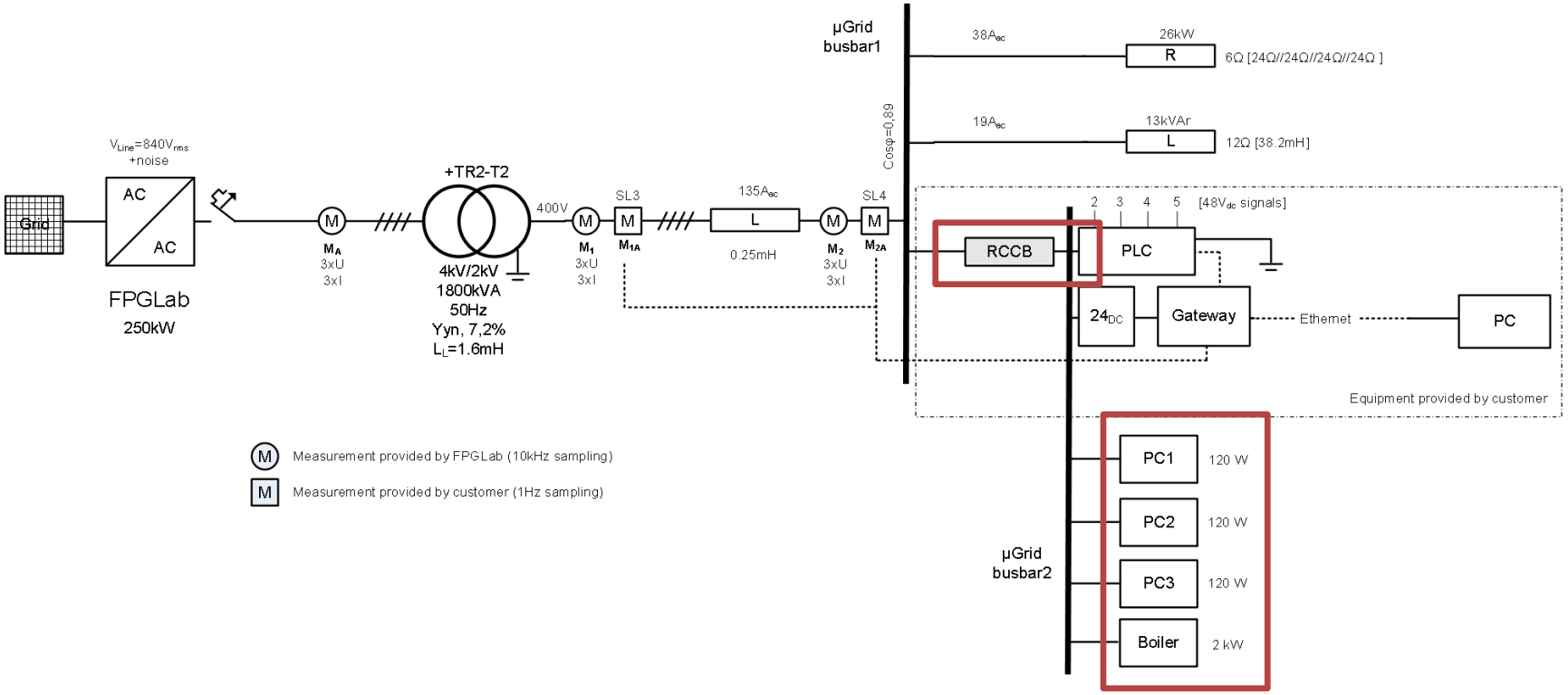
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6. Conclusions

Tests performed

- Several tests were performed in a laboratory to study the influence of electronic loads in RCCB nuisance tripping
- A 250kW AC to AC voltage source is used to generate the desired voltage waveforms (containing transients)
- Three non-linear loads (computers) were connected downstream of an RCCB 20A 30 mA
- The voltages waveforms were the same in all the tests

Tests performed

- Test layout for transient analysis in RCCB tripping



Tests performed

- Description of the tests performed at DNV KEMA

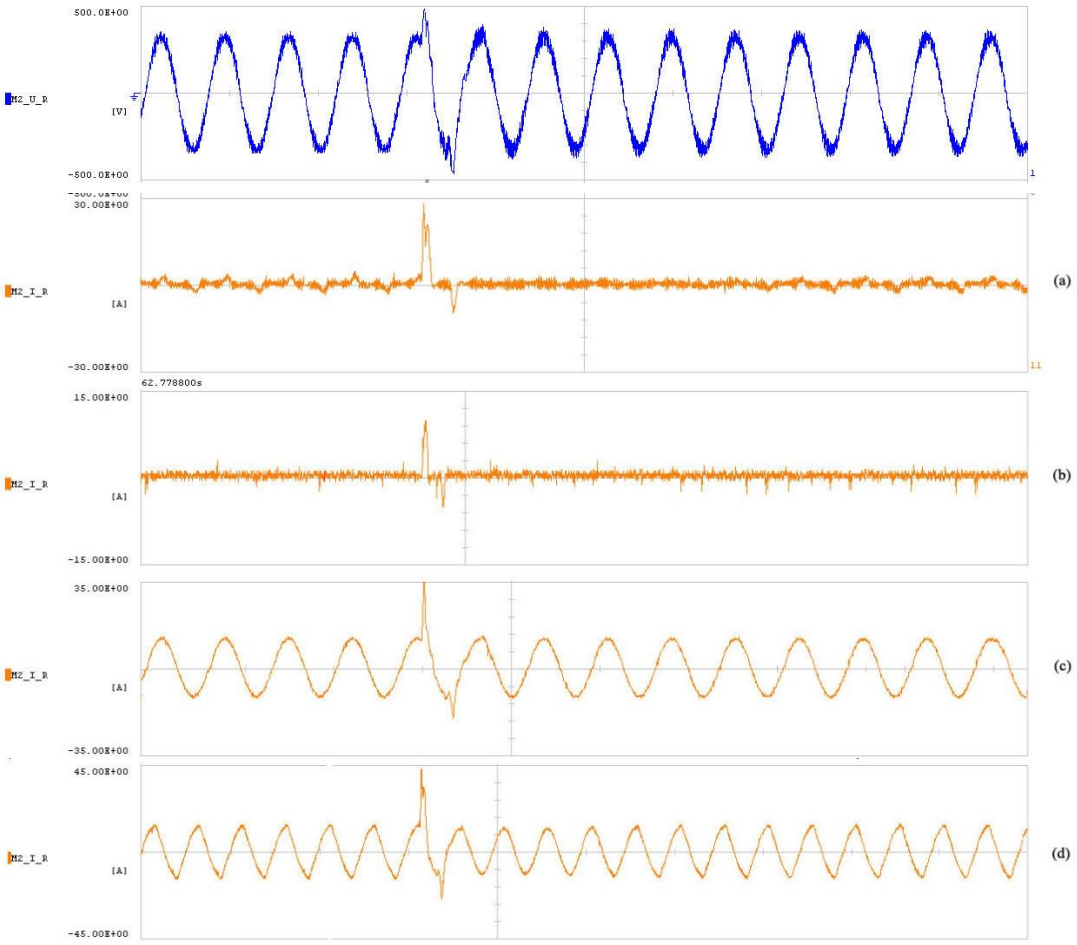
Number	Description	Label
Test 1	3 computers ON connected in phase R	(a)
Test 2	3 computers OFF connected in phase R	(b)
Test 3	1 boiler ON connected in phase R	(c)
Test 4	1 computer ON and 1 boiler connected in phase R	(d)

- Test 1: was performed with three computers ON in phase R. An increase of approximately 1000% with respect to the nominal current is observed in the computer load current

- Test 2: was performed connecting three unplugged computers in phase R. An increase of 10 times of the current is observed. This may explain why in rooms with many computers, nuisance trips sometimes occur even when the computers are turned off.

Tests performed

- Waveforms as a response of a perturbation in the voltage supply



Test 1

Test 2

Test 3

Test 4

Tests performed

- Test 3: A resistive load (a boiler) is connected in phase R. A value of the amplitude of 14.2 A changed to 35 A during the event
- Test 4: A computer and a resistive load is connected in phase R. Voltage disturbances in circuits feeding resistive loads with electronic loads have current increases greater than those without those electronic loads (a value of the amplitude of 14.7 A changed to 45 A during the event)
- In conclusion, non-linear electronic loads (such as computers) have a profound reaction to voltage perturbations/transients. Computers magnify the effect of the transient. This reaction is reduced due to the damping effect of resistance in the load

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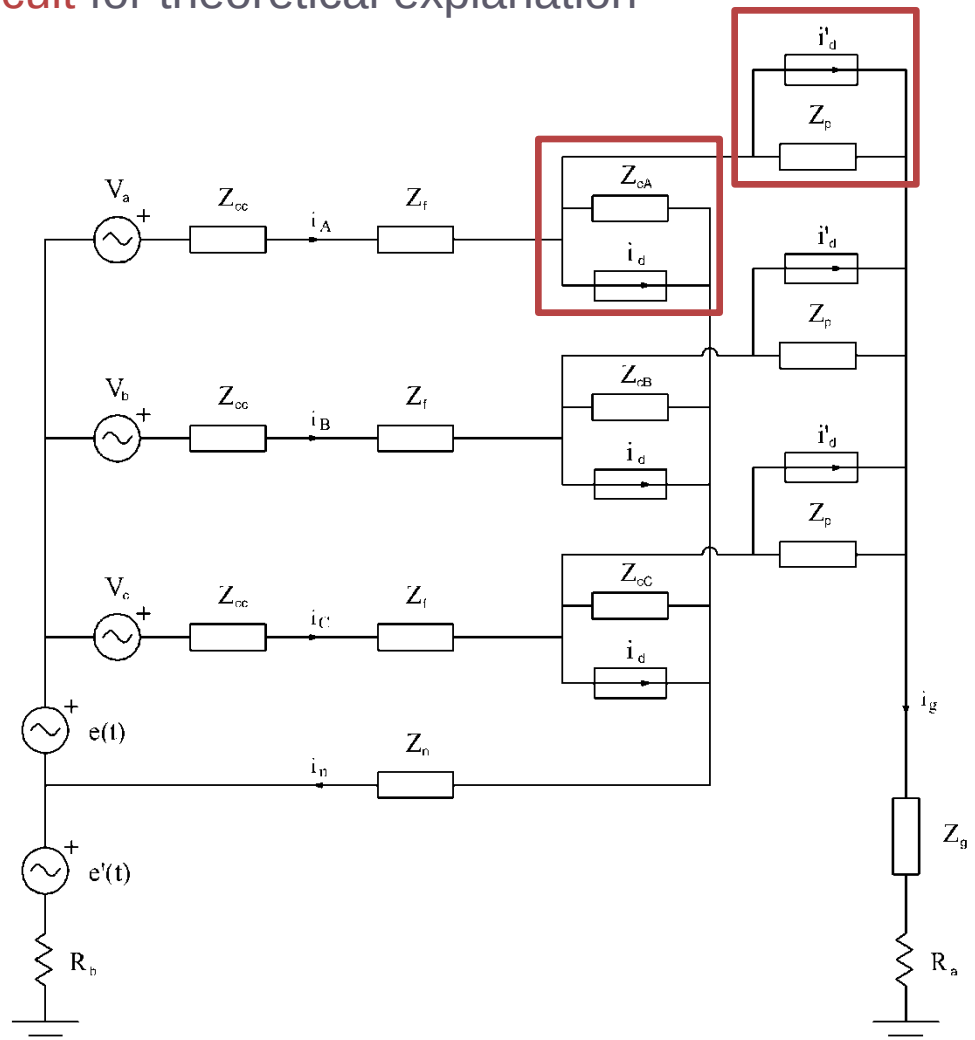
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Equivalent circuit for theoretical explanation

- A simplified equivalent electrical circuit of the data measured in the hospital is presented to obtain the main data related to the phenomenon
- The circuit is obtained as an equivalent circuit of a T-T three phase system and uses a Norton equivalent model to represent the nonlinear behaviour of the loads
- This circuit enables to further analyse the results and theoretically explain the phenomena

Equivalent circuit for theoretical explanation

- Equivalent circuit for theoretical explanation



Equivalent circuit for theoretical explanation

- $i_d(t)$ current source in the nonlinear loads as a result of a disturbance of the voltage and showing an increase in consumption of the load in response to a disturbance. A Norton equivalent model is used to represent the nonlinear behaviour of the loads

- $i'_d(t)$ current source that represents the capacitive effect and varistors present in the nonlinear loads that forces a discharge current in reaction to a voltage surge using the Norton model. The value is modelled as the expression $i'_d(t) = \alpha \cdot |e(t)| \cdot [v(t) + e(t)]$, for each phase

- Values of the parameters used in the model are shown. Real values are used for the three-phase system and tuned values for the Norton equivalents

Variable	R_a (Ω)	R_b (Ω)	e' (V)	e (V)	Z_{CC} (Ω)	Z_f (Ω)	Z_n (Ω)	Z_{cA} (Ω)	i_d (A)	Z_p (kΩ)	Z_g (Ω)	i'_d (A)
Value	1	1	0	-150	0,0016	0,7	1	180	0	100	10	-20

Equivalent circuit for theoretical explanation

- This model explains all the phenomena in the analysed circuits when a disturbance voltage between phases and neutral and an event occurs:
  - Peak voltages are detected in the neutral voltage to ground
  - Currents in phases reached higher peak values (depending on the value of the voltage in each phase at that moment). These values may also trip the circuit breaker
  - Neutral current is increased in the same proportions as the phases
  - Current discharge to earth increases and may force the RCCBs to trip

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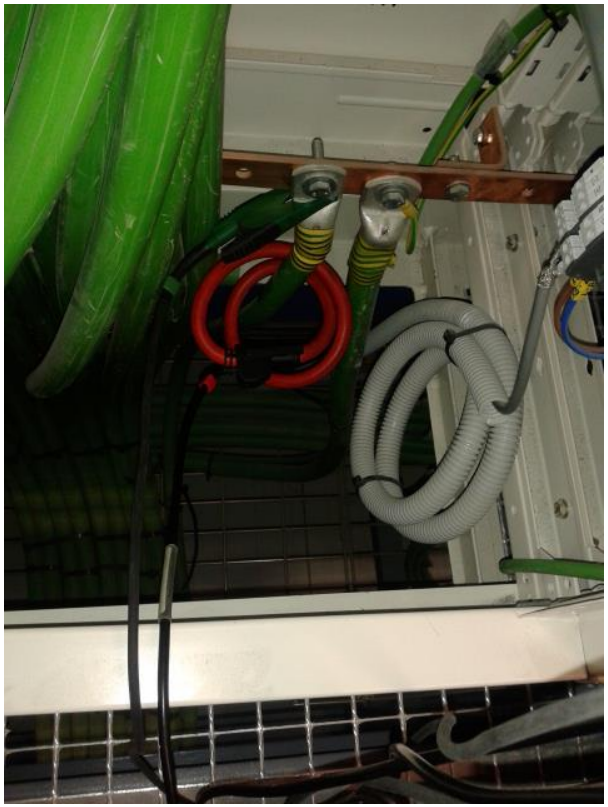
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Other cases of study. Food manufacturing factory

- Measurements in an electrical panel







Other cases of study. Food manufacturing factory

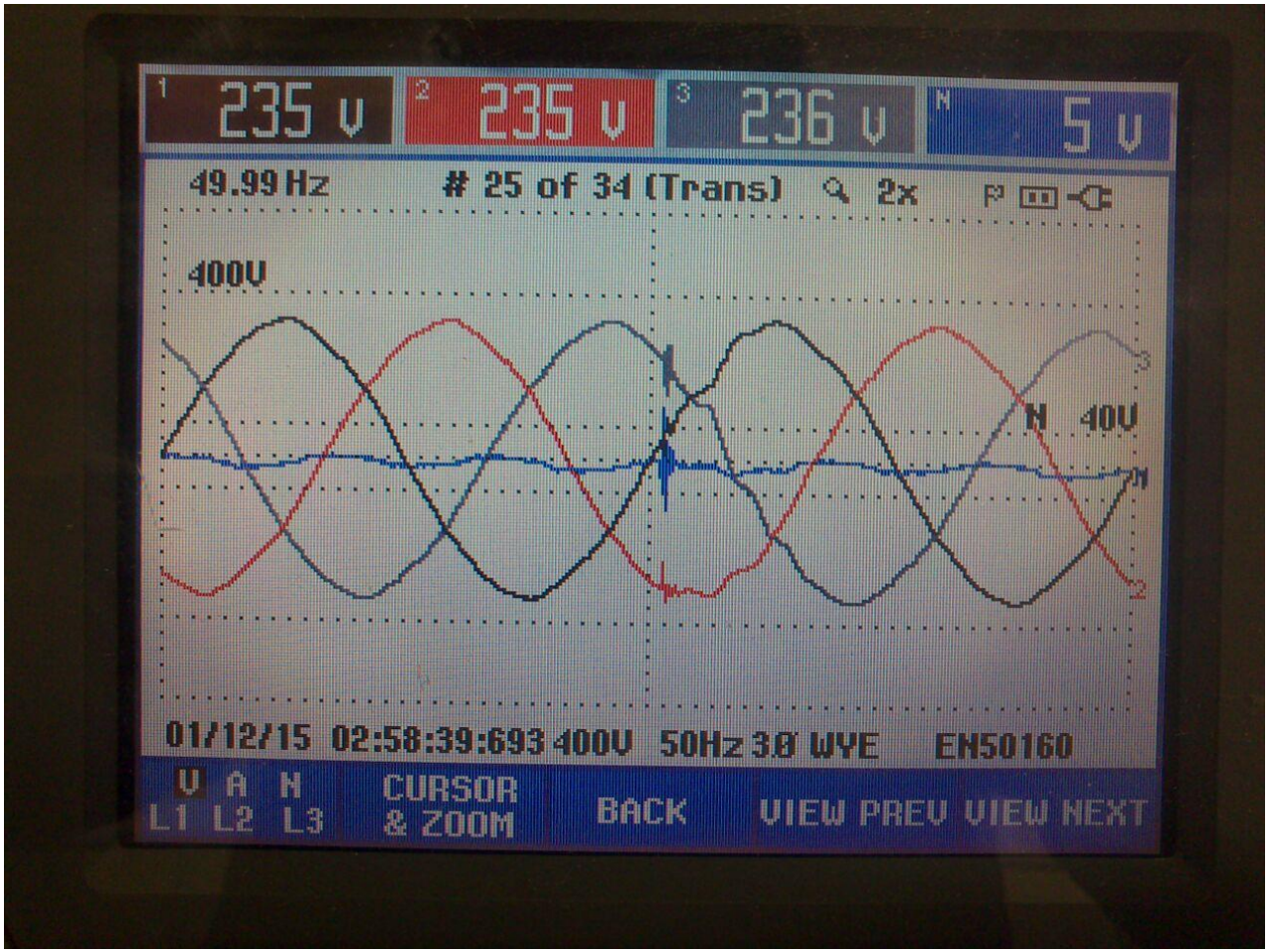
- Electronic equipment for the process





Other cases of study. Food manufacturing factory

- Measurements of an event. Voltages



Other cases of study. Food manufacturing factory

- Measurements in an electrical panel. Voltage and current in phase R



Other cases of study. Food manufacturing factory

- Measurements in an electrical panel. Voltage and current in phase S



Other cases of study. Food manufacturing factory

- Measurements in an electrical panel. Voltage and current in phase T



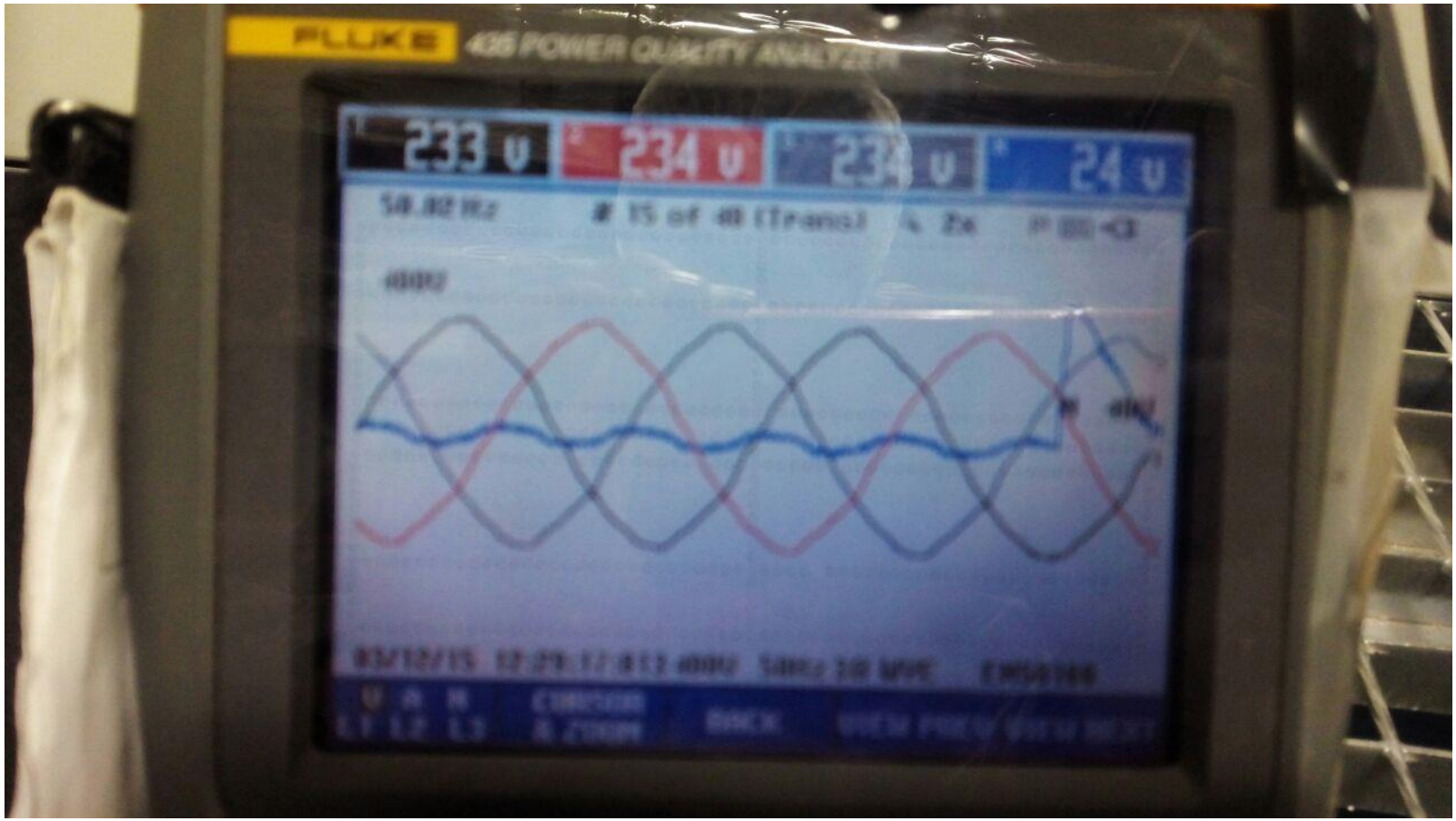
Other cases of study. Food manufacturing factory

- Measurements in an electrical panel. Voltage neutral to earth and leakage current



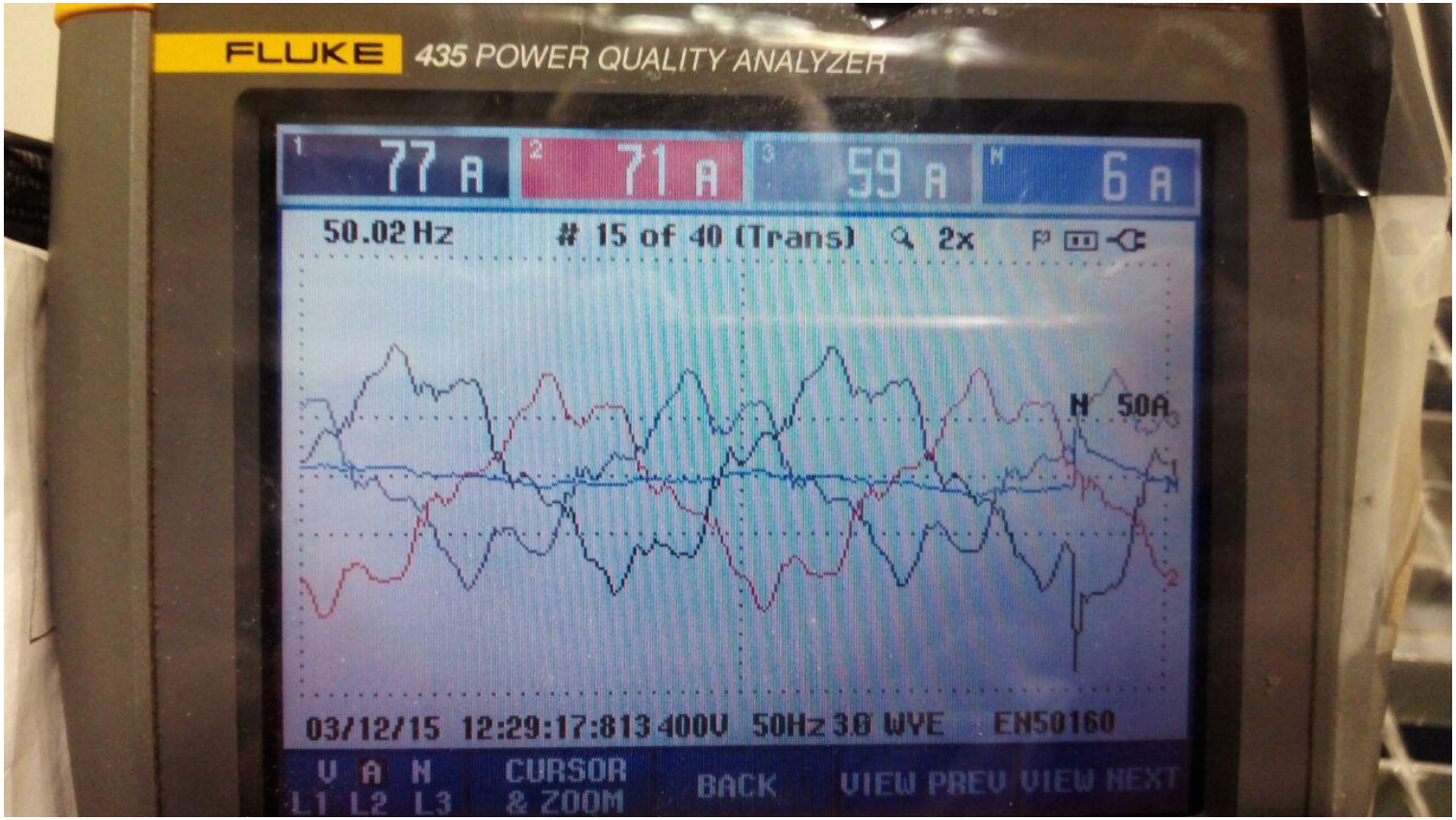
Other cases of study. Food manufacturing factory

- Measurements of an event. Voltages



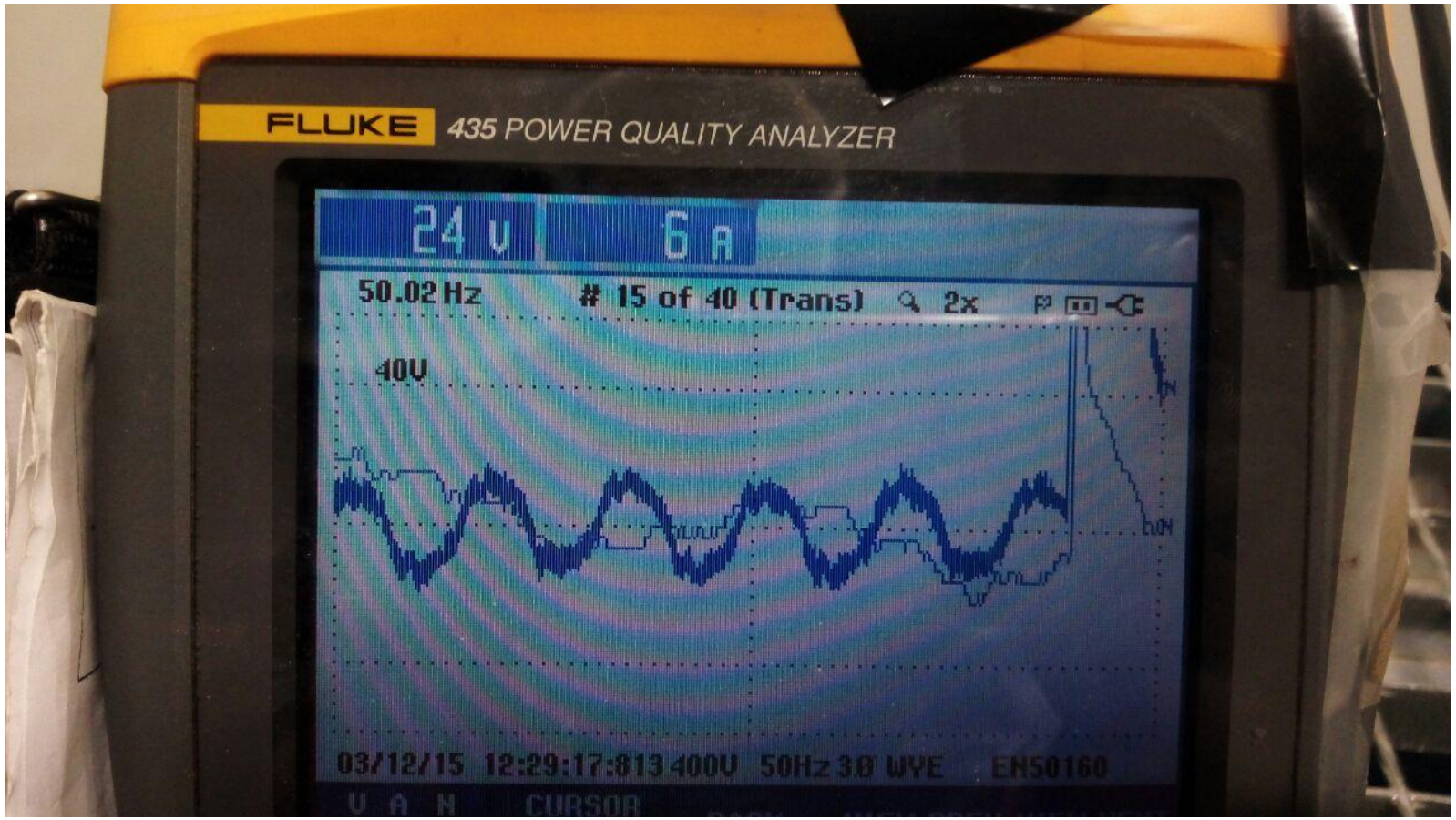
Other cases of study. Food manufacturing factory

- Measurements of an event. Currents



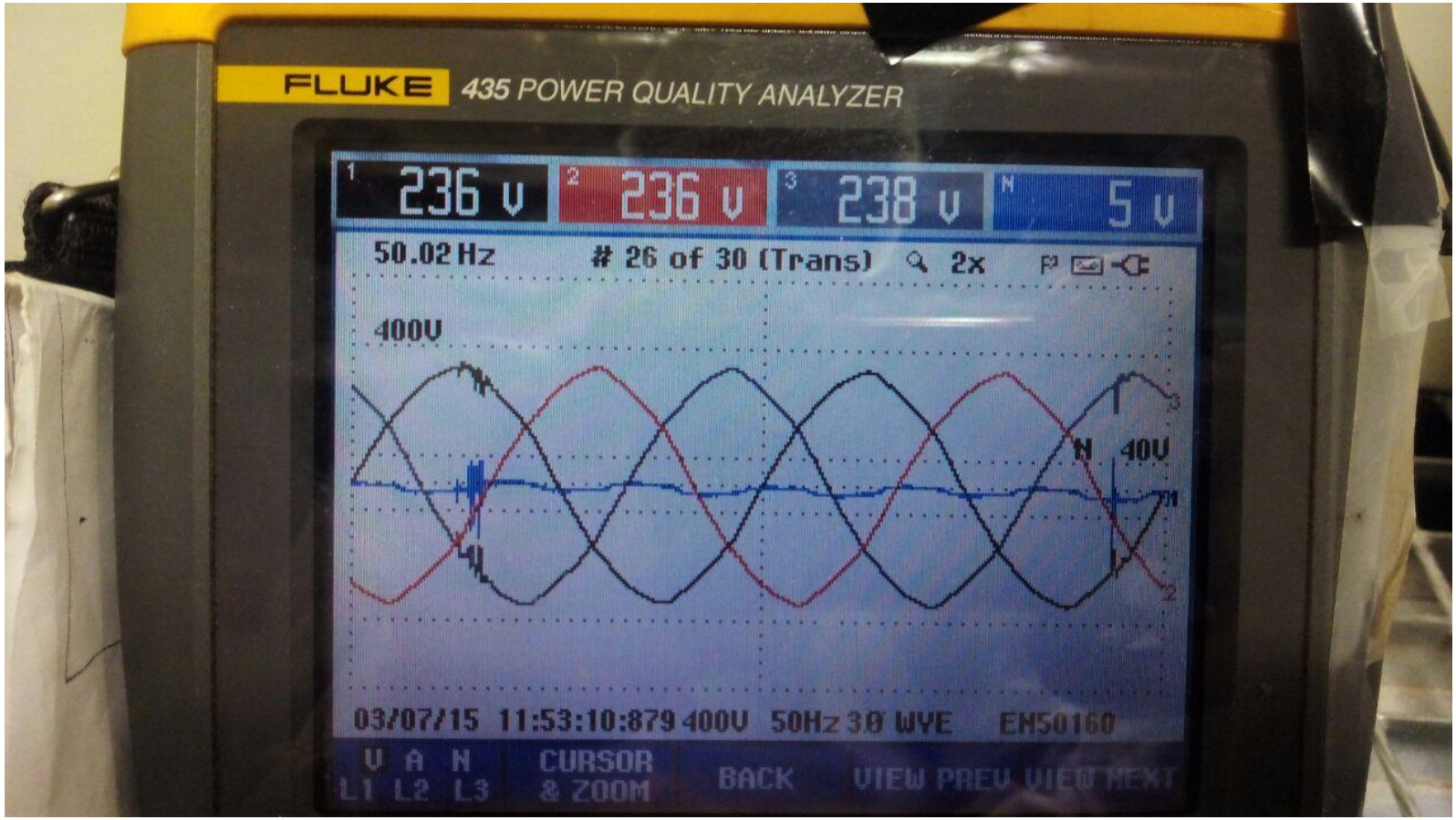
Other cases of study. Food manufacturing factory

- Voltage neutral to earth and leakage current



Other cases of study. Food manufacturing factory

- Measurements of an event. Voltages (start up of the factory)



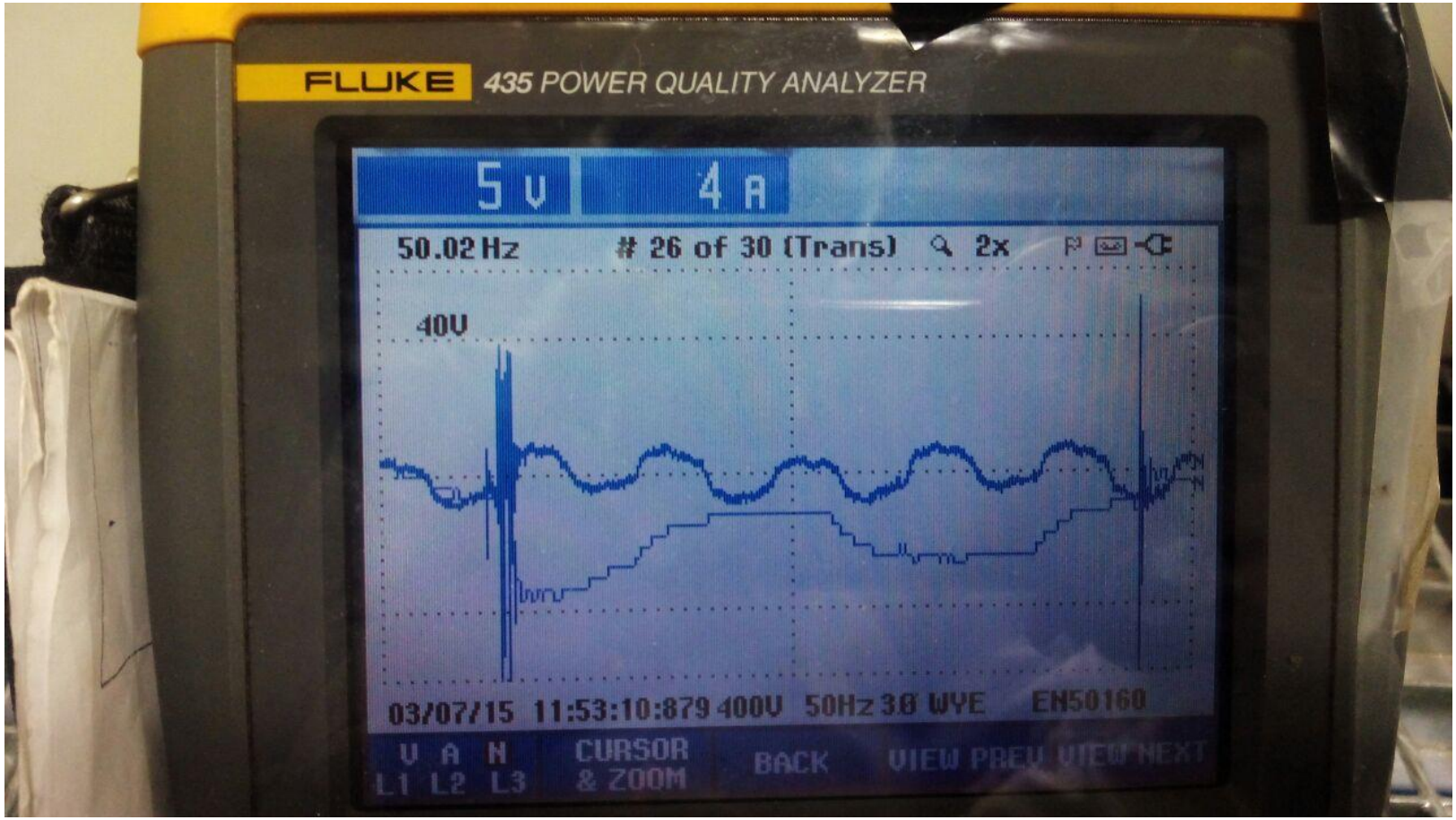
Other cases of study. Food manufacturing factory

- Measurements of an event. Currents



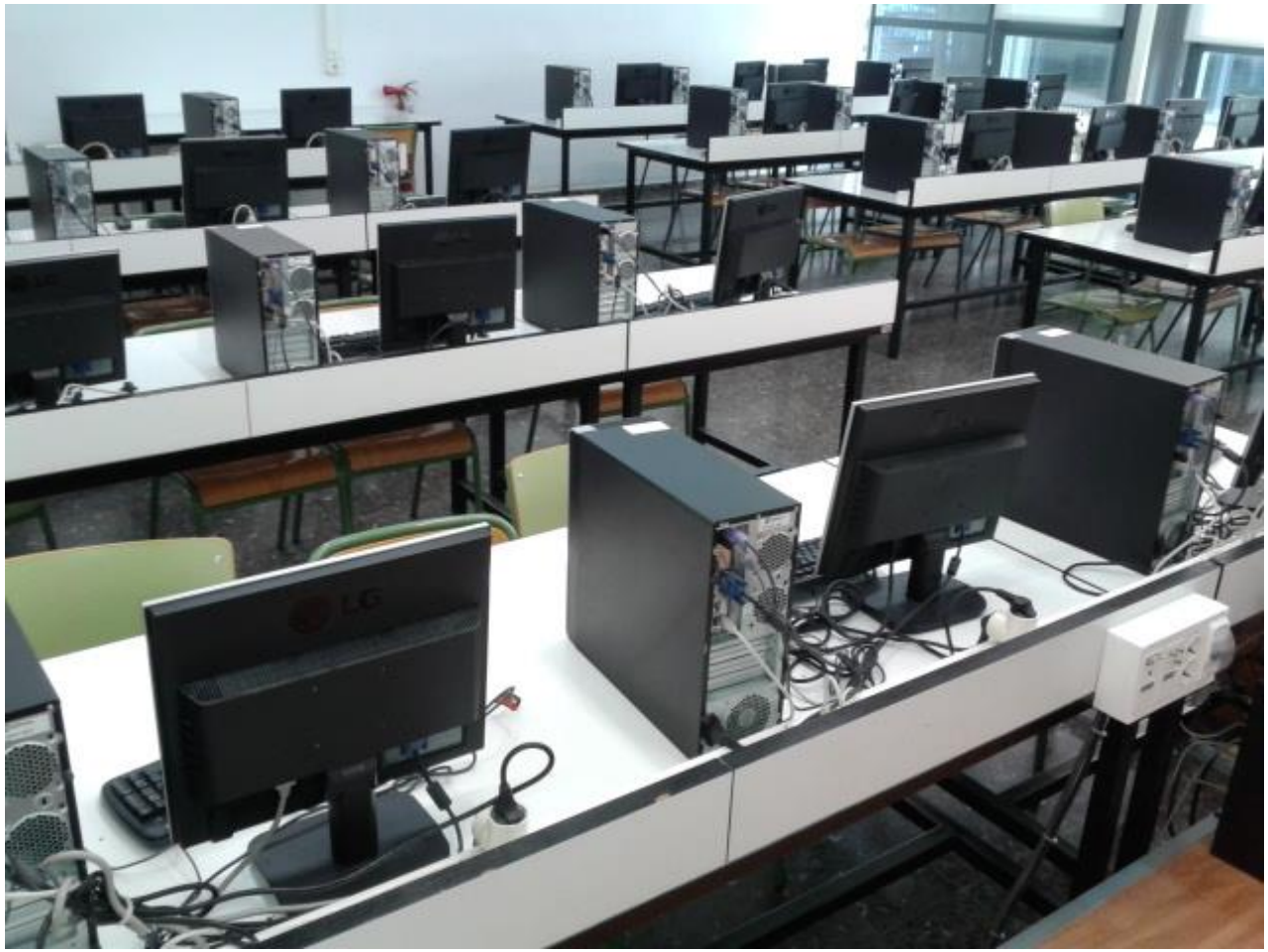
Other cases of study. Food manufacturing factory

- Voltage neutral to earth and leakage current



Other cases of study. Computer laboratory

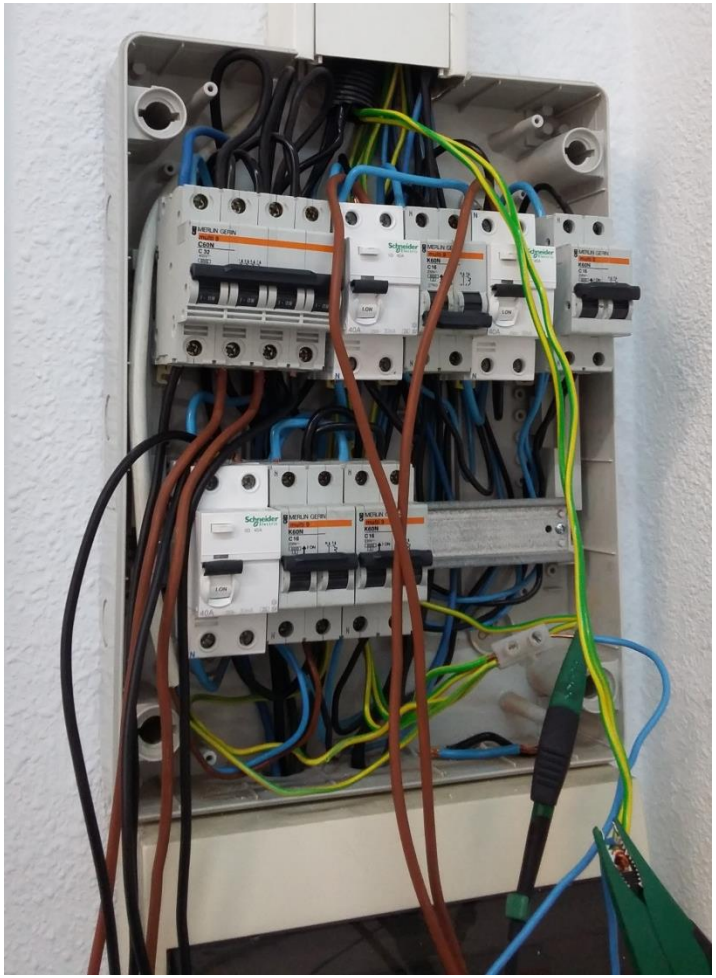
- Measurements in computer laboratory



Other cases of study. Computer laboratory

- Electrical panel of the computer laboratory





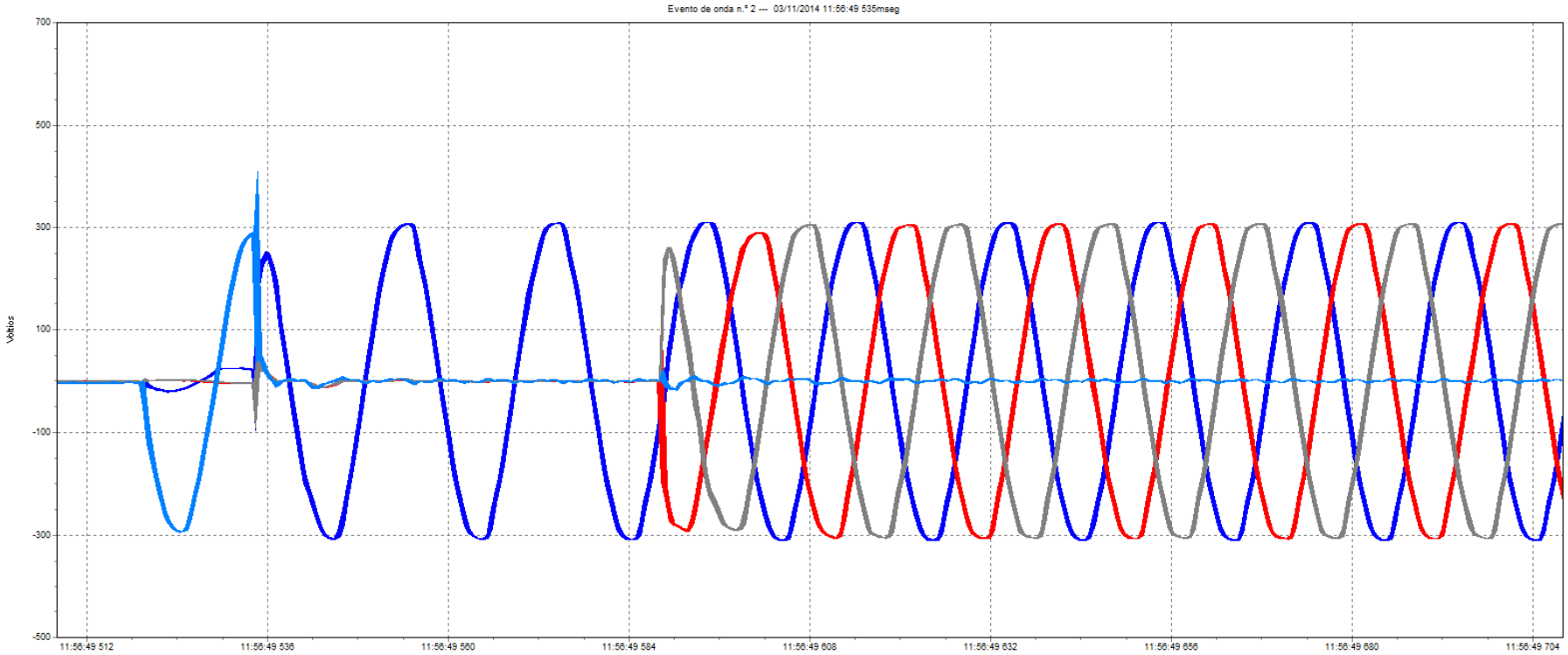
Other cases of study. Computer laboratory

- Leakage current measurement



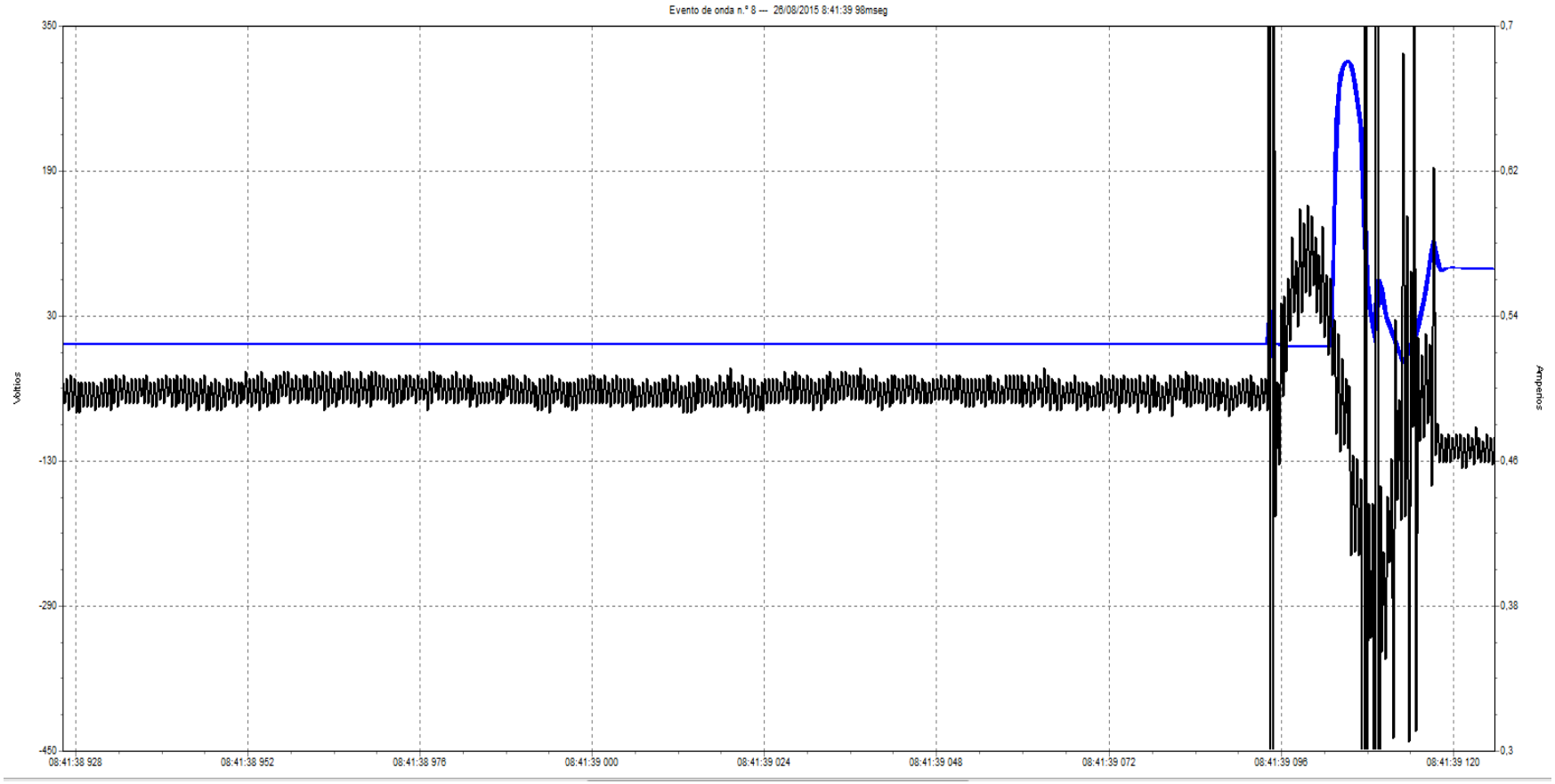
Other cases of study. Computer laboratory

- Voltage measurements in a RCCB trip



Other cases of study. Computer laboratory

- Leakage current measured in a RCCB trip



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Conclusions

- Harmonic are not the cause of the nuisance tripping of residual current circuit breakers (RCCBs)
- In circuits feeding electronic loads when there are supply voltage disturbances, suffer current surges magnified by the electronic loads and discharge currents to ground that cause RCCBs to trip
- Disturbances produce leakage currents by capacitive effect and varistor discharges in electronic equipment
- Currents in phases reached higher peak values. These values may also trip the circuit breaker

Conclusions

- The results may enable RCCBs manufacturers to make the necessary changes to avoid nuisance tripping and, electronic component manufacturers to modify designs in order to avoid this behaviour during voltage surges
- In real facilities in use suffering nuisance tripping of RCCBs:
  - To request the utility to improve the power quality of the supply voltage
  - To install uninterrupted power suppliers (UPS)
  - To use SI RCCBs in sensitive circuits
- In the design stage of facilities with electronic loads:
  - To use a T-N earthing system to avoid installing RCCBs
  - To use a dedicated line from the transformer centre to supply the sensitive loads

Thank you for your attention

Any question?

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