Power Quality Audits

Understanding and analyzing a power quality issue

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Agenda

1. What is power quality?
2. Case Studies
3. The real game changer: continuous monitoring

What is Power Quality (PQ)

- The standard that covers power quality issues is the IEEE 1159 standard. Its definition for power quality is as follows

"The ability of a system or an equipment to function satisfactorily in is electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment."

Satisfactory

Intolerable

- The voltage that is supplied to customers is neither ideal nor immune to disturbances.
- Analogy with water supply. If an industry is polluting the water with their process, the water coming back from the WWW tanks is also polluted. Part of the responsibility lies with the industry to not introduce too many contaminants.

Importance of Power Quality

Compliance to Utility PQ Guidelines
Grid Power quality compliance, reliability & sustainability are becoming Greater concerns.

Energy Efficiency
Reducing Energy consumption, and Carbon Emissions. As PQ decreases, energy efficiency decreases.

Changing customer loads
Electronics, automation systems & modern manufacturing systems all require near-perfect power quality to function properly.

Reducing maintenance costs
Nothing can improve profitability and productivity as equipment lasting longer

Power Quality Audit will support **Power Quality System Analysis, Mitigation, and Metering selection** for the design of an Efficient Power Distribution Solution

Why care about Power Quality?

Complexity of today's installations make our process more sensitive to electrical disturbances.

Deregulated networks and proximity of Renewable Energies impact power quality.

Main consequences are usually:

- Unexpected interruptions of industrial and business processes
- Risks of fire due to overheating or loss of insulation
- Unwanted operation of circuit breakers
- Extra noise or vibration on machines
- Degradation of processes quality
- Financial impacts and penalties from energy provider or due to downtimes

3-6%

of manufacturing sales dollars are spent correcting Power Quality problems

Benefits of good Power Quality:

- Improved energy efficiency
- Reduced utility costs
- Reduced waste and improved operational efficiency
- Reduced emissions
- Increased productivity
- Decreased unplanned downtime
- Increased equipment and power reliability
- Lower operating costs

50%

of mission-critical power outages are due to Power Quality issues

70-80%

of power disturbances originate inside the facilities

17 hours

average restart time after a shutdown

Case studies

Case study 1


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Power Quality Assessment
Consulting Services

FROST & SULLIVAN
2020 BEST PRACTICES AWARD
GLOBAL ACTIVE HARMONIC FILTERS/POWER QUALITY PRODUCT LEADERSHIP AWARD

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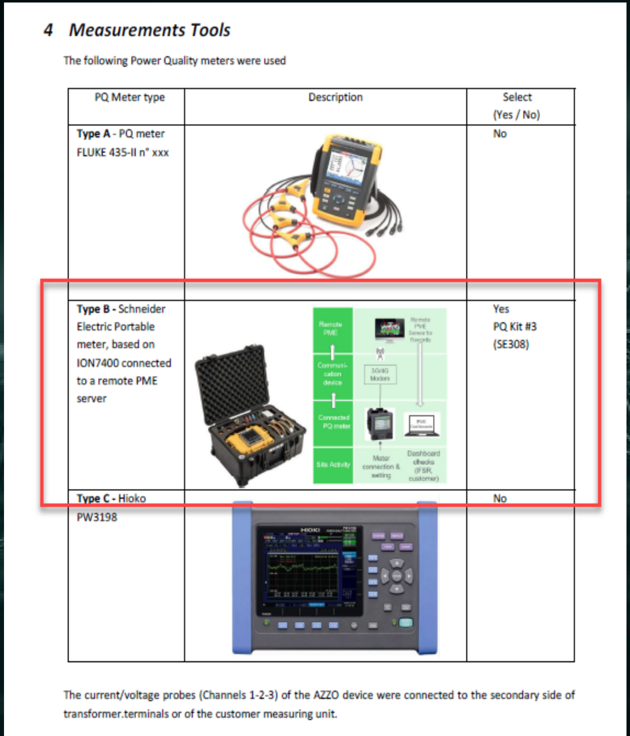
4 *Measurements Tools*

The following Power Quality meters were used

PQ Meter type	Description	Select (Yes / No)
Type A - PQ meter FLUKE 435-II n° xxx		No
Type B - Schneider Electric Portable meter, based on ION7400 connected to a remote PME server		Yes PQ Kit #3 (SE308)
Type C - Hioko PW3198		No

The current/voltage probes (Channels 1-2-3) of the AZZO device were connected to the secondary side of transformer.terminals or of the customer measuring unit.

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Case study 1

Hospital

Existing establishments looking to renovate and replace electrical equipment are looking for an “overlook” of their power quality

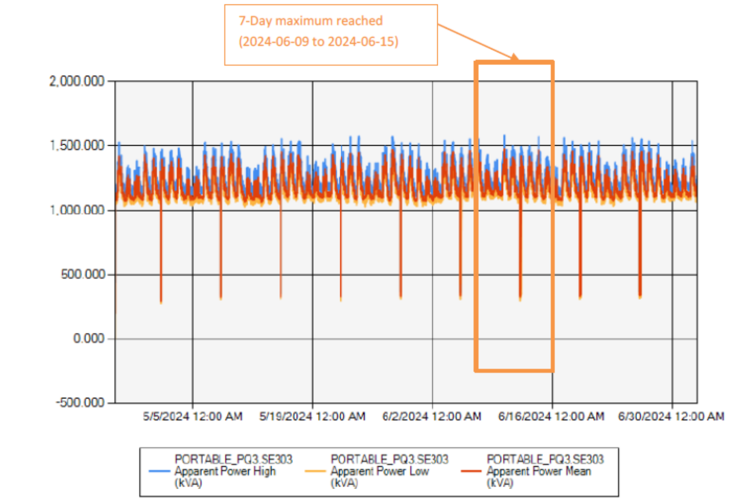
Scope

1. Measurements over 2 week period at one point
2. Detailed Report on Power Quality issues (Eg: harmonics, sag events and power factor)
3. Recommendations

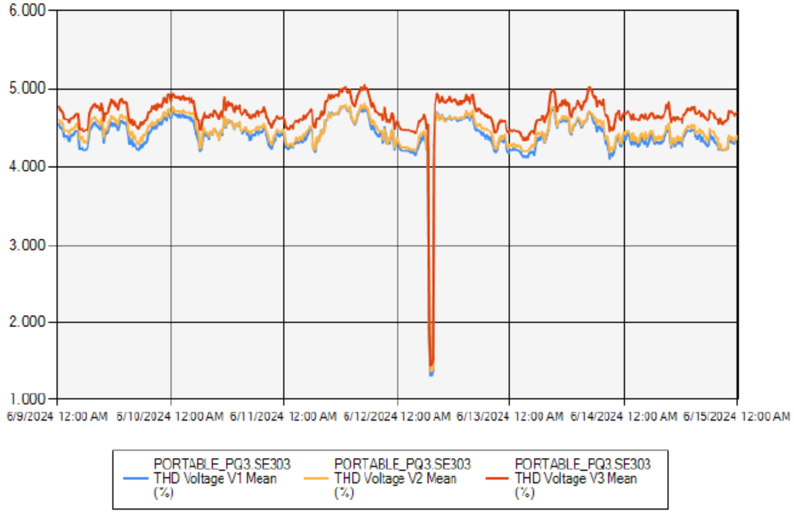
Case study 1

5.2.3.1 Weekly Load Apparent Power (over all period)

Next graphics show the overall period where meter was installed from 2024-06-09 to 2024-06-15.



7.2.1.1 THDv Measurement report



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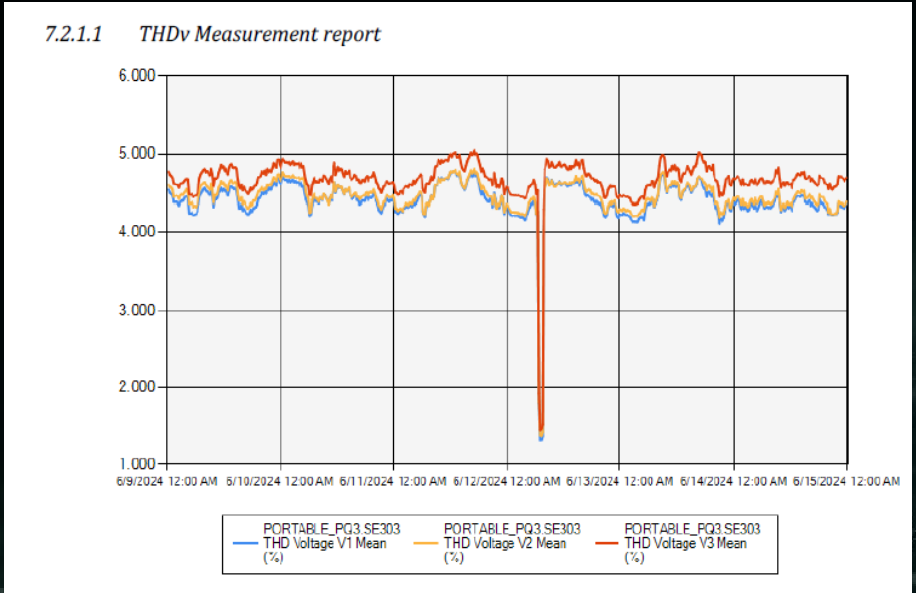
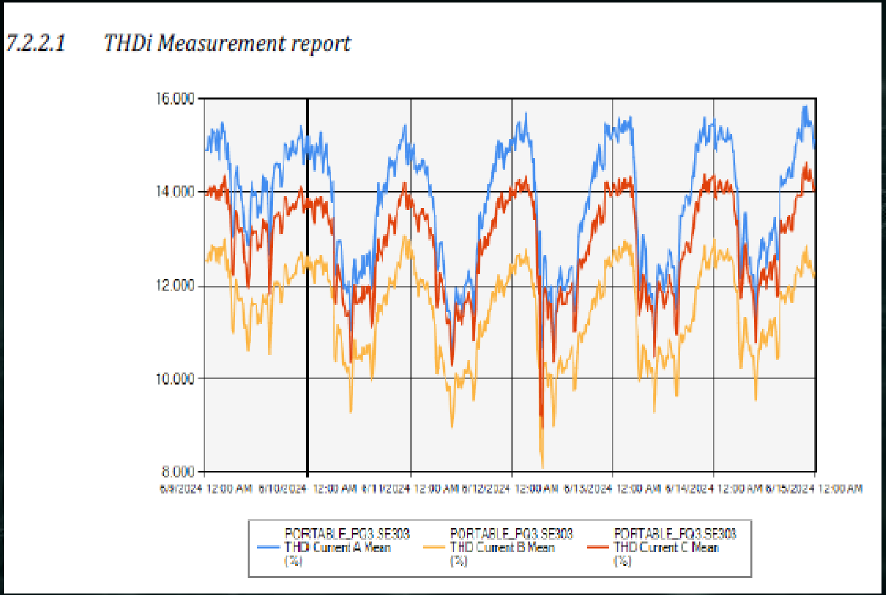
Case study 1

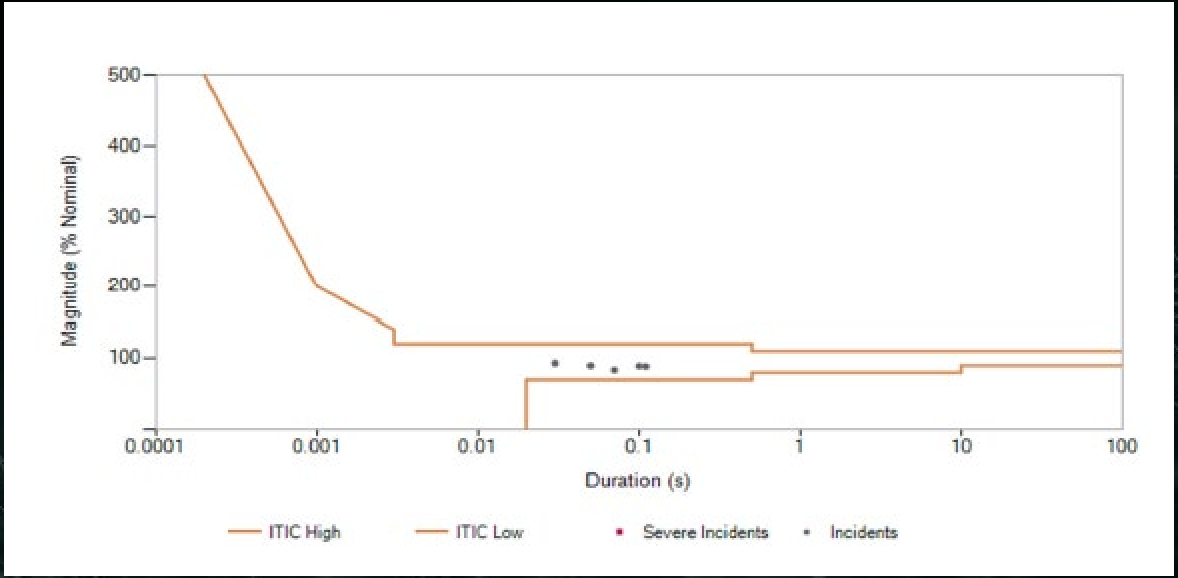


7.2.1.1 THDv Measurement report
6.000
5.000
4.000
3.000
2.000
1.000
6/9/2024 12:00 AM
6/10/2024 12:00 AM
6/11/2024 12:00 AM
6/12/2024 12:00 AM
6/13/2024 12:00 AM
6/14/2024 12:00 AM
6/15/2024 12:00 AM
PORTABLE_PQ3.SE303 THD Voltage V1 Mean (%)
PORTABLE_PQ3.SE303 THD Voltage V2 Mean (%)
PORTABLE_PQ3.SE303 THD Voltage V3 Mean (%)



7.2.2.1 THDi Measurement report
16.000
14.000
12.000
10.000
8.000
6/9/2024 12:00 AM
6/10/2024 12:00 AM
6/11/2024 12:00 AM
6/12/2024 12:00 AM
6/13/2024 12:00 AM
6/14/2024 12:00 AM
6/15/2024 12:00 AM
PORTABLE_PQ3.SE303 THD Current A Mean (%)
PORTABLE_PQ3.SE303 THD Current B Mean (%)
PORTABLE_PQ3.SE303 THD Current C Mean (%)

Case study 1



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Consequences of harmonics

The current itself has few consequences:

- The harmonic current does not produce work but still circulates in the conductors → in the same way as the reactive current, it "clogs" the network…

- Very bad for transformers, because the losses are a function of the square of the frequency…

Harmonic voltage can cause a variety of problems!!!

If the voltage source has a large source impedance → harmonic current causes distortions!!!

Consequences of harmonics

Heating of the neutral conductor $P = RI^2$. We must also consider the skin effect, which means that higher frequencies flow on the outer layers of the conductor, i.e. closer to the insulation

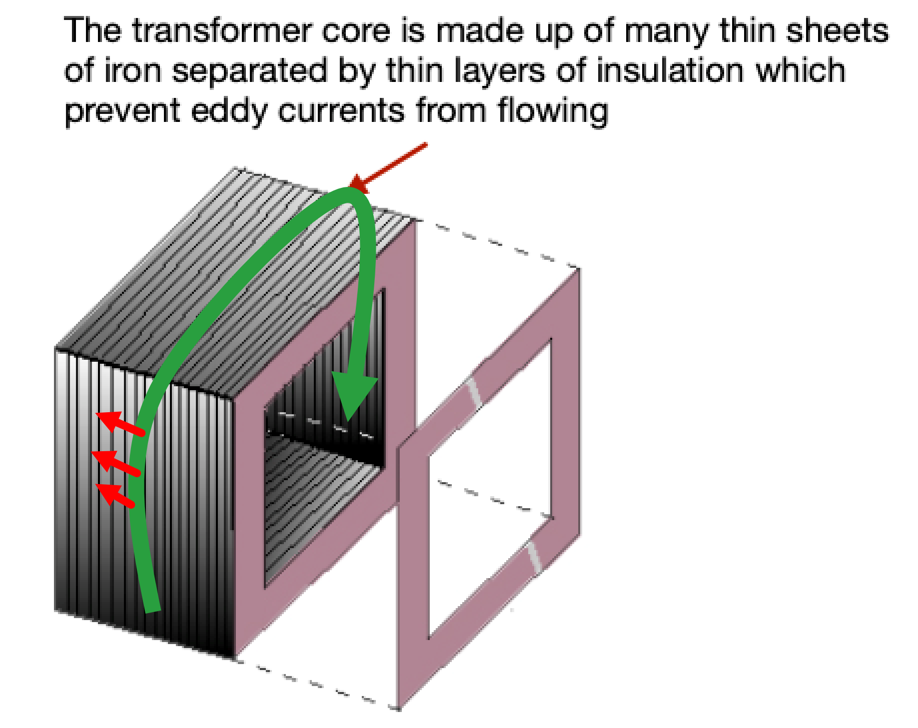
True RMS detection *: The detection system responds to current flow through the circuit breaker. Electronic trip circuit breakers are limited to AC systems because the electronic trip system uses current transformers to sense the current. The MicroLogic trigger samples the current waveform to provide true* ***effective protection up to the 15th harmonic****.*
This true RMS detection gives accurate values for the amplitude of a non-sinusoidal waveform. Consequently, the heating effects of the conductors due to the presence of harmonics are taken into consideration by the thermal protection of the circuit breakers.

Consequences of harmonics

Transformers: Eddy currents

$$P = K_e B_m^2 f^2 t^2 V$$
$$B = \mu \frac{NI}{l}$$

Where V represents the volume and t the thickness
Iron losses are proportional to the square of the frequency!!!



Consequences of harmonics

Transformers with k factors: designed to TOLERATE (and not mitigate) harmonics

K-factor transformers are not just conventional oversized transformers. They are designed to limit losses due to eddy current specifically and will be cheaper and smaller than if we simply chose a transformer of equivalent power.

$$K = \sum_{h=1}^{h_{max}} I_h^2 \, h^2$$

h	I_{pu}	h^2	I_{pu}^2	$h^2 I_{pu}^2$
1	1.000	1	1.000	1.000
3	0.300	9	0.090	0.810
5	0.350	25	0.123	3.063
7	0.250	49	0.063	3.063
9	0.010	81	0.000	0.008
11	0.091	121	0.008	1.002
13	0.077	169	0.006	1.002
15	0.059	289	0.003	1.006
17	0.053	361	0.003	1.014
			K=	11.967

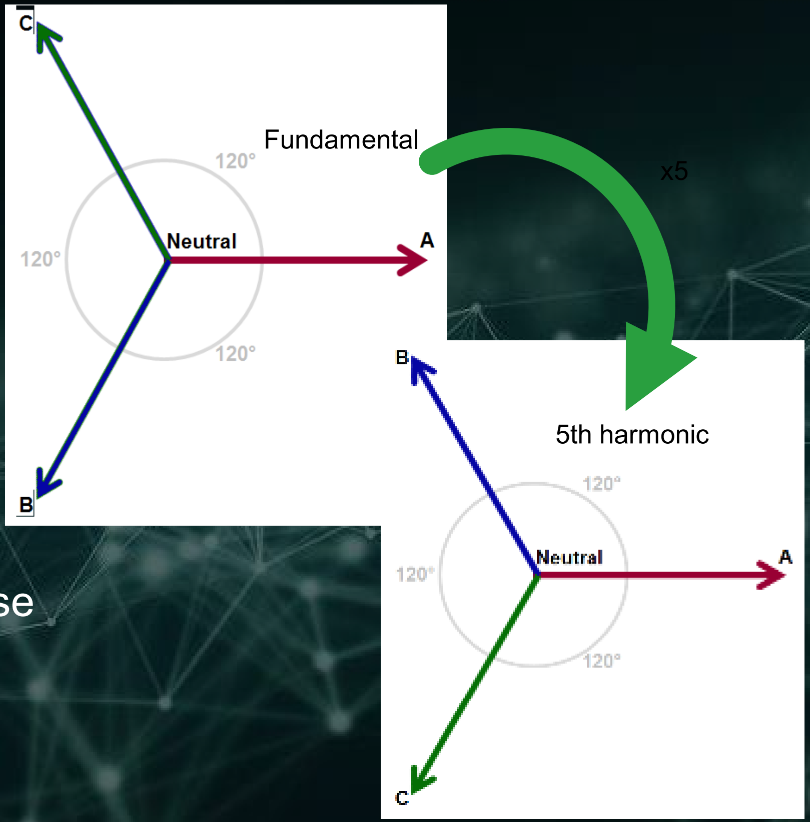
Consequences of harmonics

$$I_{A5} = \sin\big(5(\omega_1 t - \phi)\big) = \sin(\omega_5 t - 5\phi)$$

$$\mathrm{I}_{A5} = \sin(\omega_5 t - 0°)$$

$$\mathrm{I}_{B5} = \sin(\omega_5 t - 5 * 120°) = \sin(\omega_5 t - 600°)$$
$$= \sin(\omega_5 t - 240°)$$

$$\mathrm{I}_{C5} = \sin(\omega_5 t - 5 * 240°) = \sin(\omega_5 t - 1200°)$$
$$= \sin(\omega_5 t - 120°)$$



The 5th harmonic results in the creation of a reverse torque on rotating machines!

Consequences of harmonics

Voltage distortion can cause the waveform to “flatten” and prevent the converter capacitors from charging properly…

Voltage distortion creates harmonic current throughout the network and can damage capacitors, transformers, etc.

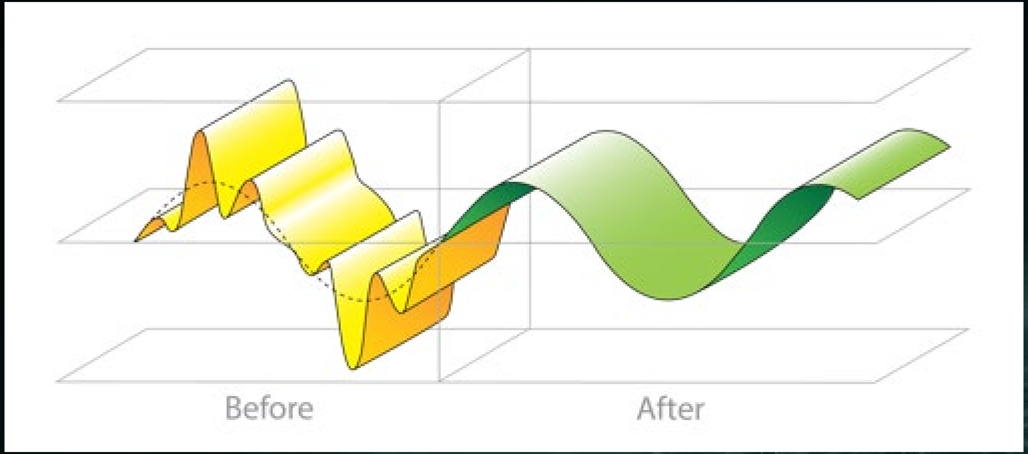
It can also cause noise, mechanical vibrations, damage conductor insulation, etc.

Solutions

- K-rated transformer will <u>tolerate</u> the harmonics, not filter them
- Passive filters are system-specific, they cannot evolve with the facility
- Passive filters will inject capacitive kVAR permanently
- Possible to filter *at the source* (AFE drives)

- Active filter : one solution for all harmonics, var compensation, unbalance correction, power factor correction

Solutions



Solutions

BEST PRACTICE (for all active harmonic filter manufacturers)

Impedance: =>3% to 5% input line reactors on every nonlinear load

- First level in harmonic reduction for 6-p PWM VSD
    - ~90% to ~ 30-35% TDD
    - Z% of LR + Z% of DC choke = Total Z%
- Reduces THDv due to voltage notch for thyristor (SCR) rectifiers
- Optimizes AHF selection
    - Minimizes AHF size and costs
    - Maximizes TDD performance

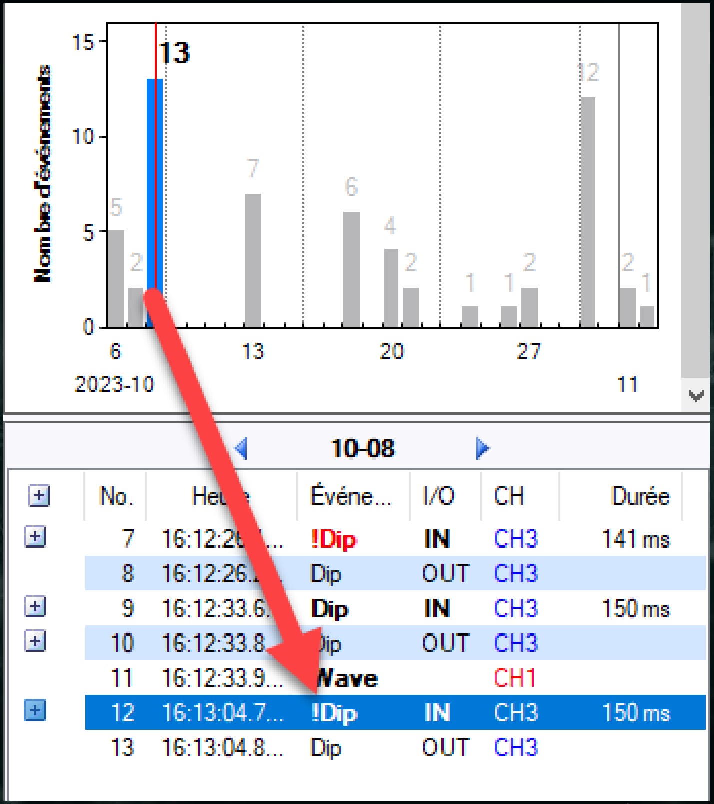
No capacitors downstream of CT (bare or detuned or broadband filters)

- Minimizes resonance potential
- Streamlines installation expense
    - Don't need auxiliary CT

Case study 2: a costly sag

Voltage sags were causing the water Treatment system to shut down

Monitoring over 1 month period to detect and characterize sags



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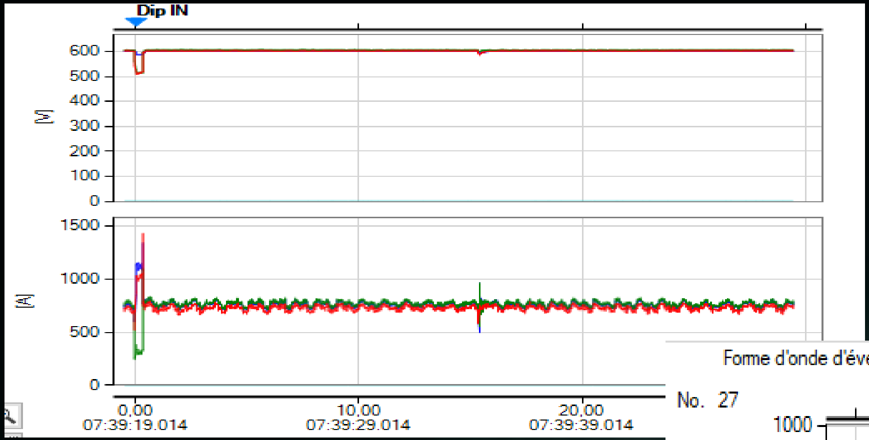
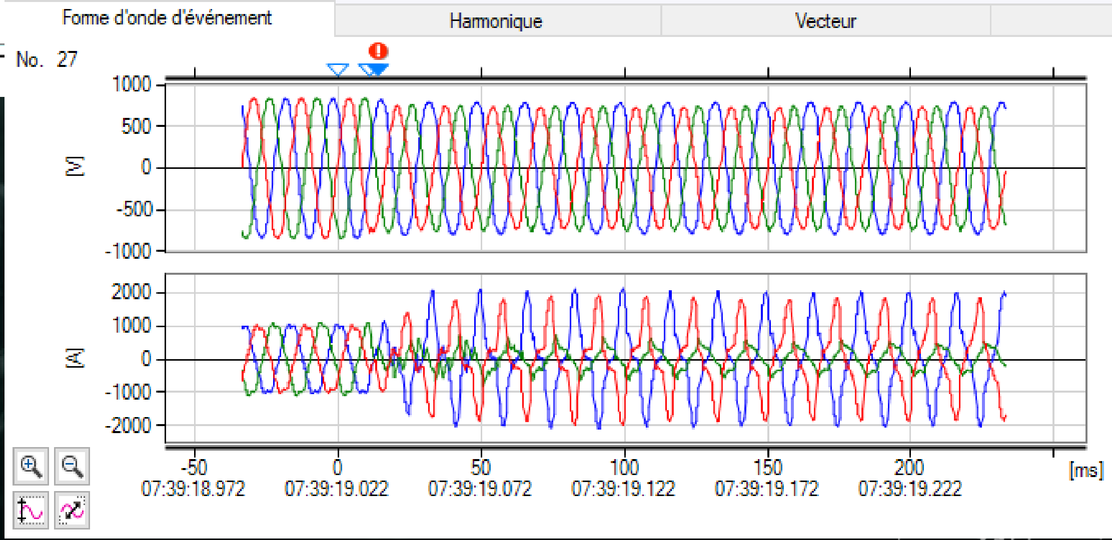
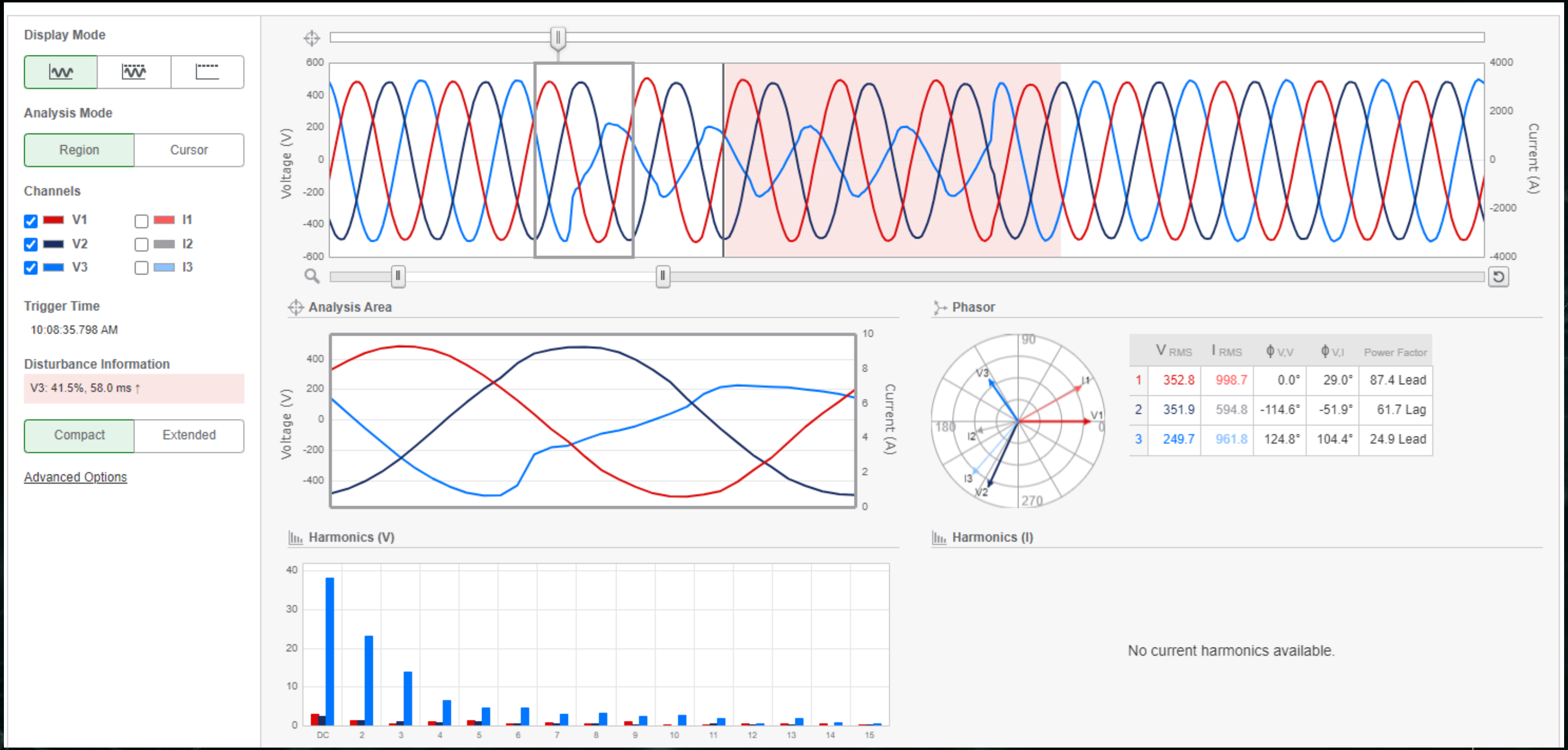
Case study 2: a costly sag





First step: capture it!



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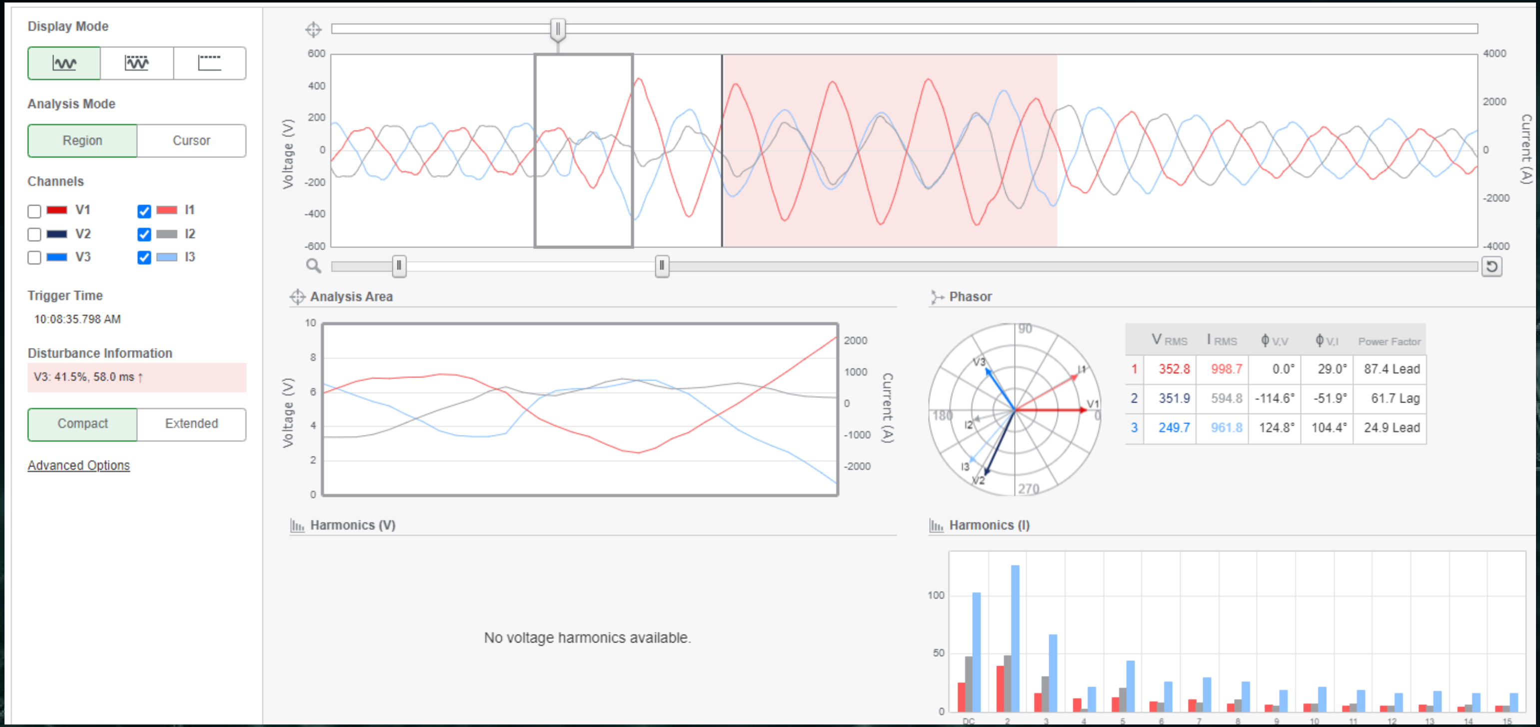

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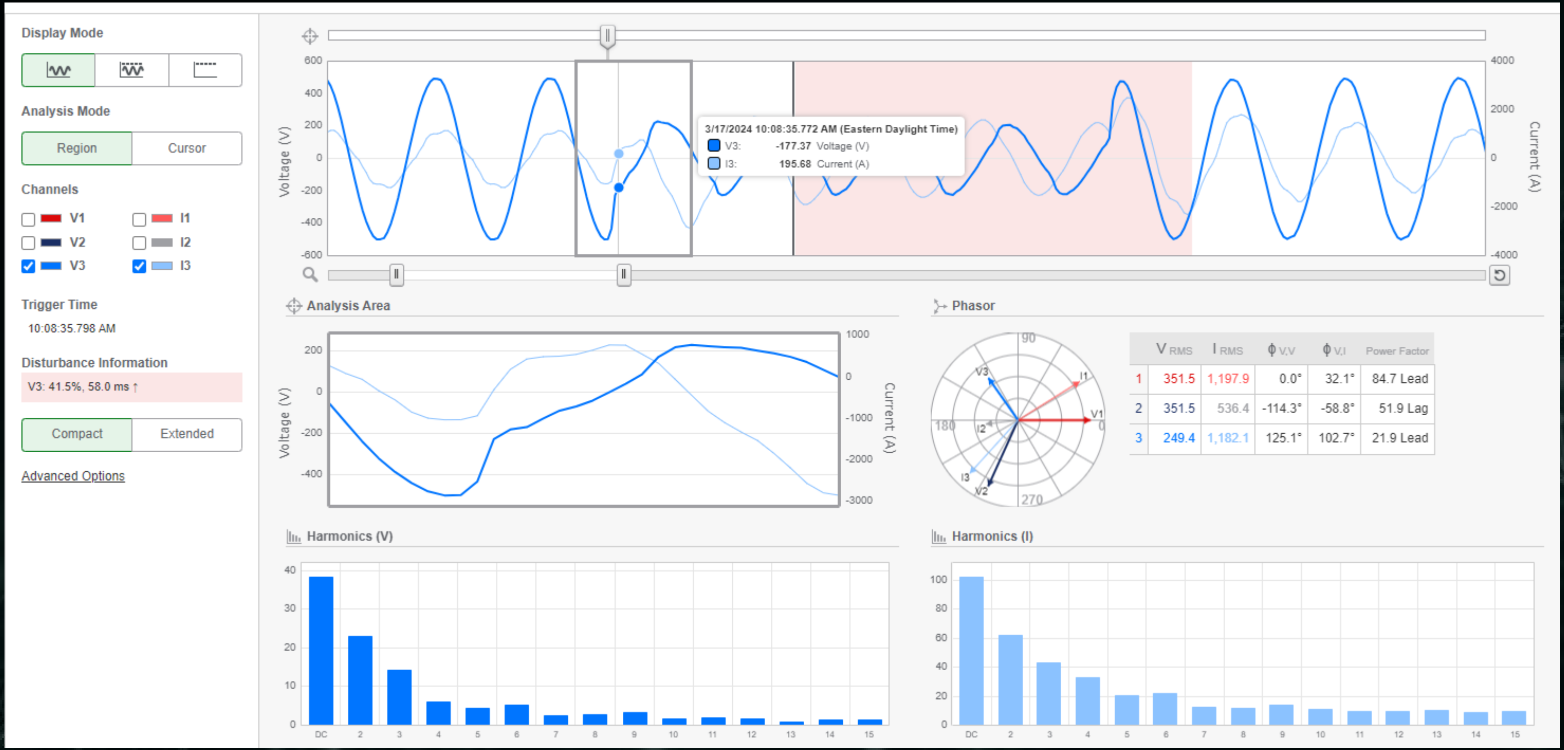


What is a voltage sag (dip)

•Can be caused by inrush currents (high impedance source)

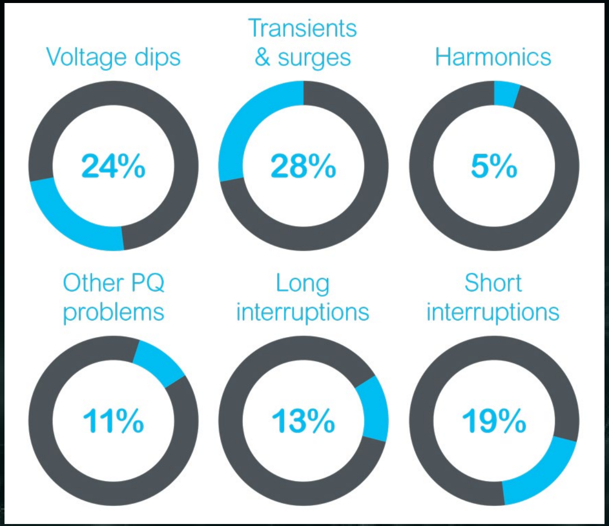
•Can be caused by weather: wind, tree branches, lightning strikes will create short circuits onto the electrical network → voltage goes down

•Higher currents may damage the equipment

•Longer duration might trip protection of the drives

•Longer duration might overheat motors

What is a voltage sag (dip)



Multiple solutions

- Change settings on sensitive equipment
- Add phase loss or undervoltage protection relay
- Ride-through solution : the sag fighter

Solutions

How do I troubleshoot Supply Mains UnderVoltage faults on the Atlivar Process drives?

Issue:
Drive is tripping on Supply Mains UnderV (USF) fault code.

Product line:
Altivar Process, ATV630, ATV930, Altivar 600, Altivar 900

Environment:
all

Cause:
Supply voltage drops below trip level setting or transient drop in voltage.

Resolution:
Measure the line voltage with a meter. Confirm the voltage reading matches on the Drive under the Main Menu > Display > Drive Parameters > Mains Voltage.

Check the settings for Undervoltage. Go to Complete Settings > Error/Warning Handling > Undervoltage handling.
Mains Voltage (URES) should match the measured and monitored line voltage. For example, if using a 240V drive and the supply voltage is only 208V then change Mains Voltage to 200 VAC. If using a 480V drive and your supply voltage is 450-470V, then change the Mains Voltage to 460V.

UnderVolt Timeout (UST) - factory setting is 0.2 seconds. Try increasing this to ride through a momentary voltage sag.

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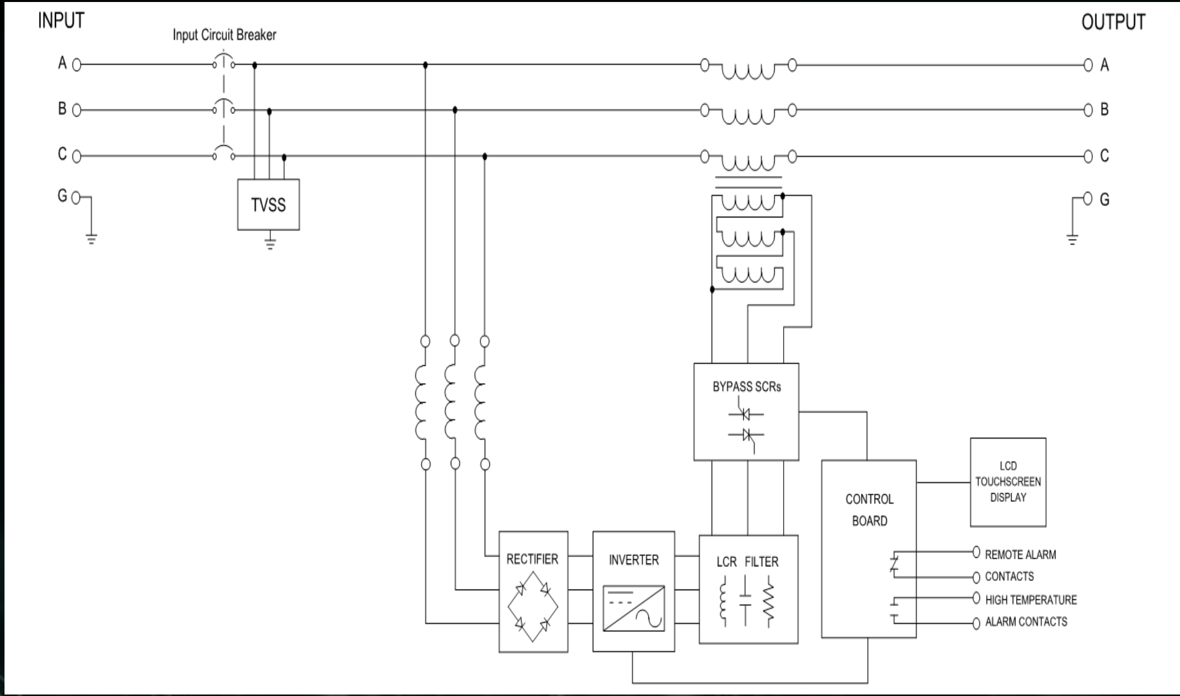
Solutions



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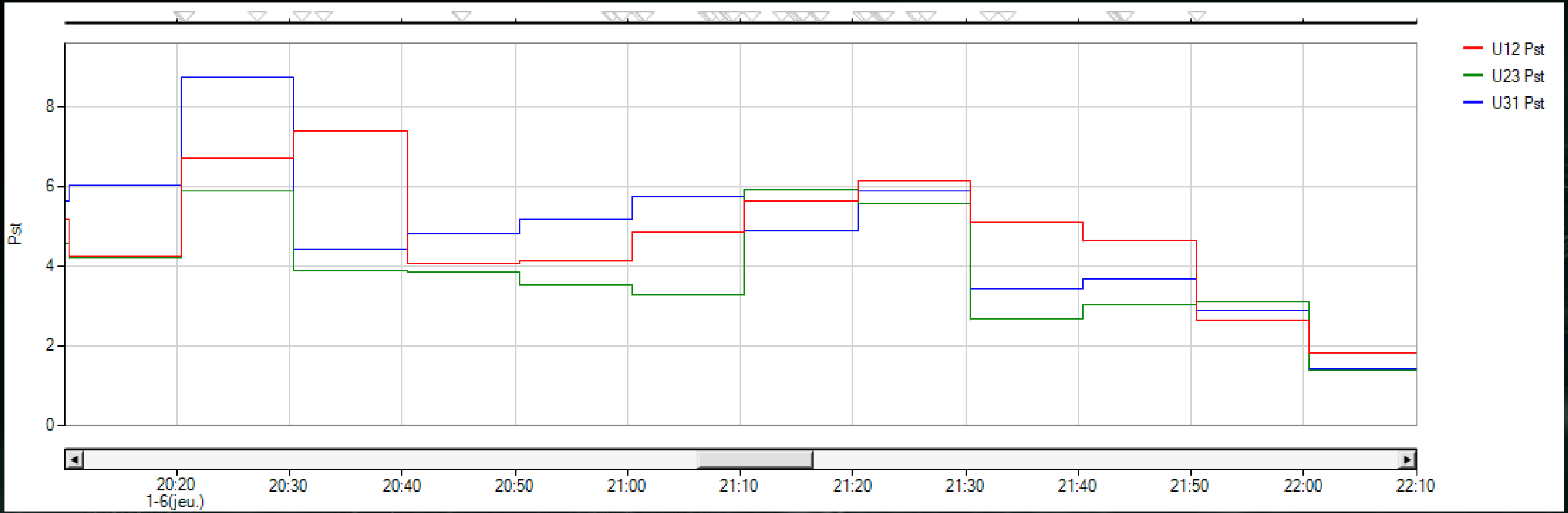
Solutions

SagFighter Single-Phase Response
Line to Line Voltage – Input and Output
Utility Single-Phase Sag Remaining Voltage
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
110%
SagFighter Input L1-L2, L3-L1
SagFighter Input L2-L3
SagFighter Onput L1-L2, L3-L1
SagFighter Output L2-L3

Case study 3: flicker



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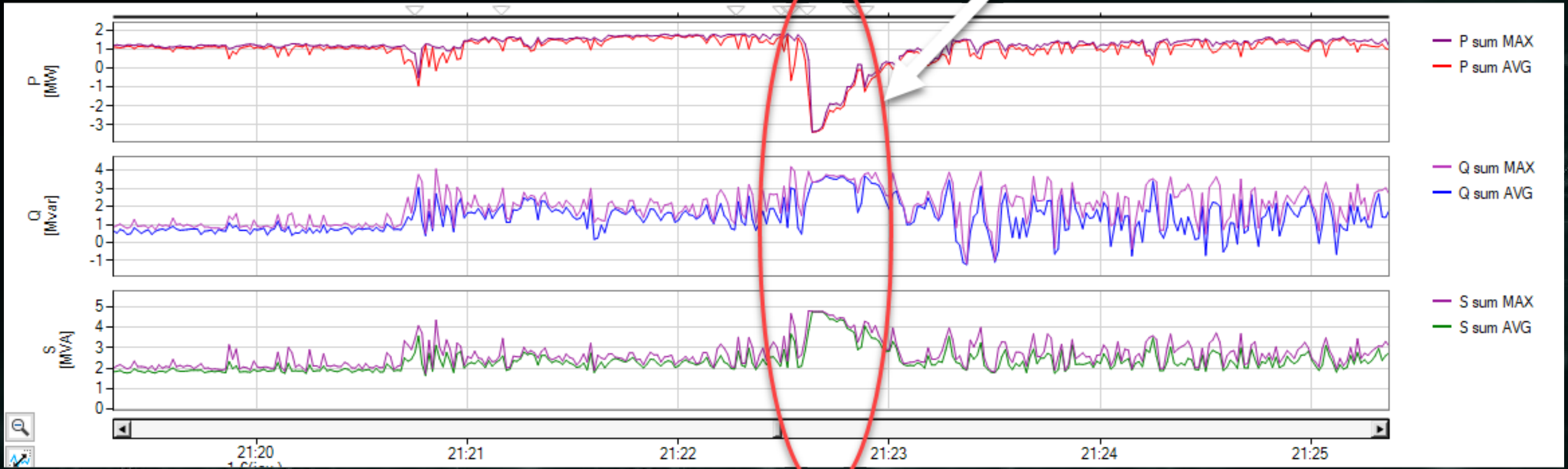
Case study 3: flicker

Identify worst reactive demand (1s recording intervals)



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Case study 3: flicker

A measure of the probability of receiving a complaint from customers (curve of equal severity)

0.2 variation per minute → 5.5% gives 1

so if we have 3% → $P_{st} = \frac{3\%}{5.5\%} \times 1 = 0.55$

Also if we have a transformer with short-circuit capacity S_2, the flicker at the primary (P_1) will be a function of the flicker at the secondary P_{st-2} :

$$P_{st-1} S_1 = P_{st-2} S_2$$

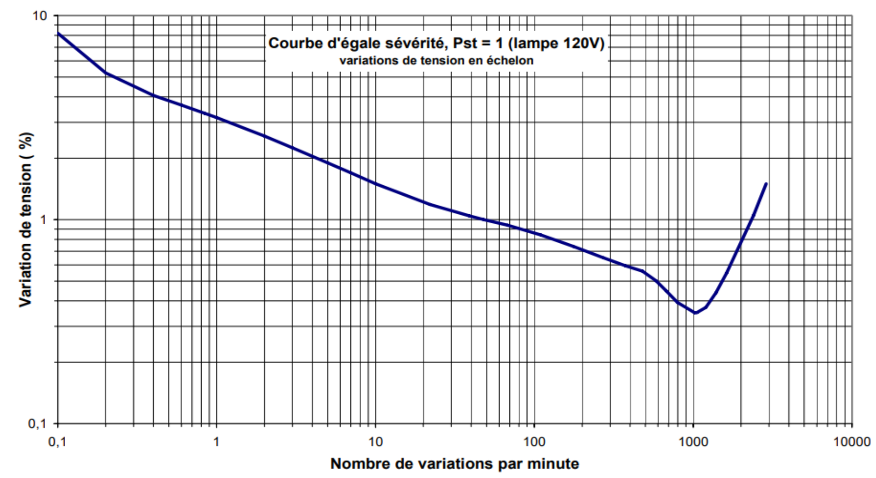

Figure 2 - Courbe d'égale sévérité, Pst = 1 d'une lampe 120 V

Case study 3: flicker

4 MVAR of var compensation required

4ms response time is CRITICAL

Capbanks much too slow

STATCOMs are an option

Or Accusine active filter!

Case study 3: flicker

Need to record 1 second intervals

Huge memory required

Can only be done at maxim flicker time → how to determine?

The real game changer: continuous monitoring

Training & Awareness

Device remotely accessible!

Adaptative learning: Doing PQ audits is basically detective work. As we accumulate data, we can “zoom in” on the data we wish to see

No need for a technician to go on site: All the setup of the meter can be done remotely

Typically, random issues are the hardest to catch. Gotta catch 'em all!™

Might even catch issues before they become a problem!

Key Contacts & Resources

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Thank you!