Power Quality Monitoring - A Metering Perspective

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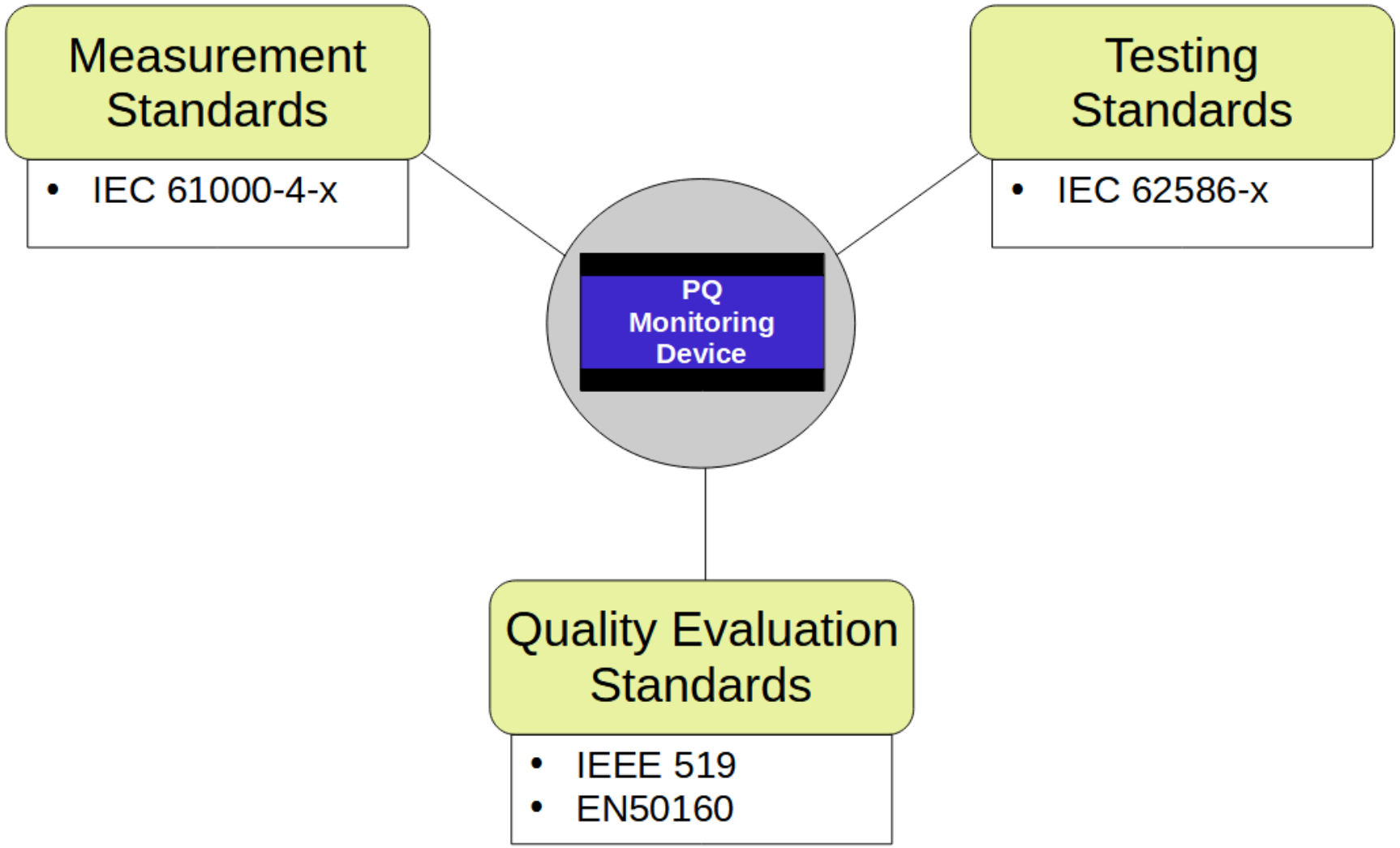
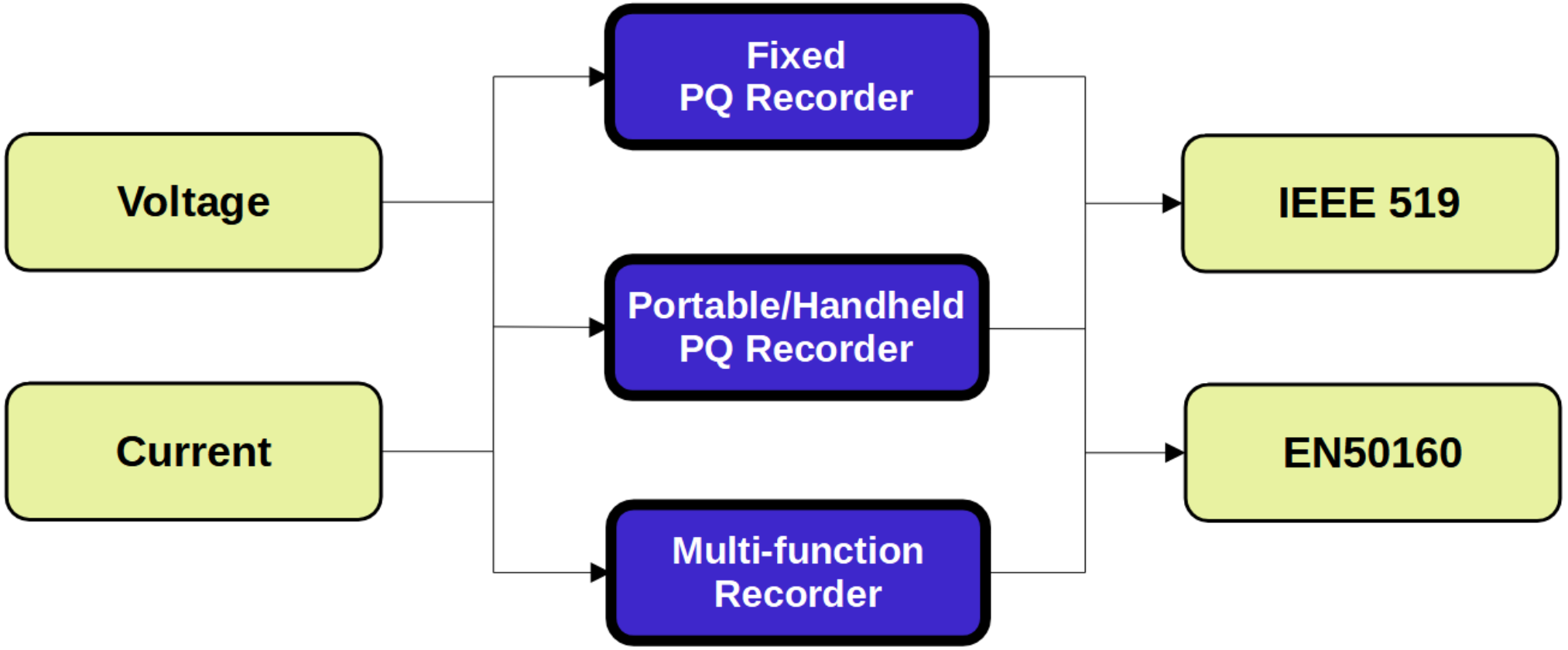
Overview

- Uniqueness of PQ in metering – **What**'s it about?
- Impact of harmonics – **Why** does it matter?
- Measurement principles – **How** do we do it?
- Case Study – Power Quality Monitoring at an Industrial Site

PQ Monitoring - Fundamentals

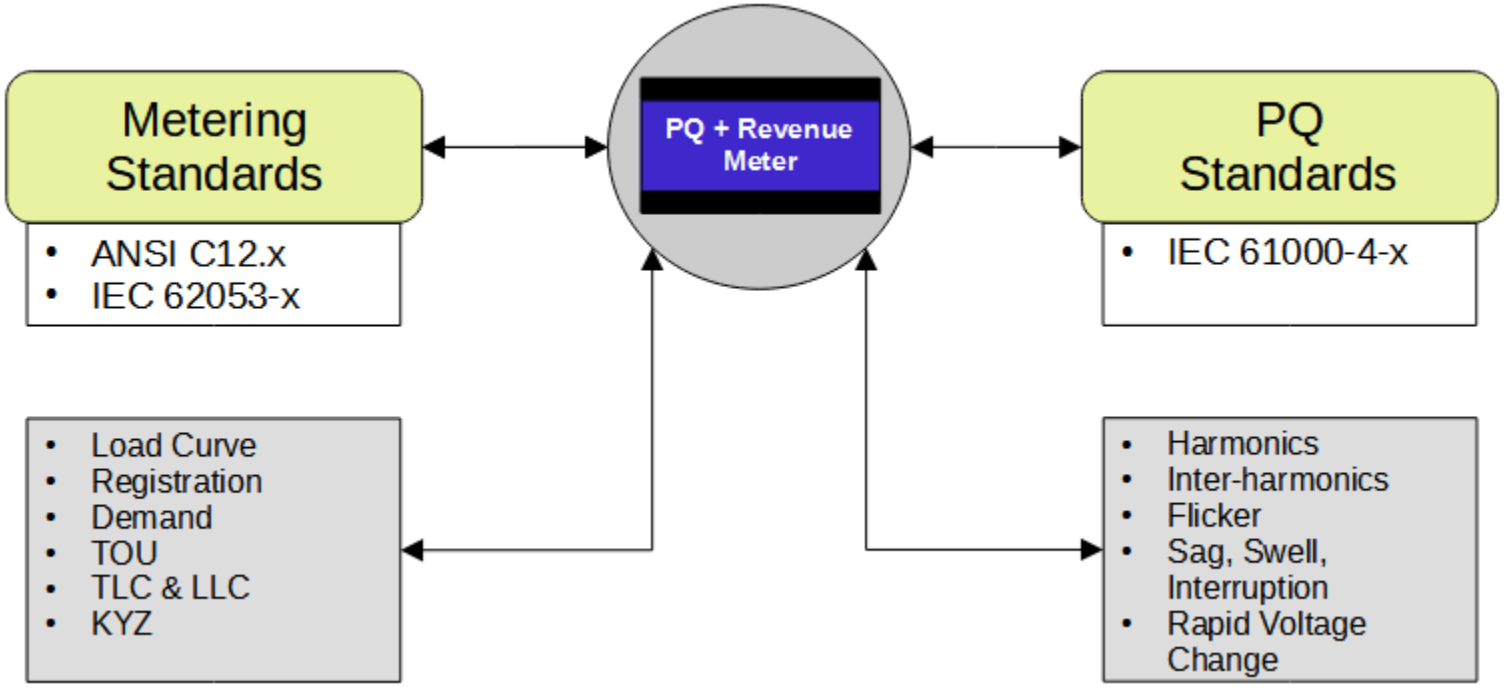


PQ Monitoring - System Overview



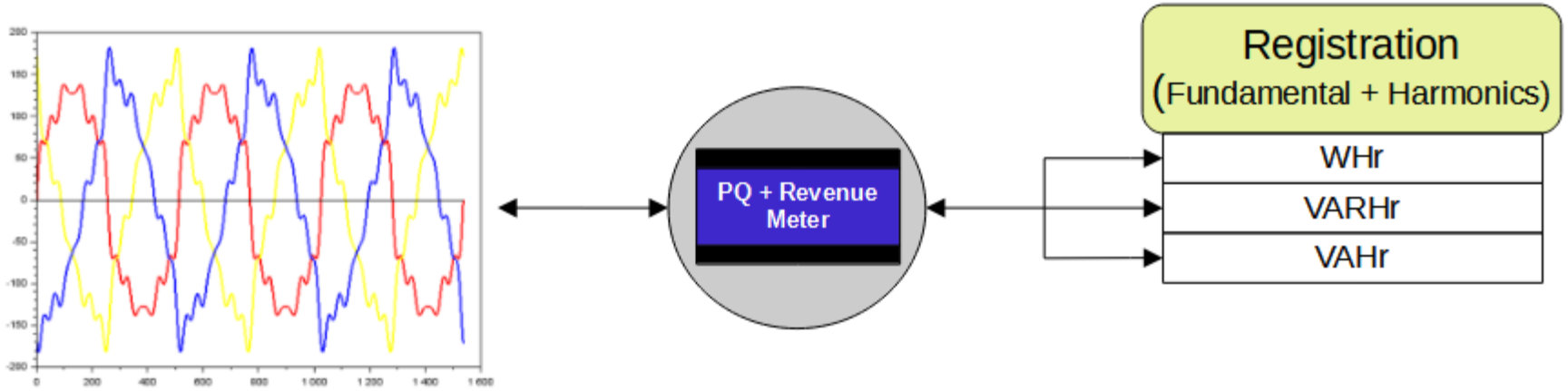
- Many instrument types capable of PQ monitoring & compliant with the same standards.
- Functional differences driven by primary/secondary capabilities of the instrument.

PQ & Metering



- Revenue meters “quantify” harmonic distortion through registration.
- PQ recording supports “qualitative” analysis.

Harmonics in Metering



ANSI C12.1 - 4.7.4 Harmonics influence—effect of non-sinusoidal waveforms

- 90 degree phase fired waveform
- Quadriform waveform
- Peaked waveform
- Pulse waveform
- Multiple zero crossings on current
- Multiple zero crossings on voltage

Harmonics – Impact on Revenue

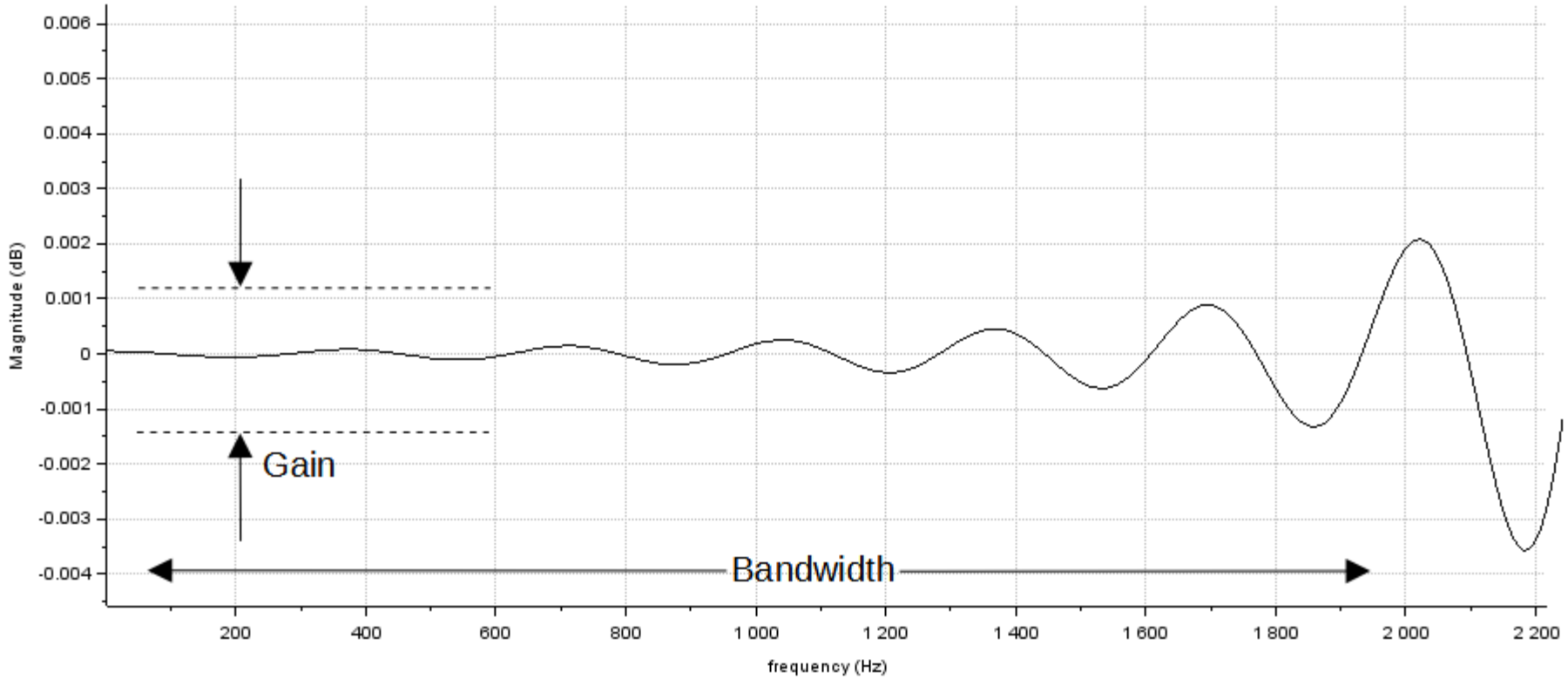
Test Conditions				
Harmonics	**Volts THD (%)**	**Amps THD (%)**	**Error per Harmonic (%)**	**Total Error (%)**
H3, H5, H7, H11, H13	5	39%	0.5	0.067294457

Power & Energy With Harmonics						
Meter Load (MW)	**kW (Ideal)**	**kW (Measured)**	**kW (Max Error)**	**kWh (Yearly Error)**	**Cost/kWh ($)**	**Total Yearly Cost ($)**
100	107493.0037	107420.6668	72.33683347	633670.6612	0.1	63367.06612

- ANSI C12.1 permits 0.3% error for class 0.1s meters in simultaneous voltage and current distortion tests.
- Higher unaccounted revenue on meters with low harmonic accuracy under high THD/TDD load conditions.

* Test conditions derived from ANSI C12.1 “4.7.4.2 Test No. 40: Quadriform waveform”

Harmonics – Calibration & Frequency Response



- Gain consistency over time – Dependent on component deterioration due to aging.
- Drop in bandwidth – Reduction in number of harmonics captured and/or their amplitude.
- Faster the deterioration, sooner the need to recalibrate.

Metering and PQ - Simultaneous Problems

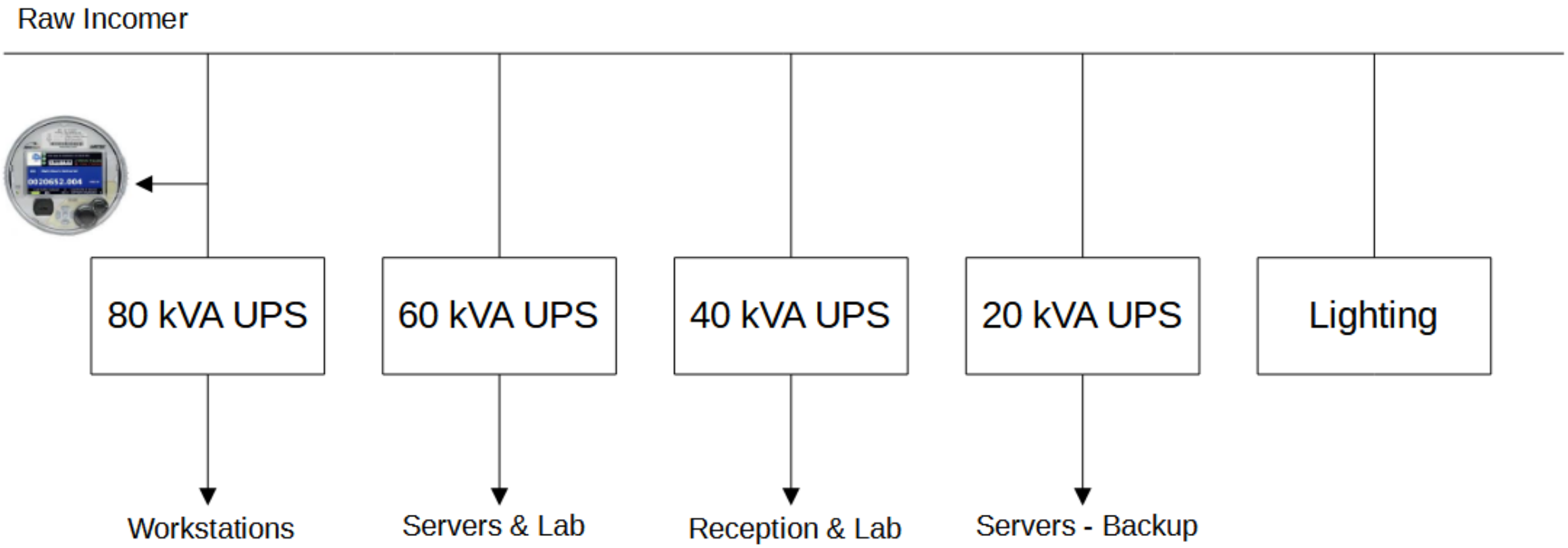
Harmonics in PQ & Metering		
	Power Quality	**Metering**
Measurement	Typically, via Fourier based methods to extract individual harmonics	Power & energy measurement with all harmonics included
Analysis	Qualitative study of distortion using THD, TDD, etc.	Quantification of distortion through revenue
Impact	Secondary impact on transformers, cables, transmission lines, etc.	Direct impact on metering accuracy & revenue
Events	Capture and analysis of anomalies	Focus on continuous revenue

PQ Monitoring at an Industrial Tech Park

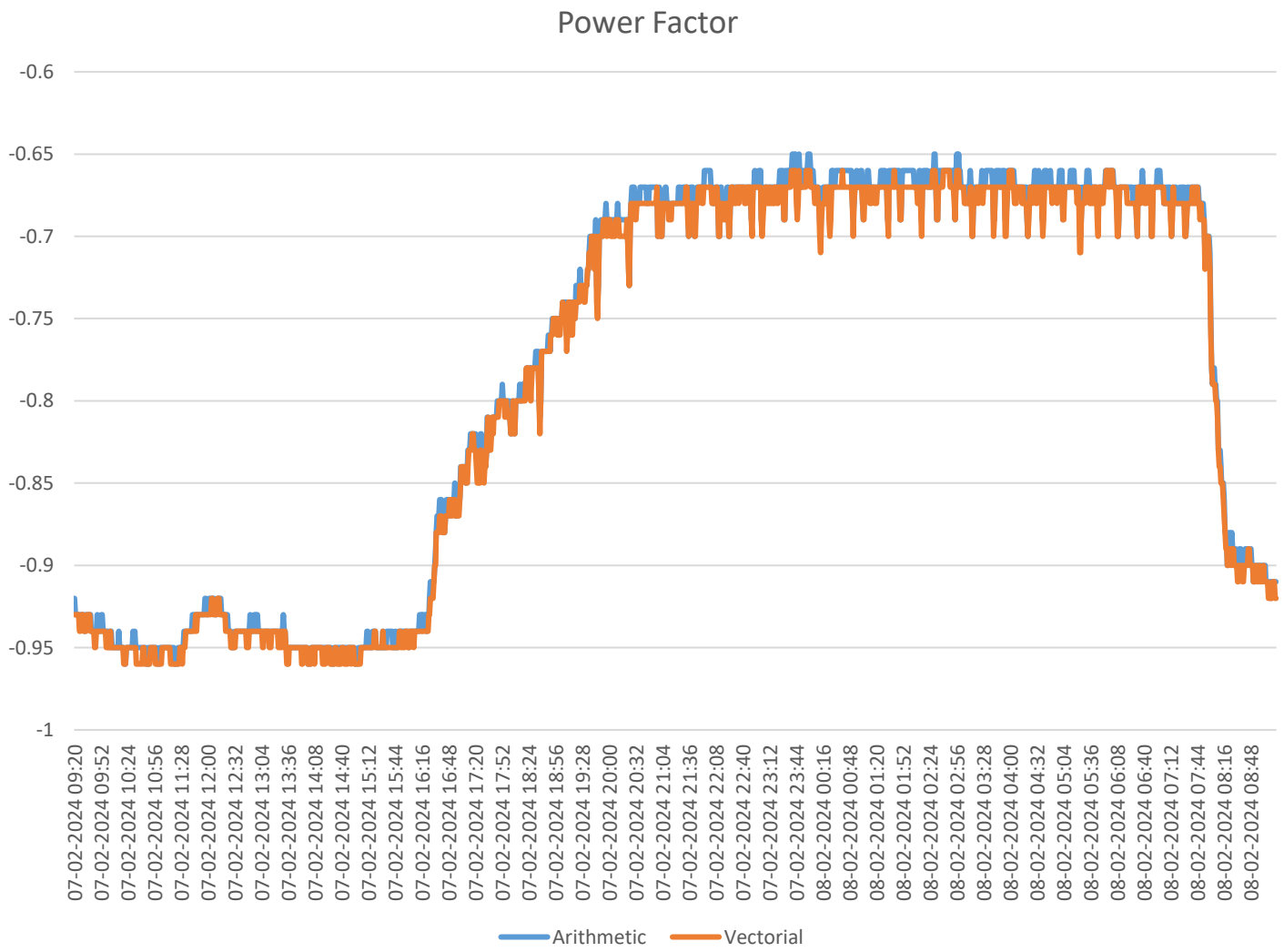
Facility Overview

- 500,000 sq. ft building with multiple tenants across 6 floors.
- Diverse electricity consumption patterns – R&D, finance, IT, etc.
- Busbars shared among tenants.
- Critical loads backed by UPS systems.
- Problems with high electricity bills, brief interruptions, etc.

Facility Power Distribution

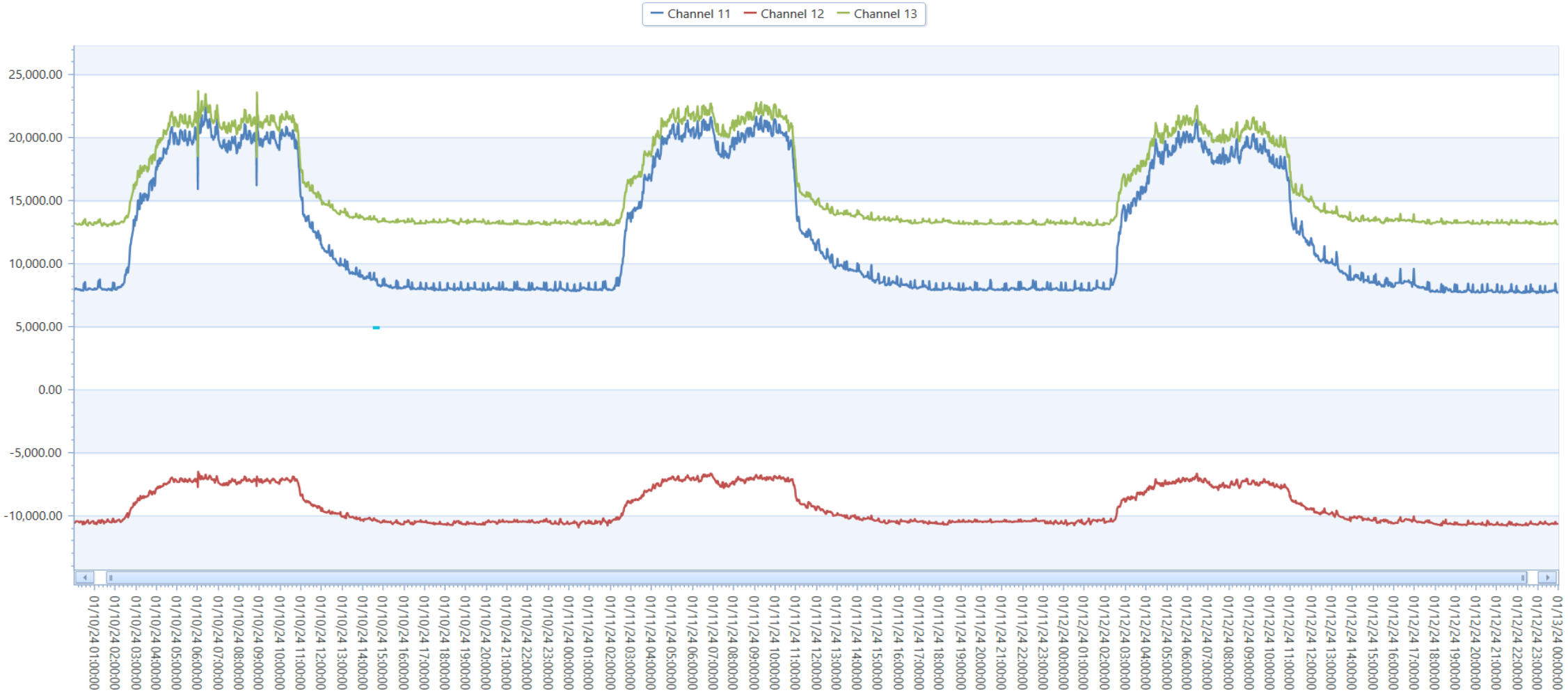


Load Study (80 kVA UPS) – Power Factor



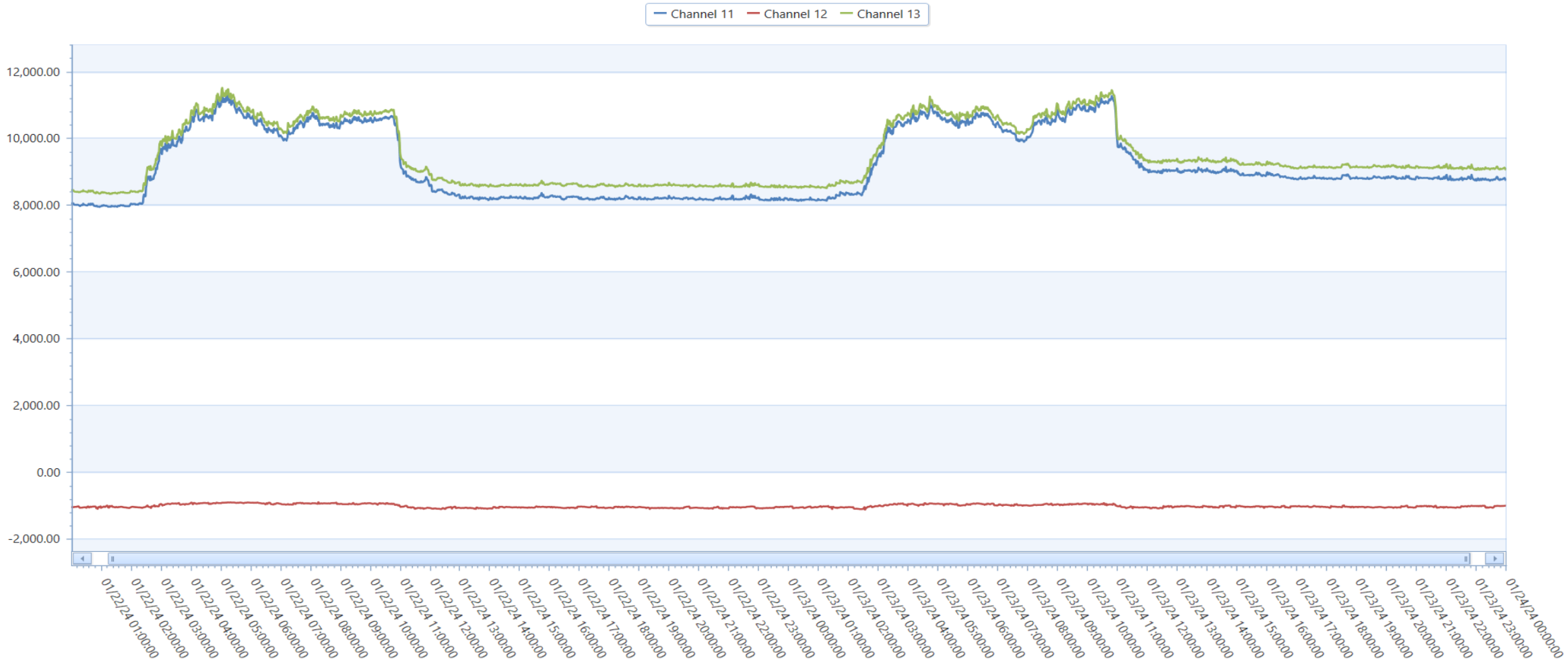
- Supplies power to employee workstations – monitors, desktops, laptops, etc.
- Peak load during typical operational hours – 9AM to 5PM.
- Expectation – PF better than 0.9.
  Observation – Long periods of poor PF.

Load Study (80 kVA UPS) – Load Curves



Instantaneous real (blue), reactive (red) and apparent (green) power vs time (UTC)

Load Study (80 kVA UPS) – vs 60 kVA



Instantaneous real (blue), reactive (red) and apparent (green) power vs time (UTC)

Load Study (80 kVA UPS) – Energy Consumption

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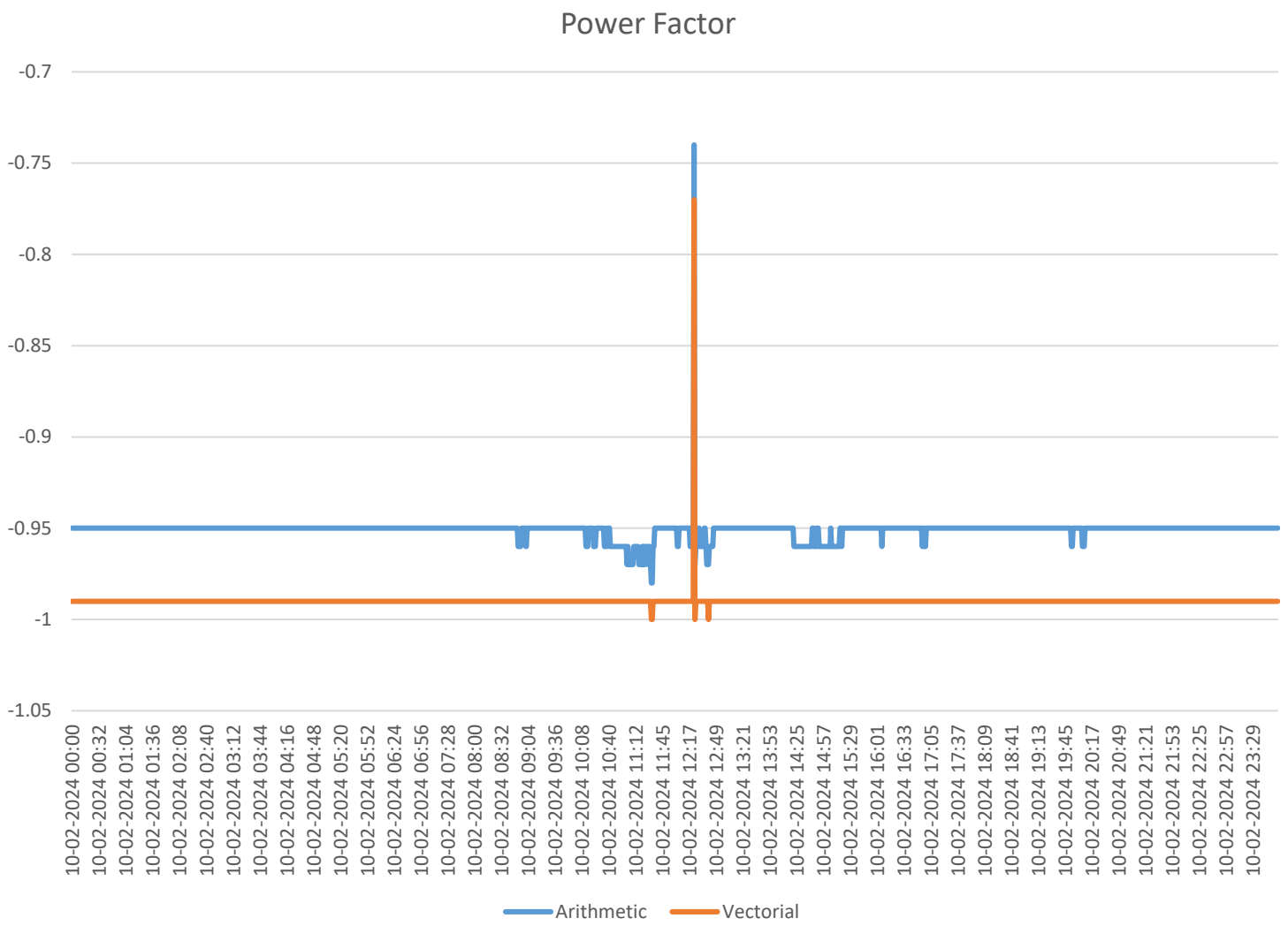
kVA Rating	Wh	VARh	VAh	VARh/Wh %	VARh/VAh %
80	299177.77	-220535.00	387660.09	73.71	56.89

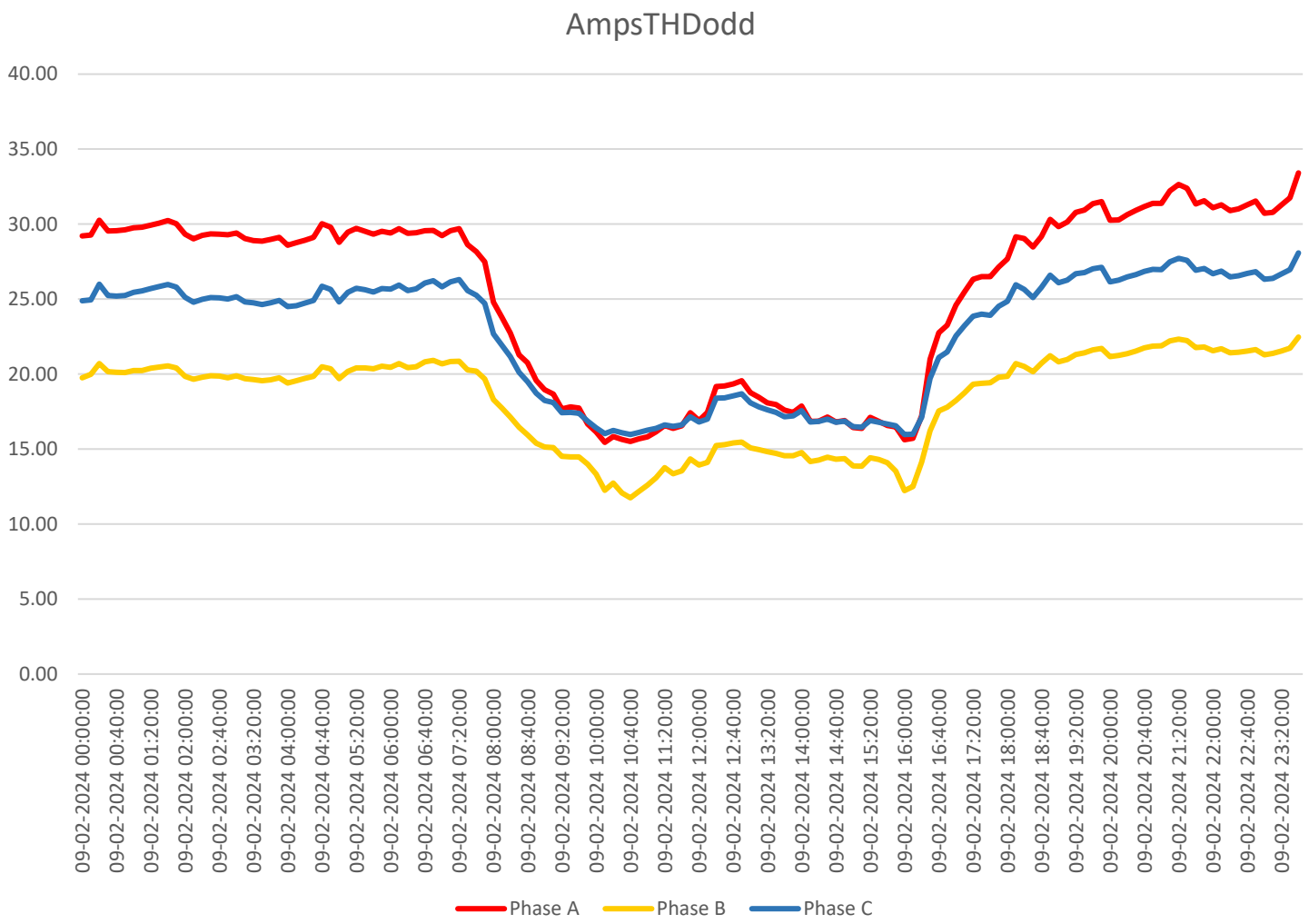
- Prolonged hours of high reactive power draw leading to increased utility bills.
- Poor PF - UPS design & performance under low load conditions.
- Accurate power budgeting to ensure optimal load during all hours.

Harmonic Distortion Analysis (60 kVA UPS)



- Supplies power to IT server equipment & few workstations.
- 24x7 power consumption by servers. Additional load from workstations during 9AM-5PM.
- Energy meter data reports good PF 24x7. Typically, > 0.94.

Harmonic Distortion Analysis (60 kVA UPS)



- Moderate THD levels during typical operational hours (9AM to 5PM). High THD during off-hours.
- Moderate TDD value due to low load during off-hours but significant load current draw by servers.

Harmonic Distortion Analysis (60 kVA UPS)

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Root Causes –

- Power supply unit (PSU) design – Higher harmonics injection during light load conditions. Design optimized for efficiency (at the cost of THD).
- Single phase equipment with SMPS – Source of additive triple-n harmonics.
- Variable frequency drives used in cooling equipment.

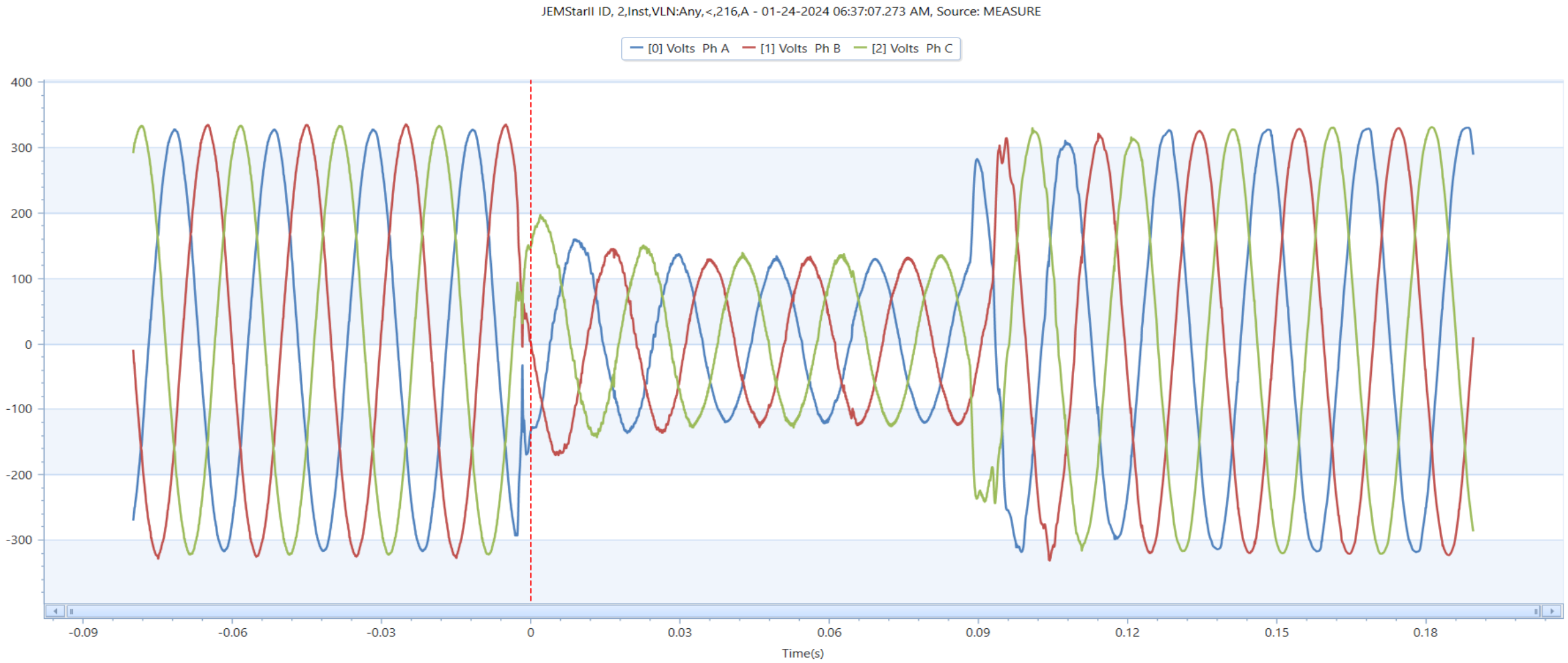
Impact –

- Drop in the overall efficiency due to increased heat from harmonic currents and subsequent increase in cooling costs.
- Higher RMS current and subsequent increase in power consumption.
- Interference with upstream equipment affecting the quality of operation.

Event Analysis – Voltage Dips

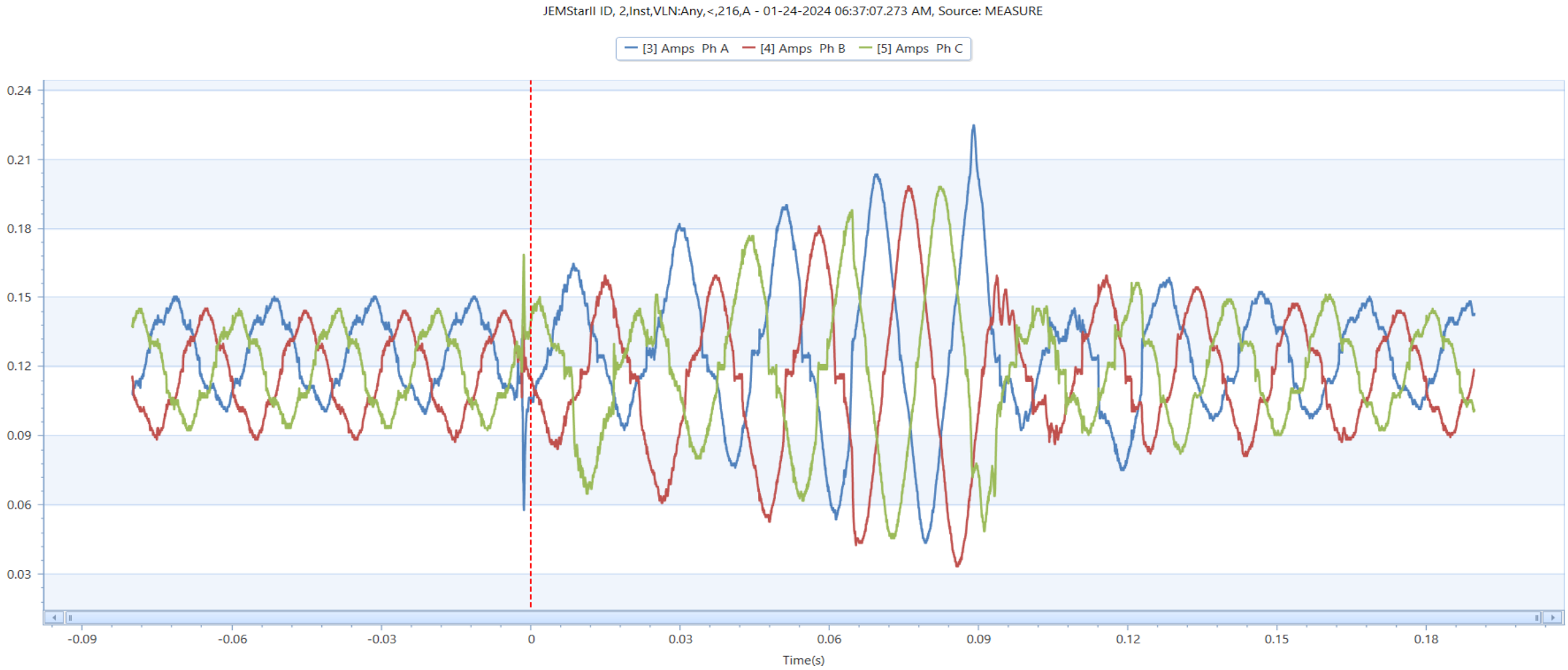
- Continuous Power Quality – Capture without the need for trigger settings. Ex: - Harmonics, Flicker, Power Factor, etc.
- Event Based Power Quality – Indeterministic anomalies such as sags, swells, outages, etc.
- Significant fluctuation in voltages leads to equipment failure/resets.
- Incidents of flickering lights and equipment resets observed at the facility.

Event Analysis – Voltage Dips



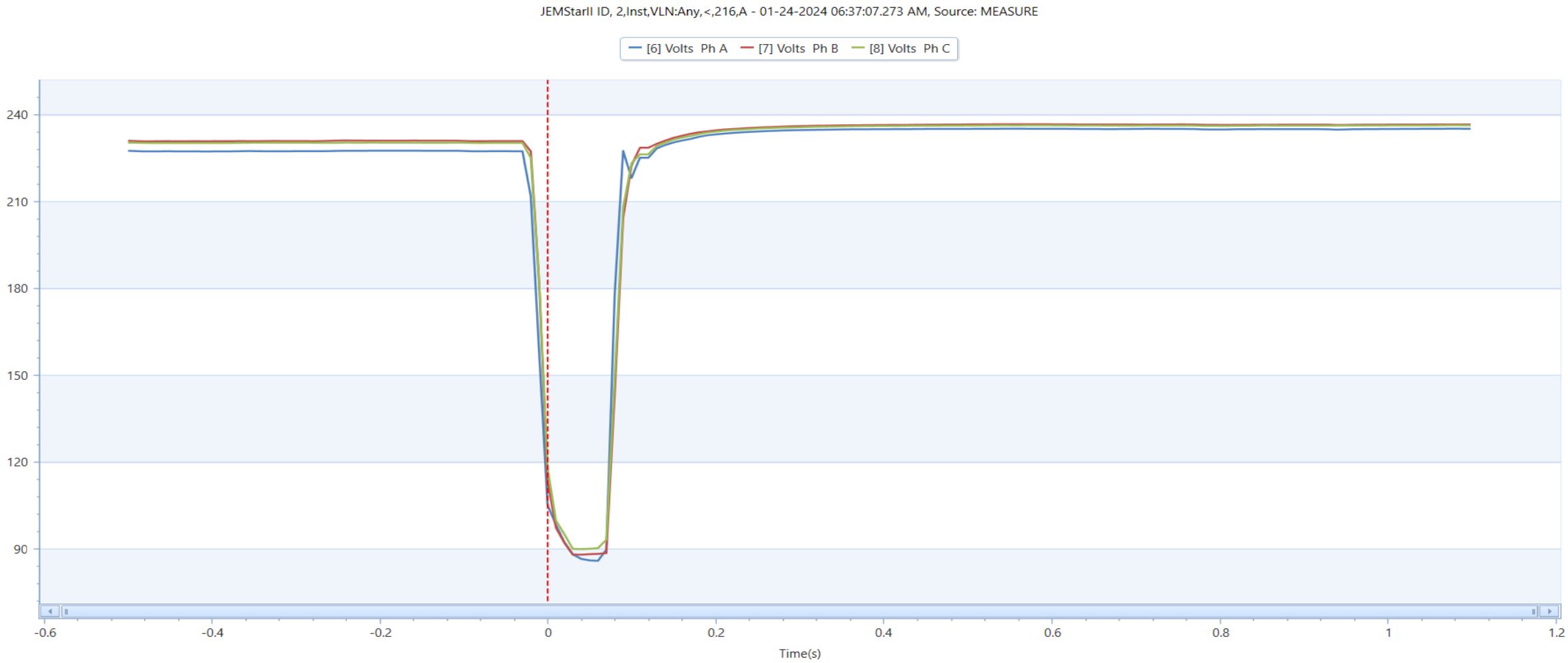
Phase to neutral three phase voltage waveforms

Event Analysis – Voltage Dips



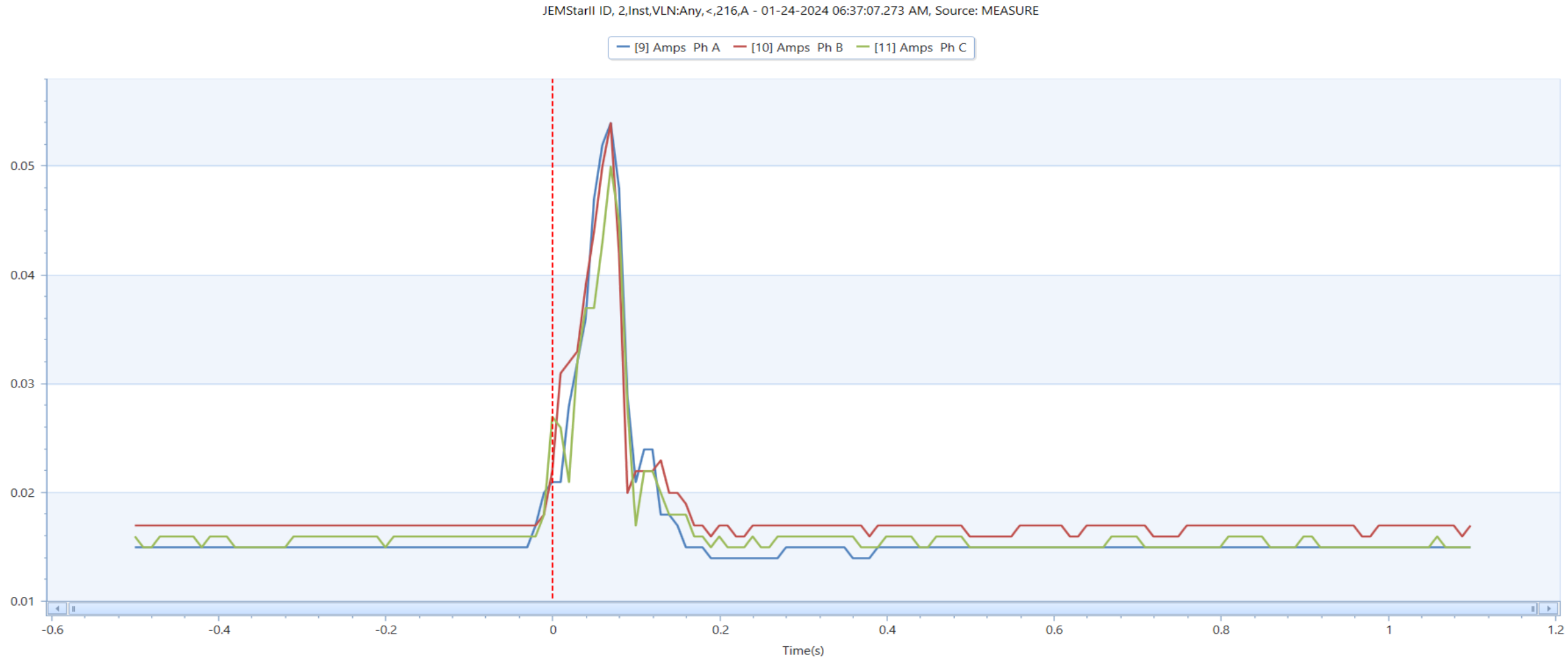
Phase to neutral three phase current waveforms (x1000 scale)

Event Analysis – Voltage Dips



Phase to neutral three phase RMS phasor voltage (fundamental) measurements

Event Analysis – Voltage Dips



Phase to neutral three phase RMS current (fundamental) measurements (x1000 scale)

Event Analysis – Voltage Dips

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Takeaways –

- Shared busbar – Anomaly in one part of the power distribution network can affect the voltage across several points in the system.
- Difficult to isolate and pinpoint the source of such issues. Advisable to backup critical loads with adequate UPS systems.
- Large voltage drops can cause loads to draw a large amount of current to compensate for the lower operating voltage. UPS systems may draw a large amount of current to maintain a steady output voltage. Potential equipment damage, nuisance breaker tripping, etc.

Conclusion (Case Study)

- Load pattern at industrial facilities can vary significantly based on the nature of the facility. Electronic loads, electromechanical loads, etc. can induce different types of power quality issues.
- High levels of THD with electronic loads such as IT servers, computer/networking equipment, etc. results in lower overall efficiency, equipment damage, heating issues, increased cooling requirements & upstream propagation of harmonic content. Active power quality monitoring essential to capture such problems.
- Beneficial to perform load curve analysis on a 24x7 basis and not just during peak operational hours of a facility. Issues pertaining to power factor, efficiency, load distribution, etc. can be analyzed in a comprehensive manner to determine the best operating conditions.
- Ability to capture short term anomalies such as dips, swells, etc. can help identify latent issues as well as aid in root cause analysis. Large set of configurable trigger conditions aids in this process and recording capabilities should include both waveform capture and high-speed RMS. Capturing unpredictable/ indeterministic issues is just as important as continuous monitoring.

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THANK YOU!

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