# Case Study – Power Quality Monitoring at an Industrial Tech Park


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## Abstract

Industrial tech parks rely on uninterrupted supply of high-quality power to drive a variety of loads such as computers, servers, lighting, lab instruments, air conditioning, etc. These loads can introduce several power quality problems in the network leading to equipment failures, low efficiency, high operational costs, overheating & reduced equipment lifespan. The use of UPS systems in such facilities is quite common to ensure uninterrupted operation.

An IEC 61000-4-30 class A power quality meter was installed at such a facility in India to assess potential power quality issues. This paper covers the findings of this study & highlights different types of power quality problems associated with such a site. Load pattern, power factor, reactive power & harmonics are some of the key areas, with special focus on the use of UPS systems.


## 1 Facility Power Distribution

The following diagram provides an overview of the concerned portion of the power distribution within the facility –

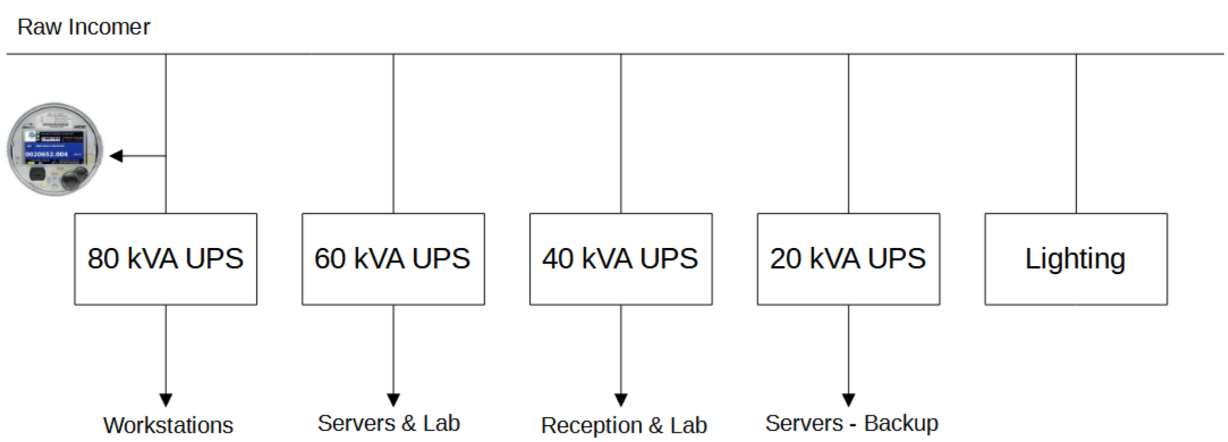


**Fig.1:** Power Distribution Overview – PQ meter installed on the incoming side.

A total of 4 UPS systems are used at this facility to power various types of loads, some of which are critical in nature –

1. Office workstations – Monitors, desktops, laptops, etc.
2. Server equipment – IT servers, networking devices, etc.
3. R&D Laboratories – Scientific instruments, test equipment, etc.
4. Building lighting

As part of an overall building energy consumption study, an Ametek JEMStar II meter was installed on the incoming side of each connection for a few weeks. The meter captured both the energy usage pattern (load study) as well as the power quality information, which are discussed in the sections below. The ability to capture both types of data simultaneously in a single device is extremely useful in drawing a correlation between the load usage and associated power quality issues.

## 2 Load Analysis

### 2.1 80 kVA UPS – Power Factor Study

This UPS system is responsible for supplying power to about 400 workstations in the facility. A typical workstation consists of a desktop PC, accessories such as keyboards, monitors, etc., & charging facility for phones, tablets, etc. Most employees in the facility additionally use laptops which are only plugged in during typical office hours. As such, the expected energy usage pattern comprised of a relatively steady load outside of the peak hours (8AM – 5PM) where there would be a spike in the power consumption. Considering the nature of the load (electronic), the assumption was that the power factor would be close to unity at all times. However, the load profile data obtained from the meter indicated that this wasn't the case.

The following plot shows the instantaneous real, reactive, and apparent power consumption captured with a resolution of 1 minute over a three-day period during the weekdays –

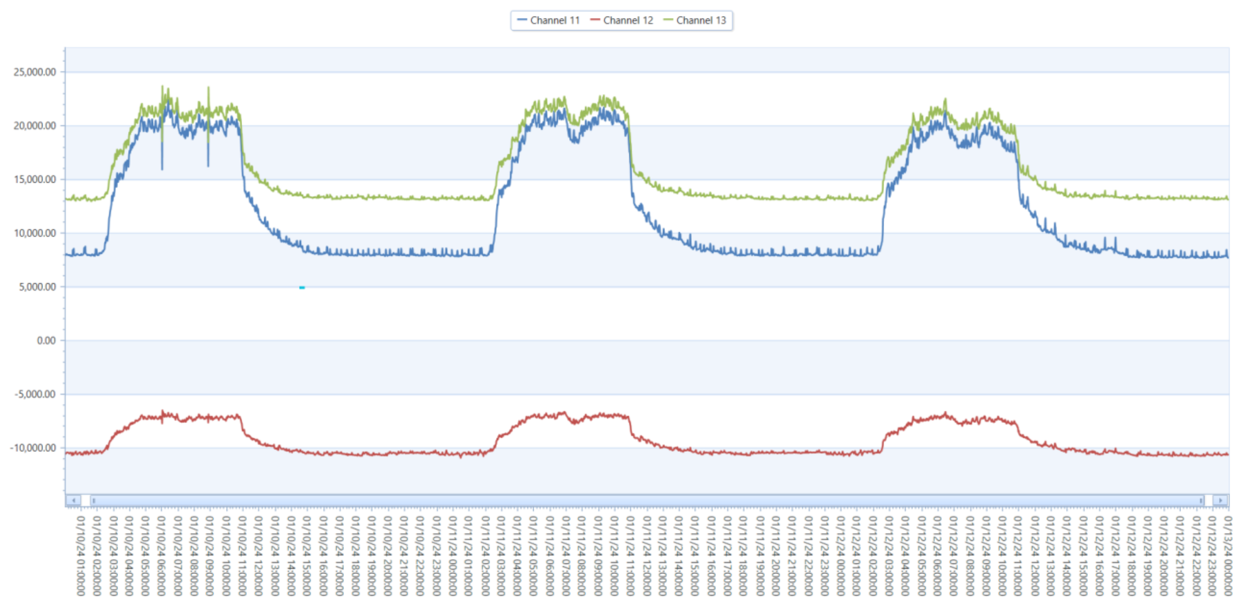


**Fig.2:** Instantaneous real (blue), reactive (red) and apparent (green) power vs time (UTC) – 80 kVA UPS

1. During typical operational hours of 8AM – 5PM, there's a clear spike in the energy usage as expected and the real and apparent power values are nearly identical during this time. This implies that the power factor is close to unity. Prior to the installation of the power quality meter, the assumption at the facility was that the power factor recorded during this time via a panel meter was indicative of no issues being present and that this was the behaviour throughout the day. During off peak hours, it was assumed that the load would be so low that any drop in the power factor wouldn't cause much of an impact.

2. Contrary to the above assumptions, the load profile data from the power quality meter showed a relatively high level of reactive power draw during off peak hours. As a result, it can be seen that

real and apparent energy curves deviate from each other during 5PM – 8AM. This implies a drop in the power factor during these hours, but the load is not negligible. Rather, it's reactive in nature.

The plot below shows the power factor captured over a 24-hour period –

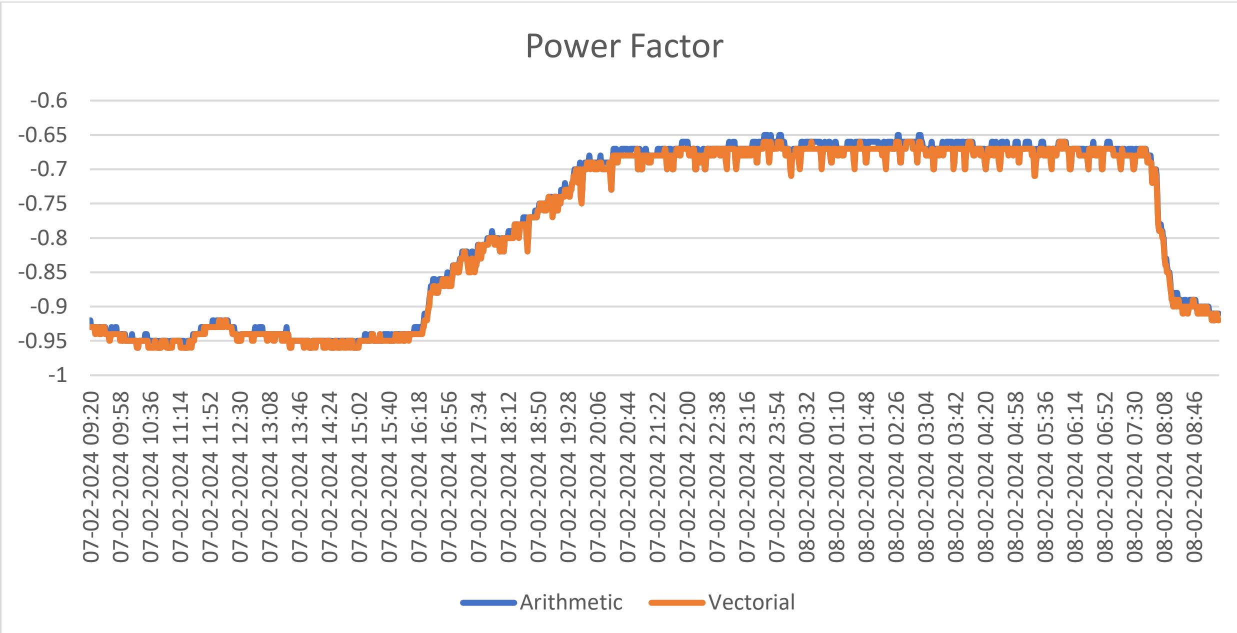


**Fig.3:** Arithmetic PF (blue), Vectorial PF (orange) vs time (local) – 80 kVA UPS

Considering that the nature of the load serviced by the UPS is electronic, the daily increase in the reactive power draw for several hours was peculiar. It was even more mysterious that this increase would only happen during off peak hours where all variable load (typically laptops) would be disconnected.

**Root Cause**: While initial suspicions were regarding some additional load that was switched on during off peak hours, it was later identified that the excess reactive power draw was due to the behaviour of the UPS system under low load conditions.

In comparison, the plot below shows the load curve for the 60 kVA UPS system. The usage during off peak hours as a percentage of the total capacity is similar, but this model is still able to maintain a power factor close to unity.

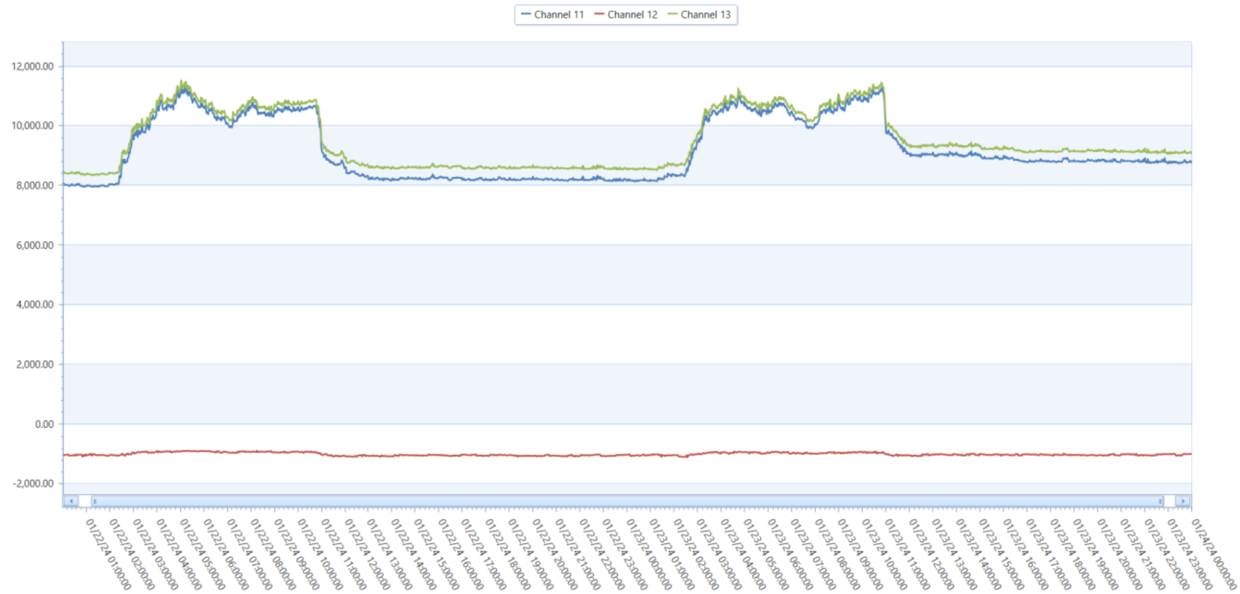


**Fig.4:** Instantaneous real (blue), reactive (red) and apparent (green) power vs time (UTC) – 60 kVA UPS

**Takeaways**:

1. In a facility with a large amount of IT equipment such as a data center, accurate budgeting of the power requirements during all hours of the day (including weekends) and the use of an advanced revenue + power quality meter to periodically validate, verify & update these budget estimates can help identify power quality issues owing to the load pattern.

2. Additionally, careful examination of UPS parameters such as the PFC thresholds, low load behaviour and cross verification via the metering system can aid in ensuring optimal and efficient power supply to the load.

3. Long periods of high reactive power draw leads to an increase in utility bills. Depending on the tariff scheme, this may be in the form of penalties or included in the billing units. The table below shows the real, reactive and apparent energy consumption over a 24-hour period.

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

**Table.1:** Real, reactive and apparent power consumption over a 24-hour period

The overall energy consumption is higher due to the impact of the prolonged periods of reactive power draw.

### 2.2 60 kVA UPS – Harmonic Distortion Analysis

Equipment such as laptops, desktops and other accessories can present a different type of load in comparison to server grade machines used by IT departments. The latter may draw high levels of harmonic currents even during normal operating conditions. The 60 kVA UPS system is designated to supply an array of such machines along with a small number of workstations. From the load curve shown in fig.4, it can be seen that there's a spike in the power consumption during peak operational hours and the power factor remains very close to unity throughout the day as seen in the figure below. The increase in power consumption is owed to the additional workstations which are actively used during operational hours.

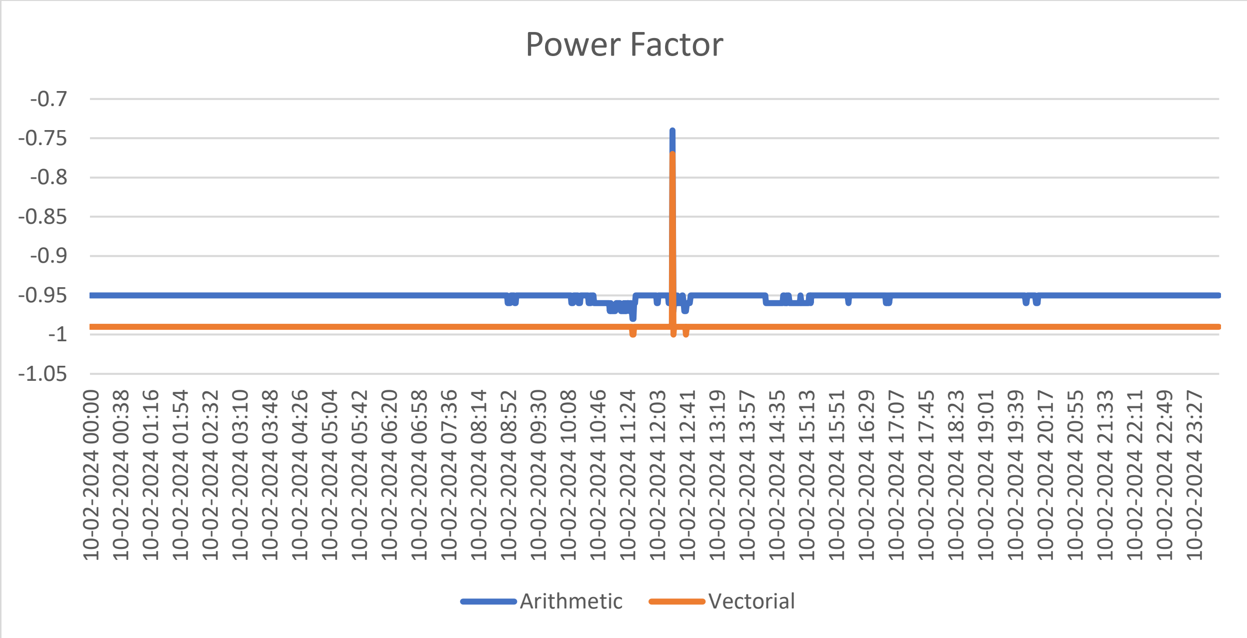


**Fig.5:** Arithmetic PF (blue), Vectorial PF (orange) vs time (local) – 60 kVA UPS

This is the level of data captured by a typical advanced energy meter. On the other hand, a power quality meter can capture information about harmonics, inter-harmonics, flicker, etc. along with the load curve simultaneously. The plot below shows the average current THD captured for odd harmonics on each phase over a 24-hour period.

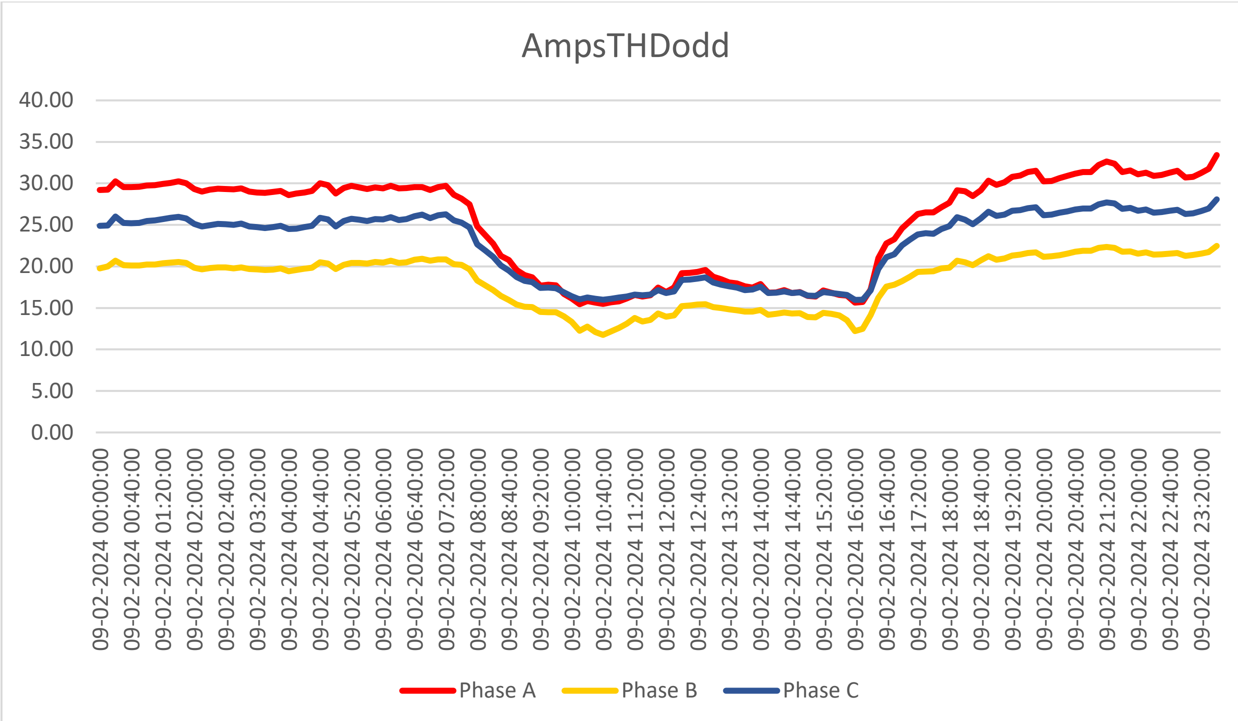


**Fig.6:** Three-phase current THD for odd harmonics vs time (UTC)

The THD levels are relatively high outside of typical working hours of 8AM – 5PM. As THD is expressed as a ratio between the harmonic components and the fundamental, the additional current drawn from the workstations brings this value down. This can be correlated with the instantaneous current consumption curve shown below.

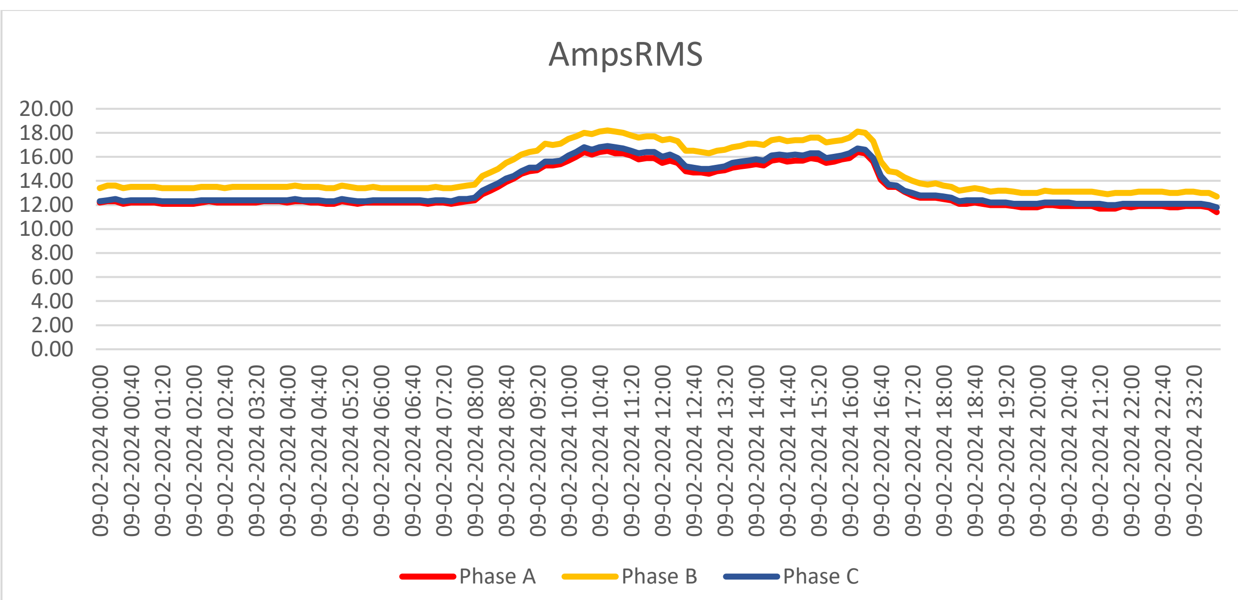


**Fig.7:** Three-phase RMS current vs time (UTC)

The THD values outside the working hours of 8AM – 5PM represent the true harmonic levels due to the IT server equipment. Such high THD values can be observed at all times since the server equipment runs 24x7 and is accessed across multiple time zones.

**Root Cause**: High THD in the context of IT server equipment can be owed to various reasons –

1. Power supply unit (PSU) design – During light load conditions, some PSUs can inject higher harmonics due to their design being optimized for efficiency (at the cost of THD).
2. Single phase equipment that uses switched mode power supplies (SMPS) can act as a source of triplen harmonics which are additive in nature.
3. Variable frequency drives used in cooling equipment.

**Impact**: High levels of harmonic currents in a data center type environment with several IT servers operating in cascade can lead to multiple issues –

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

## 3 Event Analysis

Continuous power quality monitoring focuses on issues related to harmonics, flicker, power factor, load pattern, etc., i.e. power quality parameters which can be captured without the need for anything to trigger the system. Event based power quality covers issues related to anomalies occurring in the system on an indeterministic basis such as outages, sags, swells, rapid voltage change, etc. These events can have catastrophic effects in the short term.

### 3.1 Voltage Dips

Critical loads require steady voltage for optimal operation & fluctuations beyond certain limits can lead to adverse issues. A significant drop in the voltage even for a short duration can cause equipment failure or resets.

Occasional incidents of lights flickering & equipment restarts had been observed at the facility and shown below is one such event –

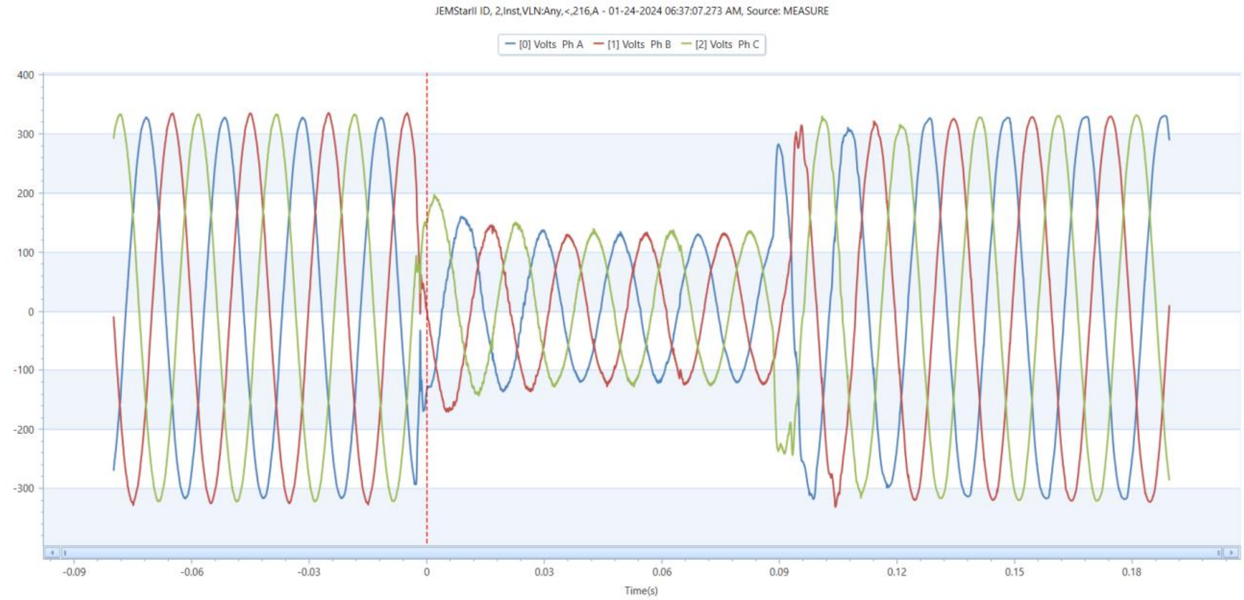


**Fig.8:** Phase to neutral three phase voltage waveforms

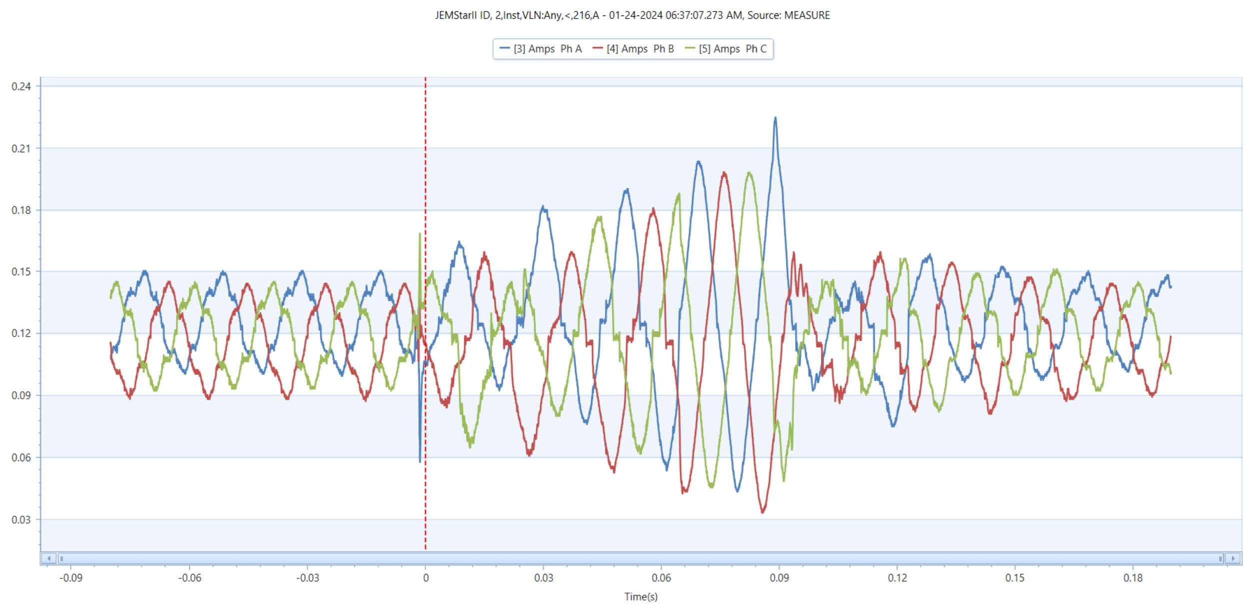


**Fig.9:** Phase to neutral three phase current waveforms (x1000 scale)

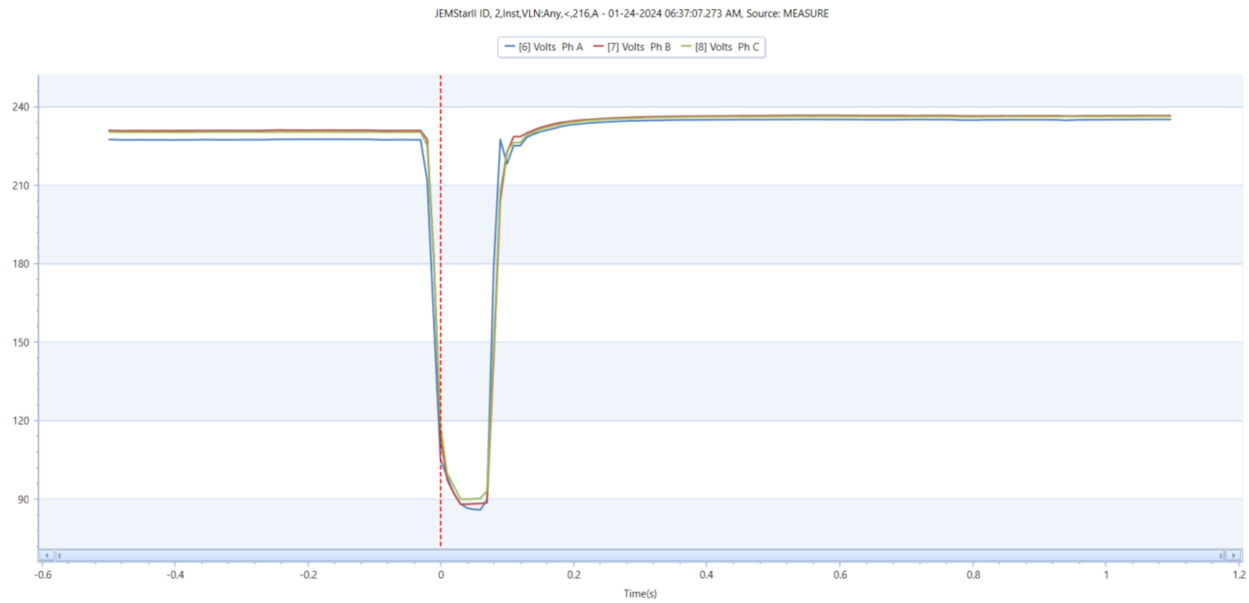


**Fig.10:** Phase to neutral three phase RMS phasor voltage (fundamental) measurements

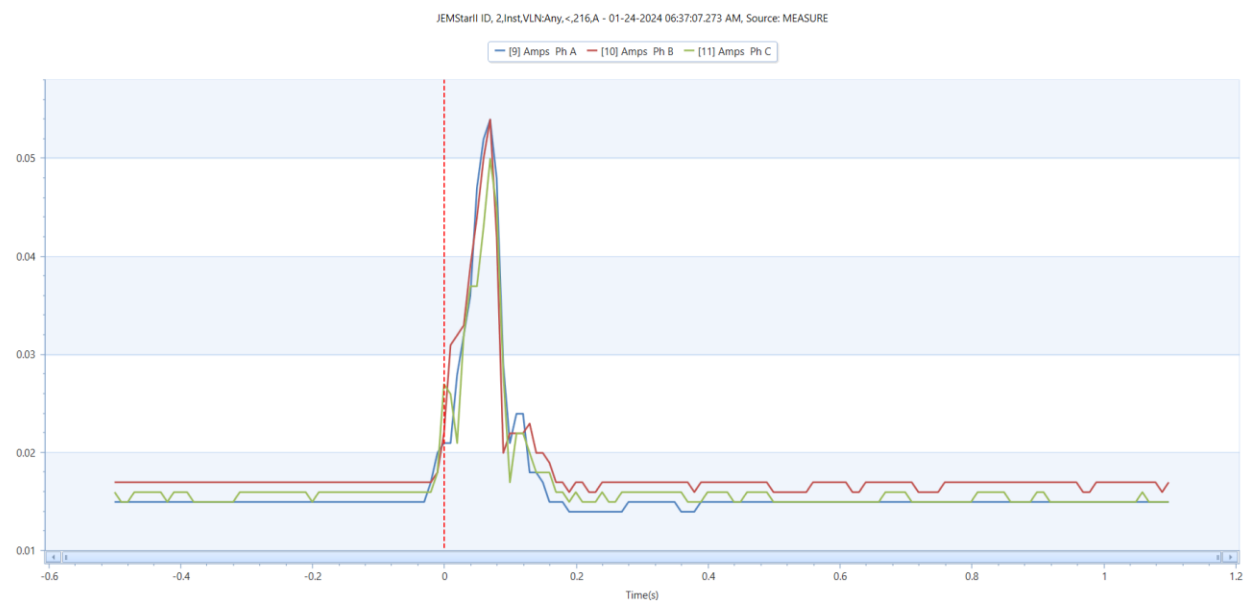


**Fig.11:** Phase to neutral three phase RMS current (fundamental) measurements (x1000 scale)

The voltage on all 3 phases was seen to drop by ~60% with a corresponding 3.6x increase in the phase currents. The event lasted for approximately 4.5 cycles and caused some devices to reset. The most visually noticeable effect was the momentary sharp flickering in the part of the lighting system driven directly by the raw power.

**Takeaways**: As seen in fig.1, all UPS systems in the facility are connected to the same bus bar along with the lighting load. The power distribution also extends to other tenants in the same building.

1. Incidents such as the one above demonstrate how an anomaly in one part of the power distribution network can affect the voltage across the several points in the system.
2. In large facilities with multiple tenants or multiple departments (manufacturing, marketing, etc.) present in the same building, it may not be possible to isolate and pinpoint the source of such issues easily. As such, it’s advisable to backup critical loads with adequate UPS systems.
3. When a large voltage drop happens in the system, it’s not uncommon for loads to draw a large amount of current to compensate for the lower operating voltage. This can have serious consequences including equipment damage, nuisance breaker tripping, etc. If a UPS system is in use, it may draw a large amount of current to maintain a steady output voltage, as seen above. Careful review of the UPS specifications as well as the power distribution scheme is essential under such conditions.

**Conclusion**

This paper showcases a variety of issues that can be observed at an industrial facility covering a broad spectrum from load pattern inefficiencies to power quality issues. The use of a meter that combines both revenue metering as well as power quality monitoring makes it possible to analyse such issues simultaneously with correlation among both types of problems. The following are some of the key takeaways from this case study –

1. The 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.
2. With electronic loads such as IT servers, computer/networking equipment, etc., there may be high levels of THD which results in lower overall efficiency, equipment damage, heating issues, increased cooling requirements & upstream propagation of harmonic content. Active power quality monitoring in addition to power quality metering is essential to capture such problems.
3. It’s 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 analysed in a comprehensive manner to determine the best operating conditions.
4. The ability to capture short term anomalies such as dips, swells, etc. can help identify latent issues as well as aid in root cause analysis. A 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. While the latter focuses on efficiency, the former is required to ensure uninterrupted operation during contingencies.