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## Introduction

This case study explores how advanced power quality measurement technology facilitated the diagnosis of severe power quality disturbances in a bus depot. These disturbances, which neither the bus operator nor the bus manufacturer initially attributed to electrical quality issues, were ultimately traced to deficiencies in the depot's charging infrastructure.

## Background


A bus depot, integrating both AC and DC charging infrastructure, was experiencing operational disruptions. The facility contained AC chargers (22 kW) designated for minibuses and DC fast chargers (200 kW) for larger electric buses. Depot operators observed that the AC chargers were intermittently failing when the DC chargers were in use. These issues impacted vehicle availability and overall operational efficiency. The root cause of these disruptions remained undetermined until an extensive power quality analysis was conducted.



*Figure 1: Aerial view of the bus depot. Large buses are DC charged; minibuses are AC charged (overnight charging)*

## Diagnostic Assessment

A power quality investigation revealed that the power disturbances originated from the absence of necessary electrical filters in the DC chargers. Without these filters, the operation of DC chargers induced significant harmonic distortions in the local voltage, interfering with the stability of the AC charging units.

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## Power Quality Analysis

The measurement data indicated that the Swedish power quality standard (EIFS) had been exceeded due to harmonic content in the 7th and 11th harmonic. EIFS is a local adaption of the European EN50160 norm.

### 5 Individual harmonic analysis

The individual harmonic analysis is assessed according to EIFS 2023:3 section 7.4-7.6.

All 10m values for each individual harmonic voltage must be less than or equal to the limit values in the table.

Harmonic no: limit in % of fundamental

#	Limit [%]	MaxU1 [%]	95% U1 [%]	MaxU2 [%]	95% U2 [%]	MaxU3 [%]	95% U3 [%]	Result
2	2	0,10	0,03	0,07	0,02	0,09	0,03	Passed
3	5	0,48	0,29	0,57	0,45	0,57	0,37	Passed
4	1	0,12	0,02	0,06	0,02	0,04	0,02	Passed
5	6	3,63	1,92	3,69	1,99	3,65	1,91	Passed
6	0,5	0,11	0,02	0,05	0,02	0,05	0,02	Passed
7	5	4,79	4,14	5,19	4,28	5,32	4,32	Failed
8	0,5	0,06	0,02	0,06	0,02	0,05	0,02	Passed
9	1,5	0,61	0,34	1,16	0,67	1,00	0,65	Passed
10	0,5	0,10	0,02	0,11	0,02	0,10	0,02	Passed
11	3,5	4,23	3,53	4,10	3,61	3,83	3,36	Failed
12	0,5	0,04	0,02	0,03	0,01	0,04	0,02	Passed
13	3	1,81	1,27	1,87	1,34	2,00	1,34	Passed
14	0,5	0,05	0,01	0,03	0,01	0,04	0,01	Passed
15	1	0,91	0,65	0,73	0,53	0,78	0,61	Passed
16	0,5	0,03	0,01	0,03	0,01	0,02	0,01	Passed
17	2	1,74	1,26	1,73	1,23	1,64	1,25	Passed
18	0,5	0,02	0,01	0,01	0,01	0,02	0,01	Passed
19	1,5	1,32	0,84	1,32	0,81	1,38	0,77	Passed
20	0,5	0,02	0,00	0,02	0,00	0,02	0,00	Passed
21	0,75	0,61	0,40	0,57	0,34	0,57	0,28	Passed
22	0,5	0,02	0,00	0,01	0,00	0,02	0,00	Passed
23	1,5	0,88	0,47	0,85	0,44	0,84	0,40	Passed
24	0,5	0,02	0,00	0,01	0,00	0,01	0,00	Passed
25	1,5	0,00	0,00	0,00	0,00	0,00	0,00	Passed


Figure 2: 7th and 11th Harmonic are failing

Additionally, the analysis revealed that the power factor was significantly below optimal levels, causing energy inefficiencies within the depot's electrical distribution system.

## Implementation of Mitigation Measures

Following the identification of these power quality issues, the DC charger manufacturer installed appropriate electrical filtering solutions. A subsequent measurement campaign was conducted to assess the effectiveness of these interventions. The results demonstrated a significant improvement:

- **Substantial reduction in harmonic distortions**, bringing them within regulatory compliance limits.

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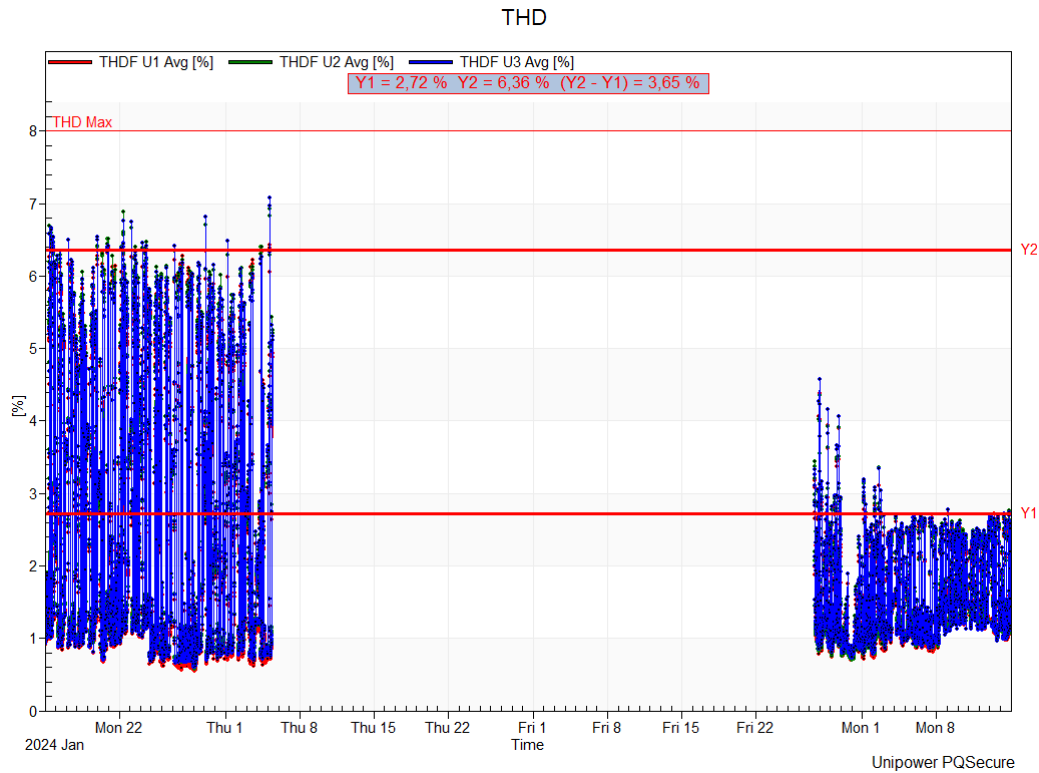


Figure 3: THD before and after filters were installed

- **Power factor improvement from 88% to 97%, enhancing overall energy efficiency by 9%.**

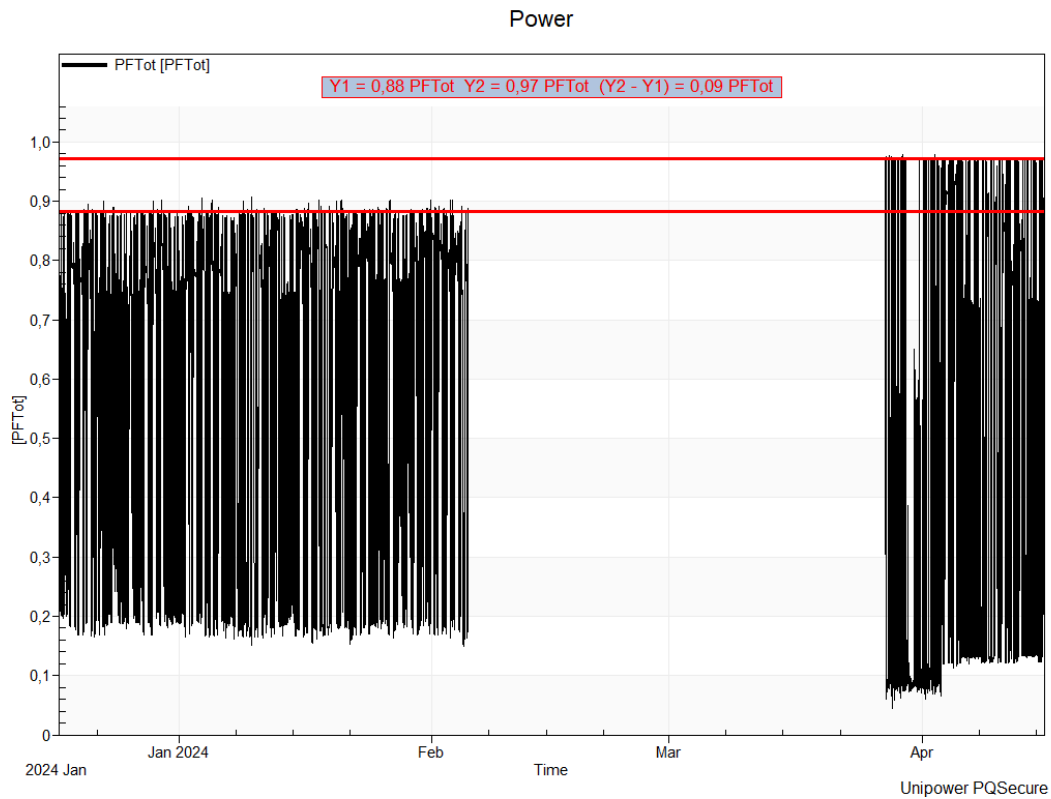



Figure 4: Power factor before and after filters were installed

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### Lessons Learned & Next Steps

- **Implement continuous monitoring:** Regularly measure power factor, harmonic distortion, and other vital parameters to detect potential issues before they escalate.
- **Evaluate expansion opportunities:** As the electric fleet grows, continuously assess whether the existing filters, chargers, and electrical network remain adequate.
- **Strengthen collaboration with manufacturers:** Ongoing dialogue with both bus and charger suppliers helps ensure that proper filters and components are in place from the outset.
- **Analyze economic implications:** Beyond energy savings, conduct a return-on-investment (ROI) analysis of the filter installation and the improvements in system stability.
- **Educate relevant staff:** Ensure that electrical technicians and depot managers understand fundamental power quality principles, enabling rapid response to emerging anomalies.

This case study underscores the critical role of advanced power quality diagnostics in identifying and resolving electrical disturbances. By systematically analyzing power parameters and implementing targeted mitigation strategies, significant improvements in charging infrastructure reliability and energy efficiency were realized. The findings highlight the necessity of continuous power quality assessments for ensuring optimal performance and compliance in electric bus depots.