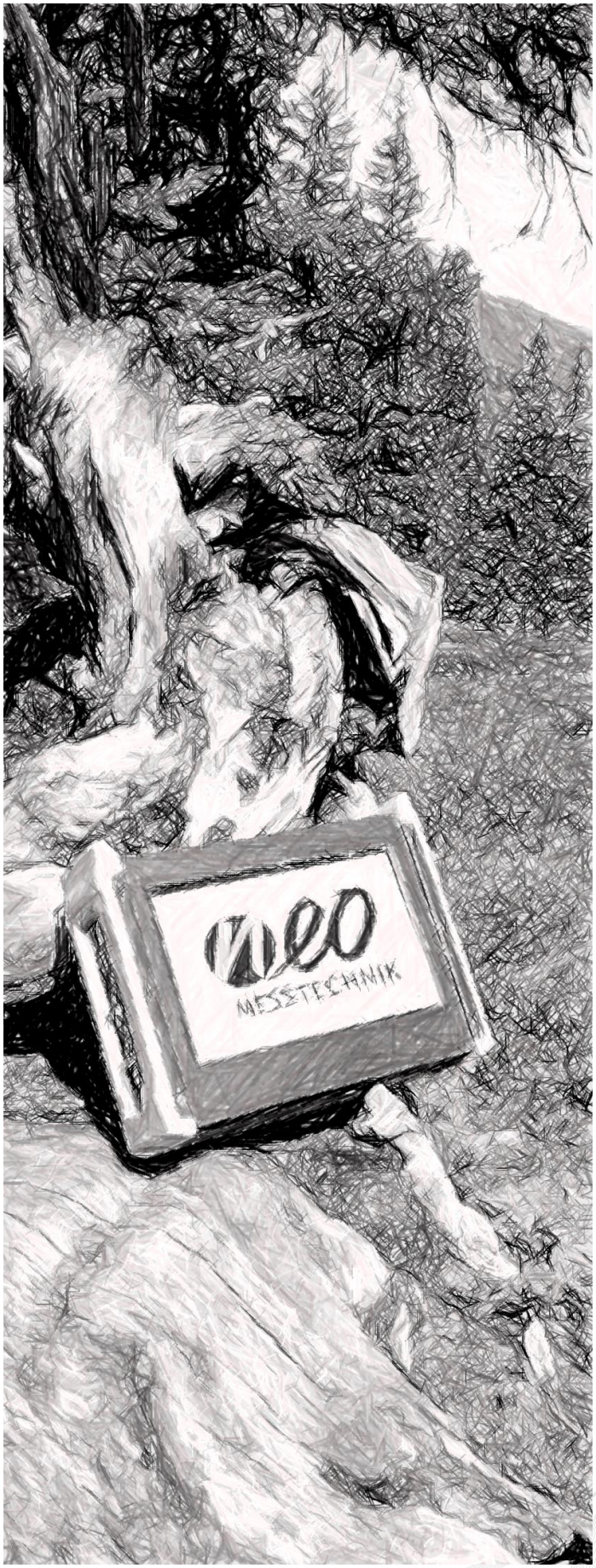

Application Note

Supraharmonics Influence on Power Line Communication (PLC) – Smart Meter

Introduction

The rollout of smart meters in a couple of European countries showed that signal transmission via PLC is not always as smooth as we thought. In-depth Troubleshooting of communication disturbances with the NEO PQA8000H show that Supraharmonics and PLC are not a good combination.

Keywords:
#PowerQuality #Supraharmonics #PLC #CENELECband #FCC #ARIB #PQA8000H

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Troubleshooting PLC problems

Requires the integration of various information sources:

- Spectrum analysis up to 500 kHz for voltage and current
- Digital information, protocol analysis (encrypted SPS data stream)
- Grid impedance measurement up to 500kHz

The NEO advantage
Additional PQ Analysis with the PQA 8000H

Importance of current measurement

Most measurement equipment only measures voltage and thereby **cannot** give any indications about the source or sink of Supraharmonics. The mere voltage measurement only partly help for problem detection on the connection point and for normative assessments, e.g. according to IEC 61000-2-2.

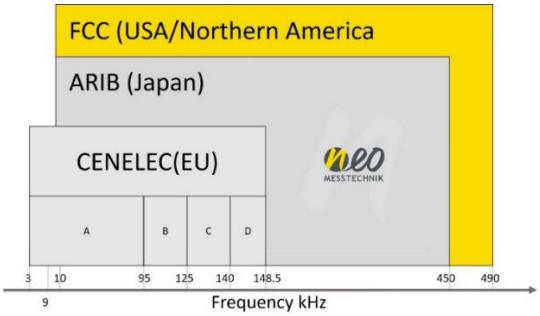
The NEO advantage – Multi Channel Current Measurement

The PQA 8000H allows to measure up to 8 current channels to carry out in-depth Supraharmonic measurement and analyses.

- Residential building with 20 flats and multi-channel measurements for rapid determination of the disturbing source and sink.

Power Line Communication

Smart meters often use this technology (G3) for meter data transmission. The CENELEC A band is reserved for power utilities in the frequency range from 3 - 95 kHz. CENELEC B/C/D, ARIB or FCC are the frequency bands used in other regions of this world.



The following graph shows that data transmission is done with modulated signals of up to 490 kHz. However, PLC data is distorted and shows lack of reliability under certain circumstances or time spans which we will further discuss in this article.

Region	Regulatory Body	Frequency Band	Note
Europe	CENELEC	3 – 95 kHz 95 – 125 kHz 125 – 140 kHz 140 – 148.5 kHz	A – Energy Providers B – Reserved for users C – Reserved for users, regulated CSMA access D – Reserved for users
Japan	ARIB	10-450 kHz	
China	EPRI	3 – 90 kHz 3-500 kHz	Not regulated
USA	FCC	10 – 490 kHz	

Supraharmonics

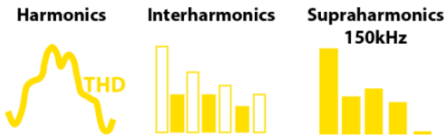
Supraharmonics are voltage and current emissions in the frequency range of above 2 kHz (up to 150 kHz or even 500 kHz). Until 2030 about 80% of all electric loads will connect to the grid via electronic interfaces. On one hand, this development promises a major increase in efficiency and better handling of electrical equipment. In exchange, the emission increase in the higher frequency range asks for more attention on our side.

As of right now, international and national standards often define emission limits up to 50th order Harmonics only. Although a majority of electric equipment will be compliant to these limits, the higher emissions starting from 2 kHz should catch our attention. Modern electric equipment already operates with switching frequencies up to 500 kHz.

Implications on the grid

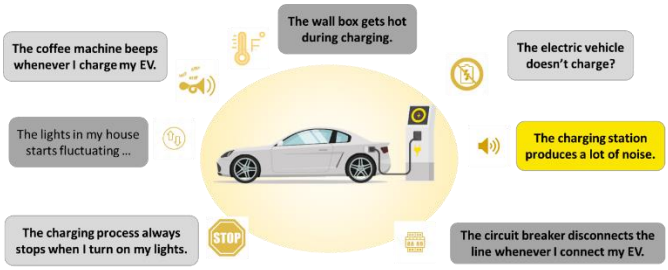
Supraharmonics cause problems and failures of electric equipment in various ways.

- Noise
- Thermal stress and ageing to electrical equipment
- Interferences of other electric equipment
- Damping/Deviations of the PLC signals



The closer the electric equipment is to the emission source, the higher are the implications. Electric Vehicle (EV) charging stations nowadays operate with switching frequencies at around 20-40 kHz, while inductive charging works in areas of 80-90 kHz.

These EV charging stations are popular examples where customers experience noise emissions, failures of other electrical equipment (coffee machines beep, hair dryers operate randomly) or thermal stress (heating).



In other words, it leads to poor Power Quality and distortion of PLC in Smart Meters. Already small disturbances in this frequency range can influence PLC signal transmission and therefore make it a substantial part of PQ investigations.

PLC Signal quality

A dampening of 10dBµV between transmitter and receiver equals information loss (packages).

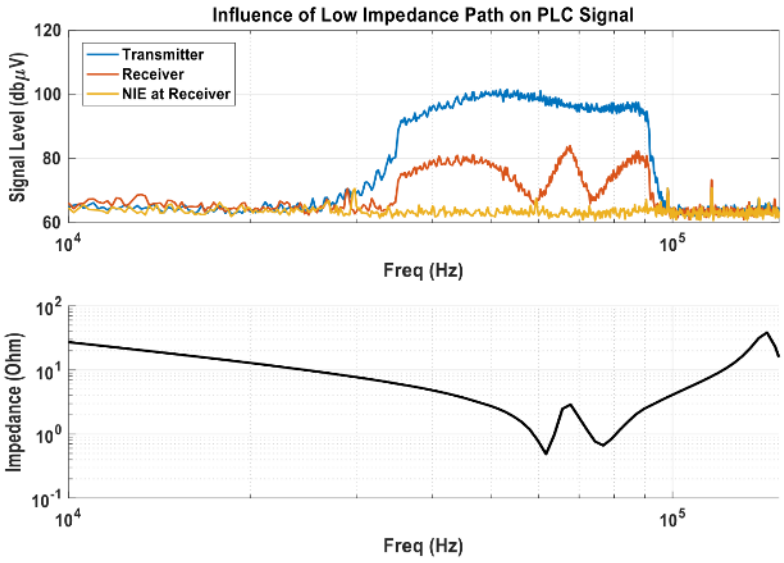


Fig. 36: Einfluss eines EMV-Filters auf das PLC-Signal und Eingangsimpedanz des Filters

Source: Schori, Roggo, Evequoz (2020)
OptiQ – Bericht WP4, Effekt der Zunahme von nichtlinearen Geräten auf die Ausbreitung von Oberschwingungen und auf die Netzimpedanz, Bundesamt für Energie BFE, Nidau/Schweiz

Troubleshooting

The troubleshooting of PLC problems requires the integration of various types of information.

- Spectrum analysis up to 500 kHz for voltage and current
- Digital information, protocol analysis (encrypted PLC data stream)
- Power Quality Analysis of the electric grid
- Scope and FFT Analysis to view the higher frequency components
- Grid impedance measurement up to 500kHz

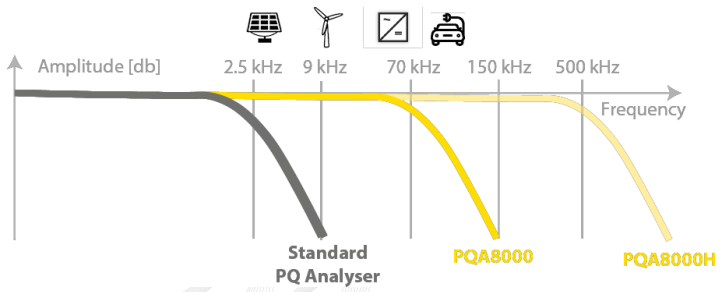
Unfortunately, we still see the use of complicated and outdated measurement approaches that make life harder in the trouble shooting process. This includes using three separate instruments and by doing so making investigations difficult and expensive.

Furthermore, it is needless to say that the data set synchronization presents further challenges to customers. To finally complete this picture of How Not To, we see that quite often instruments don't even fulfil the required safety categories for these kind of measurements (CAT III 1000V / CAT IV 600V).

The NEO advantage

The PQA 8000H allows doing Power Quality, FFT Analysis, Scope view up to 500 kHz and streaming of digital PLC data with just one instrument – completely simultaneous and synchronous.

When we look on the Power Quality side of the measurement, we see that classical PQ Analyzers present problems because of their limited bandwidth. Typically they can measure up to the 50th Harmonics (2.5 kHz), but cannot detect higher emissions of voltage and currents. By design, they are **not able** to be used in the troubleshooting process at all. Analyzing the effects of Supraharmonics asks for Power Quality Analyzer that cover the following frequency range up to 500 kHz, as seen in the following picture.



The PQA8000H allows sampling rates up to 1 MS/s per channel. This allows analysis of Supraharmonics up to 500 kHz which is sufficient for all the different frequency bands used for PLC communication. Together with an additional PLC data stream recorder also the digital data can be analyzed:

PQA 8000H investigation possibilities

- FFT Analysis up to 500kHz in 2kHz bands (according to international standard IEC61000-4-30)
- Scope View with 1MS/s
- View and Record of PLC digital data stream

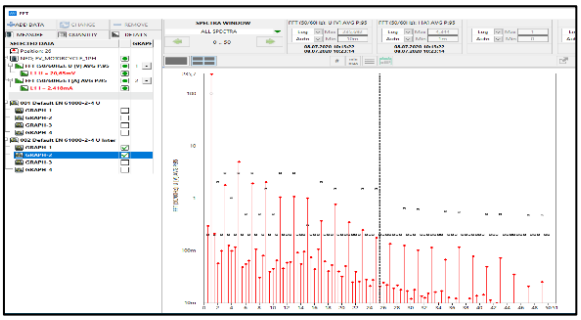
All of this data are captured completely synchronously with the same time-stamp.

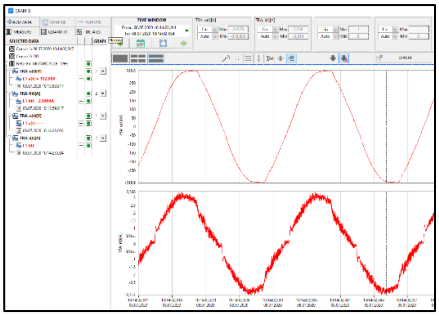
Of course also all standard PQ parameters can be calculated (Harmonics, Interharmonics, Unbalance, THD, Resonances, Phase angle jumps, etc.)

Measurements

1. Supraharmonics up to 500kHz

The troubleshooting of PLC problems requires the integration of various types of information.



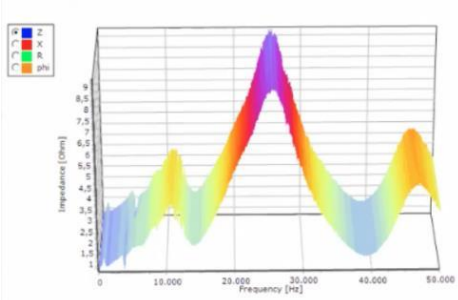


The NEO advantage – Measurement of

- Higher Frequencies up to 9kHz in 200Hz bands for voltage and current
- Supraharmonics up to 500kHz in 2kHz bands for voltage and current
- Waveform and FFT analysis

2. Grid Impedance up to 150kHz/500kHz (additional hardware)

The measurement of the grid impedance is getting more and more important due to the increased use of power electronic equipment (LED, inverter, AC/DC, DC/AC conversion). This leads to significant changes of the frequency dependent behavior of the grid impedance (amplitude and phase).



Dynamic Changes in Higher-Frequencies and Grid Impedance

The behavior of higher frequency emissions of electronic equipment can change within very short time. Harmonic amplitudes can change within a few milli-seconds (e.g. peak for all 5 ms). Similar to that, the grid impedance can vary as well, if e.g. the amplitude drops down each 8ms or changes the angle significantly.

The NEO advantage – PQA 8000H + Grid Impedance Analyzer box

A high bandwidth, highly accurate and dynamic measurement instrument needs to be used for investigations of these problems.

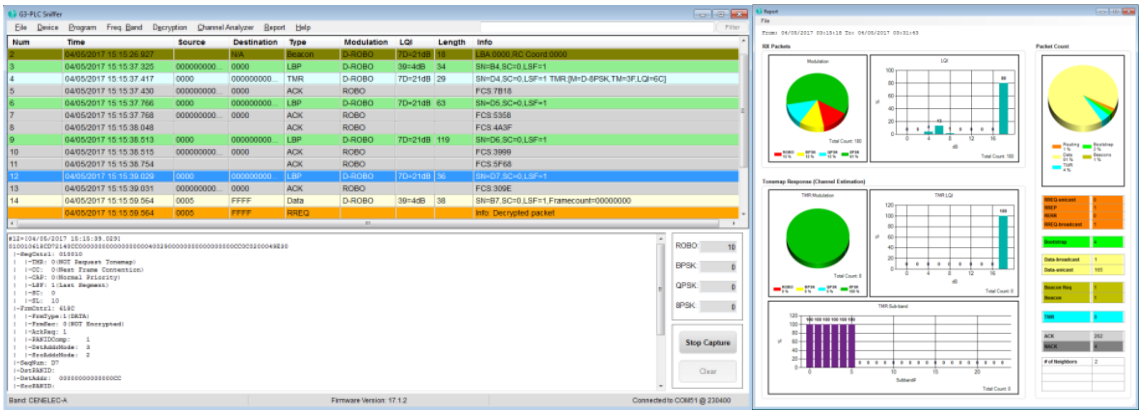
It is essential to capture raw data in these events.

Be capable of measuring emissions (U,I) and grid impedance (Z, phi, Re, Im, R, X / Zero-, Positive- Negative Sequence) up to 500kHz

3. PLC data stream

The PLC data stream can be recorded via external USB dongle, a lightweight test and monitoring device for G3-PLC powerline communication networks. Accompanied by a user-friendly Windows® application, this portable dongle enables capturing and analysis of data and command packets on powerline.

A multifunction button allows the user to conveniently change the frequency band to CENELEC-A, CENELEC-B, FCC, or ARIB. The dongle is powered by a standard mini-USB port that can be connected to a power bank and used as a handheld test device in the field to check the signal phase and quality.



The NEO advantage – PLC Streamer Key Features

- Captures and Displays Packets
- Demonstrates Color Coded and Time-Stamped G3-PLC PHY and MAC Frames incl. Beacons, Bootstrapping, Routing, Tonemap Response, ACK/NACK and Data Packets
- Configurable Decryption Keys Enable Real-Time Display of Decrypted Packets
- Channel Analyzer Function Graphically Visualizes the Channel Quality of Each OFDM Tone
- One-Click Report Generation for Statistical Analysis of Network Stability, Topology, and Communication Quality
- Programmable for Frequency Notching Supportigher Frequencies up to 9kHz in 200Hz bands for voltage and current
- Supraharmonics up to 500kHz in 2kHz bands for voltage and current
- Waveform and FFT analysis

Measurement System

PQA8000 Portable Power Quality Analyzer

4x Voltage Measurement up to 1600V DC / 0.05% accuracy

8x Current Measurement via High-Bandwidth Rogowski Coils 300A

1x PLC STREAM Digitizer

GPS-Time Synchronization

Sampling Rate: 1MS/s per channel / 18 bit resolution

Accessories & Options

PLC-STREAMER

easy non-invasive measurement of PLC signal

AC Measurement Adapter

easy access of voltages and currents for CEE16A and CEE32 connector

AC Adapters

AC/DC Current Sensor

up to 500kHz bandwidth