MESSTECHNIK

Power Quality Explained

V 1.0

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Thank you!

Thank you very much for your interest in NEO Messtechnik and our multi-part series Power Quality Explained. This guide includes all chapters that have been published so far. However, as new chapters will be published in the future, we recommend that you follow us on our LinkedIn presence as well as on our YouTube channel to stay up-to-date!

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1 Power Quality Analysis – A Reintroduction

The electricity sector's development of recent years certainly points towards an increasing complexity and holistic problem-solving approaches. That doesn't mean it is not manageable any longer. Thoughts and conclusions on the increasing measuring efforts and necessary adaptions for the future of Power Quality Analysis.

1.1 Welcome to Power Quality Explained

You are currently reading the introductory chapter of our new Multipart-Series about the challenges of the energy and electricity sector from our perspective. In the end of this chapter you will find the link to Chapter 1 – Foundational Knowledge.

Power Quality also means working together for a safe and reliable power supply. Similar to that, this blog aims to start conversations and highlight the importance of co-operation by every party involved. Let's hear from you – we're ready to answer your comments, questions or suggestions for future articles!

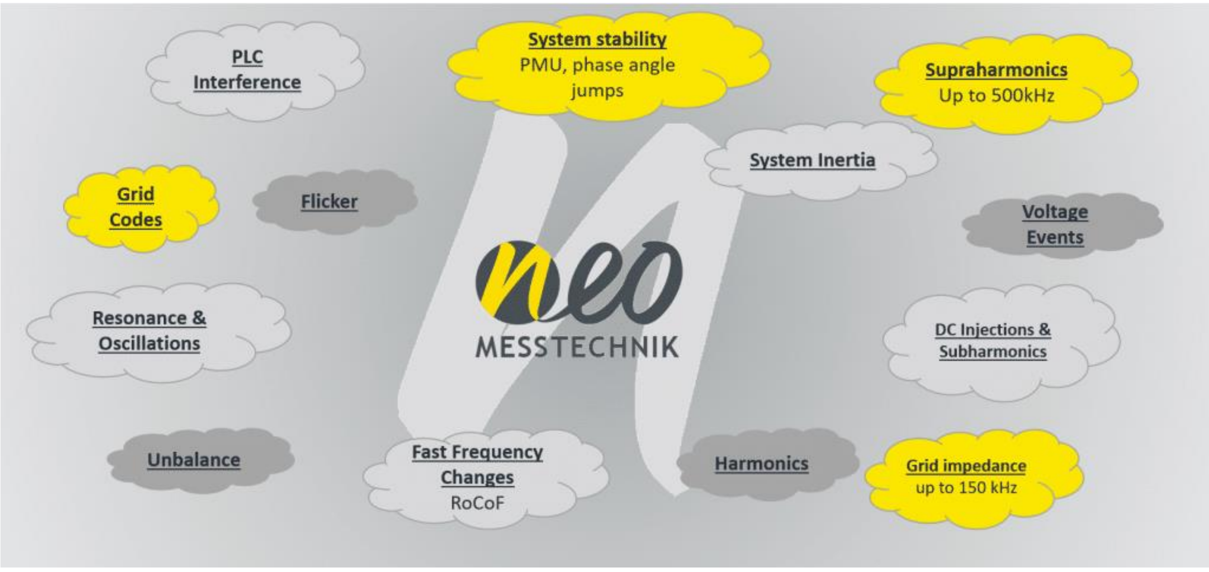
1.2 The power grid in change

While the almost-Blackout was the main talking point in the last Blog article, we are taking a step back for a reintroduction of Power Quality Analysis as we know it. The basic concept of power supply has always been taught in a very simple yet comprehensible way. You mainly talked about the interaction of (large) conventional power plants, the grid and concepts of load-flow regulations. Consumers completed the whole picture of generation, transmission and consumption by, well, consuming the provided energy. However, all three areas have certainly evolved dramatically in the last years.

Consequently, measurement and analysis solutions have to keep up with these developments as well. Experienced engineers determine very quickly which hardware and software specifications are still, by design, tailored to the old-fashioned measuring and analysis needs of the past – and which ones aren't limiting the engineer's capabilities and tasks any longer.

1.3 Let's take a look at Power Quality phenomena

Whenever electric wave signals deviate from ideal sinus waveforms, Power Quality phenomena arise. As a result, Power Quality Analysers and Monitors are needed to ensure grid stability. From our experience, PQ Analysis nowadays goes way beyond EN50160 and other reports defined by the measurements of Voltage Variations, Frequency, Harmonics (50th order), Flicker or Unbalance.



1.4 Power Quality Analysis paradigm – Switching frequencies

Let's take a look at an example. The increase of power-electronic interfaces and operating switching frequencies require emission analysis up to the range of 500kHz. Smaller and separated generation units influence the emissions of the total system and demand more troubleshooting. Power Quality Analyser must blend in seamlessly in various application areas throughout the power grid.

Summing up, Power Quality Analysis and Monitoring solutions should reflect the customer's understanding and make life easier for power grid applications of today. Depending on your specific field of application, NEO Messtechnik offers you the proper analysing and monitoring solutions. Our great strengths are in supplying complete and reliable measurement systems that are easy-to-use. This includes mobile PQ Analyser with multi-touch display and 4 hours of mobile operation as well as monitoring solutions with up to 48 channels, 144kS/s and 24 bit resolution. Beyond that, intuitive software simplifies the analysis, report generation and data exports by working in the cloud.

2 Foundational Knowledge

The force of electric power is hard to imagine unless you explain it by means of other forms of energy. It is all the more challenging to understand the importance of Power Quality as all effort put into it only improves the familiar and excellent status quo. Which itself is a testimony of Power Quality provided by all parties involved.

2.1 Introduction

2.1.1 Back to the Basics

While the energy and electric power supply is rightfully considered a complex and interdisciplinary topic, it certainly affects everyone. In today’s society, a safe and reliable power supply only allows us to casually charge our phones or make life easier by various household devices. Electric power is much more – you could say it is essential for the functioning of our day-to-day life. It is hard to fully appreciate, because we are almost never left without it. In the rare case it happened or may happen again, our view changes dramatically.

2.1.2 Power Quality Explained – Welcome to our Multipart-Series

Throw away old Power Quality books, stop looking for new ones. In 2021, the NEO Power Quality Blog explains what you need to know about Power Quality Management. Over the next chapters we give you an introduction to the world of electric power and Power Quality. Starting with the grid operator’s perspective will help us talking about real-life deviations from the ideal power supply. Thereby we will automatically underline the importance of Power Quality and how it affects both industrial and private consumer.

> *You will be surprised how diverse the effects of poor Power Quality can be. Even more intrigued about how both challenging and easy it can be to troubleshoot.*

2.1.3 One last thing before you start reading

You maybe ask yourself why we started this Power Quality Blog in the first place? Well, it is a great platform to share our experience and knowledge. Experience that we have gained in the last 20 years in the fields of hardware and software development and the PQ Analysis and Monitoring Market.

Power Quality also means working together for a safe and reliable power supply. Similar to that, this blog aims to start conversations and highlight the importance of co-operation by every party involved. Let's hear from you – we're ready to answer your comments, questions or suggestions for future articles!

2.2 The grid operator's perspective

Coming back to the introductory chapters of this article, we highlighted the importance of electric power in our day-to-day life. Talking about the increasing challenges, grid operators ensure that Power Quality phenomena stay within given limits according to standards and Grid Codes.

Power Quality defines the framework of the electric power delivery consumers need – and expect – to run their equipment properly. While a power failure may be the obvious worst case scenario for every end user or factories, even small disturbances like voltage dips, transient currents or unbalance endanger the continuity of power supply as well. Very often end users start to notice problems because of their sensitive equipment. On the other side, PQ also holds end users accountable to limit their influence on the power system. For example by means of limiting harmonic currents.

By monitoring and analysing voltage and current over a certain period of time, both grid operators and consumers gather information about the current state of the grid. Furthermore they are able to manage problems, as certain PQ phenomena can often be traced back to a certain cause.

2.3 Foundational Knowledge Power Quality

2.3.1 Classic PQ Phenomena

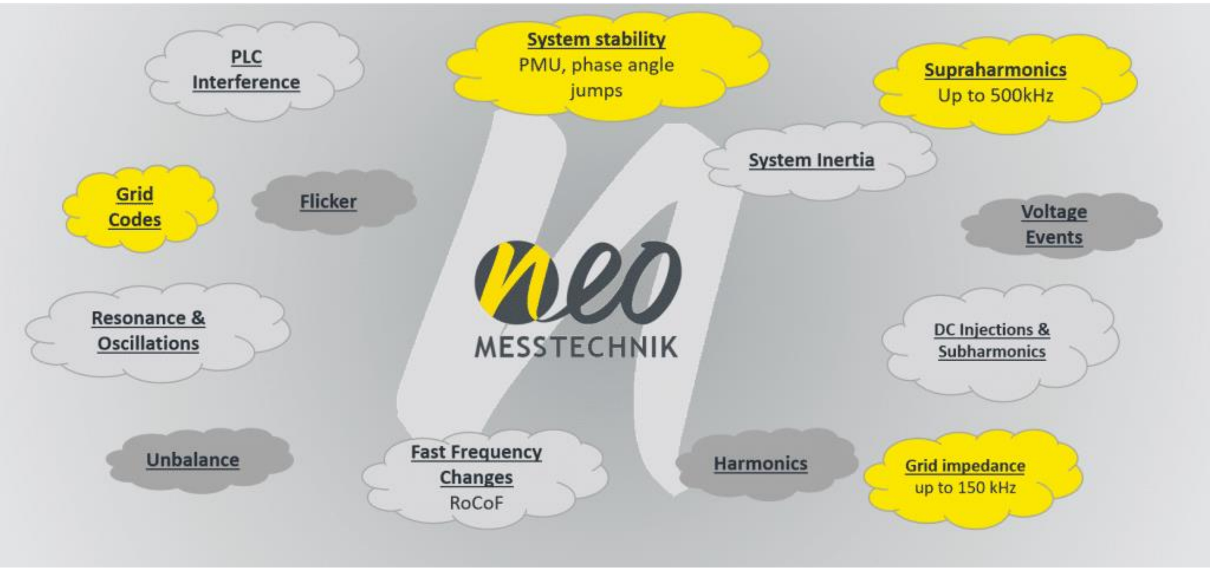
Whenever electric wave signals deviate from ideal sinus waveforms, Power Quality phenomena arise. As a result, Power Quality Analyzers and Monitors are needed and used to ensure grid stability. From our experience, PQ Management nowadays goes way beyond EN50160 and other reports. We will cover the following phenomena in Chapter 2 very soon:

- Power and Energy (Apparent, Active and Reactive Power, Power Factor, Distortion)
- Voltage Variations (Dips, Swells, Spikes, Rapid Voltage Changes)
- Harmonics (Interharmonics, Total Harmonic Distortion (THD))

- Flicker (Short- and Long-time Flicker, Pinst, Pst, Plt, Flicker current, phase angles)
- Unbalance (Symmetrical components: Zero, Positive and Negative Sequence)

2.3.2 Emerging PQ Phenomena

As we have already discussed in our previous article, a various number of PQ phenomena shift into the focus of our customers and the Analysis and Monitoring market in general. For these phenomena we will go into greater detail in future blog posts. Furthermore, you can soon access specific AppNotes in your personal NEO Download Area.



2.4 Fundamentals on Computer-based PQ Analyzer

2.4.1 Skip the past. Look at present-day technology.

In this chapter we spare you a lot of hassle and headache by **not** talking about (outdated) measurement equipment and approaches where you will end up with several different instruments or data merging catastrophes that will consume too many hours of your time.

So let's cut corners straight to computer-based PQ Analyzers. Why? Because we believe that you shouldn't spend a single hour on devices designed for the power grid of the past. Measurement equipment must not limit engineers any longer. We don't want to rely on separate instruments with different time stamps and file formats, when you can have everything on a single instrument or platform. Taking our devices as examples, they combine the functionality of multiple instruments. They also measure and analyse according to international standards IEC 61000-4-7, IEC 61000-4-15, EN 50160, and IEC61000-4-30, the Analyzers fully comply with IEC 61000-4-30 standard, class A.

2.4.2 Foundations of AC-Conversion

The performance of hardware, bandwidth, accuracy and resolution has increased dramatically over the past 10 years to the point that the performance of computer-based digitizers is comparable to traditional instruments. Today, virtually all common measurements and complex applications, such as FFTs and signal processing routines, can be done in less time and at a lower cost due to the declining prices of measurement components. Moreover, these components are tightly integrated with the software. It is easy to reconfigure the computer-based system to follow your demands.

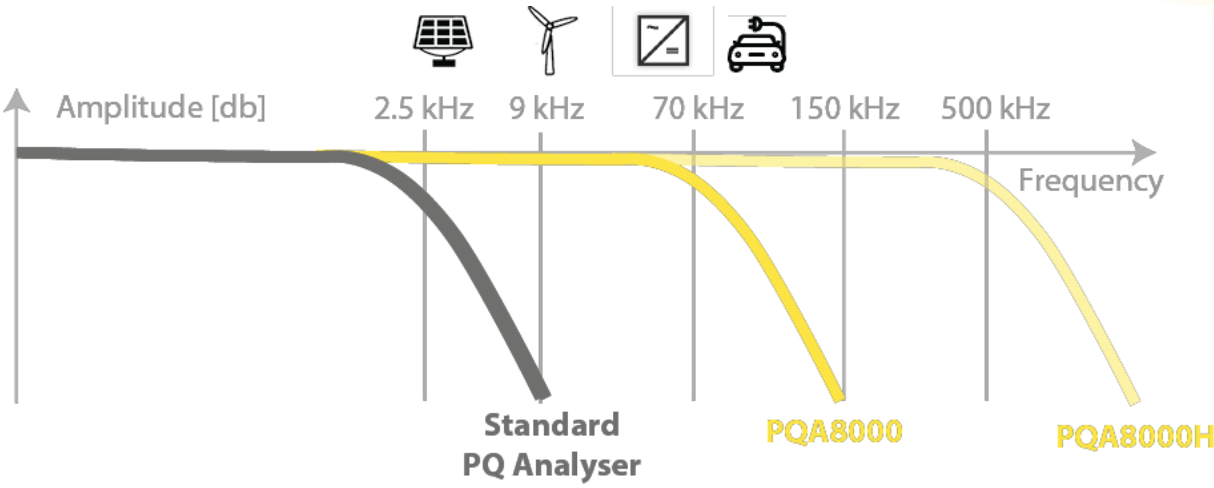
Which factors are to consider for AD-conversion? Bandwidth or measurement range probably first come to mind. For us, it’s something different. Have you ever thought about the necessity of **correcting frequency-dependent behaviour** of voltage and current sensors or integrated electronics? Ok, to be fair, we maybe just skipped a step or two..

Measuring voltage signals with Data Aquisition (DAQ) devices requires knowledge about the following:

- range of input signals (µV up to kV)
- Bandwidth (up to MHz)
- using the right amplifiers,
- selecting the according measurement range
- being aware of phenomena like ground loops, disturbances and noise signals.

2.4.3 Choosing the right amplifier

In terms of isolation voltage, this is very important for a safe and reliable measurement setup. In order to avoid electrical accidents, we strongly emphasize the importance of safe instrument design. Unfortunately, we quite often see instruments that don’t even fulfil the required safety categories for the respective measurements (CAT III 1000V / CAT IV 600V). As a matter of fact, the High-Voltage inputs of our PQA 8000 instrument (CAT IV 600V) are isolated up to 6kVp – while maintaining high precision (0.05%) and sampling rate (up to 1MS/s).



Does your measurement equipment keep up with the rapid increase of switching frequencies?

2.4.4 Measurement range & Resolution

Selecting the right measurement range for input channels is vital for the further conditioning and analysis of signals. Configurable amplifiers allow users to select the right measurement range via the software. At this point we would like to take a closer look at how the selected range is vital for the accuracy and reliable results.

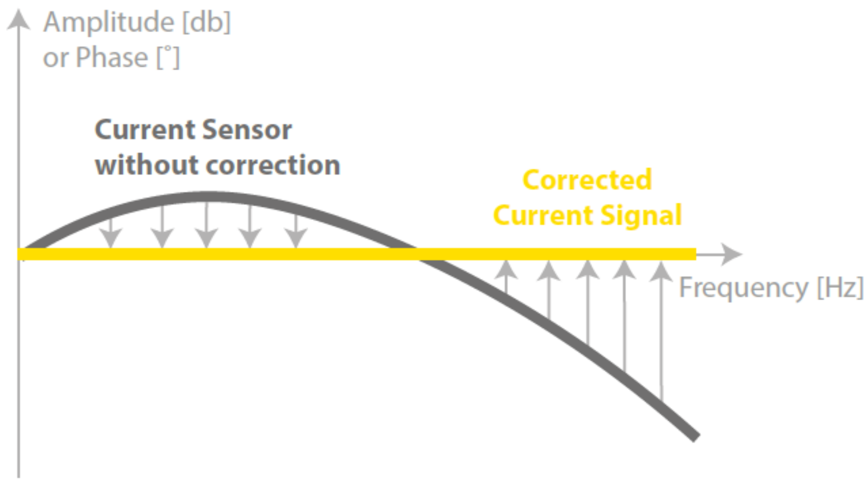
- Choosing a range that is smaller than the expected input signal will result in a channel overload.
- Choosing a range that is too big, the inaccuracy within this measurement range will result in a high uncertainty of the read-off signal value. Which means it is impossible to make correct readings.

Number of bits	Discrete steps	Smallest resolution for input range of		
		+/- 1V	+/- 5V	+/- 10V
8	256	7.813 mV	39.1 mV	78.1 mV
12	4096	0.488 mV	2.441 mV	4.883 mV
14	16384	0.122 mV	0.610 mV	1.221 mV
16	65536	0.031 mV	0.153 mV	0.305 mV
24	16777216	0.119µV	0.596 µV	1.192 µV

Are your analysis results limited by inadequate converter resolution? Choosing the right range actually means taking advantage of the best resolution offered by the equipment you use.

2.4.5 Frequency-dependent sensor correction

Following the discussion about the wide frequency spectrum of power grid applications, we also need to take phase shift and amplitude damping effects of sensors into account. We tackle this topic by generally providing highest quality sensors **and** calibrating them over the full bandwidth. Needless to say, the calibration is done over multiple points for each measurement range. Which improves the accuracy and precision especially at low currents, e.g. of 1% of the nominal measurement range. By doing so we ensure that our customers receive measurement equipment that is ready to use for their particular application.



Sensor correction ensures validity of your measurement results.

2.5 Summary and Outlook

In this first part of our Multi-Part-Series, we built up the foundational knowledge on Power Quality Analysis. By starting with the grid operator's perspective, we have come to understand the importance of Power Quality as well as expectations and benefits for all parties involved. Furthermore, it helped us differentiate between classic and emerging PQ phenomena of today and tomorrow. Complementing these parameters with a fundamental yet compact knowledge on data acquisition gives us a common ground for upcoming articles. This allows us to discuss the first batch of PQ parameters in the upcoming Chapter 2.

3 Electric Power & Energy Explained

Having the measurement know-how and right equipment in our hands, it's on us to take the next steps. But what do we need to do for determining Electric Power and Energy? Without giving too much away – we will find the answers in the frequency domain. Please leave your Watt–meters at home.

3.1 IEC 61000-4-30 Ed. 3 Standard Class A

3.1.1 What is our main purpose here?

Whether it is for your own interest, regulatory reasons or customer complaints – our main goal is to gain knowledge on how to detect Power Quality issues. Furthermore, we want to talk about PQ Monitoring systems that fit these needs and requirements. Which brings us to the central standard that defines how to correctly measure PQ parameters. First introduced in 2003, it's latest version published in 2015 – we already see you nodding your head. Without further saying – we are certainly talking about the ***IEC 61000-4-30: Ed. 3 Testing and measurement techniques – Power quality measurement methods***.

> *It defines the methods for measurement and interpretation of results for power quality parameters in a.c. power supply systems with a declared fundamental frequency of 50 Hz or 60 Hz.*
>
> IEC 61000-4-30 Ed. 3

3.1.2 No standards, no problems?

Although it seems like a long time ago, Power Quality Assessments lacked standards and comparable limits. Your reports and hence Power Quality level depended on your PQ instrument. This certainly was not a satisfying situation for engineers like us. The IEC 61000-4-30 then established a common framework for PQ Monitoring systems. To obtain reliable and comparable results, independently of the PQ instrument of your choice.

By choosing a ***Class A complying*** instrument, you make the first important step for getting reliable results according to the IEC 61000-4-30. However we know from experience that you probably won't be happy with standard solutions only. Especially when you can have PQ Analyzers and Monitors that not only exceed standards, but your expectations. For now, it is important to summarize that the standard defines

- measurement methods,
- time aggregation and
- specifics about accuracy, limits and evaluation of PQ parameters (Flicker, Unbalance, RVC, among others).

3.1.3 Time aggregation of PQ data & Frequency determination

The IEC 61000-4-30 defines the time windows for parameter magnitudes (supply voltage, harmonics, inter-harmonics and unbalance). It is a 10 cycle time interval for a 50 Hz power system or 12-cycle time interval for a 60 Hz power system. Furthermore, aggregations of the measured time intervals takes place over three different time intervals:

- 150/180 cycle interval (150 cycles for 50 Hz nominal or 180 cycles for 60 Hz nominal)
- 10-min interval
- 2-h interval

3.2 Power & Energy Analysis

3.2.1 Voltage measurement

Basically, the potential difference of two points defines the electric voltage. Measuring voltage with DAQ devices requires knowledge about the range of input signals (µV up to kV), using the right amplifiers and selecting the right measurement range. Furthermore it is important to consider ground loops, disturbances and noise signals.

3.2.2 Current measurement

Electric current basically flows when an electric circuit is closed and the potential difference of an energy source, e.g. battery, can be equalized. Basically, Ampere-meters measure current in series of the electric circuit. The drawback is that you need to open the circuit. Moreover, the input impedance of Ampere meters must be as low as possible to not affect the actual circuit too much.

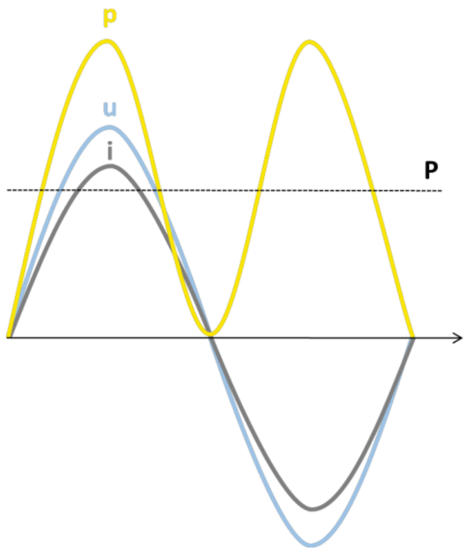
In contrast, you measure electric current **directly** or **indirectly** using DAQ amplifiers for applications in the power and energy sector.

- The **direct** method involves opening the circuit/conductor to connect a sensor in series. Therefore, a **Shunt resistor** with a highly accurate and very low resistance value. The actual current value is determined by the means of the voltage drop-off over the Shunt and Ohm's Law.

– In contrast, **indirect** methods allow current measurements via the magnetic field without the need of opening the circuit. Thereby, leading to galvanic isolation of the sensor from the conductor. For example, Rogowski coils, Hall compensated clamps or zero flux transducers work on these indirect principles among others.

3.2.3 Electric Power & Energy calculation

Electric Power is the product of current and voltage in every occurring moment. Using the integral over the cycle time T, it is equal to the mathematical sum. We can also understand power as energy flow in a certain time period. The unit of electric power is Watt [W].



Relationship between Voltage, Current and Power signal

Phase Lock Loop (PLL) synchronizes the sampling rate with the frequency of measured voltage signals. As we have already touched upon the beginning of this chapter, all of our devices ensure Class A power calculations. This is done on the basis of the period time in the frequency domain. First of all they carry out a FFT analysis on voltage and current, for 10/12 cycles and the specific sample rate. This gives us the **amplitude and cos(phi) of every single harmonic**.

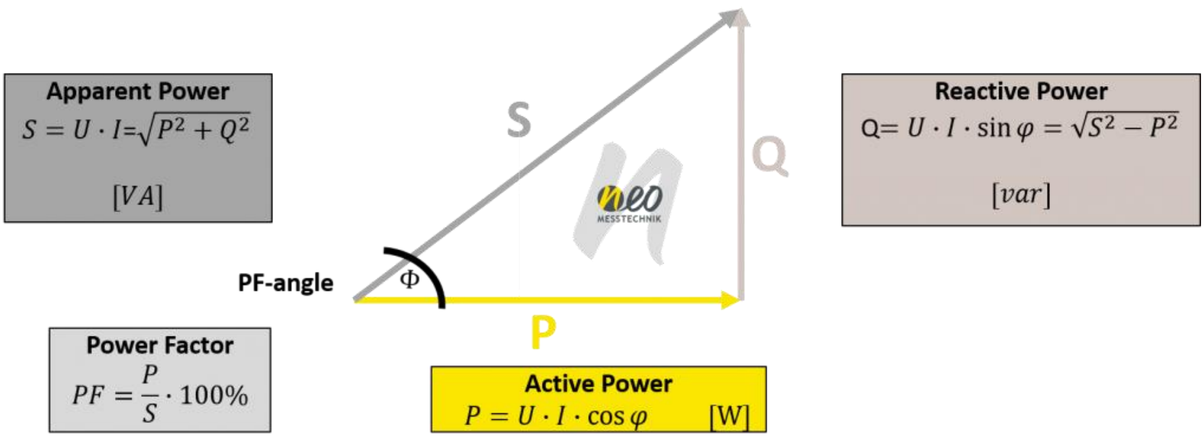
By doing this, it is possible to consider amplifier or transducer shifts (amplitude or phase) that distort your results over the whole frequency range. By simply correcting them. Furthermore, this determination in the frequency domain also completely synchronizes all PQ parameters with the fundamental frequency of the measured system. Once the FFT values are corrected, the individual harmonic RMS values sum up to the respective total value for voltage or current. Which brings us to the calculation of the three main power quantities.

Power	certain harmonic h	Total value
Apparent	$S_h = U_h \cdot I_h$	$S = U_{rms,total} \cdot I_{rms,total}$
Active	$P_h = U_h \cdot I_h \cdot \cos\varphi_h$	$P = \sum_{h=1}^{H} P_h$
Reactive	$Q_h = U_h \cdot I_h \cdot \sin\varphi_h$	$Q = \sqrt{S^2 - P^2}$ or $Q = \sum_{h=1}^{H} Q_h$

Apparent, Active and Reactive Power calculation

3.2.4 Transforming the classic power triangle

Apparently, the basic relationship of active and reactive power visually describes a triangle. While it is important to address, it mainly serves as basis for everything that is yet to come.

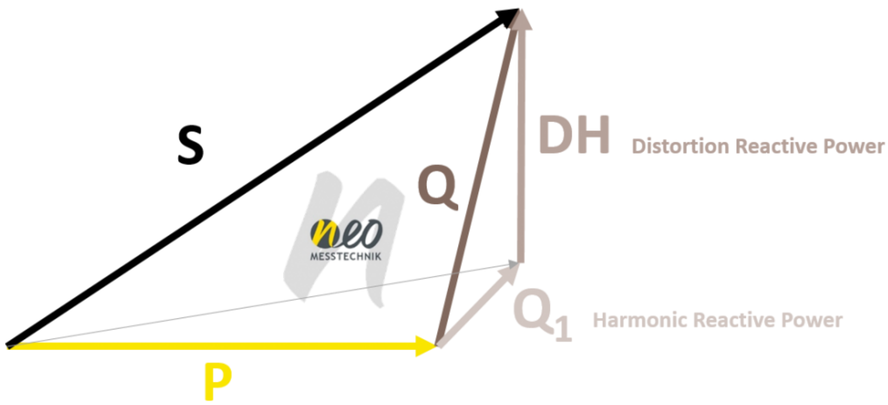


The classic power triangle

- **Active Power P** is transferred to the electric consumer/load and can be "used". For example, being transformed to mechanical energy.
- **Reactive Power Q** is the natural part of the electric grid that is needed/provided for magnetic fields (motors, generators) of generators or capacitors. It symbolizes the unusable power part for the consumer and influences the transfer capacity. It only increases the system's effort to deliver the same energy or rather power for a certain time period. In addition, it stresses power lines and engineers to compensate the reactive power. You find the positive or negative Q on the imaginary axis of the triangle.

3.2.5 Power Factor and Transferred Energy

- A high **Power Factor** equals high transmission efficiency. As you see in the formula above, this comes from the lower current flow and therefore losses in the system.
- The **cos-phi** gives the phase angle between the voltage and current of a certain harmonic. While the power factor takes the whole system into consideration, the cos-phi exists for each harmonic.



Introducing Distortion to the triangle

Inverters among other non-linear loads and especially renewable energy generation units (wind, PV) bring two new parameters into the triangle.

- **Harmonic Reactive Power $Q_{1,2,...}$** of single harmonics result from phase shifts between the current and voltage of the respective harmonics. It's sum brings us to the
- **Harmonic Reactive Power Q_H**

$$QH = \sum_{h=1}^{H} Q_h$$

Harmonic Reactive Power calculation

- Combining voltage and current quantities from different harmonics leads to the **Distortion Reactive Power D_H**

$$DH = \sqrt{Q^2 - QH^2}$$

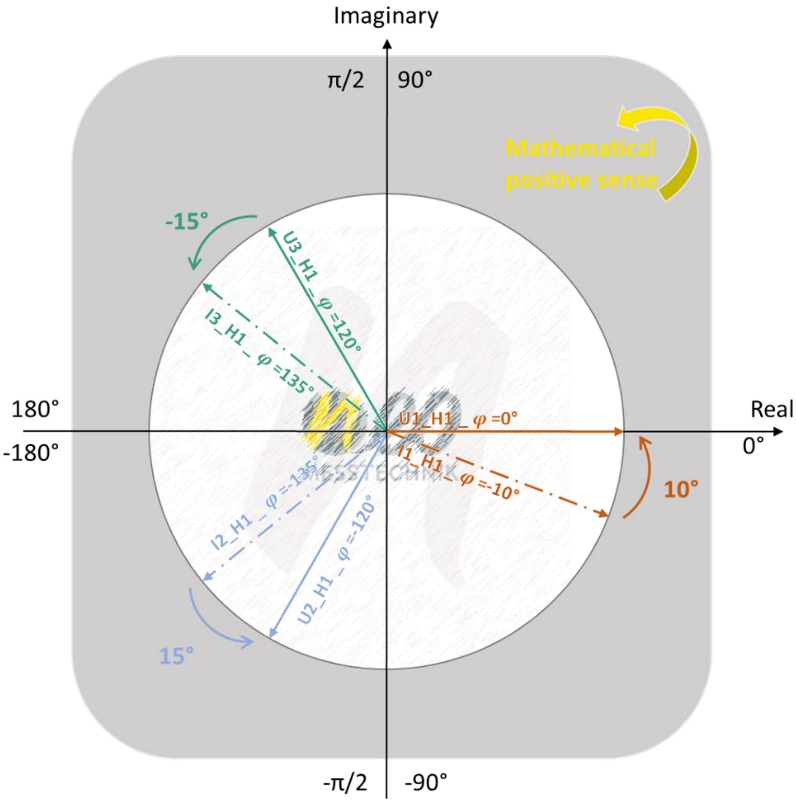
Distortion Reactive Power

- Considering all harmonics **except** the fundamental equals the **Distortion D**:

$$D = \sqrt{Q^2 - Q_{h=1}^2}$$

Distortion D

3.2.6 Phase angles



No more confusion.

The definition of phase angles and how values relate to each other always cause confusion and sometimes frustration. That's the main reason we visualized **our** understanding that we use for NEO instruments.

The voltage of U_L1 is defined with 0°, being in line with the real axis, serving as **the reference point to all phase angles**. We will certainly come back to this image when we will be talking about phase angle jumps in the future.

3.2.7 Relationship Power & Energy

Description	Function
Energy (total)	$E = \int_{t=0}^{T} p(t)dt$
Positive Energy $P_{mot}(t) > 0$	$E_{motor} = \int_{t=0}^{T} p_{mot}(t)dt$
Negative Energy $P_{mot}(t) < 0$	$E_{recuperation} = \int_{t=0}^{T} p_{mot}(t)dt$

Energy & Efficiency calculation

We already defined electric power as the energy flow in a specific period of time. As a consequence, we can easily conclude to the calculation of energy consumption. The direction of the power flow thereby determines the sign (positive or negative) of the energy value. It defines if we are about consumed (positive value) or delivered energy (negative value).

These simple principles allow us to make conclusive statements about the energy flow and efficiency for various applications. The energy unit is Watthours [Wh]. Under efficiency we understand the ratio between output and input values of a system, whether it is power or energy efficiency. Efficiencies are always given in per cent [%].

3.3 Powerful Summary. Energetic Outlook!

In this 3rd part of our Multi-Part-Series we talked about the essentials of frequency, voltage and current determination. While we touched upon the IEC 61000-4-30 Ed.3, we further focused on the (new) power triangle. The relation between power, energy and phase angles concluded today's article.

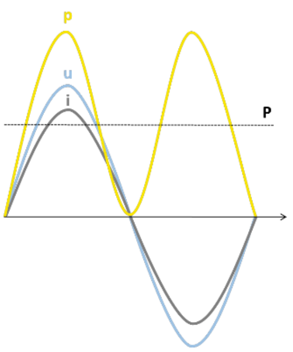
Slowly but surely we are gaining some momentum here! As our knowledge builds up and we establish common ground, it allows us to cover increasingly exciting PQ topics in the future. For Chapter 4 we are planning to shine some light on the IEEE 519. Whether you are new to Power Quality or following this Blog to know exactly what NEO Messtechnik is currently up to – we hear you. Expect another refreshing take on another PQ parameter in Chapter 4.

4 IEEE 519 & Harmonics Explained

Non-linearity in the power grid results in the emergence of Harmonics. As a result, this causes various problems and effects throughout the grid. It stresses sensitive equipment, power lines and engineers. Let's find out what we need to know about the IEEE 519 so we can re-establish harmony and good Power Quality.

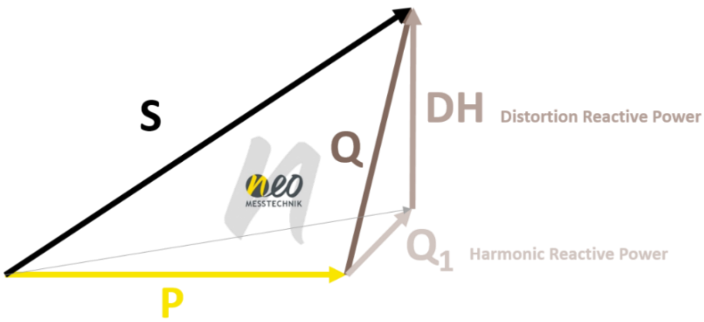
4.1 Harmonics explained

4.1.1 Ideal signal conditions



Fundamental frequency – nothing more

Pure sinus waveform signals only consist of the fundamental frequency, which is well known to be 50Hz, 60Hz or 16 2/3 Hz for electric grids around the world. On the left side you see examples for ideal voltage and current signals.

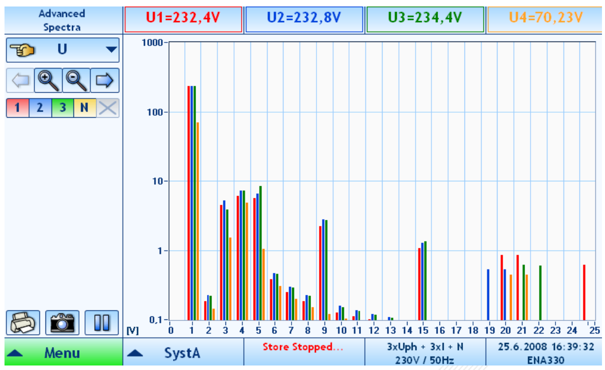


Introducing Distortion to the triangle

4.1.2 Real-life signals

small deviations – Big Consequences

Although even small deviations from the pure sinus waveform appear insignificant, they are not. Because they can hardly be seen or detected in the time domain, we illustrate the signals in the frequency domain to see the effects.



What we actually see here are integer multiples of the fundamental frequency of 50Hz for all three phases – so the 3rd, 5th, 7th Harmonics actually inform us about the order of the harmonic.

4.1.3 Reasons for non-linearity

Harmonics generally exist due to non-linearity on both sides of source and load, or generation and consumption. On the one hand, engineers certainly do their best to design and produce electrical equipment on the highest (symmetry) levels. However, Harmonics remind us that the complexity of the whole power system still brings out minor non-linear relations by default. On the other hand, the **major** reason for the emergence of Harmonics is the *Power-Electronics era* we live in today. With the increasing replacement of linear loads by non-linear ones, Harmonics became a focal point of Power Quality Analysis.

The shift to non-linearity and Harmonics		
Resisitive Heating	→	Heatpumps
Conventional Air Conditioning	→	High-efficienct Air Conditioning
Resistive Lighting	→	LED
Resisitive Cooking	→	Inductive cooking
Washers, Dryers, etc.	→	High-efficienct equipment
Commercial fans	→	Inverter controlled fans/pumps
	+	**Photovoltaics**
	+	**Battery storage systems**
	+	**Electric Vehicles**

Shift to Non-Linearity

4.1.4 Effects of Harmonics

Harmonics don’t only influence the signal shapes, but operation and the life span of electrical devices and equipment. Harmonic frequencies in motors and generators can result a various mechanical phenomena that all lead to efficiency reduction. Among these are higher audible noise, faster ageing of the shaft, insulation and mechanical parts. Furthermore pulsating or reduced torque as well as increased heat development.

4.1.5 Sidebands, Half-bands and Interharmonics

In order to sum up a minimal yet clearly defined frequency range around a specific harmonic, sidebands and half-bands exist. They define what +/- area belongs to, let’s say, the 5th

Harmonic of 250Hz. For example, a single sideband leads to the area of 245-255Hz, while one sideband generally regards the square root of half amplitude between 240-260Hz. Last but not least, Intraharmonics define the frequencies that are not within the harmonic definitions. For further information we would like to refer you to the specifics in the IEC 61000-4-7.

4.2 IEEE 519

By establishing a standard and goals for the design of electrical systems, the IEEE 519 is the focal point of this article. The goals include both linear and non-linear loads and aim to minimize interference between electrical equipment.

> *[..] The limits in this standard represent a shared responsibility for harmonic control between system owners or operators and users. Users produce harmonic currents that flow through the system owner's or operator's system which lead to voltage harmonics in the voltages supplied to other users. [..] Limits are provided to reduce the potential negative effects on user and system equipment.*
>
> *Institute of Electrical and Electronics Engineers*

4.2.1 New and updated definitions – At a glance

- **Point of Common Coupling (PCC):** As the standard lays out, it is the interface between sources and loads. Observing the design goals will minimize interference between electrical equipment.
- **Maximum Demand Load Current:** Taking into account the maximum load on the PCC. This is done by building the average sums of the currents of the previous 12 months.
- **Total Demand Distortion (TDD):** A %-value that relates the harmonic RMS parts to the maximum demand current. It is important to note that the standard thereby specifies the Harmonics parts up to the 50th order and explicitly excludes interharmonics.
- **Total Harmonic Distortion (THD):** Another percentage-value, it is defined as the sum of all harmonics in relation to the fundamental.

Summing up, our solutions and FFT analysis provide amplitude and phase spectra, thus the U, I, P, Q spectra can be provided. In power spectra, the power flow can easily be recognized on a particular harmonic that can be useful to identify sources of disturbances.

$$F_{n,vs} = \sqrt[2]{\frac{1}{15}\sum_{i=1}^{15} F_{n,i}^2}$$ Very short time Harmonic Measurement	$$F_{n,sh} = \sqrt[2]{\frac{1}{200}\sum_{i=1}^{200} F_{(n,vs),i}^2}$$ Short time Harmonic Measurement
Very short time harmonic values are assessed over a 3-second interval based on an aggregation of 15 consecutive 12 (10) cycle windows for 60 (50) Hz power systems.	Short time harmonic values are assessed over a 10-minute interval based on an aggregation of 200 consecutive very short time values for a specific frequency component. The 200 values are aggregated based on an RMS calculation with the subscript used to denote “short”.
Observation period – 24 hours – The 99th percentile value (i.e., the value that is exceeded for 1% of the measurement period) should be calculated for each 24-hour period for comparison with the recommend limits in Clause 5. – Applied to both voltage and current harmonics.	**Observation period** – 7-day period (1 week) – The 95thand 99thpercentile values (i.e., those values that are exceeded for 5% and 1% of the measurement period) should be calculated for each 7-day period for comparison with the recommended limits in Clause 5. – These statistics should be used for both voltage and current harmonics with the exception that the 99th percentile short time value is not recommended for use with voltage harmonics. – Current harmonics evaluate based on 95th and 99th-percentile. – Voltage harmonics evaluate based on 95th-percentile only.

Individual frequency components are aggregated based on an RMS calculation with F representing voltage (V) or current (I), n representing the harmonic order, and i as a simple counter. The subscript vs is used to denote “very short.” In all cases, F represents RMS values.

4.2.2 Limits for Voltage Distortion

Bus voltage V (PCC)	Weekly 95th percentile short time: Individual harmonic (%)	Weekly 95th percentile short time: THD (%)	Daily 99th percentile short time: Individual harmonic (%)	Daily 99th percentile short time: THD (%)
$V \leq 1.0$ kV	5.0	8.0	7.5	12
1 kV < $V \leq$ 69 kV	3.0	5.0	4.5	7.5
69 kV < $V \leq$ 161 kV	1.5	2.5	2.25	3.75

Table 1 (IEEE 519-2014)

4.2.3 Limits for Current Distortion

Newly defined limits based on 3 percentile limits:

- Daily 99th-percentile very short time (3 s) harmonic currents should be less than 2.0 times the values given in the Tables.
- Weekly 99th percentile short time (10 min) harmonic currents should be less than 1.5 times the values given in Tables.
- Weekly 95th percentile short time (10 min) harmonic currents should be less than the values given in Tables.

I_{SC}/I_L	Individual harmonic limits (Odd harmonics) [a,b] Harmonics values are in % of maximum demand load current					TDD
	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	
<20[c]	4.0	2.0	1.5	0.6	0.3	5.5
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0

Table 2 (IEEE 519-2014) Current distortion limits for systems rated 120 V – 69 kV

I_{SC}/I_L	Individual harmonic limits (Odd harmonics) [a,b] Harmonics values are in % of maximum demand load current					TDD
	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	
<20[c]	2.0	1.0	0.75	0.3	0.15	2.5
20<50	3.5	1.75	1.25	0.5	0.25	4.0
50<100	5.0	2.25	2.0	0.75	0.35	6.0
100<1000	6.0	2.75	2.5	1.0	0.5	7.5

Table 3 (IEEE 519-2014) Current distortion limits for systems rated 69 kV – 161 kV

I_{SC}/I_L	Individual harmonic limits (Odd harmonics) [a,b] Harmonics values are in % of maximum demand load current					TDD
	3 ≤ h < 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h ≤ 50	
<25[c]	1.0	0.5	0.38	0.15	0.1	1.5
20<50	2.0	1.0	0.75	0.3	0.15	2.5
≥50	3.0	1.5	1.15	0.45	0.22	3.75

Table 4 (IEEE 519-2014) Current distortion limits for systems rated gr. 161 kVa

- a Even harmonics are limited to 25% of the odd harmonic limits above
- b Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed
- c All power generation equipment is limited to these vales of current distortion, regardless of actual ISC/IL.
- ISC = maximum short circuit current at PCC
- IL = maximum demand load current (fundamental frequency component) at PCC

4.2.4 Challenges for most PQ equipment

Following the framework of the IEEE 519 we now leave the world of standards and come back to our initial situation. In which we want to make reliable statements about the grid and possible harmonic disturbances. Ideally, we are only one set-up and one report away from that. Well, ideally.

Connecting to the previous chapter about limitations – are there any to get to a sound report? As you might expect, there is an answer to the question. Although the observation period according to the IEEE 519 is indeed very long – many measuring solutions don't have the required memory space for even a week of data. For a rough estimation we would state the required memory between 200-500MB for a single week – depending on the set-up. The limited instruments help themselves by building average values that find their way into Reports. For us this is a major flaw we don't need to face with today's possibilities.

4.2.5 IEEE 519 – Harmonic Compliance Report

Summing up this chapter about the IEEE 519, we show you how the Harmonic Compliance Report looks like for our customers. As you can see in the schematic illustration, the limits and eventual excesses are clearly stated according to the standard. Needless to say, the list continues up to the 50th order, but we are sure you get the point. Anyway, in the next chapter you will see that NEO Messtechnik solutions don't even stop at the 50th Harmonic..

<table>
<tr><th>Harmonic U</th><th></th><th>[% Uh1]</th><th>[%]</th><th>[%]</th><th></th></tr>
<tr><td>Uh 1: 50Hz</td><td>-</td><td>100 | 100 | 100</td><td>0 | 0 | 0</td><td>100 | 100 | 100</td><td>>= 95%</td></tr>
<tr><td>Uh 2: 100Hz</td><td><= 2%</td><td>0,0452 | 0,0776 | 0,1292</td><td>0 | 0 | 0</td><td>100 | 100 | 100</td><td>>= 95%</td></tr>
<tr><td>Uh 3: 150Hz</td><td><= 5%</td><td>2,18 | 2,527 | 1,82</td><td>0 | 0 | 0</td><td>100 | 100 | 100</td><td>>= 95%</td></tr>
<tr><td>Uh 4: 200Hz</td><td><= 1%</td><td>0,2153 | 0,2313 | 0,2377</td><td>0 | 0 | 0</td><td>100 | 100 | 100</td><td>>= 95%</td></tr>
<tr><td>Uh 5: 250Hz</td><td><= 6%</td><td>3,634 | 3,251 | 4,007</td><td>0 | 0 | 0</td><td>100 | 100 | 100</td><td>>= 95%</td></tr>
<tr><td>Uh 6: 300Hz</td><td><= 0,5%</td><td>0,0404 | 0,0496 | 0,0529</td><td>0 | 0 | 0</td><td>100 | 100 | 100</td><td>>= 95%</td></tr>
<tr><td>Uh 7: 350Hz</td><td><= 5%</td><td>0,0255 | 0,0324 | 0,0328</td><td>0 | 0 | 0</td><td>100 | 100 | 100</td><td>>= 95%</td></tr>
</table>

Green = Harmony

Red = Harmonics violation

4.3 Higher Frequencies and Supraharmonics

4.3.1 Limits of the IEEE 519

Harmonics are generally regarded as basic and well covered topic in the Power Quality industry. But on this occasion we would like to point out that it is not like that after all. Let's find out why.

So far, we have only talked about frequency parts of up to the 50th order. Although the specs of many PQ Analyzer and Monitoring solutions try to convince you otherwise – we can certainly assure you that Power Quality doesn't stop right there. Even more so, this is where the real challenges begin. Let's refresh with a basic rule of electric measurement technology. The sampling frequency should be, at least, twice the value of the expected measurement signal.

By following the IEEE 519, analyzing up to the 50th has always been on the safe side of the whole. But if you limit yourself to this observation window, you miss the area beyond 2 kHz.

4.3.2 No standards. No problems?

There is a reason why we actively write about these higher frequencies in greater detail. The increase of Power electronics and inverters will further increases the measurement demand of Higher Frequencies and Supraharmonics. Emissions in the frequency range from 9 kHz to 150 kHz are sources of electromagnetic interference to various electric equipment in the grid. You can find a more in-depth article about Supraharmonics and its implications in our separate AppNotes.

5 Flicker, Unbalance & RVC Explained

The power supply and its electric voltage are not always as steady as you may think. Therefore Flicker, voltage changes in a short period of time (Rapid Voltage Changes) and symmetrical components are central parameters to assess power quality. Let's learn how we get back to symmetry and all grid parameters by means of the symmetrical components!

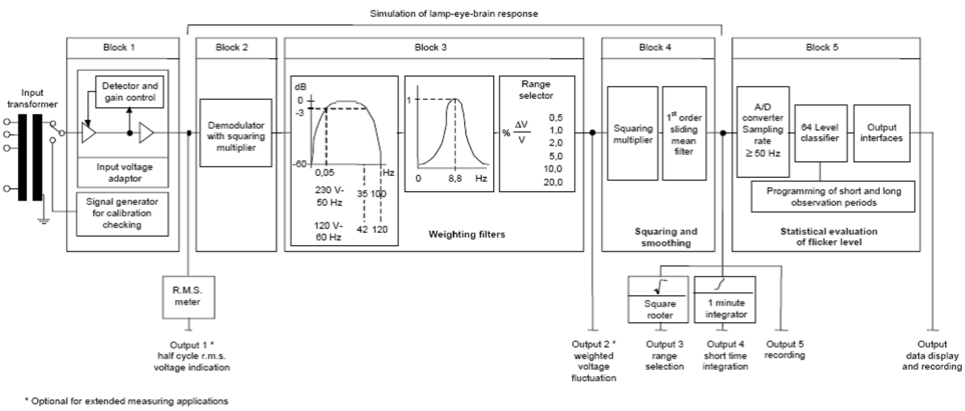
5.1 Flicker

5.1.1 Definition

Flicker is a visible change in lamp brightness due to voltage fluctuations. These changes emerge in power grids with a low short-circuit resistance and as response to rapid connection or separation of loads. A high level is considered to be harmful and irritating to people. While we are focusing on how to measure Flicker according to the standards, under this link you can find a closer look on the implications on the human eye.

5.1.2 IEC 61000-4-15 Flicker meter

The standard provides understanding for the correct determination of flicker level perception for all practical voltage fluctuation waveforms. Based on the simulation of the lamp-eye-brain chain, the flicker signal is statistically evaluated and calculated in the normed parameters. Creating a reference signal in Block 1, the next three Blocks simulate the human perception of it. The Flicker parameters are calculated in Block 5.



Flicker meter block diagram IEC 61000-4-15

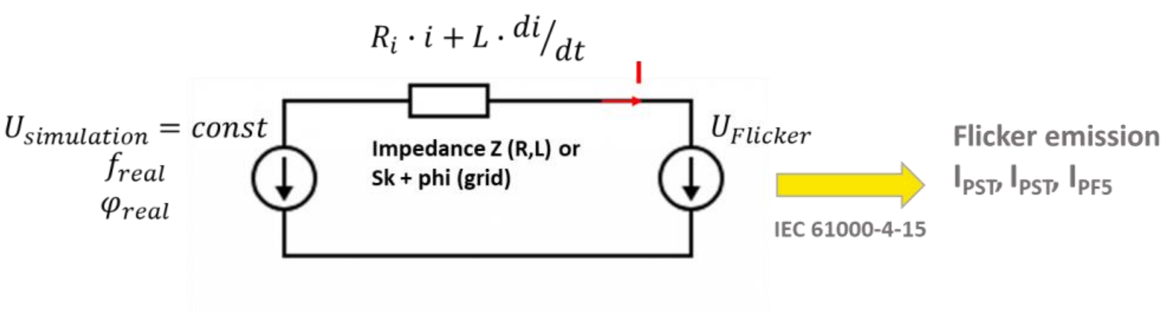
5.1.3 Definition of Flicker values

Flicker	Description
P_{inst}	**Instantaneous Flicker Sensation** from IEC 61000-4-15
P_{st}	**Short Term Flicker** every 10 minutes for voltage input signals
P_{lt}	**Long Term Flicker** every 2 hours from the previous 12 P_{st} values
I_P_{inst}	**Instantaneous Flicker Sensation** from IEC 61000-4-15 for current
I_P_{st}	**Short Term Flicker current**
I_P_{lt}	**Long Term Flicker current**
$I\_P_{inst}\_L1\_30$, $I\_P_{st}\_L1\_30$, $I\_P_{lt}\_L1\_30$	**Flicker values** for a specific phase angle

Flicker values for PQ Analysis, e.g. for L1

5.1.4 Current Flicker Definition

IEC 61400-21 defines the calculation of Flicker emission, caused by renewables like wind power plants. Producers as well as consumers are the originators and thereby effecting the power grid. The internal voltage drip in the following picture is calculated on the basis of the grid impedance and the current flow.



5.2 Rapid Voltage Changes (RVC)

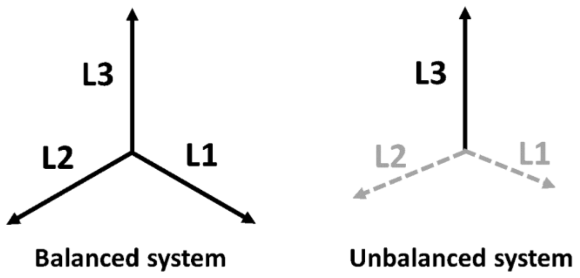
5.2.1 Definition of RVC

- The EN 50160 defines RVCs as: “A single rapid variation of the rms value of a voltage between two consecutive levels which are sustained for definite but unspecified durations.”
- The IEC 61000-3-3 defines voltage change characteristic as following: “the time function of the RMS voltage change is evaluated as a single value for each successive half period between the zero-crossings of the source voltage and the time intervals in which the voltage is in a steady-state condition for at least 1 s.”
- In IEC61000-4-30, rapid voltage changes are defined as: A quick transition in RMS voltage between two steady-state conditions. To measure rapid voltage change, thresholds must be defined for each of the following minimum ..
  - rate of change
  - duration of the steady-state conditions
  - difference in voltage between the two steady-state conditions
  - plus Steadiness of the steady- state conditions

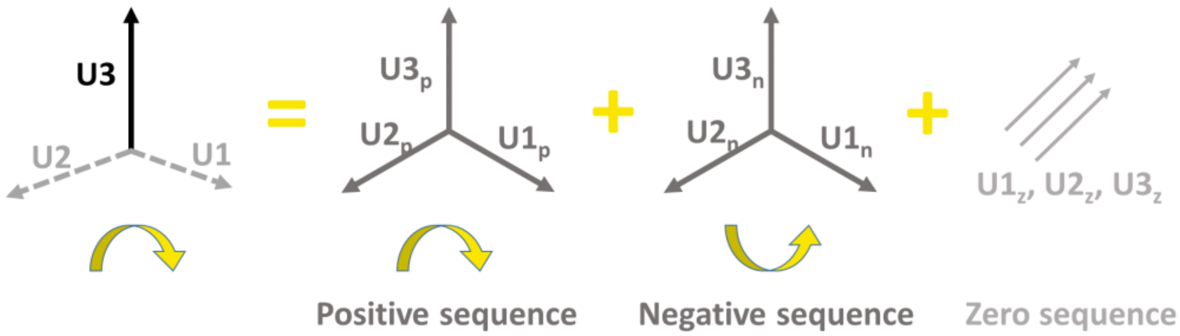
The voltage during a rapid voltage change must not exceed the voltage dip and/or the voltage swell threshold. Otherwise, it would count as a voltage dip or swell. The characteristic parameter of rapid voltage change is the difference between the steady state value reached after the change and the initial steady-state value.

5.3 Symmetrical Components

5.3.1 What is Unbalance?



Disturbances or short circuits among others result in an unbalanced system. The concept of symmetrical components enables the transformation of any desired unbalanced 3-phase system (unbalanced electric grid system influenced by a number of factors) into three separated symmetrical components.



5.3.2 Zero-sequence

In a symmetrical system, without any disturbances, the phase voltages sum up to zero.

$$U\_L1 + U\_L2 + U\_L3 = 0$$

This symmetrical state never appears in real-life grids. The zero sequence results due to disturbances and from current flow in the neutral line U_N. The following voltage difference determines said current flow:

$$U\_L1 + U\_L2 + U\_L3 = \underline{\Delta} u$$

This voltage difference divided by three is the zero-sequence system:

$$U\_0 = 1/3 * \underline{\Delta} u = u10 = u20 = u30$$

- The zero sequence has the same amplitude and phase for all of three phases (u10, u20, u30).
- This is the reason you usually find only one value, U_0, in literature or within our software.
- The calculation of the current zero-sequence is analogue to this procedure.
- Multiplying the zero-sequence system of the current by 3 (3 x I_0) equals the current over the neutral line U_N.

5.3.3 Positive-sequence

This part rotates in the same direction as the given system (e.g. grid or electric motor/generator) and is a symmetric system for itself. This means the amplitude for all three positive phases is the same and only having a 120° phase shift to each other. This is where the unit vector a comes in to simplify the formulas.

5.3.4 Negative-sequence

This part rotates in the opposite direction as the real system (e.g. grid or electric motor/generator) and is a symmetric system for itself. Like the positive system, the phase values are the same with a 120° phase shift to each other.

5.3.5 Matrix of symmetrical components

The three symmetrical components for voltage and current in matrix form give a clear overview on the whole system and the importance of the operator a.

Symmetrical Components	Matrix Notation
U0, U1, U2	$\begin{bmatrix} \underline{U}^0 \\ \underline{U}^1 \\ \underline{U}^2 \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \cdot \begin{bmatrix} \underline{U}_{L1} \\ \underline{U}_{L2} \\ \underline{U}_{L3} \end{bmatrix}$
I0, I1, I2	$\begin{bmatrix} \underline{I}^0 \\ \underline{I}^1 \\ \underline{I}^2 \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \cdot \begin{bmatrix} \underline{I}_{L1} \\ \underline{I}_{L2} \\ \underline{I}_{L3} \end{bmatrix}$

5.3.6 Calculation of phase voltages or currents

By using the formulas from above it is possible to calculate the phase voltages and current flow of the 3-phase system with the help of the symmetrical components.

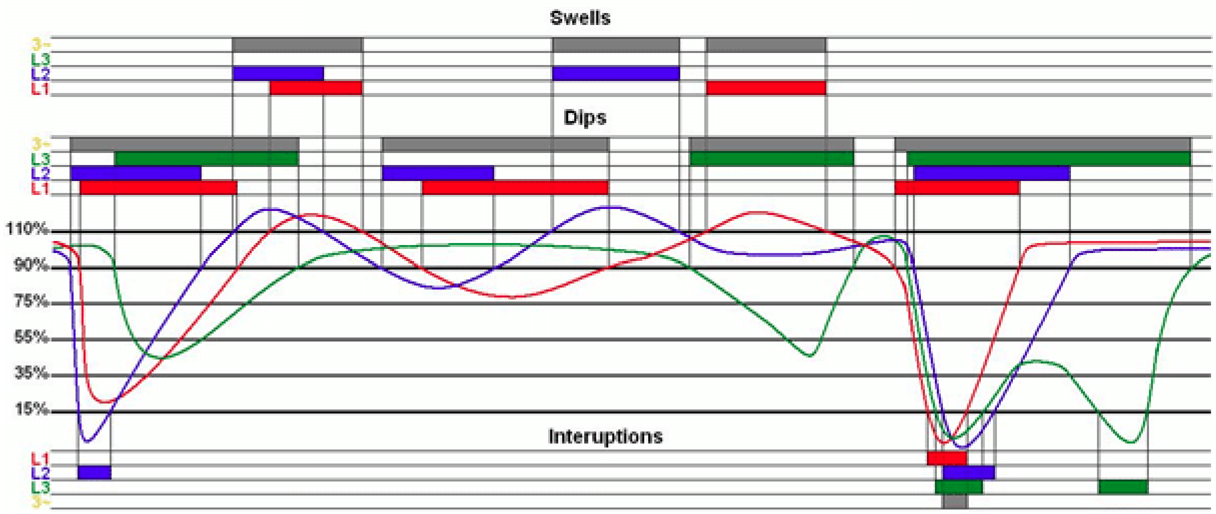
5.3.7 IEC 61400-21 Annex C

According to Annex C of IEC 61400-21, the Fourier coefficients (cos- and sin-parts) of both measured phase voltages and currents are calculated over one fundamental cycle T. Using NEO PQ solutions allows you to easily access all the parameters you need for in-depth analysis. This includes all RMS values for every active, reactive and apparent part of the three symmetrical systems. For more information about how the calculation within the software, drop us a line on LinkedIn!

5.4 Voltage Events & Flagging

5.4.1 Voltage Dips, Swells & Interruptions

For voltage dips, swells and interruptions, the RMS voltage must be evaluated over 1 cycle (on base of sliding ½ period values estimation), commencing at a fundamental zero crossing, and refreshed every half-cycle. Events are detected if the voltage leaves the pre-defined range (usually ±10% of Un). By following IEC61000-4-30 according to the illustration, single phase or three-phase events are evaluated in a different way.



5.4.2 Flagging

Voltage monitor data must be stored as ‘flagged’. During a dip, swell, or interruption, the measurement algorithm for other parameters (for example, frequency measurement) might produce a unreliable value. The flagging concept therefore avoids counting a single event more than once in different parameters (for example, counting a single dip as both a dip and a frequency variation) and indicates that an aggregated value might be unreliable.

Flagging is only triggered by dips, swells, and interruptions. The detection of dips and swells is dependent on the threshold selected by the user, and this selection will influence which data has been ‘flagged.’

6 The Ultimate Guide to Power Quality 2021

From "½ period storing" to "Zero sequence", here are all the terms, standards and abbreviations you need to understand Power Quality in 2021.

6.1 The Modern Power Quality Dictionary

After all, it's really easy to get lost in all the Power Quality terms, standards and their relations to each other, even for us. Earlier this month in one of our meetings the idea of a Power Quality Dictionary was born. In other words, who stops us to write the ultimate guide to Power Quality for 2021? Long story short, here we are, sharing our first draft with you.

Maybe we needed and wanted to write this for ourselves, because we didn't find anything similar on the net. Then again, maybe you can profit as well or even propose terms to be added in the future?

So without further ado, here are all the Power Quality terms you need. Some are basic or self-explanatory, others require in-depth knowledge. But all will help you to understand Power Quality as of today.

½ period storing

Comes in very handy when your PQ instrument let's you choose this option. Recording and Analysing 10-period values makes it impossible to make short-time interruptions visible. In addition, the 10-period value will only show a reduced peak value of disturbances, as it is averaged over a couple of periods. The peak of ½ period values (real value) can be a couple of times higher than the measured 10-period value. For example, we offer our customers to store half-period values of U,I,P,Q,S, phi, symmetrical components, fundamentals, among others.

Active, Apparent and Reactive Power

Shape a beautiful rectangular triangle (click for the famous power triangle).

AC/DC Hall clamps

Easy-to-mount. AC and DC current measurements. Based on the Hall Effect – the measured current through a magnetic core's aperture equals magnetic flux change leading to induced voltage. Ideal for Grid & Renewables.

AppNotes

Comprehensive theoretical and practical discussions on measurements, applications and successful handling of partner's or customer's challenges, similar to white papers. Reach out to us or access our AppNotes by simply navigating to your personal NEO Download Area.

More in-depth information

Often referenced in this article. Easy accessible in your Download Area. Sign up!

Bandwidth, Resolution and Sampling Rate

By choosing the wrong instrument without a high bandwidth, among others, you potentially limit your measurement capabilities from the get-go. Standard PQ Analyser come with the standard problem of being outdated for detecting various problems in today's power grid. See **Supraharmonics** or Chapter 1 of Power Quality Explained.

Blackout

Worst-Case Scenario that is prevented through the common effort and co-operation of TSOs and all parties involved in ensuring a safe and reliable power supply. Almost happened at the beginning of 2021 in Europe.

CAT III 1000V / CAT IV 600V

In brief, safety is very important and should be regarded in the design process of PQ instruments. However, you would be surprised how often we see instruments that don't fulfil the safety category requirements for the respective measurements. Therefore HV- inputs that are labelled as CAT IV ensure users and engineers safety and an instrument design that prevent electrical accidents. As an example, the inputs of the NEO PQA8000 are CAT IV 600V, isolated up to 6kVp while maintaining high precision (0.05%) and high sampling (up to 1MS/s).

Class A

Basically, by choosing a ***Class A complying*** instrument, you make the first important step for getting reliable results according to the IEC 61000-4-30. At the same time, let us guide you through all the reasons to aim for even higher Power Quality standardsin our Multi-Part Series Chapter 2.

DER

Distributed Energy sources like wind, solar or PV power plants.

Efficiency

Essentially drives the whole industry to work resource-saving and manage both economic and technical bottlenecks throughout the whole electricity sector. Generally puts output into relation to input to a system in per cent [%].

EV Charging – Efficiency Analysis


APPLICATION NOTE

MESSTECHNIK

Electric Vehicle Charging Station

Power Quality & Efficiency Analysis

Introduction

The reason of charging problems can have different sources. The PQA8000 instrument allows to quickly analyze & troubleshoot the charging process of electric vehicles. Whether the problem is related to the charging station, the charging cable, the electrical installation, the electric vehicle itself or any other electronic equipment close-by .... the PQA8000 will find the reason.

Keywords:
#PowerQuality #Supraharmonics #Unbalance #CP-Signal #PLC #Efficiency #PQSpreading #PQA8000

The reason of EV charging problems can have different sources. The PQA8000 instrument allows to quickly analyse & troubleshoot the charging process of electric vehicles. Whether the problem is related to the charging station,the charging cable ,the electrical installation, the electric vehicle itself or any other electronic equipment close-by…. the PQA8000 will find the reason. Read more.

EN50160, IEC61000-2-2/-4/-12, IEEE 1159, IEEE 519, NRS048

International and national Grid Standards.

FGW-TR3, IEC61400-21, IEC61400-12, BDEW, TOR

International and National Standards for Renewables.

Fundamental frequency

Pure sinus waveform signals only consist of the fundamental frequency, which is well known to be 50Hz, 60Hz or 16 2/3 Hz for electric grids around the world.

Power Quality Explained

Grid Impedance

Measuring the frequency-dependent grid impedance allows drawing conclusions on the propagation and distribution of Supraharmonics (absolute value and angle) and determining how this impedance change is caused by the PE (consumer generator).

AppNote in our Download Area. Don't miss out.

IEC 60076-1 / IEC60034

Motor and Transformers Standards

IEC 61000-3-2 /-12 and IEC 61000-3-3 /-11

Equipment Standards

IEC 61000-4-15, IEC61400-21 & Short-time and Long-time Flicker

Flicker is a visible change in lamp brightness due to rapid fluctuations/voltage changes. Learn more about Pst, Plt, IEC 61000-4-15 Flicker meter and Current Flicker and the IEC 61400-21 in our NEO-Blog.

IEEE 1159

Recommended Practice for Monitoring Electric Power Quality

IEEE 519 (Inter-) Harmonics, Full-, half- and sidebands and Higher Frequencies

Harmonics in the grid heavily influence waveforms as well as the operation and life span of electrical equipment. Learn about the guide to Power Quality Measurement and Analysis and it's implications for the EN 50160 report.

Inverter

Following the previous subchapter about Harmonics, let's talk about the their cause. Inverters are power electronic devices converting from DC to AC with the specific frequency of the grid. Pulse-width modulation is central to reach this goal and ideally produces minimal harmonic distortion.

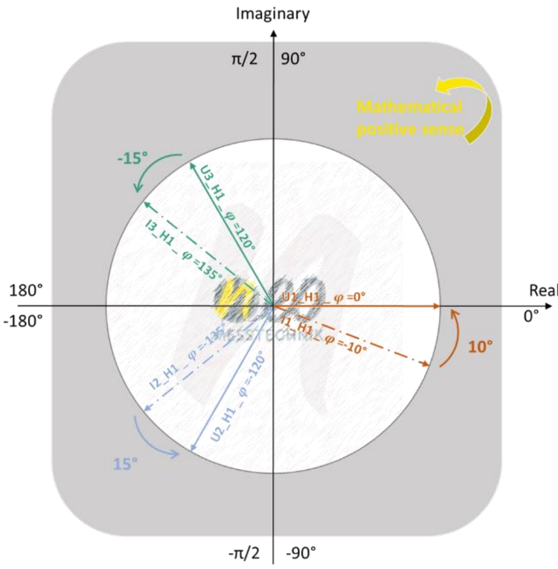
Mitigation Analysis

Mitigation of some Power Quality parameters very often increases the penetration of other Power Quality parameters. Typical example is using higher switching frequencies of inverters while reducing lower number harmonics often increases emission at higher frequencies. These types of analyses require synchronous measurements of multiple input channels and instruments.

Negative sequence

As the name already hints, this part of the symmetrical components rotates in the opposite direction as the grid. The phase values are the same with a phase shift of 120° to each other, similar to the positive sequence. Read more.

Phase Angles



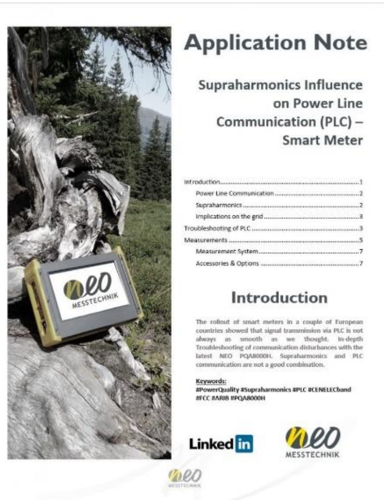
[A picture is worth a thousand words](#)

Phase Angle Jumps & System Dynamics

Designing a stable grid that meets the rising share, connection and reconnection of micro-grids or Renewable power plants is where our expertise and instruments come into play. Phase Angle jumps, frequency variations, dips, swells all appear and ask for increasing measurement and analysis efforts.

PLC and Smart Meter

AppNote Available



The rollout of smart meters in a couple of European countries showed that signal transmission via PLC (Power Line Communication) 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. [Read more.](#)

PMU

Phasor Measurement Unit – enables accurate synchrophasor measurements for detecting the status of the electrical grid online. Learn how to achieve a total vector error of 0.01% and angle accurarcy of 0.003° according to I*EEE C37.118* [here](#).

Positive sequence

Part of the symmetrical components that rotates in the same direction as the grid, or electric motor, as examples. Is a symmetric system for itself. That said, three positive phase amplitudes with a 120° phase shift to each other. Read more.

Power & Energy

Our daily business and competence for more than 20 years. Read more about central power and energy relations and formulas in [Chapter 2](#).

Power Factor and cos-phi

Must-know knowledge for every electrical/measurement engineer and Power Quality Guide. Click to [refresh your memory](#).

Power Quality Analysis & Monitoring

Recording several electrical and non-electrical inputs and parameters over a short or longer period of time. Goes hand-in-hand with the need of powerful and central instruments that can both handle the high amount of entities as well as storage needs. While in the past several instruments combined enabled Monitoring purposes with missing synchronization options, nowadays integrated instrument solutions like our PQM 200 cover the need within one instrument and solution. Enabling engineers up to 48 channels and the functionalities of Disturbance Recorders, PQ Analyser, Transient Recorder and [way more..](#)

PQA 8000H

18bit, 1MS/S, multi-touch display and 4 hours of mobile operation. Read more about [How To Spot a Highly Evolved PQ Analyzer](#). (**Disclaimer** – this guide about our flagship Power Quality Analyser may cheer you up and lead to giggling in your (home) office).

PQ Explained

Our online success story this Power Quality Guide is a part of! Further build up essential PQ knowledge and get insider tips over several chapters and [many more to come](#)!

PQ SCADA

Enterprise management software for Power Quality Analysers and Disturbance Recorder and visualizes live data as well as historic data and reports. [Learn more.](#)

RoCoF

Rate of change of frequency. High time derivations of the grid frequency potentially endangers reliability and security of the power supply. Increasing importance due to increasing DER.

Rogowski-Coil

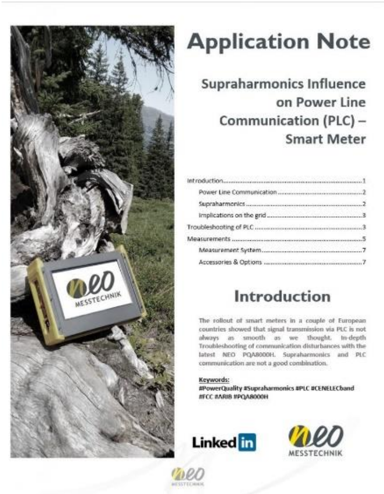
Easy-to-Mount. Ruggedized & Flexible. AC Current induces a voltage as time derivative (di/dt) and passes through an integrator, being proportional to the measured current flow. Ideal for Grid measurements.

Sensor correction

Corrects phase shifts and damped amplitudes due to frequency dependence. Thus enabling high precision measurements from the DC range up to high frequency. Read more.

Supraharmonics

AppNote Available



Power Quality Analysis doesn't stop at the 50th Harmonic order. Emissions in the frequency range from 9 kHz to 150 kHz are sources of electromagnetic interference to various electric equipment. By design, classic PQ Analysers **cannot be used** for troubleshooting due to their limited bandwidth. Learn how NEO Messtechnik tackles the challenges of high-frequency disturbances of non-linear loads in today's power grid here or by reading the AppNote in your Download-Area. Read more.

Switching frequency

In the past, traditionally taught and located in the area of 2-10 kHz. Nowadays experiences major shifts into higher frequency areas, thereby driving various developments of non-linear loads in the grid and stressing PQ instruments with application areas up to 2kHz.

Symmetrical Components

Deviations from the ideal symmetrical power supply result and burden producer and consumers of electrical energy as well as grid components and equipment. The symmetrical components help to make sound statements about the grid status and are major evaluation parameters of Distributed Energy Sources. Learn more about the basics and standards like FGW-TR3, IEC61400-21 and other grid codes renewable power plants need to fulfil to connect to the power grid.

TDD & THD

Total Demand Distortion (TDD) and Total Harmonic Distortion (THD) are both essential IEEE 519 per-Unit values providing information about the share of harmonics.

Transients & Trigger

Detecting any kind of waveform deviations by the help of a multitude of trigger options – the duty of our PQ solutions our customers appreciate. Trigger can be set on input signals (U, I), calculated parameters (P,Q,S, THD, specific Harmonic, etc.) and dynamic signal analysis (1/2 Period values, Phase angle Jumps, RoCoF, Envelope trigger). Furthermore, you can also combine multiple triggers at once.

TSO

A transmission system operator (TSO) is a term defined by the European Commission as an organisation committed to transporting energy in the form of natural gas or electrical power on a national or regional level, using fixed infrastructure. The certification procedure for TSOs is listed in Article 10 of the 2009 Electricity and Gas Directives.

ENTSO-E

Voltage dips and swells

In short, the power supply and it’s voltages are not as steady as you might think.

WAMS

Wide Area Monitoring Systems that visualize and monitor several different parameters which can, optionally, be processed to SCADA or other systems. Aforementioned parameters include phasors, islanding detection, resynchronization and black start detection, oscillations detection, stability and voltage monitoring. Find out more.

Zero-Flux Transducer

Highest Accuracy. AC and DC. Ideal for R&D.

Zero Sequence

Doesn’t exist in a perfect world/grid with symmetry and no losses. As you might guess, a faithful companion and central parameter in real-life measurements.

7 Contact Information

When you are working with our products we want to provide you with the greatest possible benefits.

If you need any support, we are her to assist you.

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