

Current and voltage curve in the main power supply of a Swiss electronics producer

# Trends in power quality measuring instruments

**Measuring methods, standards and certification** | Power quality is increasingly suffering from the use of power electronics since the latter generate undesired current portions, for example in converters. Electronic devices may be disturbed by these current portions. The acquisition of power quality is thus gaining in importance. However, on what does their measurement depend?

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**D**istribution systems for electrical energy have been operated with alternating voltage since the feud between Thomas Edison and Nikola Tesla. Voltage and current were sinusoidal with a frequency of 50Hz or 60Hz. The sinusoidal voltage curve resulted from the use of inductive generators to convert mechanical into electrical power. The current curve was identical since most consumers, e.g. classic light bulbs, heating devices and motors, were linear at that time.

With the invention of thyristors and triacs and the increasing use of power electronics starting in the seventies, modern control systems could

be developed. These permitted a considerable increase in efficiency and flexibility. The disadvantage is that they constitute non-linear loads, i.e. the input current has frequencies not contained in the voltage. This causes continuously higher system contamination by harmonics and interharmonics thus also raising system losses. In addition, electronic consumers are increasingly sensitive to such disturbances. The concept of power quality was introduced in response to this issue.

## Why does power quality concern us?

Safeguarding sufficient power quality is important for the reliable operation of both

systems and connected devices. Different disturbances have various effects. For example, harmonics increase system losses in transformers, lines and cables – the transmission capacity declines. In addition, the peak voltage can surpass  $\sqrt{2}$  times the effective value which affects the insulation. Power quality may also have an influence on people, for example, if voltage fluctuations cause flickering lamps. Voltage drops can impair sensitive production processes and lead to costly production downtimes.

Since it is impossible to prevent all power quality disturbances or to make all devices immune against these disturbances, limits are agreed for disturbance emission and immunity. (Figure 1). This principle has been established in the field of electromagnetic compatibility taking technical feasibility and economic efficiency into account.

In the area of standardisation, the consideration is limited to the power quality in the frequency range from 0 to 9kHz. An extension to 150kHz is planned.

Measuring of the power quality requires instruments specifically developed for this purpose. It is of central importance that different instruments provide at least similar measured values for the same input signal. This requirement seems trivial today because, meanwhile, standards have been achieved with definitions which are clearly, unambiguously and generally recognised. This was not the case for a long time. Instruments complying with the relevant standards provide comparable results for the same input signal.

### System phenomena become knowledge

«A chain is only as strong as its weakest link». This old saying is also applicable in the age of digitalisation. Therefore, we refer to some known but often not applied requirements at this point. It is imperative for measurement planning to clarify exactly the expectations of measuring results, measuring accuracy and measuring uncertainty and to select harmonised elements for the measuring chain on this basis. Power quality measurements absolutely require the awareness of transmission characteristics (frequency and phase response) of currency and voltage transformers in order to obtain meaningful and usable measuring results. Other preconditions for successful measurements are the safe and correct electrical installation of measuring transformers, instruments as well as EMC-conforming wiring of measuring and communication lines. And finally, a test or calibration traceable to a recognised normal must ensure that the measuring results are comparable – to other measuring results and to the requirements of standards, contracts

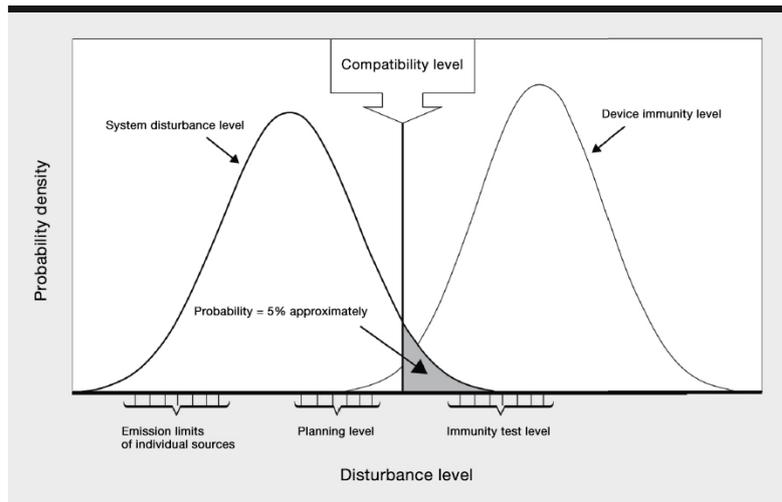


Figure 1 Principle of electromagnetic compatibility.

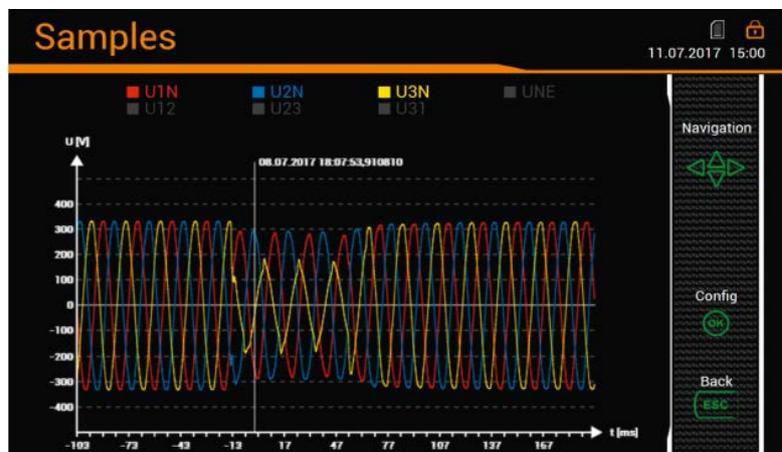


Figure 2 Voltage drop (samples) during a summer thunderstorm in the main power of an electronics producer.

or laws. Only a suitable measuring chain can generate relevant raw data from physical system events, select data of interest from the same, condense it and obtain usable knowledge by suitable analysis software. This transformation process of system phenomena into knowledge is only as good as the weakest link in the measuring chain.

### Standards – the key to reliable measurements

The area of power quality constitutes a complex field of tasks since experience is required both in width and depth, e.g. in relation to energy engineering, power quality phenomena, measuring instrumentation and signal processing. The most important power quality standards are developed by the IEC SC 77A WG 9 working group, but also Cenelec is active in this respect. The working groups are composed of experts of measuring instrument producers, the electricity industry, universities, national metrological institutes like Eidgenössisches Institut für Metrologie Metas and private test institutes. The wide support of developed consensus enables practice-oriented solutions even if there are opposing interests

The respective IEC standard series consists of several parts which, e.g. cover general principles, emission limits, test and measuring techniques, installation guidelines and rectification measures. The standards listed in Table 1 are particularly important for power quality.

However, the standardisation of measuring methods unfortunately does not lead to the intended implementation unification in PQ instruments. In some cases, instruments supported by this standard have provided deviating measuring results. Device classes and test procedures had to be subsequently standardised (Table 2).

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**IEC 61000-4-30:2015**

Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods

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**IEC 61000-4-15:2010**

Electromagnetic compatibility (EMC) – Part 4-15: Testing and measurement techniques – Flicker meter – Functional and design specifications

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**IEC 61000-4-7:2009**

Electromagnetic compatibility (EMC) – Part 4-7: Testing and measurement techniques – General guide on harmonics and interharmonics measurement techniques and instrumentation, for power supply systems and equipment connected thereto

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**EN 50160:2010**

Voltage characteristics of electricity supplied by public distribution systems

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**Table 1** Standards in the context of power quality.

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**IEC 62586-1:2017**

Power quality measurement in power supply systems – Part 1: Power quality instruments (PQI)

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**IEC 62586-2:2017**

Power quality measurement in power supply systems – Part 2: Functional tests and uncertainty requirements

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**Table 2** Standards for device classes and test procedures

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Furthermore, certification, i.e. the verification by independent third parties, has gained in importance. These standardisation activities are part of a continuous improvement process and reflect changes in the electricity industry. Particularly in respect of power quality, the requirements have considerably changed during the last two decades. At the time the IEC 61000-4-30 standard was published in 2003, almost all power quality measurement devices on the market were manual instruments. These used proprietary algorithms. The standard generated uniform algorithms for different power quality phenomena. Furthermore, it achieved that the measuring instruments of different manufacturers provided comparable measuring results. It is this requirement, which was previously only apparently trivial, that permits proving undoubtedly and in a manner utilisable in court whether power quality requirements have been met in case of a dispute.

**Certification – what is that?**

Certification is increasingly gaining in importance. According to ISO 17000, it concerns a confirmation supported by tests that a device complies with requirements – if it is performed by an independent third party, usually a national metrology

institute or an accredited private test institute. Certification is not demanded by law. Contrary to the confirmation of a manufacturer or importer, it offers buyers an added value since the certifying body is independent – it is not biased by commercial interests of the manufacturer or participation in development. The certification of a power quality measuring instrument according to IEC 62586-2 requires more than 150 partly extensive tests and needs both an elaborate test infrastructure traced back to the International System of Units SI by calibration and experience.

Metas has extended its measuring and test infrastructure for Phasor Measurement Units (PMUs) to power quality variables and can now, being one of a few laboratories worldwide, calibrate, test and certify PMUs according to IEEE C37.118 and power quality measuring instruments according to IEC 62586. The PMU measuring station permits generating UTC-synchronised voltage and current signals and is traced back to the International System of Units SI by calibration.

**Future power quality topics**

Power demand will probably continue rising world-wide in future. Reasons are the increase in world population, urbanisation, the advance of electric mobility as well

as the digitalisation wave. This increase cannot be sufficiently compensated by energy efficiency measures. The additional power demand will, therefore, be covered by more decentralised producers like photovoltaic, wind and hydropower plants. This development will cause known physical phenomena to become significant power quality topics. Two of these important topics, we are presenting below:

**Extension of the measuring range**

The utilisation of the range from 2kHz to 150kHz is internationally not regulated by standards at present. There are manufacturers who intentionally place the disturbance frequencies of their devices in this band which may cause disturbances of, e.g., electric meters. Cases of incompatibility due to unregulated frequency bands are considerably increasing. The IEC has thus reacted: At present, the IEC 61000-2-2 standard for compatibility limits in public low voltage systems for the range from 2kHz to 150kHz is in consultation. The competent IEC SC 77A WG 9 PQ working group is revising the existing 61000-4-30 IEC standard to determine appropriate measuring methods for power quality phenomena in this frequency range.

### Demand side power quality

A technical report for Demand Side Power Quality – DSPQ is presently being prepared by the CLC/TC 85X Cenelec working group and determines recommendations for power quality measurement and its evaluation in plants. Most standards only determine the voltage quality at the point of transfer from the energy provider to the system user (PCC). The DSPQ describes the phases required for the preparation of a demand side power quality measuring plan for buildings and industrial plants. The demand side is defined as the electric installation beyond the PCC and under the responsibility of the facility manager. Such a power quality measuring plan permits optimising energy availability and efficiency, improves the useful life of plants and facilitates the diagnosis and rectification of quality problems. A power quality measuring plan comprises the following steps:

- Definition of context, goals and limitations
- Assessment of the original PQ situation
- Definition of an action plan to improve the PQ situation
- Implementation of the PQ measuring system
- Utilisation of the measuring system to improve the PQ situation
- Maintenance of the PQ measuring system

Such reports help facility managers to harmonise their measuring plans with the specific requirements of their electrical plant. They contain all of the disturbances present in such systems but they do not cover the disturbances in public power distribution systems (supply side) since these are regulated by specific standards and prestandards like EN 50160 and IEC TS 62749. Apart from these topics there are other subjects in international expert discussion:

- Power quality acquisition networks in low voltage plants
- Power quality monitoring in DC plants
- New fast frequency measurement methods for frequency acquisition to recognise changes in less than 10s, as is the present standard value
- Statistical evaluation of power portions
- Standardisation of data formats
- Fast transients
- Co-ordination of measuring method standards with those of current sensors

### Summary

Power quality monitoring will continue gaining in importance for all stakeholders due to increased demands for electric energy, rising decentralised energy production and power quality topics. It will be divided into two main tasks also in future: The statistical evaluation of power quality variables (conformity) as well as observing, monitoring and analysing dynamic power quality events (**Figure 2**). In both cases, the comparability of measuring results as ensured by certification, testing and calibration is essential. It can be seen already today that the new power quality topics will generate a vast quantity of additional data. This flood of data is to be intelligently acquired, selected, condensed and interpreted. Efficient power quality monitoring can make the invisible in the system visible before it affects people and assets detrimentally. In this way, it will make a significant contribution to the presently plentiful availability of electric energy also in future.

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