POWER QUALITY: NEW TENDENCIES IN STANDARDIZATION AND CHALLENGES OF ENERGIEWENDE

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ABSTRACT

Energiewende changes the structure of power supply networks from traditional supply structures to decentralized structures. The measurement of power quality has to be adapted to these changes. This article shows the requirements for reliable electric power supply which complies with normative power quality. The utilities plans the development of their networks such that they have at their disposal a power supply system which is adequately dimensioned for the projected tasks, and which allows secure, efficient and environmentally compatible operation and economical system use at an adequate quality of supply. [1]. New international standards and further development of existing standards are already released or are under way to reach this goal.

CHANGES IN THE POWER SYSTEM STRUCTURE

The implementation of the energiewende fosters serious changes in the structure and operation of the power supply system. The classical power supply structure generation-transmission-distribution-consumer (**Figure 1**) with centralized generation and an unidirectional power flow is changing to distributed and bidirectional network structures (**Figure 2**).

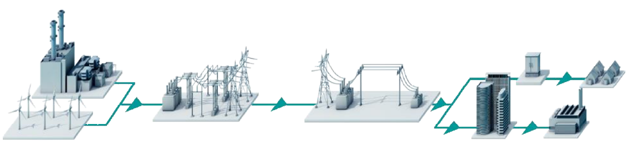

Figure 1 - Centralized and unidirectional power system structure

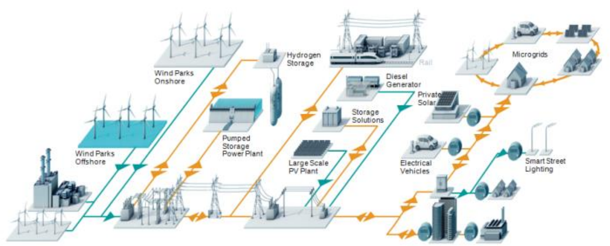

Figure 2 - Distributed and bidirectional power system structure

The deployment of more and more distributed renewable energy sources with their fluctuating power infeed are having an increased negative impact on the power supply system. But customers (private households and small-scale industry) and with even higher requirements industry are expecting a proper supply of electrical power with a certain level of high power quality. They are expecting a power supply with only a minimum number of incidents with only very short duration of power interruptions.

The new circumstances and challenges combined with increasing complexity leads to the following problems:

- Fluctuating power infeed from renewable sources:
  - at the upper voltage levels (wind parks),
  - at low voltage level (small PV installations),
- Changing energy flow direction, incl. energy transmission in higher voltage levels.
- Decreasing short-circuit power and with that decreasing power system ruggedness and elasticity.
- Infeed of harmonics at all voltage levels, caused by inverters and non-linear loads.
- Voltage and currents peaks in distribution network.
- Unbalance, particularly on the low voltage level.

By area-wide utilization of electronic voltage inverters a negative influence on the supply quality has to be considered particularly for harmonics. It is expected that the energiewende will have further influences on the supply quality, whereby in this paper only the aspects voltage quality and continuity of supply are considered. Generally the number of short dips and interruptions has increased over the last few years however there is no official registration of these disturbances by the regulators. Only unplanned interruptions which last longer than three minutes are considered in the system average interruption duration index (SAIDI). The SAIDI (System Average Interruption Duration Index) is an indicator for the supply quality in a electrical power supply system. Industries with their modern processes and sensitive technical equipment are reacting even to short interruptions in the millisecond area very sensitive.

These developments must be taken into account for the measurement of power quality.

NEW REQUIREMENTS TO THE MEASUREMENT OF POWER QUALITY

Tendencies in international standardization

At present, the new requirements for the measurement of power quality are taken into account during the revision of existing standards as well as new standards.

The standard IEC 62586-1 Ed. 1 [2] specifies the requirements for instruments for the measurement of power quality (Power Quality Instruments - PQI) and provides a common system of references in order to

facilitate their selection, comparison and evaluation. This standard specifies a classification based on product performance, environment and safety. This product standard is specifying product and performance requirements for instruments whose functions are including the measurement, recording and possibly the monitoring of power quality parameters in power supply systems, whereby the measuring methods (class A or class S) are defined in IEC 61000-4-30.
The IEC 62586-2 Ed. 2 [3] is a standard specifying functional and uncertainty tests intended to verify the compliance of a product to class A and class S measurement methods defined in IEC 61000-4-30. IEC 62586-2 therefore complements IEC 61000-4-30.
This standard may also be utilized by other product standards (e.g. digital fault recorders, revenue meters, MV or HV protection relays) specifying devices embedding class A or class S power quality functions.
The edition 3 of IEC 61000-4-30 [4] defines new measurement methods for rapid voltage changes and conducted emissions in the 2 kHz to 150 kHz range (informative) as well as the recording of currents for analysis of power quality limit violations.
Limits and thresholds which are specified in the technical specification IEC/DTS 62749 Ed.1 [5] are exceeding the power quality limits defined in EN 50160.

Requirements to the location of power quality measurements

The increasing complexity of the power system structure requires the gapless measurement and recording of voltage and currents characteristics for conformance evaluation at more locations. Measurements at the classical point of connection between supplier and customer are not sufficient enough, because decentralized generation are connected and alternating power flows over all power network levels and in customer systems are existing. Applications like the direction detection of harmonious/interharmonics and Flicker are becoming more important.

Requirements to PQ measurement methods and PQ evaluation

The implementation of IEC 61000-4-30 class A method guarantees comparable measurements of instruments provided by different manufacturers by a defined measurement method and gapless recording of power quality characteristics of the power supply. The evidence of compliance to defined emission limits at the point of connection between public network and customer as well as the analysis of problems (limit violation, decreasing tendencies of characteristics) and the derivations of measures for improvement are possible.

New measurement methods (IEC 61000-4-30) and new specifications (IEC/DTS 62749) are considering the circumstances risen be the change of the power supply network structures.
Additionally to the classical characteristics of voltage quality (power frequency, magnitude of the supply voltage, voltage unbalance, voltage harmonics and interharmonics, flicker and mains signalling voltages) and to the continuity of supply measurement (dips, swells, interruption) in edition 3 of IEC 61000-4-30 new characteristics (measurement method for rapid voltage changes (normative) and for conducted emissions in the frequency range between 2 kHz and 150 kHz (informative)) and the measurement of currents and current characteristics (without regulatory evaluation) are taken into account.

The measurement of load profiles which are sometimes very fluctuating due to the energiewende can be used to determine the utilization of the electrical power grid (**Figure 3**).

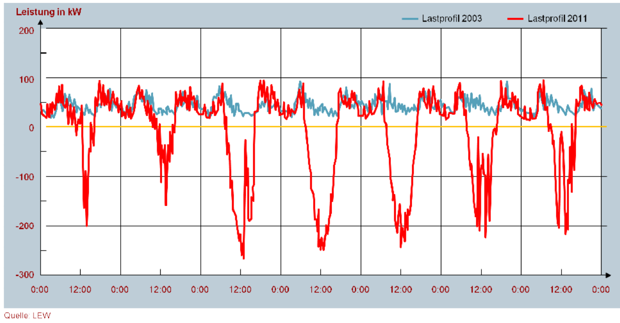

Figure 3 - Typical load profile change in a transformer station in a rural area (LEW-Verteilnetz GmbH) from 2003 to 2011

Requirements to measurement devices

The compliance with relevant product standards (IEC 62586-1/-2) and the implementation of standardized measurement methods lead to a manufacturer independent comparability of instruments for the end user thus increases transparency and guarantees future–proof investment.
The use of standard data formats and interfaces for data exchange is another advantage for customers. This approach is actually incorporated in the communication standard IEC 61850. The IEC/TR 61850-90-17 [6] describes the modeling and data exchange between power quality instruments and network control, power automation or SCADA systems.

POWER QUALITY MEASUREMENT IN PRACTICE

Power quality instruments, which were developed and/or certified according to standardized measurement methods and product standards, are (gapless) measuring and recording

- the continuity of power supply and
- voltage/current characteristics

at the point of delivery. Measurements and records are suitable for the following customer applications:

1. **SCADA systems: PQ operational values**
   - Real-time operational values (10 s, 10/12 periods, 150/180 periods, 10 minutes…),
   - Support the network operator in network management of power supply system,
   - Simulation of different network states and network faults.
2. **Fast detection of continuity of power supply**
   - Detection of voltage events (dips, swells, interruptions, rapid voltage changes) in real-time (time resolution: ½ cycle),
   - Network operators can quickly react on disturbing situations and can initiate immediate remediation measures.
3. **Power Quality compliance reports: data base analysis**
   - Regular report on the voltage quality characteristics, statistical assessment over certain observation intervals,
   - Supervision of the voltage quality at the point of delivery as a quality assessment between energy supply company and their customers with their related contractual obligation
   - Analysis of voltage events and voltage quality disturbances
   - Information of customers whose plants or processes are delicate compared with limiting values of the voltage quality,
   - As a basis to derive information about the necessity and the dimensioning of optimization measures of existing nets as well or for future network expansions.

Power Quality reports

Voltage characteristics are derived from continuous records with defined observation intervals (day or week) as well as from detected voltage events.

The standard EN 50160 „Voltage characteristics of electricity supplied by public distribution networks“ is a European standard which specifies and defines main characteristics of the voltage at the point of connection under normal operating conditions. Technical Specification IEC/DTS 62749 „ Assessment of power quality - Characteristics of electricity supplied by public networks“ extends the set of limits defined in EN 50160 and takes current trends additionally into account.

Table 1 shows the coverage of limits for voltage characteristics for low voltage, medium voltage and high voltage networks (LV, MV, HV).

Table 1 - Definition of limits in EN 50160 and IEC/DTS 62749 Ed. 1

	EN50160			IEC/DTS 62749 Ed. 1		
	LV	MV	HV	LV	MV	HV
	Continuous characteristics					
Power frequency	+	+	+	+	+	+
Voltage magnitude	+	+	+	+	+	+
Unbalance	+	+	+	+	+	+
Flicker	+	+	+	+	+	+
Harmonics	+	+	+	+	+	1)
THD	+	+		+	+	+
Interharmonics				+	+	+
THDG				+	+	+
Mains signalling voltages	+	+		+	+	+
	Voltage events					
Interruptions				SARFI-X		
Dips/swells						
Rapid voltage changes				+	+	+
1) Up to harmonic 13.						
+ limits are given						

Recording of voltage events

A voltage event will be recorded with the concerning voltage value (minimum for dip and interruption or maximum for swell) together with the corresponding duration of the event (see **Figure 4**).

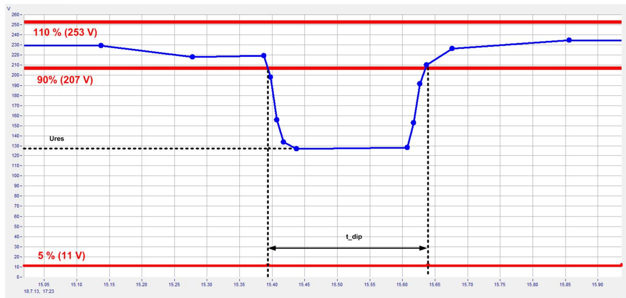

Figure 4 - Voltage dip with limits (90 %, 110 %, 5 %) and additional record of ½ cycle voltage values

A complete voltage event description acc. IEC/DTS 62749 is given in **Table 2.**

Table 2- Example of single event assessment acc. IEC/DTS 62749

Event attribution	Detailed Characterization
Location	BlnW5, 230 V
Time stamp	2013-07-18 17:23:15,39
Capturing threshold	90 %
Residual voltage	55,3 %
Time duration	247 ms
RMS trend	see **figure 4**
Fault record	see **figure 5**

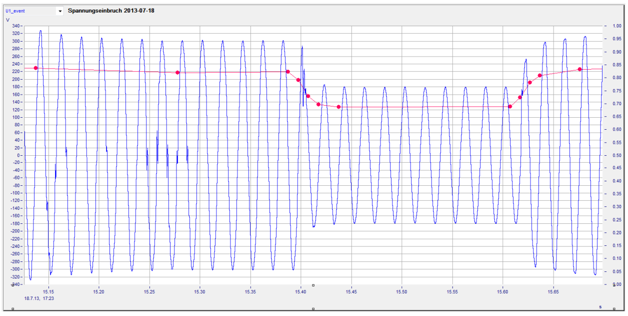

Figure 5 - An example showing information of single event assessment: voltage dip with record of ½-cycle RMS values and fault record

Rapid Voltage Changes (RVC)

The installation of renewable energy sources may lead to critical network situations:

- E.g. calm wind and cloudy sky combined with high network load or
- Low network load at a simultaneous high infeed of photovoltaic and wind energy.

Also in these cases the permitted voltage band (±10 % of the nominal voltage) has to be guaranteed.
Rapid voltage changes are defined as the changes of the effective value of the voltage magnitude of a stationary value to another stationary value within the tolerance band of ±10 % from Udin or Un.
E.g. rapid voltage changes arise from the attempt of motors or switching operations in the net particularly in nets with a low short-circuit power. You e.g. have an effect on consumers by brightness change of lamps; however RVCs are not periodical events as opposed to Flicker.
Rapid voltage changes are characterized by voltage change ΔUss (new steady state voltage magnitude), the maximum deviation ΔUmax and the event duration T (see **Figure 6**). ΔUmax has to be smaller than ±10 % of Udin or Un, otherwise the event becomes a voltage dip or swell classification.

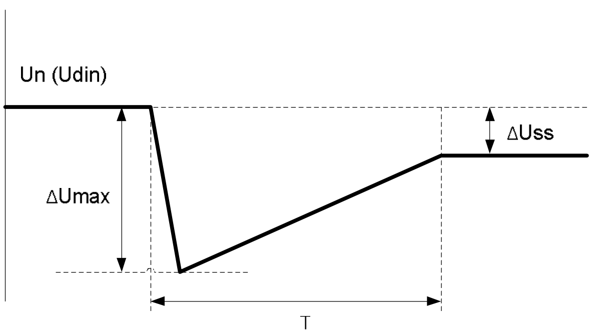

Figure 6 - Characteristics of rapid voltage changes

It is recommended to count rapid voltage changes per hour or per day or both. In this context the standard IEC/DTS 62749 Ed.1 recommends values between 3 % and 5 % of Udin (LV) or Un (MV, HV).

SUMMARY

The energiewende and the increasing infeed of distri-buted renewable sources require a reorganization of the electrical power network. A continuous assessment of the power quality by a gapless monitoring must be carried out by default and on a long-run and mustn't be carried out only in the case of need.
Within the last few years there were many activities in the international standardization on the field of the measurement of the power quality (measurement methods and product standard for Power Quality instrument - PQI), the specification of limit values for power quality characteristics and the standardization of communications protocols as well as the data interchange formats (IEC 61850). This represents a basis for and future-proof power quality instruments and systems.

REFERENCES

[1] Transmission Code 2007: Network and System Rules of the German Transmission System Operators, Verband der Netzbetreiber – VDN – e.V. beim VDEW, August 2007

[2] IEC 62586-1, Ed. 1.0, Power quality measurement in power supply systems - Part 1: Power quality instruments (PQI)

[3] IEC 62586-2, Ed. 1.0, Power quality measurement in power supply systems - Part 2: Functional tests and uncertainty requirements

[4] IEC 61000-4-30 Ed. 3.0: Electromagnetic compatibility (EMC) - Part 4-30: Testing and measurement techniques - Power quality measurement methods

[5] IEC/DTS 62749 Ed.1: Assessment of power quality – Characteristics of electricity supplied by public networks

[6] IEC/TR 61850-90-17: Using IEC 61850 to transmit power quality data