Instruments of change

The growing importance of power quality in electrical networks, coupled with an increase in sources of network pollution, has amplified the challenges facing modern measuring technology

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Changes in load composition are leading to an increase in the significance of power quality as a key issue in electrical networks. In the past, the large number of linear loads and the small number of electronic components and their greater simplicity, ensured that a high proportion of the total network load was ohmic. However, a gradual process of reversal is currently underway: a large number of non-linear loads and a multitude of electronic components are leading to a steady decrease in the ohmic portion of the network load.

The proliferation of power electronics has brought about a rise in emitted interference and an increase in network pollution. At the same time, modern electronic devices are becoming more susceptible to electromagnetic interference as a result of their growing complexity, the reduction of signal levels and the cost optimisation of network filters.

These changes are leading to an increase in the coincidence of interference and immunity levels. A rise in the number of failures and malfunctions experienced by electronic devices and systems is the consequence.

The lion's share of network pollution is not caused by bulk users or large loads but rather by the large number of small loads with network-side rectification and capacitive smoothing. Peak detection creates high harmonic currents, increasing the pressure on conductors and causing additional losses. Televisions, computers and energy-saving lamps all contribute to the problem, but they are just a few of the many examples.

A further contributing factor worthy of mention is the competition among the various different suppliers of electrical energy, which increases the price pressure on the operators of supply systems and considerably reduces the scope for measures designed to maintain and improve quality.

What is network pollution?

Network pollution manifests itself mainly in the form of voltage changes, voltage fluctuations, imbalance, harmonics, inter-harmonics and flicker (Table 1). Voltage failures are not included in network pollution, they are classified as 'impaired operating status'.

The frequencies to be examined for network pollution lie between 0 and (approximately) 10kHz, but it should be noted that the DC components of the voltage are not at present covered either by national or international standards.

Power quality standardisation

The EN50160 was created in response to a request for standardisation made by the European Commission to the European Committee for Electrotechnical Standardisation (CENELEC). It describes the voltage characteristics of electricity supplied by public distribution systems. The second version, which is valid at the present time, was released in 1999 and was incorporated into the German body of standards in March 2000 as DIN EN50160. It describes the characteristics and limit values of the supply voltage at the service entry to the customer in low and medium voltage networks under normal operating conditions. EN50160 has now been supplemented by two further documents. The first is an application guide containing tips and background information on how to apply EN50160. The second is named DIN EN 61000-4-30 (VDE0874 part 4-30):2004-1 and is taken from the IEC 61000-4-30 international standard which describes the measurement methods for voltage characteristics in 50/60 Hz power supply systems, the accuracy requirements for the measuring equipment employed and the interpretation of the measurement results. Table 2 shows the characteristics of the supply voltage according to EN50160.

The exact definition of measurement methods makes it possible to achieve reproducible measurement results. DIN EN 61000-4-30 differentiates between two classes of device:

Class A – high accuracy class. Various devices, even from different manufacturers, deliver results which are reproducible within the specified influencing variables and deliver the same results within the specified accuracy limits.

Class B – less accurate devices with less stringent requirements intended for more general applications.

The challenges facing measurement technology

The demands placed on power quality measurement systems vary widely and it is not unusual for them to far exceed what is actually stipulated by the body of standards applicable at any given time. For this reason, modern measurement and analysis systems should not only comply with current standards but should also be easily adaptable to

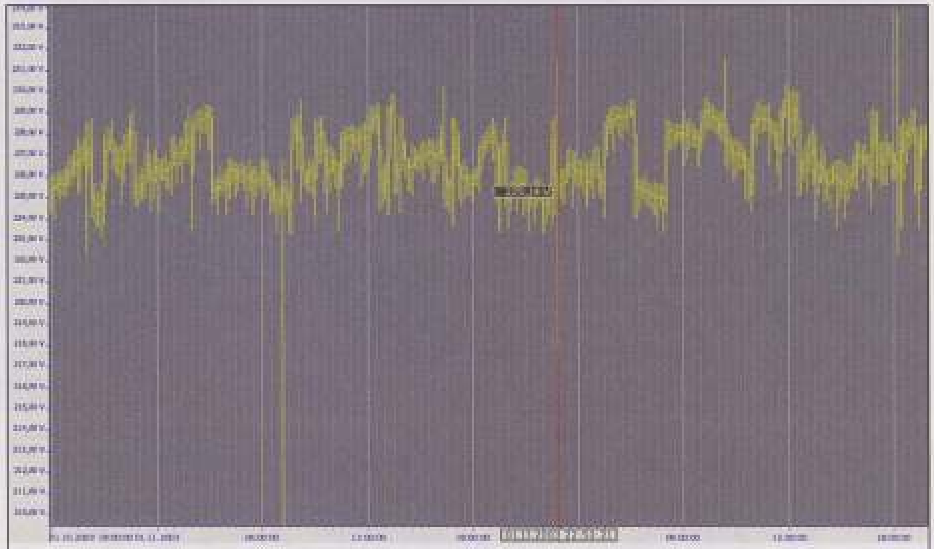

Figure 1. Long-term record of 10 minute mean values with superimposed min.-max. values.

Table 1. Network pollution – glossary of terms

Voltage change	Change in the RMS value of the voltage
Voltage fluctuation	A series of voltage changes
Voltage imbalance	A deviation in amplitude or phase difference of the three voltages of a three phase system
Harmonics	Sinusoidal oscillations whose frequency is a whole-number multiple of the fundamental frequency
Inter-harmonics	Sinusoidal oscillations whose frequency is not a whole-number multiple of the fundamental frequency
Flicker	Subjective impression of fluctuating luminance

Figure 2. Graphical overview of measured values in relation to the standardised limit value. (IEC61000-4-30)

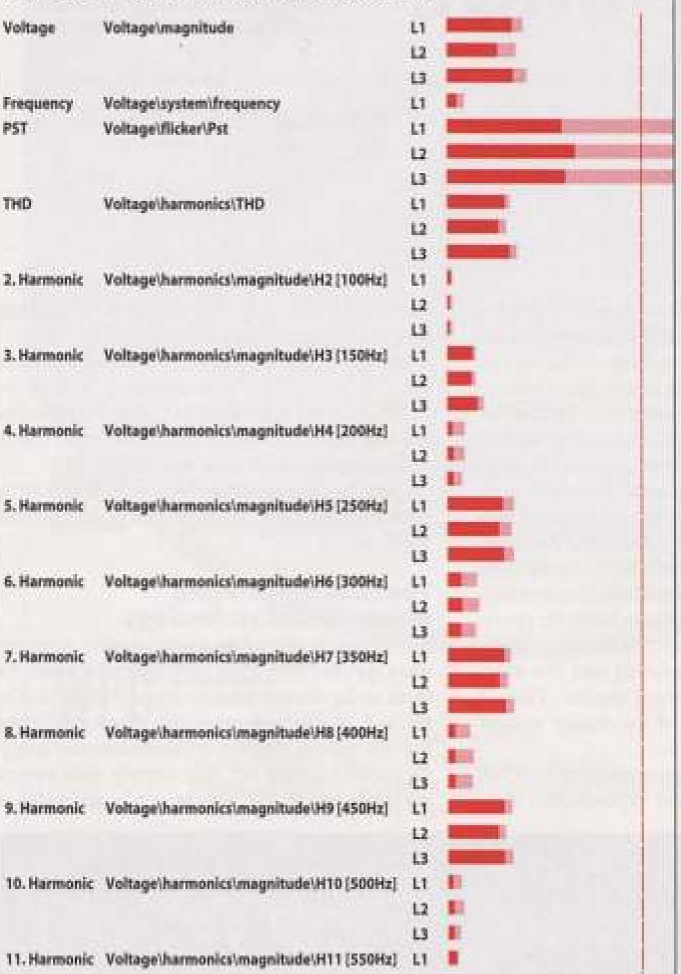

Figure 3. Event analysis according to the ITIC method: tolerance of equipment to voltage faults and tabular representation of events with event type. Lower table - classification of events according to the UNIPEDE method.

No.	Date		Phase	Duration [sec]	Extremum [%]	Event type
1	08.05.2001	15:25:15	L1	0.916	41.63	Dip
2	08.05.2001	15:25:21	L1	0.920	89.58	Dip
3	08.05.2001	15:25:23	L1	0.064	89.38	Dip
4	08.05.2001	15:25:24	L1	0.048	88.65	Dip
5	09.05.2001	11:05:28	L1	3.964	82.00	Dip
6	10.05.2001	10:32:58	L1	4.081	0.00	Short interruption
7	08.05.2001	15:25:16	L2	0.004	41.32	Dip
8	08.05.2001	15:25:23	L2	1.032	88.82	Dip
9	10.05.2001	10:32:58	L2	4.018	0.00	Short interruption
10	08.05.2001	15:25:15	L3	0.916	35.82	Dip
11	08.05.2001	15:25:21	L3	0.936	79.73	Dip
12	08.05.2001	15:25:22	L3	0.020	84.33	Dip
13	08.05.2001	15:25:22	L3	0.980	86.33	Dip
14	08.05.2001	15:25:23	L3	0.984	87.67	Dip
15	10.05.2001	10:32:58	L3	4.018	0.00	Short interruption

Level	< 20 ms	< 100 ms	< 500 ms	< 1 s	< 3 s	< 20 s	< 60 s	> 60 s	Sum
> 110 %	0	0	0	0	0	0	0	0	0
> 106 %	0	0	0	0	0	0	0	0	0
< 90 %	0	2	0	3	1	0	0	0	6
< 85 %	1	0	0	1	0	1	0	0	3
< 70 %	0	0	0	0	0	0	0	0	0
< 50 %	1	0	0	2	0	0	0	0	3
< 30 %	0	0	0	0	0	0	0	0	0
< 10 %	0	0	0	0	0	0	0	0	0
<= 1 %	0	0	0	0	0	3	0	0	3
Dips	2	2	0	6	1	4	0	0	15
Surges	0	0	0	0	0	0	0	0	0
Sum	2	2	0	6	1	4	0	0	15

new standards and specialist measurement tasks. This is particularly important if such measuring systems are not only intended to determine power quality but are also to be used for the purposes of fault diagnosis and network improvement.

Determining power quality at various different points of connection is doubtless the simplest of these tasks. But what if the power quality lies well within the prescribed tolerances but undesirable phenomena still arise, e.g. production downtimes occur as a result of machine control or regulation modules malfunctioning, rolls of paper rip or electronic components have a significantly reduced lifespan? This is where many measuring systems meet their Waterloo.

For a measuring system to be capable of optimum adaptation to a wide range of individual requirements, it is imperative that the real time acquisition of data is very freely configurable and that the analysis instructions for the statistical processing of measured data are extremely flexible. Just as much importance should be attributed to the way in which measurement signals are processed as to the provision of a well-designed software package. Even the simplest of measuring systems should have at least 8 analogue inputs for measuring four voltages and four currents. Galvanic isolation of the measurement inputs (both channel-to-channel and channel-to-earth) is an absolute must. Isolation via linear opto-couplers is the ideal solution here because of the broad frequency spectrum covered by these measuring systems. Isolation via electromagnetic transformers is not sensible as these transformers can cause amplitude and phase errors in the case of deviation from the nominal frequency. They are also incapable of transmitting DC components.

All measuring systems must work with an identical time basis to enable measurement results from various measurement locations to be compared. For this reason a modern measuring system should be equipped with its own GPS receiver or should be capable of being connected to one.

As the number of measuring instruments distributed across the entire network grows, communication structures are becoming increasingly complex. Serial interfaces such as RS232, RS422 or RS485 are frequently used in conjunction with copper or fibre-optic cables for transmitting data over short distances, while Ethernet networks (LAN, WAN) or analogue, GSM or GPRS modem connections are employed for greater distances.

Measuring instruments must also have enough memory to record measured data over a period of several weeks if need be, in order to ensure that no measured data is lost if there is a data communication failure. Modern flash memory products are the ideal solution to this problem. Hard disks should not be used as they are less reliable, owing to their susceptibility to mechanical wear and tear, and jolting.

Data recording methodology

For a comprehensive analysis of power quality and faults it is desirable to be able to activate the following types of data recording simultaneously.

Long-term recording

For long-term records of measured data, it should be possible to freely set various different compression levels at the same time, starting from a single period and continuing on up to several hours. The 200ms, 3s, 10 minute and 2 hour intervals defined in IEC61000-4-30 are the minimum which should be covered. These measurement values provide the basis for a statistical analysis to EN50160 and give a good and rapid overview of what is going on in an electrical network (Figures 1 and 2).

Event recording

Deviations of network parameters from freely configurable limit values, eg voltage dips, should be recorded using adaptive storage methods with a dynamic recording density and an appropriate pre- and post-fault period. The time resolution of the measurement values should be freely configurable starting from half a period (10ms at 50Hz). A high recording density makes it possible to represent network incidents which are not, or only barely, visible in a long-term recording. The measurement values from event-controlled recordings of this type can be used as the basis for analyses of network incidents in accordance with various different criteria, eg UNIPEDE, CBEMA or ITIC (Figure 3).

Transient recording/oscillographs

Transient recording delivers the signal shape of all connected measurement quantities with a very high resolution (Figure 4). It should be possible for recording to start either in response to criteria (triggers) defined by the user or in parallel with event recording. To meet the requirements of a wide variety of measurement tasks,

Table 2. The characteristics of the supply voltage according to EN50160

Characteristics of the supply voltage	Values/value ranges		Measurement and analysis parameters		
	Low voltage	*Medium voltage*	*Base quantity*	*Integration interval*	*Observation period*
Frequency (when connected to an integrated network)	50 Hz ±5 Hz 47 Hz to 52 Hz	Mean value	10 s	1 week	95% 100%
Slow voltage changes	230 V ±10 %	Uc 10 %	RMS value	10 min	1 week
Fast voltage changes	5% max. 10 %	4% max. 6 %	RMS value	10 ms	1 day
Flicker (definition for long-term flicker only)	PLt = 1	Flicker algorithm	2 h	1 week	95%
Voltage dips (< 1 min)	Several tens to 1000 per year (less than 85 % Uc)	RMS value	10 ms	1 year	100%
Short supply interruptions (< 3 min)	Several tens to several hundred per year (less than 1 % Uc)	RMS value	10 ms	1 year	100%
Long supply interruptions (> 3 min)	Several tens to 50 per year (less than 1 % Uc)	RMS value	10 ms	1 year	100%
Supply surge (phase - earth)	Usually < 1.5 k V	1.7 to 2.0 (depending on method of neutral point connection)	RMS value	10 ms	-
Transients (phase - earth)	Usually < 6 kV	Depending on insulation coordination	Peak value	none	-
Voltage imbalance (negative phase-sequence system to positive phase-sequence system ratio)	Usually 2 % in special cases up to 3 %	RMS value	10 min	1 week	95%
Harmonics (reference value Un or Uc)	Total harmonic distortion (THD) 8 %	RMS value	10 min	1 week	95%
Interharmonics	Values subject to consultation	Subject to consultation			
Signal voltages (reference value Un or Uc)	9 to 95 kHz range subject to consultation	RMS value	3s	1 day	99%

it should be possible to vary the record duration from a few milliseconds to several minutes and to configure the duration separately for the pre-fault, fault and post-fault periods. This type of measured data highlights short transient network incidents, such as those caused by switching operations or lightening strikes. Changes in signal shape which are generated by non-linear or pulse-type loads such as motors, electric arc furnaces, energy-saving lamps or frequency converters, for example, are registered at the same time.

Conclusion

In view of the wide range of functionalities and the high degree of flexibility which must be provided by modern measuring systems, it is important not to lose sight of the needs of the user: simple and intuitive operability is the order of the day. Even the very best measuring system is useless unless it is accompanied by a software package which is well-designed and easy to operate. Manufacturers far-sighted enough to bear this in mind will have a head start over their competitors.

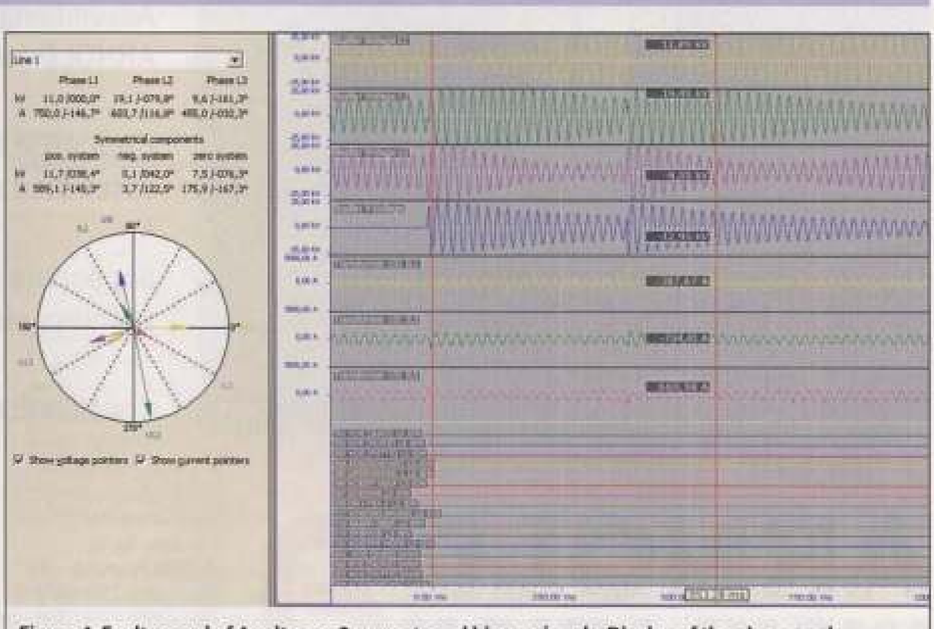

Figure 4. Fault record of 4 voltages, 3 currents and binary signals. Display of the phase angle (vector diagram) at the selected measurement point (vertical red line).