Mains Quality
- Always on the Safe Side with Clean Electrical Networks

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Industry, commerce, health care services, banks and other service providers are extremely dependent upon electrical and electronic systems. These systems influence mains quality themselves in many ways, but they react extremely sensitively to disturbances as well. It is thus the entrepreneurial responsibility of all modern business operations to keep their own electrical systems under control – 24 hours a day under any possible conditions.

Action should be taken as soon as the first signs of poor mains quality appear such as overheated transformers and cables, excessive current in neutral conductors without any explainable cause, tripped protective devices, flickering lights, computer failures and data network problems, interference in telephone lines or inexplicably increased energy costs. Causes can be pinpointed and the elimination of faults can be implemented through the use of suitable measuring equipment.

The Most Important Standards for Mains Quality

Where mains quality is concerned, “mains quality” standard EN 50160 and the EN 61000 series of EMC standards must be taken into consideration. EN 50160 describes the most important characteristic quantities for power supply reliability, whereas the EN 61000 series of EMC standards defines limit values for interference emission and interference immunity, as well as test and measuring procedures. The following standards are relevant:

Power Supply

EN 50160	Voltage characteristics of electricity supplied by public distribution networks

Limit Values for Consumers

EN 61000-3-2	Harmonic current (I < 16 A per phase)
EN 61000-3-12	Harmonic current (I > 16 and < 75 A per phase)
EN 61000-3-3	Voltage changes, voltage fluctuations and flicker (I < 16 A)
EN 61000-3-11	Voltage changes, voltage fluctuations and flicker (I > 16 and < 75 A per phase)

Test and Measuring Procedures

EN 61000-4-7	Measuring methods for harmonics
EN 61000-4-15	Flicker meters – Functional and design specifications
EN 61000-4-30	Testing and measurement techniques – Power quality measurement methods

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MAVOWATT 30/40/70 and MAVOSYS 10 measuring instruments comply with class A in accordance with EN 61000-4-30, and fulfill the requirements for the respective test and measuring procedures. EN 50160 and its distinguishing features will be considered in detail in the following pages.

Agreement Between Power Utilities and Consumers – EN 50160

EN 50160 defines “electrical power” as a product on the basis of selected voltage quality characteristics. Every customer in Europe can expect voltage quality in public low and medium-voltage supply networks to lie within a specified range of values. EN 50160 is applicable under normal operating conditions at the point of delivery from the public network to the customer, as well as from private power generating facilities to the public network. Monitoring these characteristics at the point of transfer to the network, and within the network, is an important aspect of systems management for electrical power utilities and industrial network service providers.

Table 1: An overview of EN50160 characteristics standard is provided in the following table.

Feature	Value or Range of Values		Measuring and Evaluation Parameters			
	Low-Voltage	Medium-Voltage	Basis	Integration Interval	Observation Duration	Percentage
Line frequency (integrated network)	50 Hz ±1% 50 Hz +4%, -6%		Mean value	10 sec.	1 year	99.5 % Continuous
Line frequency (isolated operation)	50 Hz ±2% 50 Hz ±15%		Mean value	10 sec.	1 week	95% Continuous
Slow voltage changes	Un ±10% Un +10%, -15%	Uc ±10%	Mean value	10 min.	1 week	95% Continuous
Individual, rapid voltage changes	<5% Un, max. 10% Un Short-term	<4% Uc, max. 6% Uc Short-term	RMS value	10 ms	1 day	Several times
Flicker intensity	Plt < 1 Long-term flicker intensity		Flicker algorithm	2 hours EN 61000-4-15	1 week	95%
Voltage dips (1% Un≤ U_{10ms}≤ 90% Un)	Fewer than several 10 ... 1000 Of which >50% with duration <1s and residual voltage > 40% Un		RMS value	10 ms	1 year	Typical value
Short voltage interruption (≤3min. & U_{10ms} <1% Un)	Fewer than several 10 ... 100 Of which >70% with duration <1s		RMS value	10 ms	1 year	Typical value
Long voltage interruptions (>3min. & U_{10ms} <1% Un)	Fewer than 10 ... 50		RMS value	10 ms	1 year	Typical value
Temporary power-frequency overvoltage (phase-ground)	Usually < 1.5 kV As a rule U_{L-N} < 1.1 * nominal value U_{L-L}	< 1.7 * Uc – grounded < 2.0 * Uc – isolated neutral point	RMS value	10 ms	No entry	Continuous
Transient overvoltages (phase-ground)	< 6 kV / µs ... ms	According to insulation coordinates	Peak value	-	No entry	Continuous

Asymmetry	0% < U (negative phase-sequence system) / U (positive phase-sequence system) < 2% Fundamental component (sometimes < 3%)	Mean value	10 min.	1 week	95%
Harmonics U_{H2} ... U_{H40}	< limit value per standard table and THD < 8%	Mean value	10 min. EN 61000-4-7	1 week	95%
Sub-Harmonics	In progress	In progress			
Signal voltages	≤standard characteristic curve f(f)	Mean value	3 sec.	1 day	99%

Voltage analyzers, such as the MAVOWATT series from Gossen-Metrawatt, clearly display all of the characteristics specified in EN50160, and indicate whether or not they are in compliance with the standard.

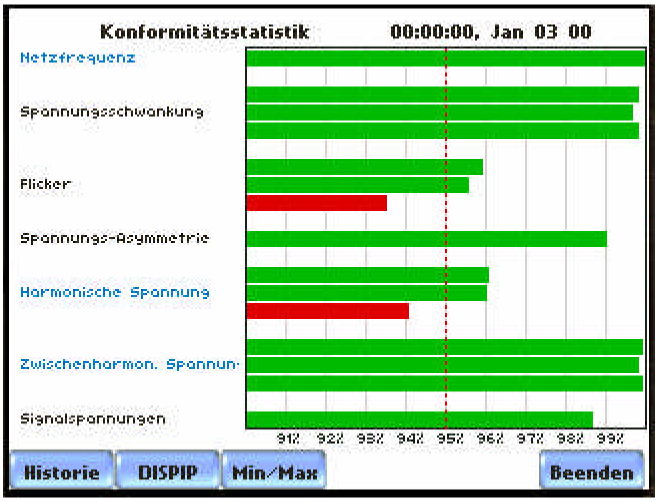

Figure 1: EN50160 Conformity Statistics Provided by MAVOWATT 30/40/70

Power Disturbances – Causes, Effects and Remedies

Power disturbances within the network are substantiated by means of voltage analyzers. The user is provided with helpful hints indicating the type of disturbance – either directly on the basis of measurement results, or indirectly on the basis of resultant effects. After the cause has been pinpointed, trained electricians are then provided with useful tips regarding effective troubleshooting methods.

Transients

Transient overvoltages occur primarily as the result of switching operations within the network. Furthermore, voltage peaks of up to several kV are caused by lightning, as well as fuses which are blown and circuit breakers which are tripped due to short circuiting.

The consequences of transients include malfunctioning of controllers, computer crashes, destruction of network components as well as motor and transformer windings, arcing into various devices and interference in signal and data transmission lines. These problems can be effectively corrected by installing varistors or surge capacitors.

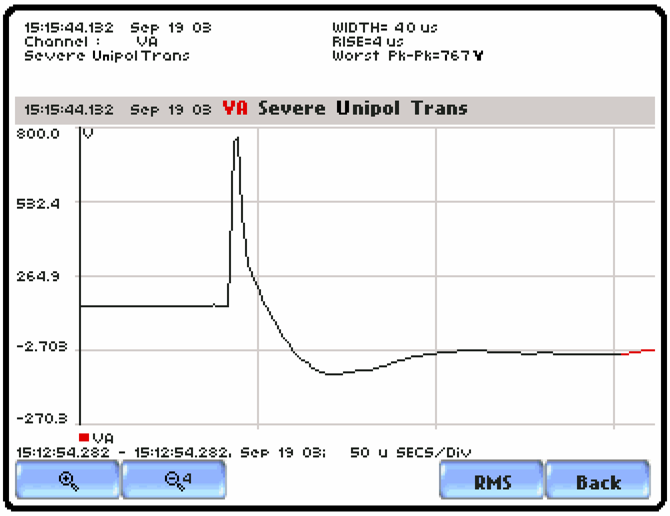

Figure 2: Transient Display

Harmonics

Harmonics are sinusoidal components superimposed on the fundamental voltage or current component. The relationship of harmonic frequency to line frequency is designated harmonic order h. Whole number multiples of the line frequency are called harmonics. Non whole number multiples are known as sub-harmonics.

Increasing use of non-linear electrical power consumers is resulting in more and more harmonics within electrical power networks. To a given extent, this is due to power packs with DC outputs which are commonly used in computers, printers, photocopiers, fax machines, low-voltage halogen lamps and electronic controllers. Additional harmonic components are caused by electronic ballasts for fluorescent tubes, energy-saving lamps, frequency converters for speed-controlled drive units, DC drives and electric arc furnaces.

The consequences of harmonics within the network include increased losses, as well as malfunctioning and failure of electrical equipment and systems. Conspicuously enough, non-linear electrical power consumers are particularly sensitive to harmonics. Within this context, special attention must be paid to the neutral conductor, within which all harmonic currents with a harmonic order divisible by 3 are dissipated. The in-phase components are added together in the neutral conductor and may result in overloading and fire hazard, or interruption with voltage offset due to open neutral point and destruction of the connected devices. Caution is also imperative in the event of large harmonic components with high harmonic order, which may influence compensation equipment and destroy their capacitors due to overheating.

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Instead of chocking power supply networks which is now viewed as a technically obsolete measure, intelligent, active filters are now used to compensate harmonics.

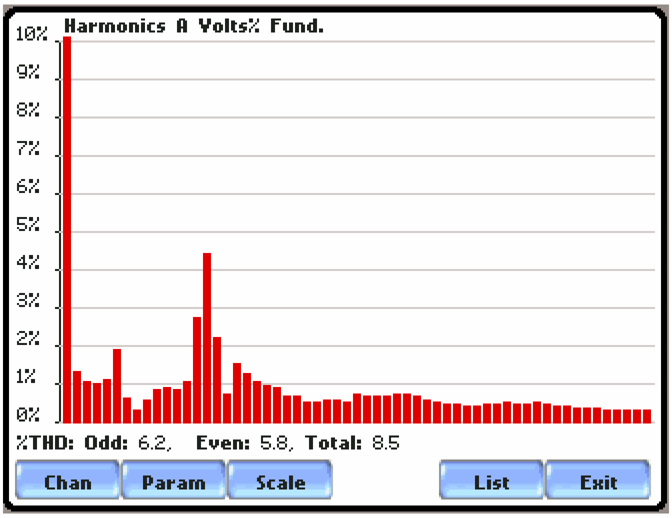

Figure 3: Harmonic Spectrum

Sub-Harmonics

Sub-harmonic voltages occur as mains pollution caused by high-powered operating equipment whose energy conversion takes place at a frequency which differs from line frequency, or in some cases is independent of 50 Hz. These include asynchronous machines, drive units with frequency converters, operating equipment with multicycle controllers and external sound frequency ripple control systems. The consequences are flicker and disturbances at ripple control systems. This can be remedied by establishing connection at a point with greater short-circuit capacity, improving smoothing within the intermediate circuits in converters or by using trap circuits.

Voltage Fluctuation

Changes in the RMS voltage value are designated voltage fluctuation. Differentiation is made between slow voltage changes during any given day which last for seconds or minutes, and individual, rapid voltage changes with durations ranging from seconds, all the way down to the millisecond range. Frequent, rapid voltage changes are perceived as flicker, and are described under the corresponding heading. Voltage fluctuations are caused by machines and equipment with great load fluctuation which are operated at power supply networks with minimal short-circuit capacity.

The consequences include malfunctioning, reduced machine performance, productivity losses and inconsistent manufacturing quality. This can be avoided through the use of voltage stabilizing systems.

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Voltage Dips

In the case of voltage dips, RMS voltage drops to a value within a range of 1% to 90% of nominal voltage due to short-term, excessive system loads, in particular within networks with minimal short-circuit capacity. This is caused by excessive starting current for large motors which by far exceeds nominal current. The same applies to motors which have to be started up while subjected to heavy loads. The consequences include system shutdown due to overcurrent, device shutdown due to undervoltage, controller malfunctioning and stopped motors. Effective improvement is provided through the use of motor start-up compensation, current limiting during motor start-up with star, delta or soft start-up circuits, or by increasing network short-circuit capacity.

Flicker

Rapid and frequent load changes influence line voltage and result in annoying light fluctuations. This leads to eye fatigue, discomfort and dizziness. Flicker is frequently caused by welding equipment, electric arc furnaces, X-ray apparatus, wind power turbines and drive units which are subjected to intermittent loads such as presses, stamping machines, shredders, cranes and elevators.

In order to equalize flicker, compensation systems are required which connect or disconnect the required compensation power within just a few milliseconds, as well as dynamic closed-loop control systems with special control units. This problem can also be remedied by isolating the lighting network, by connection to another phase or by means of a separate transformer.

Asymmetry

Transformers and power supply networks are subjected to asymmetrical loading due to non-uniform distribution of single-phase power consumers and the use of 2-phase power consumers. The power consumer's active load results in unequal phase voltages and reactive load causes phase shifting which deviates from the ideal value of 120°.

The consequences include increased transformer losses and humming, as well as irregular motor operation which results in greater losses and a shorter service life due to thermal overloading and wear at the bearings. High costs for reactive current are also caused by undefined reactive current compensation.

Asymmetry can be compensated by means of uniform phase utilization, by increasing network short-circuit capacity, or through the use of dynamic symmetry control systems. Systems with asymmetry adjustment should be used for reactive current compensation.

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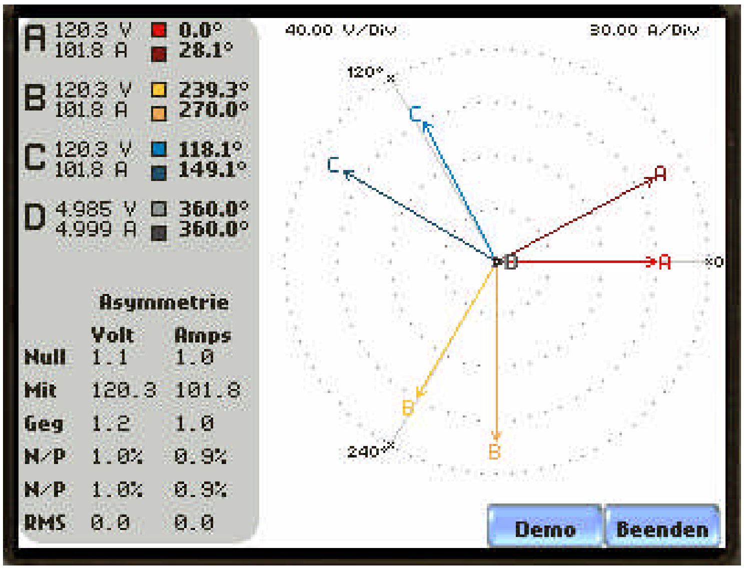

Figure: Vector Diagram

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Voltage Analyzers from Gossen-Metrawatt – Always the Right Choice

There's only one convincing solution for the numerous challenges in the field of electrical power supply: MAVOWATT and MAVOLOG – diverse voltage analyzer power tools for assuring mains quality. With the help of these innovative products, all relevant measured quantities can be acquired which are decisive for the quality of electrical supply power. Disturbances and events can be easily pinpointed, documented and analyzed with reference to applicable standards – the ideal basis for sustainable optimization. Optimization increases operating reliability, keeps product quality stable and assures high levels of cost effectiveness. And a stable electrical system provides a true sense of security.

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