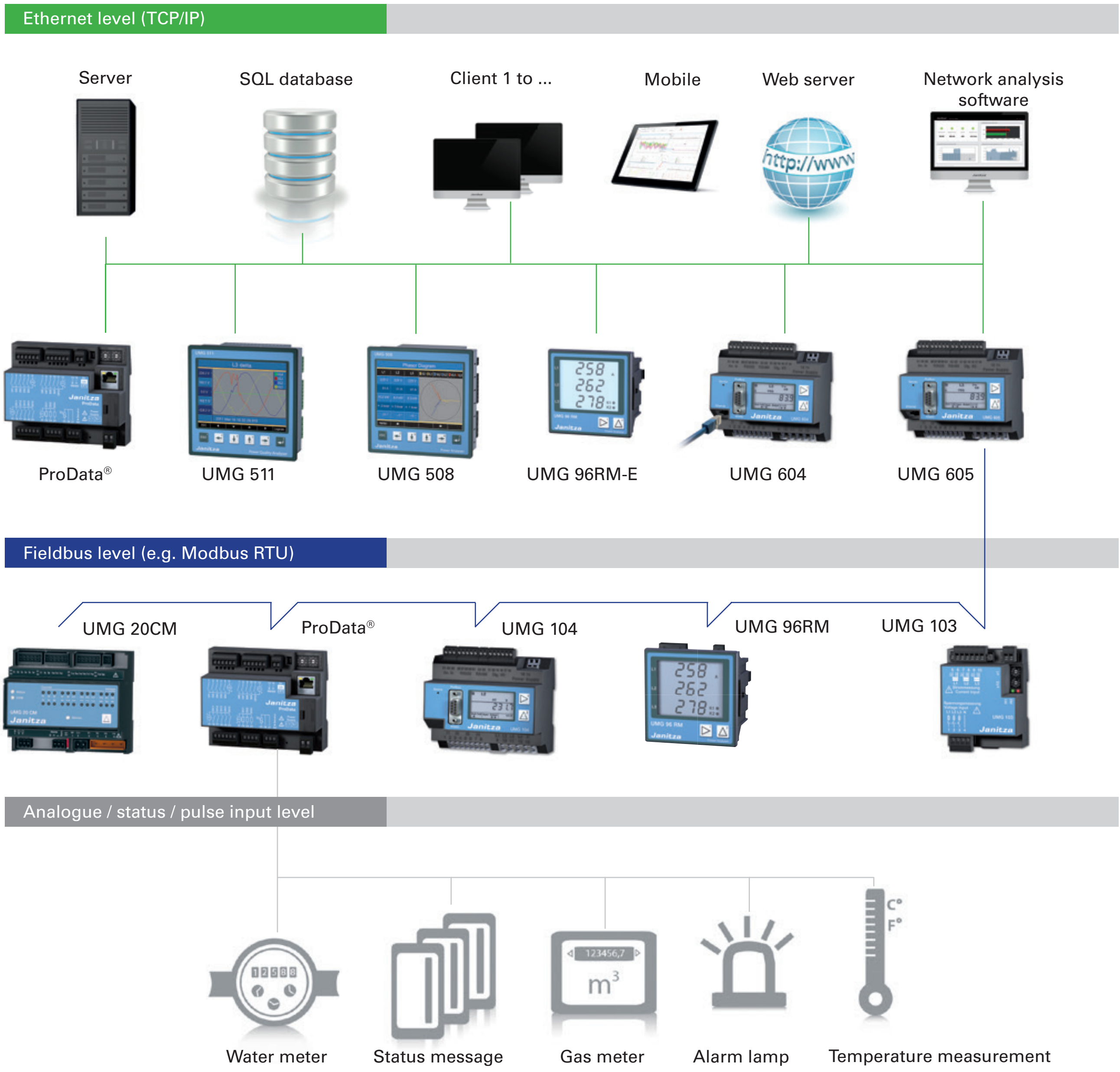
Smart Energy &
Power Quality Solutions

EN 50160 / ISO 50001
Made in Germany

Power Quality

Janitza®



UMG 508 / UMG 604 = Janitza power analyser

UMG 511 / UMG 605 = Janitza power quality analyser

UMG 96RM / UMG 96RM-E / UMG 103 / UMG 104 = Janitza multifunction energy meters

UMG 20CM = Janitza 20 channel branch circuit monitoring device, for residual current monitoring (RCM) and energy data acquisition

Overview of the various power quality parameters

In modern energy supply a wide range of single and three-phase, non-linear loads are used in industrial networks right through to office blocks. These include lighting equipment such as lighting controls for headlamps or low energy bulbs, numerous frequency converters for heating, air conditioning and ventilation systems, frequency converters for automation technology or lifts, as well as the entire IT infrastructure with the typically used regulated switched mode power supplies. Today, one also commonly finds inverters for photovoltaic systems (PV) and uninterruptible power supplies (UPS). All of these non-linear electrical loads cause grid distortion effects to a greater or lesser extent, with a distortion of the original "clean" sinusoidal form. This results in the current or voltage waveform being distorted in the same way.

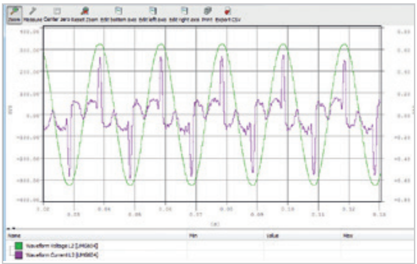


Fig.: Distorted current form through consumer electronics

The reliable operation of modern plants and systems always demands a high degree of supply reliability and good power quality.

The load on the network infrastructure through electrical and electronic loads with grid distortion effects has increased significantly in recent years. Depending on the type of generation system and the operating equipment (mains feed with converter, generator), mains rigidity at the connection point and the relative size of the non-linear loads, varying strengths of grid distortion effects and influences arise.

The following power quality parameters must be taken into particular consideration:

- Harmonics
- Current and voltage unbalance
- Rapid voltage changes - transients
- Voltage dips and short-term overvoltage
- Voltage interruption (SIs - short term interruptions)
- Flicker
- Phase shifting and reactive power

Harmonics

The constantly rising number of non-linear loads in our power networks is causing increasing "noise on the grid". One also speaks of grid distortion effects, similar to those that arise in the environment due to water and air pollution. Generators ideally produce purely sinusoidal form current at the output terminals. This sinusoidal current form is considered the ideal alternating current form and any deviation from this is designated mains interference.

An increasing number of loads are extracting non-sinusoidal current from the grid. The FFT-Fast-Fourier-Transformation of this "noisy" current form results in a broad spectrum of harmonic frequencies - often also referred to as harmonics.

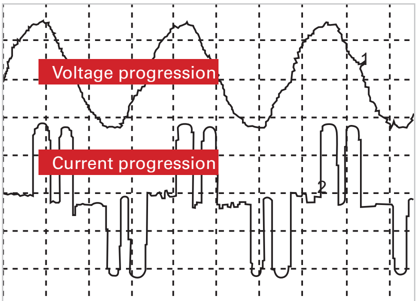


Fig.: Grid distortion effects through frequency converters

Harmonics are damaging to electrical networks, sometimes even dangerous, and connected loads are harmed by these; in a similar way to the unhealthy effect that polluted water has on the human body. This results in overloads, reduced service lives and in some cases even the early failure of electrical and electronic loads.

Fig.: Harmonics analysis (FFT)

Harmonic loads are the main cause of invisible power quality problems and result in massive maintenance and investment costs for the replacement of defective devices. Grid distortion effects of an impermissible high level and the resultant poor power quality can therefore lead to problems in production processes and even to production downtimes.

Harmonics are currents or voltages whose frequency lies above the 50/60-Hz mains frequency, and which are many times this mains frequency. Current harmonics have no portion of the effective power, they only cause a thermal load on the network. Because harmonic currents flow in addition to "active" sinusoidal oscillations, they cause electrical losses within the electrical installation. This can lead to thermal overloads. Additionally, losses in the load lead to heating up or overheating, and therefore to a reduction in the service life.

The assessment of harmonic loads usually takes place at the connection or transition point to the public mains supply network of the respective energy supplier. One speaks in this case of a Point of Common Coupling (PCC). Under certain circumstances it may also be important to determine and analyse the harmonic load through individual operating equipment or equipment

Threshold values of individual harmonic voltages at the transition point up to the 25th order as a percentage of the fundamental oscillation U1					
Odd harmonics				Even harmonics	
No multiple of 3		Multiple of 3			
Order h	**Relative voltage amplitude U_h**	**Order h**	**Relative voltage amplitude U_h**	**Order h**	**Relative voltage amplitude U_h**
5	6.0 %	3	5.0 %	2	2.0 %
7	5.0 %	9	1.5 %	4	1.0 %
11	3.5 %	15	0.5 %	6 to 24	0.5 %
13	3.0 %	21	0.5 %		
17	2.0 %				
19	1.5 %				
23	1.5 %				
25	1.5 %				

groups, in order to indicate internal power quality problems and possibly determine their causes.

The following parameters are used to assess harmonic loads:

Fig.: Capacitors destroyed due to harmonics

Total Harmonic Distortion (THD)

Total Harmonic Distortion (THD) is a means of quantifying the proportion of distortion arising due to the non-linear distortion of an electrical signal. It therefore gives the ratio of the effective value of all harmonics to the effective value of the mains frequency. The THD value is used in low, medium and high voltage systems. Conventionally, THD_i is used for the distortion of current, and THD_u for the distortion of voltage.

THD for voltage

- M = Ordinal number of harmonics
- M = 40 (UMG 604, UMG 508, UMG 96RM)
- M = 63 (UMG 605, UMG 511)
- Mains frequency fund equals n = 1

$$THD_U = \frac{1}{|U_{fund}|}\sqrt{\sum_{n=2}^{M}|U_{n.Harm}|^2}$$

THD for current

- M = Ordinal number of harmonics
- M = 40 (UMG 604, UMG 508, UMG 96RM)
- M = 63 (UMG 605, UMG 511)
- Mains frequency fund equals n = 1

$$THD_I = \frac{1}{|I_{fund}|}\sqrt{\sum_{n=2}^{M}|I_{n.Harm}|^2}$$

Total Demand Distortion (TDD)

In North America in particular, the expression TDD is commonly used in conjunction with the issue of harmonics. It is a figure that refers to THD_i, although in this case the total harmonic distortion is related to the fundamental oscillation portion of the nominal current value. The TDD therefore gives the relationship between the current harmonics (analogous to the THD_i) and the effective current value under **full load conditions** that arises within a certain interval. Standard intervals are 15 or 30 minutes.

$$TDD = \frac{1}{I_L}\sqrt{\sum_{n=2}^{M}I_n^2} \times 100\%$$

TDD (I)

- TDD gives the relationship between the current harmonics (THD_i) and the effective current value with a full load.
- I_L = Full load current
- M = 40 (UMG 604, UMG 508, UMG 96RM)
- M = 63 (UMG 605, UMG 511)

Current / voltage unbalance

One speaks of balance in a three-phase system if the three phase voltages and currents are of an equal size and are phase-shifted at 120° to each other.

Unbalance arises if one or both conditions are not fulfilled. In the majority of cases the cause of unbalance lies in the loads.

In high and medium voltage power grids the loads are usually three-phase and symmetrical, although large one- or two-phase loads may also be present here (e.g. mains frequency induction furnaces, resistance furnaces, etc.). In the low voltage network electrical loads are frequently also single-phase (e.g. PCs, consumer electronics, lighting systems, etc.), and the associated load current circuits should be distributed as evenly as possible within the electrical wiring on the three phase conductors. Depending on the symmetry of the single-phase loads, the network is operated on a more balanced or unbalanced basis.

The compatibility level for the degree of unbalance of the voltage in stationary operation caused by all mains loads is defined as ≤ 2 %. Related to individual load systems the resultant degree of unbalance is limited to = 0.7 %, whereby an average over 10 minutes must be obtained.

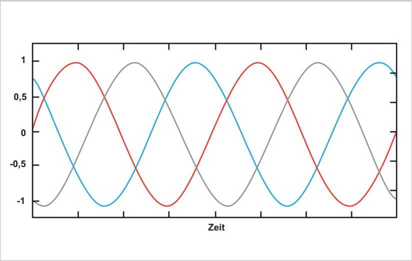


Fig.: Balance

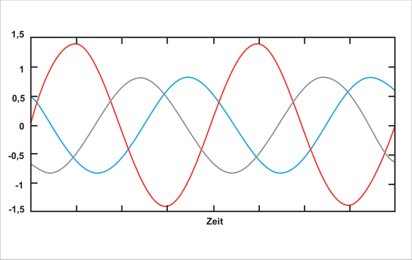


Fig.: Unbalance

The following effects arise due to unbalance in the voltage:

- Increased current loading and losses in the network.
- With equal load power the phase currents can attain 2 to 3 times the value, the losses 2 to 6 times the value. It is then only possible to load lines and transformers with half or one third of their rated power.
- Increased losses and vibration moments in electrical machinery.
- The field built up by the negative sequence component of the currents runs against the phase sequence of the rotor and therefore induces currents in it, which lead to increased thermal loading.
- Rectifiers and inverters react to unbalance in the power supply with uncharacteristic harmonic currents.
- In three-phase systems with star connection, current flows through the neutral conductor.

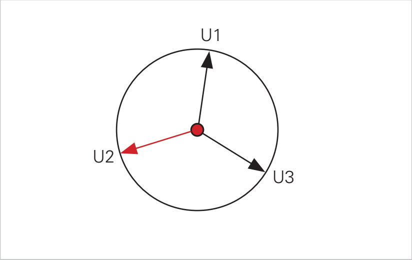


Fig.: Illustration of unbalance in the Vector diagram

You can find the related detailed formulas in the collection of formulas on page 318.

Transients

Transients are pulsed electrical phenomena, which exist for just a short period of time. These are usually high frequency, steep signals in the form of transient oscillations.

The reliable detection of transient processes in the electrical supply network is very important in order to avoid damages. Through constant changes in the electrical supply network due to switching operations and faults, new network states arise constantly, which the entire system is required to tune itself to. In normal cases transient compensation currents and compensation voltages arise here. In order to assess whether the transient processes result from a desired or undesired change in the network, and whether these still lie in the tolerance range, one requires reliable decision criteria.

High transient overvoltage, and high dV/dt-ratios, can lead to insulation damage and the destruction of systems and machines, also depending on the energy input (e.g. lightening strike).

In order to detect and record transients it is necessary to use high quality, digital power quality analysers with a high sampling rate.

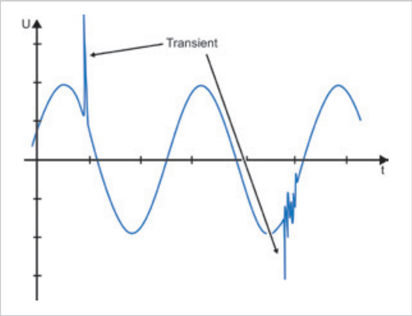


Fig.: Transients

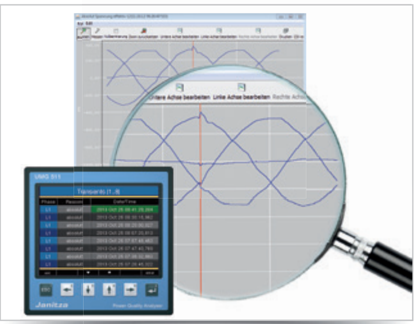


Fig.: With the UMG 511 it is possible to display the transients directly on the measuring device.

Practical example:

High transient currents often arise due to the switching – in of capacitors (without reactors or damping facility) – also with problem-free network configurations. Choking has a strongly damping effect and therefore protects against avoidable problems that are difficult to foresee. Alternatively, special capacitor contactors or switching devices should be used, e.g. with pre-charging resistors at LV side.

Voltage dips and interruptions

Voltage drops can lead to huge complications – for example the failure of production processes – and to quality problems. Such voltage drops arise much more frequently than interruptions. The commercial effects of voltage drops are seriously underestimated time and again.


Fig.: Example: Voltage dips due to bird droppings

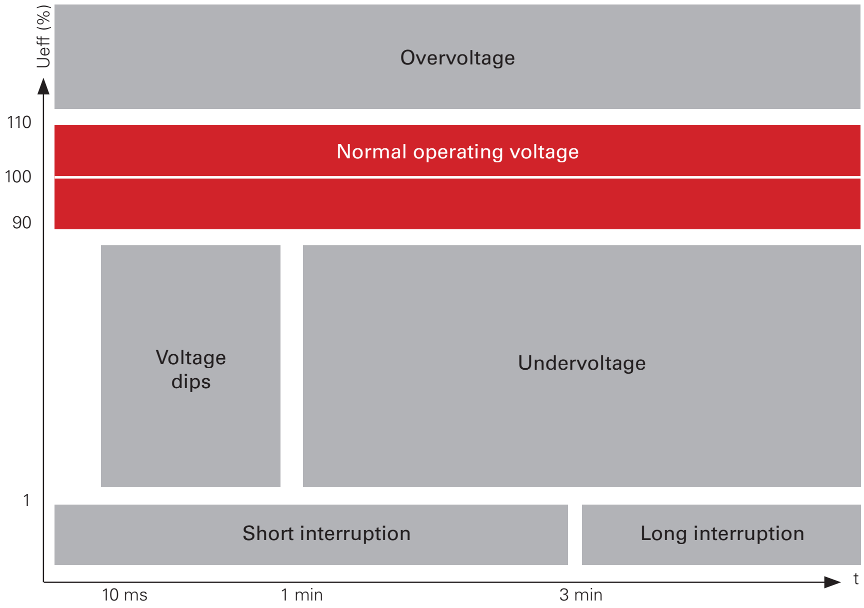
What is a voltage drop?

According to the European standard EN 50160 a voltage drop is a sudden lowering of the effective voltage value to a value of between 90% and 1% of the stipulated nominal value, followed by the immediate reinstatement of this voltage. The duration of a voltage drop lies between a half period (10 ms) and one minute.

If the effective value of the voltage does not drop below 90% of the stipulated value then this is considered to be normal operating conditions. If the voltage drops below 1% of the stipulated value then this is considered an interruption.

A voltage drop should therefore not be confused with an interruption. An interruption arises, for example, after a circuit breaker has tripped (typ. 300 ms). The mains power failure is propagated throughout the remaining distribution network as a voltage drop.

The diagram clarifies the difference between a drop, a short interruption and an undervoltage situation.



Voltage variations are caused by:

- Short circuits
- Switch-on and switch-off processes with large loads
- Starting drives (larger load)
- Load changes with drives
- Pulsed power (oscillation package controls, thermostatic controls)
- Arc furnaces
- Welding machines
- Switching on capacitors
- Construction works
- Bird droppings

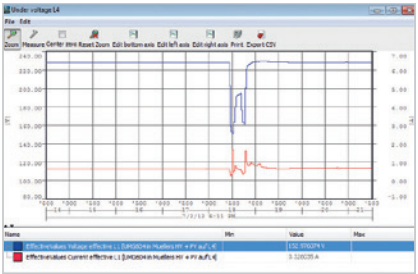


Fig.: Critical voltage dip with production standstill

Voltage drops can lead to the failure of computer systems, PLC systems, relays and frequency converters. With critical processes just a single voltage drop can result in high costs, continuous processes are particularly impacted by this. Examples of this are injection moulding processes, extrusion processes, printing processes or the processing of foodstuffs such as milk, beer or beverages.

The costs of a voltage drop are comprised of:

- Loss of profits due to production stoppage
- Costs for catching up with lost production
- Costs for delayed delivery of products
- Costs for raw materials wastage
- Costs for damage to machinery, equipment and moulds
- Maintenance and personnel costs

Sometimes processes run in unmanned areas in which voltage drops are not immediately noticed. In this case an injection moulding machine, for example, could come to a complete standstill unnoticed. If this is discovered later there will already be a large amount of damage. The customer receives the products too late and the plastic in the machine has hardened off.

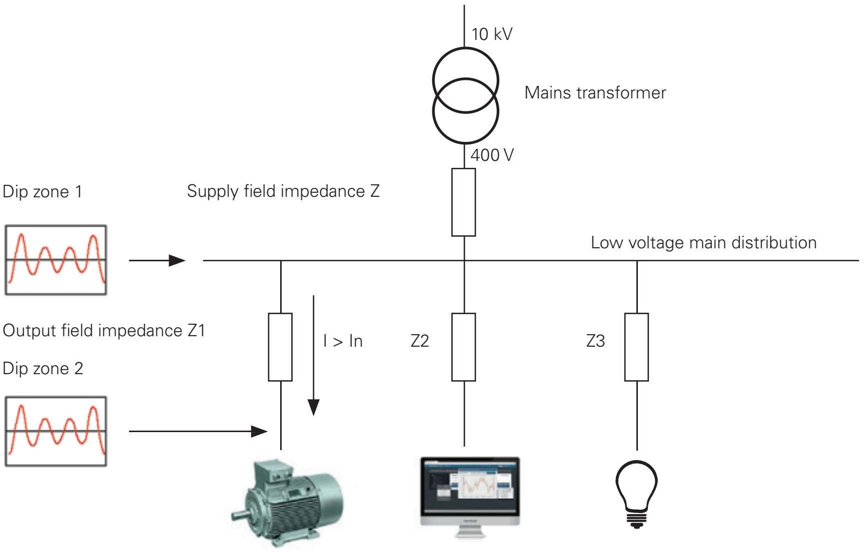


Fig.: Motor start-up currents can lead to a voltage dip

Flicker

Flicker refers to the subjective impression of light density changes or an impression of unsteadiness of visual perceptions, caused by luminous stimuli with temporal fluctuations of the light density or the spectral distribution. From a technical perspective, voltage variations cause light density changes in lamps, which can result in visual perceptions referred to as flicker. From a certain threshold value the appearance of flicker can be disturbing. The disturbing effect of voltage variations depends here on the extent of the repetition rate and the curve form of the change in voltage. The short-term flicker strength and long-term flicker strength are defined measures of the disturbing effect.

Voltage variations, caused by individual devices (on the low voltage network), are permissible if the resultant flicker disturbance factor is not greater than 1. The long-term flicker disturbance factor averaged from twelve values must not exceed a value of 0.65. The most simple method for evaluating the value is the = 1 p.u. curve. P.u. stands here for the "unit of perception" and is the maximum tolerance level for the interference sensitivity of the human eye with regards to its perception of light fluctuations. It is also not permissible to exceed the value = 1 p.u. in combination with all interferers.

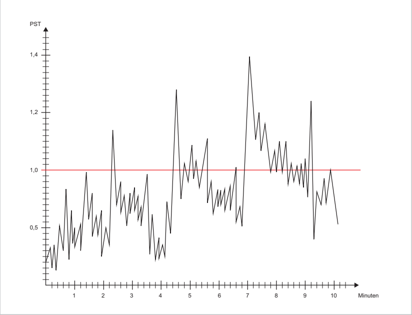


Fig.: Development over time of short-term flicker (PST)

Fig.: Practical example for flicker: Gravel quarry

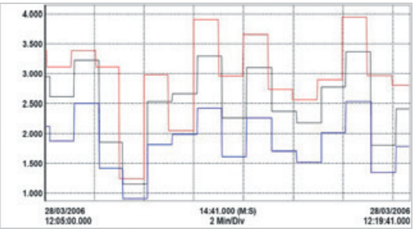


Fig.: Development of flicker

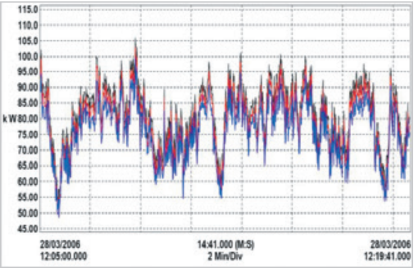


Fig.: Effective power development dependent on the volume and consistency of material

Phase shifting and reactive power

Reactive power is required in order to generate electromagnetic fields in machines such as three phase motors, transformers, welding systems, etc. Because these fields build up and break down continuously, the reactive power swings between generator and load. In contrast to the effective power it cannot be used, i.e. converted into another form of energy, and burdens the supply network and the generator systems (generators and transformers). Furthermore, all energy distribution systems for the provision of the reactive current must exhibit larger dimensions.

It is therefore expedient to reduce the inductive reactive power arising close to the load through a counteractive capacitive reactive power, of the same size where possible. This process is referred to as power factor correction. With power factor correction, the proportion of inductive reactive power in the network reduces by the reactive power of the power capacitor of the power factor correction system (PFC). The generator systems and energy distribution equipment are thereby relieved of the reactive current. The phase shifting between current and voltage is reduced or, in an ideal situation with a power factor of 1, entirely eliminated.

The power factor is a parameter that can be influenced by mains interference such as distortion or unbalance. It deteriorates with progressive phase shifting between current and voltage and with increasing distortion of the current curve. It is defined as a quotient of the sum of the effective power and apparent power, and is therefore a measure of the efficiency with which a load utilises the electrical energy. A higher power factor therefore constitutes better use of the electrical energy and ultimately also a higher degree of efficiency.

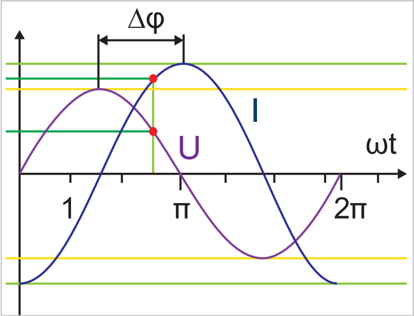


Fig.: Phase shifting between current and voltage (Δφ)

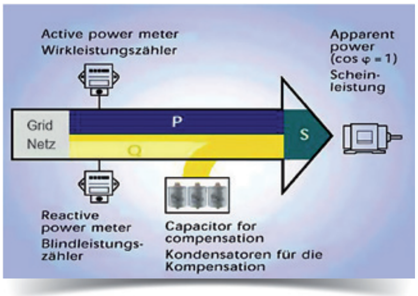


Fig.: Principle of power factor correction

Power Factor (arithmetic)
- The power factor is unsigned

$$PF_A = \frac{|P|}{S_A}$$

Fig.: Power Factor (arithmetic)

Cosphi – Fundamental Power Factor
- Only the fundamental oscillation is used in order to calculate the cosphi
- Cosphi sign (φ):
  - $-$ = for delivery of effective power
  - $+$ = for consumption of active power

$$PF_1 = \cos(\varphi) = \frac{P_1}{S_1}$$

Fig.: Cosphi – Fundamental Power Factor

Because no uniform phase shifting angle can be cited with harmonic loading, the power factor λ and the frequently used effective factor cos (φ_1) must not be equated with each other. Starting with the formula $\lambda = \frac{|P|}{S} = \frac{I_1}{I} \cos(\varphi_1) = g_1 \cos(\varphi_1)$ with I_1 = fundamental oscillation effective value of the current, I = total effective value of the current, g_1 = fundamental oscillation content of the current and cos(φ_1) = shifting factor, one sees that only with sinusoidal form voltage and current (g = 1) is the power factor λ the same as the shifting factor cos(φ_1). As such, exclusively with sinusoidal form currents and voltages is the power factor λ the same as the cosine of the phase shifting angle φ and is defined as $\cos(\varphi) = \frac{P}{S}$ = effective factor.

RCM – Residual Current Monitoring

General information

Residual currents caused by the failure of insulation can constitute a significant risk to safety in electrical systems. Using an appropriate protective concept it is possible to detect residual currents, eliminate insulation faults in good time and therefore ensure the availability of the system.

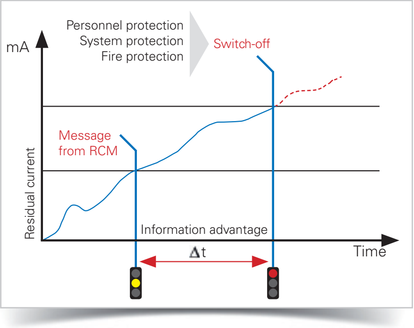


Fig.: Report prior to switching off - an aim of residual current monitoring

RCM stands for **Residual Current Monitoring** and means the monitoring of residual currents in electrical systems. This current is calculated as the sum of the currents of all conductors, apart from the protective earth (PE), which feed into the system. Residual currents are typically the result of insulation faults, leakage currents or EMC filter leakage currents for example.

Whilst RCD devices (residual current circuit breakers) switch off the power supply in the event of a certain residual current being exceeded, RCM measuring devices indicate the actual value, record the long-term development and report the exceeding of a critical value. This message can also be used in order to switch off the power supply via external switching devices (contactors, relays). Through the use of residual current measuring devices (Residual Current Monitoring, RCM) it is possible to detect and report residual currents in a timely manner. It is possible to initiate counter measures in good time, so that it is not necessary to switch the system off. This facilitates the implementation of measures in the event of slowly deteriorating insulation values or steadily rising residual currents – caused for example by ageing insulation – before the system is switched off. For example:

- Insulation faults in pumps
- Residual currents from electrical loads
- Defective PP power capacitors for the PFC
- Defective components in switched mode power supplies, e.g. in computers
- Correctness of TNS systems (Terra Neutral Separate)
- Disclosure of impermissible PEN connections
- Avoidance of neutral conductor reverse currents to grounded equipment

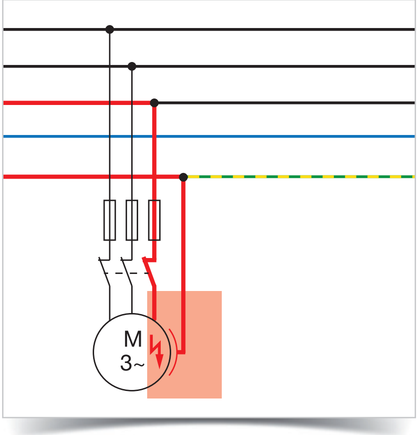


Fig.: Fault current to ground through high ohmic ground fault

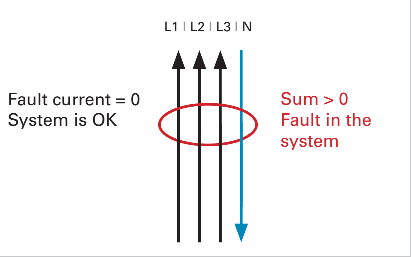
Residual current monitoring in conjunction with energy measurement in combined energy / RCM measuring devices in electrical systems constitutes a measure for fire protection and maintenance prevention. Down times and the associated costs are thereby reduced. Timely and preventative maintenance – facilitated through the information additionally gained from an RCM measuring device – also significantly enhances the efficiency and availability of a system.

Constant RCM monitoring is of particular significance in preventing unwanted surprises in ongoing operation, and provides consistent information regarding the actual status of the electrical system.

Fundamental measuring process with RCM

The functionality of RCM measuring devices is based on the differential current principle. This requires that all phases be guided through a residual current transformer at the measuring point (outlet to be protected), with the exception of the protective earth. If there is no failure in the system then the sum of all currents will be nil. If, however, residual current is flowing away to ground then the difference will result in the current at the residual current transformer being evaluated by the electronics in the RCM measuring device.

The measurement process is described in IEC/TR 60755. Differentiation is made here between type A and type B.



The UMG 96RM-E can measure residual currents in accordance with IEC/TR 60755 (2008-01)

of type A and

type B.

DIN EN 62020 / VDE 0663 / IEC 62020 standard:

The standard applies to residual current monitoring devices for domestic installations and similar applications with a rated voltage of < 440 V AC and a rated current of < 125 A.

Optimum monitoring through 6 current measurement channels

Modern, highly integrated measuring devices facilitate the combined measurement of
- Electrical parameters (V, A, Hz, kW ...)
- Power quality parameters (harmonics, THD, SIs ...)
- Energy loads (kWh, kvarh ...)
- RCM residual current

in just one measuring device. The following example shows a measuring device with 6 current inputs for this purpose:

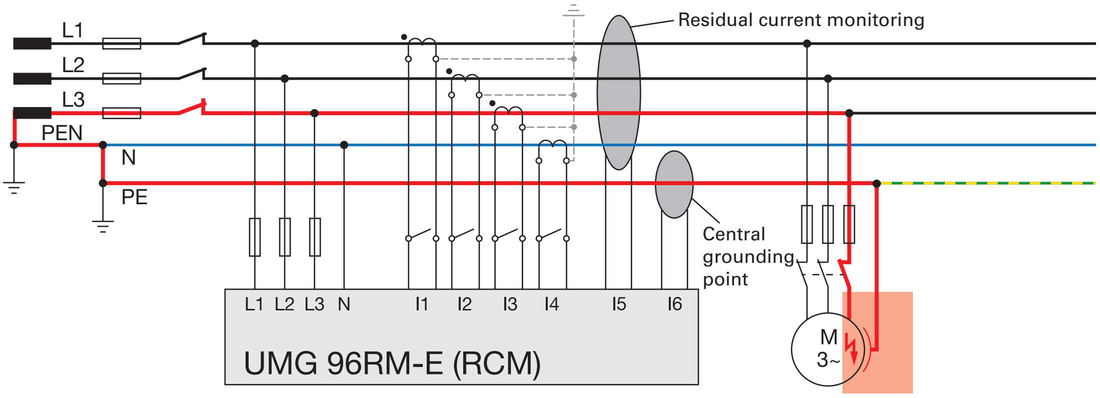


Fig.: Fault current to ground due to an insulation ageing of the motor windings. Minor current through high ohmic fault can be captured with RCM in time and remedial measures initiated to avoid a solid short circuit over time. Thus a production stop can be avoided, as well the risk of a possible fire damage in a worst case scenario.

Constant measurement

In the past

In the past, the micro-processors available on the market were not sufficiently powerful for measuring and simultaneously calculating the various parameters.

It was therefore only feasible to carry out random measurements with older measuring devices. In other words measurements were taken for a number of cycles, measuring was subsequently stopped and the values were calculated. No further measurements were taken during processing. This meant that measurements were only taken for a few periods out of 50 periods.

"Every measuring device measures constantly, doesn't it..."

Customer quote

In the present

With the new product families, such as the UMG 96RM, UMG 104, UMG 604, UMG 605, UMG 508, UMG 511, leading-edge microprocessors are used with an entirely new architecture, integrated performance scope and considerably higher capacities.

Such processors were not available in the past! These processors are more expensive than conventional processors, which are still widely used in many simple measuring devices. With the aforementioned product families, constant and gapeless measurement takes place. In this case all periods are captured, i.e. measurements are taken during 50 periods out of 50. In parallel to this, the data is processed and the various electrical, PQ and energy parameters are calculated.

It is self-evident that considerably better measurement accuracy is attained. It is also necessary to consider that random measurement can lead to considerable deviations in the measurement results and the energy measurement in the event of rapid load changes (e.g. spot welding).

Market situation

Simple measuring devices and measuring devices with economical or older measuring electronics are still available for random measurement. If one looks at the global market, random measurement is in fact dominant and remains current engineering practice!

It is also frequently the case that energy is measured constantly, although all other values are not acquired constantly but rather on a random sampling basis.

Summary

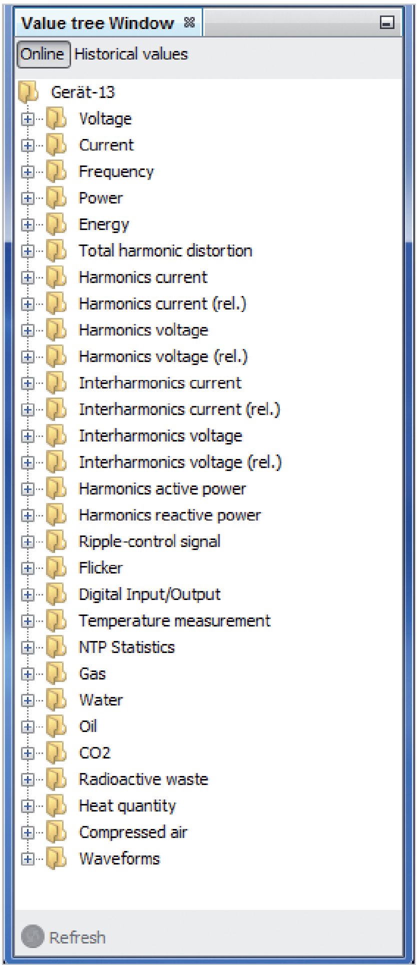
Constant measurement requires higher quality components. By constantly measuring all values, a considerably higher accuracy of measurement is attained.

Measure, calculate, store – ring buffer was yesterday!

As described in detail in the previous article, our latest generation measuring devices are equipped with highly powerful signal processors (DSP), which enable the constant and seamless determination of current and voltage, as well as the calculation of every conceivable parameter. How does this take place in detail, what is the measuring process sequence, in what form are the measured values made available, where are they saved?

Modern measuring devices such as our UMGs can essentially be considered as PCs. The average elements are the CPU (DSP), RAM, hard drive (flash memory) and communication ports (RS485, RJ45).

It is fundamentally possible to distinguish between the following measured value groups:



Gerät-13
- Voltage
- Current
- Frequency
- Power
- Energy
- Total harmonic distortion
- Harmonics current
- Harmonics current (rel.)
- Harmonics voltage
- Harmonics voltage (rel.)
- Interharmonics current
- Interharmonics current (rel.)
- Interharmonics voltage
- Interharmonics voltage (rel.)
- Harmonics active power
- Harmonics reactive power
- Ripple-control signal
- Flicker
- Digital Input/Output
- Temperature measurement
- NTP Statistics
- Gas
- Water
- Oil
- CO2
- Radioactive waste
- Heat quantity
- Compressed air
- Waveforms

Fig.: Online values, value tree UMG 605

Online values

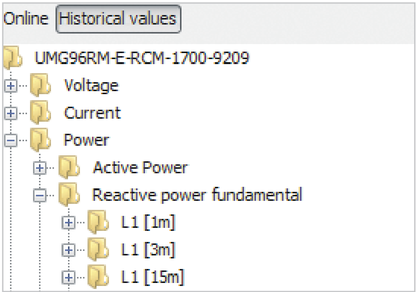
Online values are determined over a measurement interval of 200 ms or as a mean value of the full wave effective values over 10 periods. Online values are all values that are constantly determined and evaluated by the measuring device. Depending on the measuring device this can be up to 2,000 values available for all measuring channels per 200 ms. The significant values can be read out directly from the UMG displays. Using the GridVis® software and working in the topology screen it is possible to view the complete scope of measured values.

All measured values are constantly available in defined Modbus memory registers for external access via suitable third party software.

Historical values

Recordings

Historical values are generated using the online values. For this purpose one or more recording configurations are predefined in the device configuration. For the purpose of the respective recording a period is stipulated for the generation of a mean value, e.g. 15-minute mean value for the recording of load curves, 1-hour mean value for energy, etc. The time frames can lie between 200 ms and multiple days, depending on the type of device. In order to conduct power quality measurements per EN 50160, EN 61000-2-4 or EN 50160, IEEE519, pre-defined recording configurations are available and these can be activated at the click of a mouse button.



UMG96RM-E-RCM-1700-9209
- Voltage
- Current
- Power
  - Active Power
  - Reactive power fundamental
    - L1 [1m]
    - L1 [3m]
    - L1 [15m]

Fig.: Customer-specific historic recordings, value tree UMG 96RM

Historical values are generally initially stored in a measuring device on internal flash memory. This was formerly referred to as a ring buffer. Each stored value is assigned a time stamp. Using the GridVis® software the values are read out manually or automatically (Service). The measured value and time stamp are stored in a database. Using GridVis® or external database tools it is possible to evaluate these values on a tabular or graphical basis.

Events

Events are under- and overvoltages as well as overcurrents. The basis is 20-ms full wave effective values with UMG 604 and UMG 508 or 10-ms half wave effective values with UMG 605 and UMG 511. With an exceeding or undercutting of the stipulated tolerance limits the event is stored on the flash memory. Additionally, a pre- and post event period are defined, so that network incidents can be analysed directly before and after the event occurs. As such, all voltage and current channels are graphically shown as a maximum across the specified time frame.

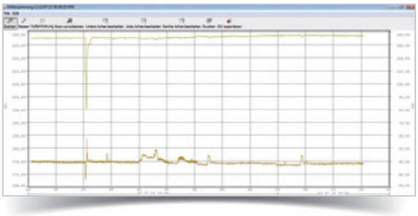


Fig.: Event recording voltage dip / undervoltage

Transients

In order to record transients the full performance of the UMGs is required. With a sampling rate of 20 kHz it is possible to capture transients from 50 µs. Similarly to with the recording of events, threshold values as well as pre- and post periods can be defined. Likewise, it is also possible to stipulate which channels are written to a graph in waveform at the time that the transients occur.

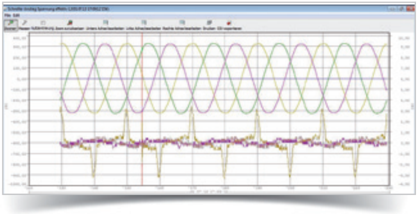


Fig.: Recording transients

Flags

Flags are used to mark and save irregularities in measurements and recordings, in accordance with IEC 61000-4-30. In this way it is possible to recognise the causes of gaps in recordings for example.

Flag	Note
LostWindow	200 ms measurement window has been lost
LostPLL	The device has lost the grid synchronisation
OverCurrent	Overcurrent A
OverVoltage	Overvoltage V
Firmware upgrade	Firmware upgrade
Initialisation	Buffer initialisation

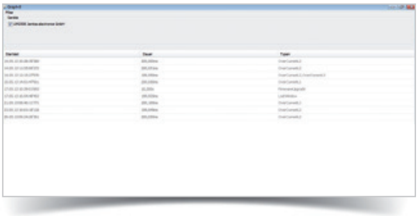
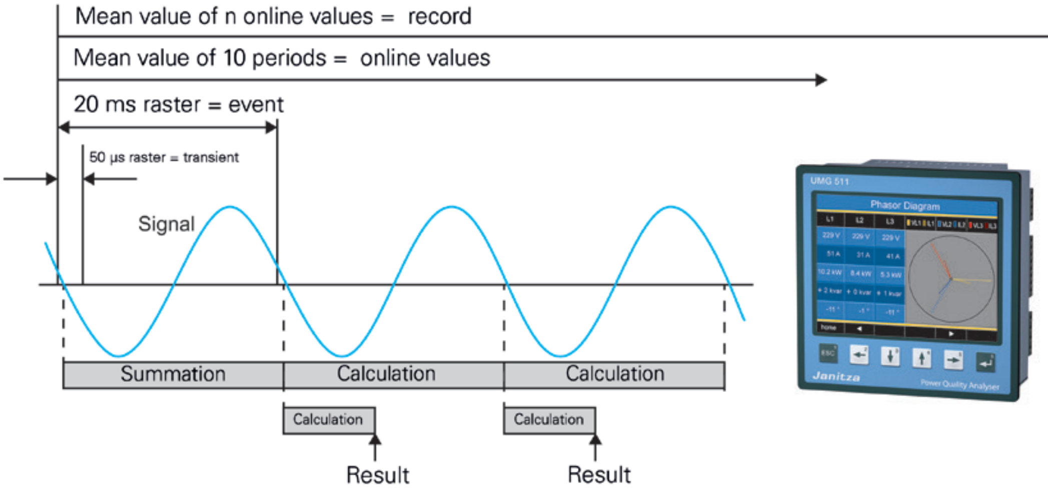


Fig.: Flag recording

All recordings of historical data, events, transients and flags run constantly, independently of each other and in parallel in the measuring device.

All saved data is historically sorted for storage. If the flash memory is full then the oldest data historically is overwritten. Through the regular reading out of the data to a database, values that are overwritten on the measuring device will already have been saved to the server, meaning that no measured values are lost.



DSP
- Firmware
- Measurement
- Calculation

RAM
- Online values
- Modbus register

Flash
- Web server
- Homepage
- Recordings
- Events
- Transients, flags

Collection of formulas (for UMG measurement devices)

Effective value of the current for phase conductor p

$$\mathbf{I_p = \sqrt{\frac{1}{N}\cdot\sum_{k=0}^{N-1} i_{p_k}^{\;2}}}$$

Effective value of the neutral conductor current

$$I_N = \sqrt{\frac{1}{N}\cdot\sum_{k=0}^{N-1}(i_{1_k}+i_{2_k}+i_{3_k})^2}$$

Effective voltage L-N

$$U_{pN} = \sqrt{\frac{1}{N}\cdot\sum_{k=0}^{N-1} u_{pN_k}^{\;2}}$$

Effective voltage L-L

$$U_{pg} = \sqrt{\frac{1}{N}\cdot\sum_{k=0}^{N-1}(u_{gN_k}-u_{pN_k})^2}$$

Neutral voltage (vectorial)

$$U_{Neutral\ voltage} = U_{1_{rms}} + U_{2_{rms}} + U_{3_{rms}}$$

Effective power for phase conductor

$$P_p = \frac{1}{N}\cdot\sum_{k=0}^{N-1}(u_{pN_k}\times i_{p_k})$$

Apparent power for phase conductor p

- The apparent power is unsigned.

$$S_p = U_{pN}\cdot I_p$$

Total apparent power (arithmetic)

- The apparent power is unsigned.

$$S_A = S_1 + S_2 + S_3$$

Ordinal numbers of harmonics

xxx[0] = Fundamental oscillation (50Hz/60Hz)
xxx[1] = 2nd harmonic (100Hz/120Hz)
xxx[2] = 3rd harmonic (150Hz/180Hz)
etc.

THD

- THD (Total Harmonic Distortion) is the distortion factor and gives the relationship of the harmonic portions of oscillation to the fundamental oscillation.

THD for voltage

- M = Ordinal number of harmonics
- M = 40 (UMG 604, UMG 508, UMG 96RM)
- M = 63 (UMG 605, UMG 511)
- Mains frequency fund equals n = 1

$$THD_U = \frac{1}{\left|U_{fund}\right|}\sqrt{\sum_{n=2}^{M}\left|U_{n.Harm}\right|^2}$$

THD for current

- M = Ordinal number of harmonics
- M = 40 (UMG 604, UMG 508, UMG 96RM)
- M = 63 (UMG 605, UMG 511)
- Mains frequency fund equals n = 1

$$THD_I = \frac{1}{\left|I_{fund}\right|}\sqrt{\sum_{n=2}^{M}\left|I_{n.Harm}\right|^2}$$

ZHD

- ZHD is the THD for interharmonics
- Is calculated in the device series UMG 511 and UMG 605

Interharmonics

- Sinusoidal form oscillations, whose frequencies are not whole multipliers of the mains frequency (fundamental oscillation)
- Is calculated in the device series UMG 511 and UMG 605
- Calculation and measurement processes according to DIN EN 61000-4-30
- The ordinal number of an interharmonic equates to the ordinal number of the next smallest harmonic. For example, the 3rd interharmonic lies between the 3rd and 4th harmonics.

TDD (I)

- TDD (Total Demand Distortion) gives the relationship between the current harmonics (THDi) and the effective current value with full load.
- IL = Full load current
- M = 40 (UMG 604, UMG 508, UMG 96RM)
- M = 63 (UMG 605, UMG 511)

$$TDD = \frac{1}{I_L}\sqrt{\sum_{n=2}^{M} I_n^2} \times 100\%$$

Ripple control signal U (EN 61000-4-30)

The ripple control signal U (200 ms measured value) is a voltage measured with a carrier frequency specified by the user. Only frequencies below 3 kHz are taken into consideration.

Ripple control signal I

The ripple control signal I (200 ms measured value) is a current measured with a carrier frequency specified by the user. Only frequencies below 3 kHz are taken into consideration.

Positive-negative-zero sequence component

- The proportion of voltage or current unbalance in a three-phase system is labelled with the positive, negative and zero sequence components.
- The symmetry of the three-phase system strived for in normal operation is disturbed by unbalanced loads, faults and operating equipment.
  - A three-phase system is referred to as exhibiting symmetry if the three phase conductor voltages and currents are of an equal size and are phase-shifted at 120° to each other. If one or both conditions are not fulfilled then the system is deemed unbalanced. Through the calculation of the symmetrical components comprising positive sequence component, negative sequence component and zero sequence component a simplified analysis of an unbalanced fault in a three-phase system is possible.
- Unbalance is a characteristic of the power quality, for which threshold values have been stipulated in international standards (e.g. EN 50160).

Positive sequence component

$$U_{Pos} = \frac{1}{3}\left| U_{L1,fund} + U_{L2,fund} \cdot e^{j\frac{2\pi}{3}} + U_{L3,fund} \cdot e^{j\frac{4\pi}{3}} \right|$$

Negative sequence component

$$U_{Neg} = \frac{1}{3}\left| U_{L1,fund} + U_{L2,fund} \cdot e^{-j\frac{2\pi}{3}} + U_{L3,fund} \cdot e^{-j\frac{4\pi}{3}} \right|$$

Zero sequence component

A zero sequence component can only arise if a total current is able to flow back via the neutral conductor.

$$U_{\text{Zero sequence component}} = \frac{1}{3}\left|U_{L1,fund} + U_{L2,fund} + U_{L3,fund}\right|$$

Voltage unbalance

$$\text{Voltage unbalance} = \frac{U_{Neg}}{U_{Pos}}$$

Downward deviation U (EN 61000-4-30)

$$U_{down} = \frac{U_{din} - \sqrt{\frac{\sum_{i=1}^{n} U_{rms-down,i}^{2}}{n}}}{U_{din}}[\%]$$

Downward deviation I

$$I_{down} = \frac{I_{\text{Rated current}} - \sqrt{\frac{\sum_{i=1}^{n} I_{rms-down,i}^{2}}{n}}}{I_{\text{Rated current}}}[\%]$$

K factor

- The K factor describes the increase in eddy current losses with a harmonics load. In the case of sinusoidal loading of the transformer the K factor = 1. The greater the K factor, the more heavily a transformer can be loaded with harmonics without overheating.

Power Factor (arithmetic)

- The power factor is unsigned.

$$PF_A = \frac{|P|}{S_A}$$

Cosphi – Fundamental Power Factor

- Only the fundamental oscillation is used in order to calculate the cosphi
- Cosphi sign:
  - = for delivery of effective power
  + = for consumption of effective power

$$PF_1 = \cos(\varphi) = \frac{P_1}{S_1}$$

Cosphi sum

- Cosphi sign:
  - = for delivery of effective power
  + = for consumption of effective power

$$\cos(\varphi)_{Sum_3} = \frac{P_{1_{fund}} + P_{2_{fund}} + P_{3_{fund}}}{\sqrt{(P_{1_{fund}} + P_{2_{fund}} + P_{3_{fund}})^2 + (Q_{1_{fund}} + Q_{2_{fund}} + Q_{3_{fund}})^2}}$$

$$\cos(\varphi)_{Sum_4} = \frac{P_{1_{fund}} + P_{2_{fund}} + P_{3_{fund}} + P_{4_{fund}}}{\sqrt{(P_{1_{fund}} + P_{2_{fund}} + P_{3_{fund}} + P_{4_{fund}})^2 + (Q_{1_{fund}} + Q_{2_{fund}} + Q_{3_{fund}} + Q_{4_{fund}})^2}}$$

Phase angle Phi

- The phase angle between current and voltage of phase conductor p is calculated and depicted per DIN EN 61557-12.
- The sign of the phase angle corresponds with the sign of the reactive power.

Fundamental oscillation reactive power

The fundamental oscillation reactive power is the reactive power of the fundamental oscillation and is calculated with the Fourier analysis (FFT). The voltage and current do not need to be sinusoidal in form. All reactive power calculations in the device are fundamental oscillation reactive power calculations.

Reactive power sign

- Sign Q = +1 for phi in the range 0 ... 180 ° (inductive)
- Sign Q = -1 for phi in the range 180 ... 360 ° (capacitive)

$$Sign\ Q(\varphi_p) = +1\ if\ \varphi_p \in [0° - 180°]$$

$$Sign\ Q(\varphi_p) = -1\ if\ \varphi_p \in [180° - 360°]$$

Reactive power for phase conductor p

- Reactive power of the fundamental oscillation

$$Q_{fund\,p} = Sign\ Q(\varphi_p) \cdot \sqrt{S_{fund\,p}^{\,2} - P_{fund\,p}^{\,2}}$$

Total reactive power

- Reactive power of fundamental oscillation

$$Q_V = Q_1 + Q_2 + Q_3$$

Distortion reactive power

- The distortion reactive power is the reactive power of all harmonics and is calculated with the Fourier analysis (FFT).

$$D = \sqrt{S^2 - P^2 - Q_{fund}^2}$$

- The apparent power S contains the fundamental oscillation and all harmonic portions up to the Mth harmonic.
- The effective power P contains the fundamental oscillation and all harmonic portions up to the Mth harmonic.
- M = 40 (UMG 604, UMG 508, UMG 96RM)
- M = 63 (UMG 605, UMG 511)

Reactive energy per phase

$$E_{r_{L1}} = \int Q_{L1}(t) \cdot \Delta t$$

Reactive energy per phase, inductive

$$E_{r(ind)_{L1}} = \int Q_{L1}(t) \cdot \Delta t \qquad \text{for } Q_{L1}(t) > 0$$

Reactive energy per phase, capacitive

$$E_{r(cap)_{L1}} = \int Q_{L1}(t) \cdot \Delta t \qquad \text{for } Q_{L1}(t) < 0$$

Reactive energy, sum L1–L3

$$E_{r_{L1,L2,L3}} = \int (Q_{L1}(t) + Q_{L2}(t) + Q_{L3}(t)) \cdot \Delta t$$

Reactive energy, sum L1–L3, inductive

$$E_{r(ind)_{L1,L2,L3}} = \int (Q_{L1}(t) + Q_{L2}(t) + Q_{L3}(t)) \cdot \Delta t$$

for $Q_{L1}(t) + Q_{L2}(t) + Q_{L3}(t) > 0$

Reactive energy, sum L1–L3, capacitive

$$E_{r(cap)_{L1,L2,L3}} = \int (Q_{L1}(t) + Q_{L2}(t) + Q_{L3}(t)) \cdot \Delta t$$

for $Q_{L1}(t) + Q_{L2}(t) + Q_{L3}(t) < 0$

The contents, performance features and diagrams provided in this catalogue are not always reflective of the actual case in their described form and may also be subject to change due to ongoing product developments. The text and images contained herein have been generated with due care and diligence. However, it is not possible to fully exclude errors from arising. The desired performance features are only binding if these are expressly agreed upon conclusion of the contract. Subject to technical change and delivery amendments.

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