EPOS 360. APPLICATION

EPOS – ELECTRONIC POWER SOURCE
CURRENT / VOLTAGE SOURCES GUIDE

EPOS 360

Signal generator EPOS 360 - A laboratory for power quality

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Power quality monitoring in the power system is an important task for utilities and their customers. Power supply operation is improved and maintained by systematic analysis of power quality disturbances.

The power supply is designed to operate with a sinusoidal voltage at a constant frequency. However, in a power supply system, various types of loads and faults cause power quality disturbances. Power quality disturbances occur when the magnitude of the voltage, frequency, and waveform deviation change significantly due to various conditions such as nonlinear loads, switching of loads, weather conditions, etc.
The effects of poor power quality depend on the duration, magnitude, as well as the sensitivity of the connected equipment. Poor power quality can cause process interruptions, loss of data, malfunction of computer-controlled equipment, and overheating of electrical equipment.

In the real power supply environment, it is difficult to generate power quality events in order to analyze their characteristics and effects.
It is important to be able to generate power quality disturbances. A variety of waveforms can be generated by simulations and be useful for disturbance detection and classification.

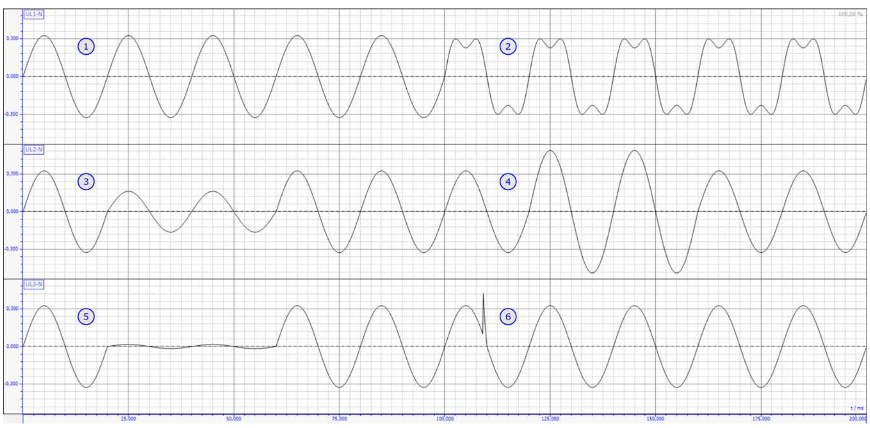

Figure 1, Mains signals: 1 Sine, 2 Harmonics, 3 Undervoltage, 4 Overvoltage, 5 Voltage interruption, 6 Transient

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The voltage quality level is defined according to the relevant international standards and regulations. For normal operating conditions, the EN 50160 standard defines the voltage characteristics that should be supplied by the power supplier.
The required quality level is determined by reference nominal values and permissible limits for standard quality parameters and network disturbances. Relevant information required for quality assessment can be provided by measuring and processing power quality parameters at specific points in the distribution network.

Therefore, a system is needed with the possibility to generate and output diverse three-phase signal characteristics. With the software-based signal generator system EPOS 360, an overall system has been realized with which three-phase power quality events can be simulated in a simple way.
Three-phase voltage and current signals with various signal disturbances can be generated with the EPOS operating software, such as voltage dips and interruptions, transient pulses and distortions of the voltage or current signal caused by the influence of higher-order harmonic components.

EPOS 360
Multifunctional three-phase signal generator

With the EPOS 360 current and voltage source, KoCoS Messtechnik AG offers a signal generator that is recommended wherever maximum power and the highest signal precision are required.
EPOS 360 has four voltage and three current signal sources. The signal waveforms are output via electronic power amplifiers.
The amplitude, phase and frequency parameters can be varied over a wide range during output.

EPOS 360 in 19" installation housing, 3 U

Intelligent amplifier technology and synthetic signal generation allow any waveform to be output over a wide frequency range or even complex transient waveforms to be played back.
The TRANSIG monitor included in the EPOS operating software allows graphical display and output of recordings available in SigDef format or in the standardized COMTRADE format. The corresponding signal progressions are „played back" by EPOS as a transient sequence during tests.
In addition, the EPOS operating software contains a Signal Editor, which allows the parameterization and calculation of any signal sequences. These can be generated from a basic function, e.g. a sine and its superposition with one or more superposition functions, such as a DC component, exponential functions, harmonics, etc..
For special requirements, e.g. for use in test stands, there is an additional simple programming interface. This can be used in COM/ActiveX supporting as well as in .NET environments.

EPOS-Operating software

Different monitors are available in the software for parameterization and output of signals and test sequences.
The **TRANSIG-Monitor** module can be used to check the function of a device under test under real conditions. The TRANSIG-Monitor enables the graphical display and output of recordings and signal curves. Signal curves can be, for example, recordings of fault recording systems or digital protection relays, which are available in the standardized COMTRADE format, or SigDef files with self-defined signals.

The functions of the TRANSIG monitor are:

- Loading of recordings in COMTRADE format or SigDef files.
- Assignment of the signals of the recording to the EPOS output signals.
- Scaling of the signals of the recordings.
- Transfer of the defined TRANSIG functions into a test plan.

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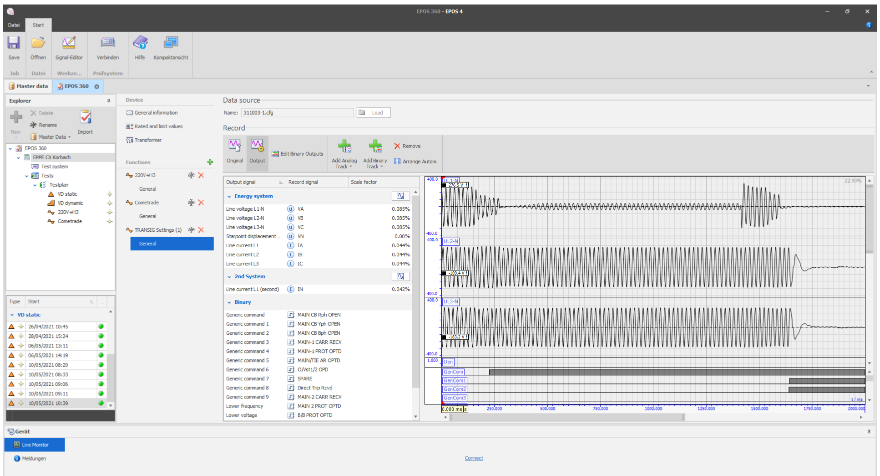

Figure 2: TRANSIG monitor with loaded COMTRADE recording

Another component of the EPOS operating software is the **Signal Editor.** The signal editor enables the definition, parameterization and calculation of any signal characteristics. The parameterization of the signals is done interactively on the screen. A signal duration can be set for each channel and each channel can in turn be divided into any number of time windows of different lengths. Within the time windows different function curves can be synthesized. It is possible to synthesize the function curves from a basic function, such as

- sine,
- rectangle,
- sawtooth,
- triangle,
- DC

and their additive or multiplicative superposition with one or more superposition functions.

Superpositions can be functions such as

- sine,
- exponential functions,
- ramps,
- DC,
- impulse,
- harmonics,
- mathematical expressions.

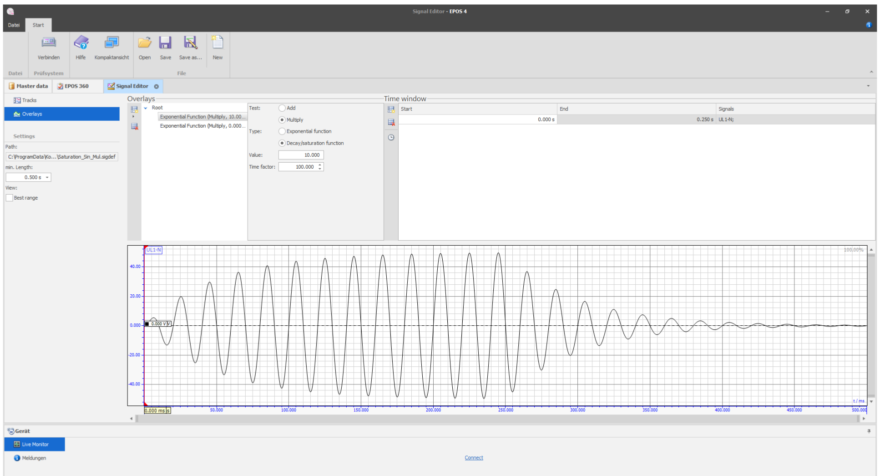

Figure 3: Signal editor with decay/saturation function and superimposed sine wave

In particular, mathematical expressions are to be referred to in the overlays, since the creation of formulas offers a wide range of possibilities for signal generation. The „Expression" overlay function is used to create a curve using mathematical inputs.

Modeling and generating power quality disturbances

The waveforms of the possible disturbances are created by mathematical models in the following. The EPOS 360 three-phase signal generator and the EPOS operating software are available for modeling and generating signals for analyzing the events in the power supply system.

The mathematical models of the power quality signals are implemented in the EPOS operating software using the „Signal Editor" module. The use of equations offers advantages as it is possible to vary signal parameters over a wide range and in a controlled manner.

The following pictures show the different power quality signals defined via the Signal Generator module.

Ideal voltage/current source

An ideal AC voltage source generates a continuous, smooth sinusoidal voltage.

	Signal *Signal*	Gleichung *Equation*	Parameter *Parameters*
1	Sinus *Sine*	$y(t) = A \cdot \sin(\omega t)$	$\omega = 2\pi \cdot f$ *A:* Amplitude des Signals *Amplitude of the signal* *f:* Grundfrequenz *Fundamental frequency* *f=1/T*

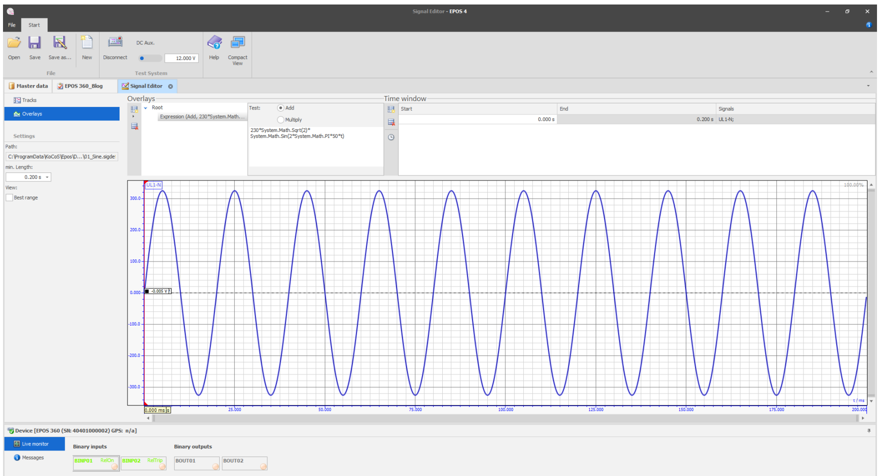

Figure 4: Sine wave

Voltage fluctuations

A drop (undervoltage, voltage dips) or rise (overvoltage, swell) of the mains voltage of at least ½ cycle up to several seconds.

2	Unterspannung *Undervoltage (Sag)*	$y(t) = A \cdot \left(1 - \alpha \cdot \left(u(t - t_1) - u(t - t_2)\right)\right) \cdot \sin(\omega t)$	$u(t) = \begin{cases} 0 & t < 0 \\ 1 & t \geq 0 \end{cases}$ $T \leq t_2 - t_1 \leq (N-1) \cdot T$ $0.1 \leq \alpha \leq 0.9$ *N:* Anzahl Zyklen der Grundfrequenz *Number of cycles of the fundamental frequency*
3	Überspannung *Overvoltage (Swell)*	$y(t) = A \cdot \left(1 + \beta \cdot \left(u(t - t_1) - u(t - t_2)\right)\right) \cdot \sin(\omega t)$	$0.1 \leq \beta \leq 0.8$

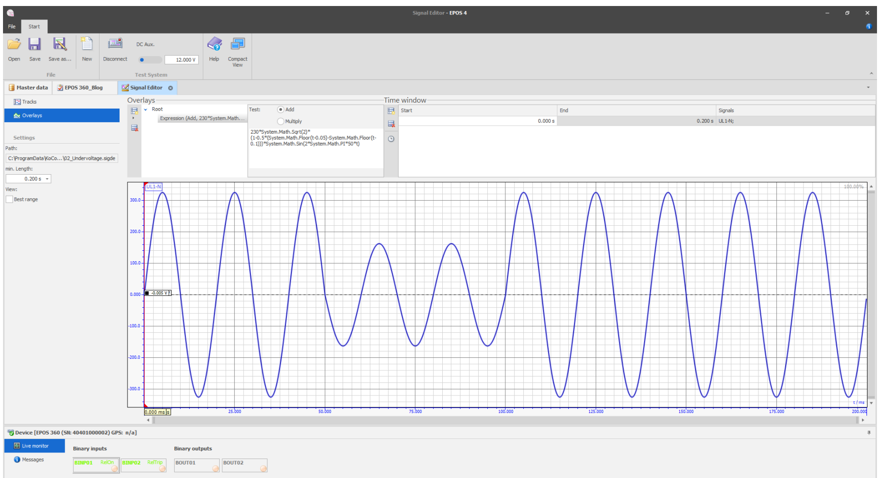

Figure 5: Undervoltage

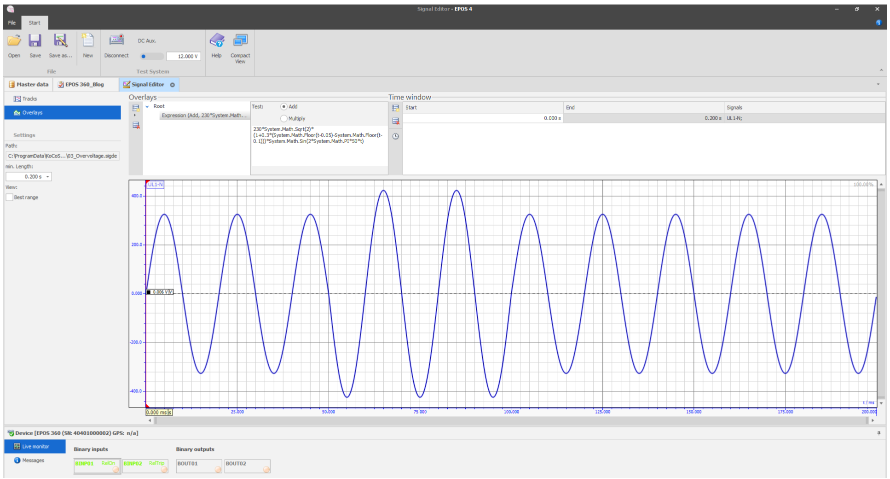

Figure 6: Overvoltage

Voltage interruptions

A significant or complete voltage interruption. The interruption can be short but also permanent.

4	Spannungsunterbrechung *Voltage interruption*	$y(t) = A \cdot \left(1 - \rho \cdot \left(u(t - t_1) - u(t - t_2)\right)\right) \cdot \sin(\omega t)$	$0{,}9 \leq \rho \leq 1{,}0$

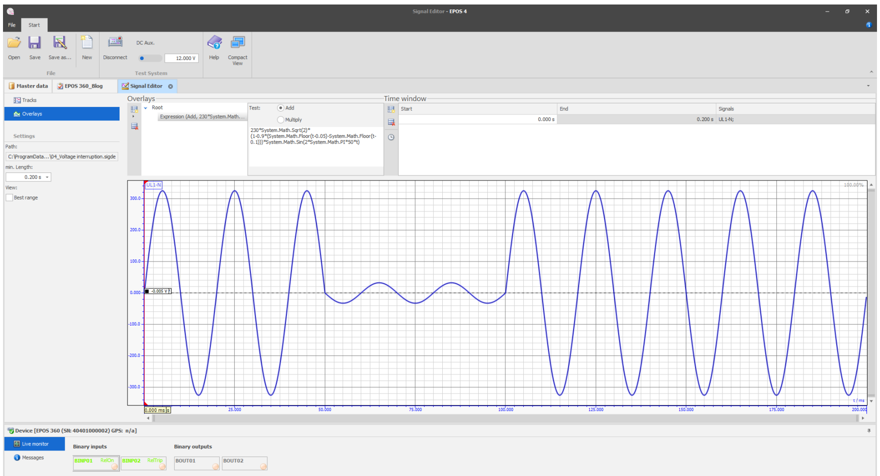

Figure 7: Voltage interruption

Harmonics

Distortion of voltage and current waveforms caused, for example, by operation of nonlinear loads.

5	Oberschwingungen *Harmonics*	$y(t) = A \cdot \left(\sin(\omega t) + \sum_{n=3}^{7} \alpha_n \cdot \sin(n \cdot \omega t) \right)$	$n = \{3{,}5{,}7\}$: $0{,}05 \le \alpha_n \le 0{,}15$

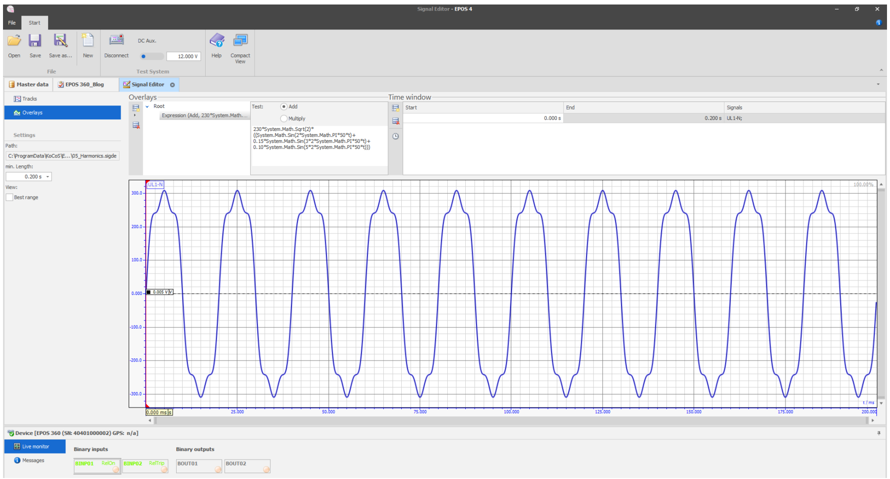

Figure 8: Harmonics

Transient

A sudden disturbance in the line voltage that typically lasts less than one period and consequently the waveform becomes discontinuous.

6	Transienten *Transients*	$y(t) = A \cdot \left(\sin(\omega t) - \psi \cdot \left(e^{-750(t-t_a)} - e^{-344(t-t_a)} \right) \left(u(t-t_a) - u(t-t_b) \right) \right)$	$T \le t_a \le (N-1) \cdot T$ $t_b = t_a + 1ms$ $0{,}222 \le \psi \le 1{,}11$

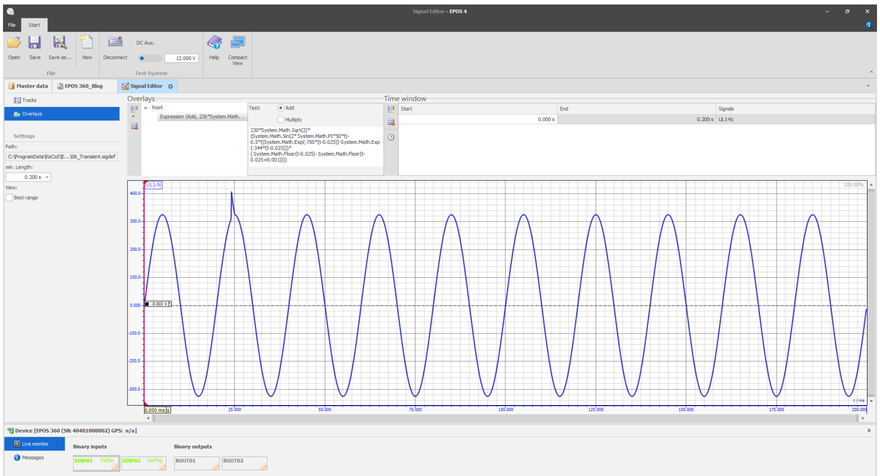

Figure 9: Transients

Verify mains signals of the signal generator

The voltage waveforms generated with the EPOS operating software and the EPOS 360 signal generator are measured and checked with the EPPE PX power quality analyzer.

Figure 10: System for checking the EPOS 360 signal generator with the power quality analyzer EPPE PX

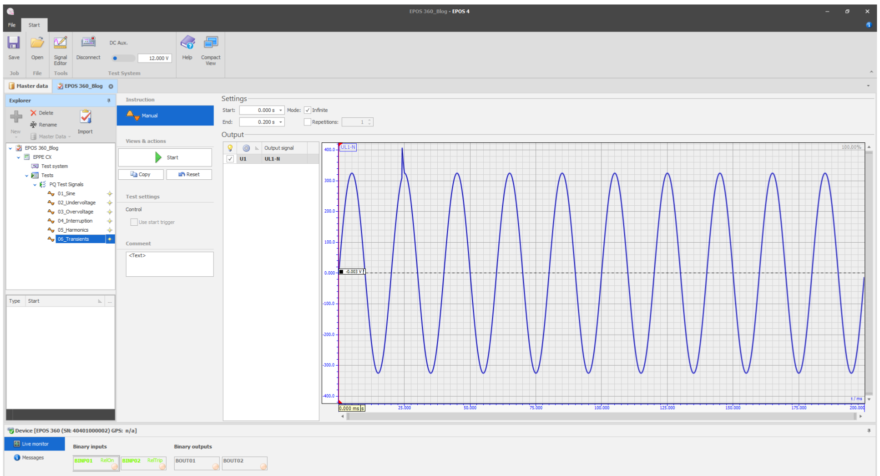

Figure 11: Test plan with mains signals in the EPOS operating software

The EPPE software enables direct communication between the EPPE PX power quality analyzer and a PC, so that the measurement results can be easily transferred to the computer and processed.

The mathematical models presented in the section „Modeling and generating power quality disturbances“ were adapted for the test to generate three-phase voltage signals, with the disturbances generated only on phase L1 (red). For the mains signals, such as undervoltage, 10 repetitions of the signal sequence were parameterized in each case.

The following pictures show voltage signals generated by the signal generator and recorded with the EPPE PX reference instrument.

Sinus

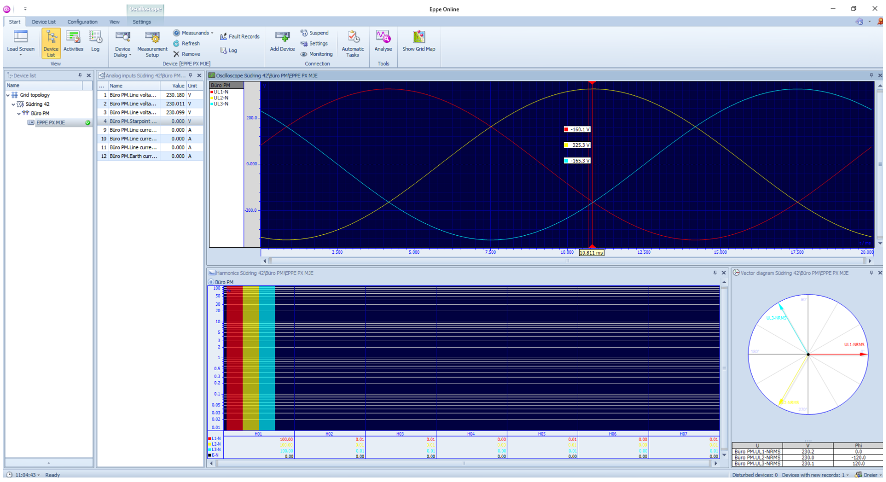

Figure 12: Sinusoidal signals recorded with the EPPE reference device (online measured values)

Un = 3 x 230 V, 120° Phase shifting

EPPE-Measurement values:
$U1_{(red)}$ = 230.18 V; 0.0°
$U2_{(yellow)}$ = 230.01 V; -120.0°
$U3_{(blue)}$ = 230.09 V; 120.0°

Harmonics

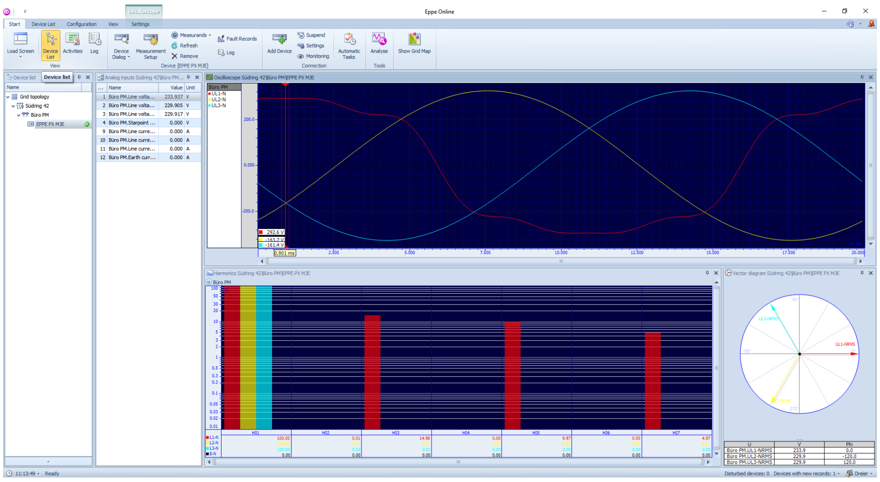

Figure 13: Measurement of harmonics on U1 (online measured values)

To the fundamental (230 V/50 Hz), the 3rd harmonic was superimposed with 15%, the 5th with 10% and the 7th with 5% related to the fundamental amplitude in percent.

EPPE-Measurement values:
H3: 14.98 %
H5: 9.97 %
H7: 4.97 %

Undervoltage

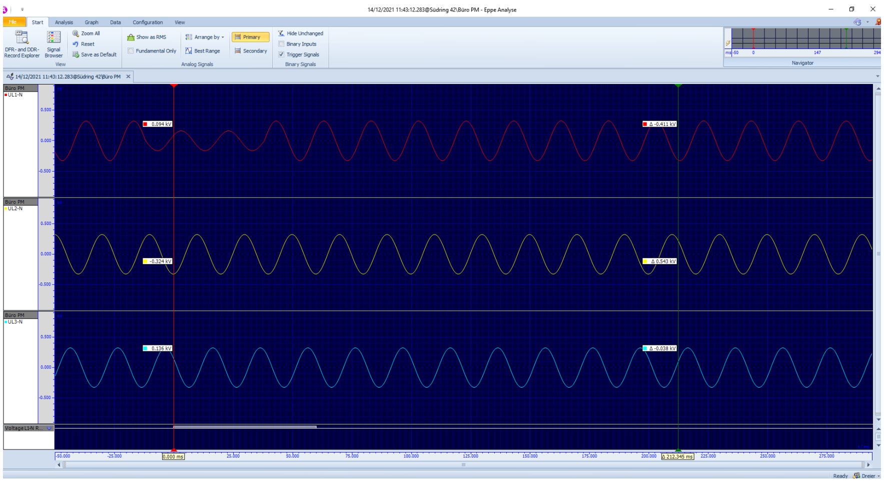

Figure 14: Fault recorder recording of the EPPE software, undervoltage

U_{UV} = 50 % Un
Duration: 50 ms
Trigger: Undervoltage trigger

Overvoltage

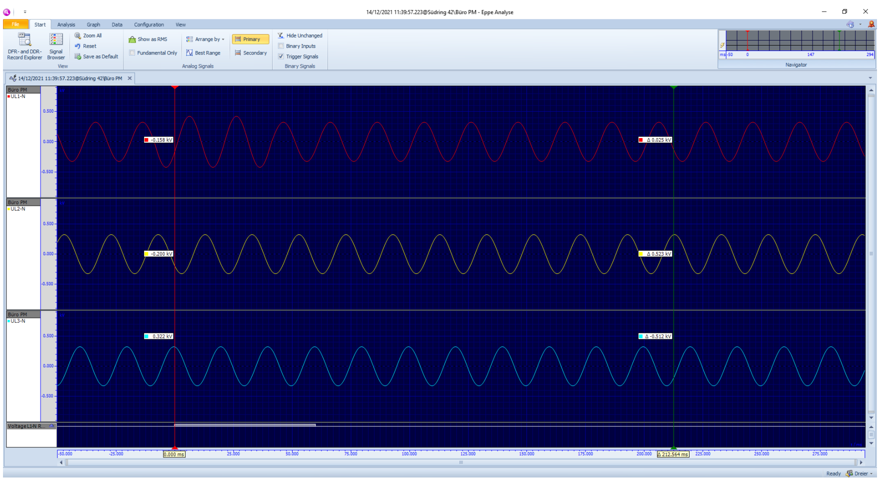

Figure 15: Fault recorder recording, overvoltage

U_{OV} = 130 % Un
Duration: 50 ms
Trigger: Overvoltage trigger

Remark:
The EPOS 360 can output a maximum peak voltage of √2*300 V = 424.2 V via the voltage outputs (300 VAC, RMS).

Voltage interruption

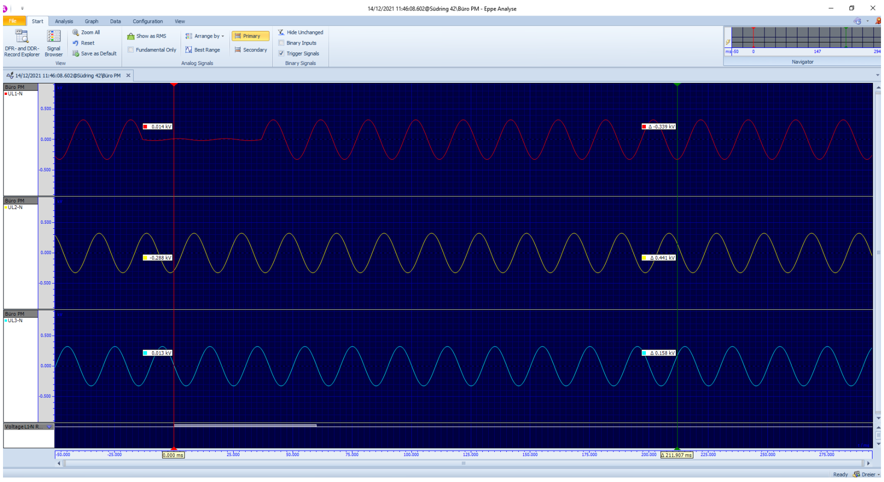

Figure 16: Fault recorder recording, voltage interruption

U_{VI} = 5 % Un
Duration: 50 ms
Trigger: Undervoltage trigger

Transient signal

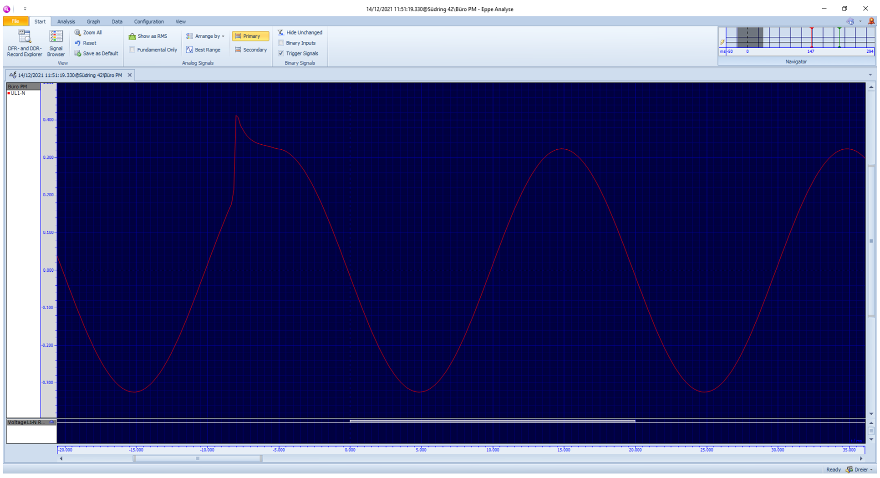

Figure 17: Disturbance recorder recording, transient signal

Trigger: Overvoltage trigger, 105 % Un
The signal has been enlarged for better display.

Conclusion

In this application note, the basis for generating typical power quality disturbances was presented. This signal generation solution includes the EPOS 360 signal generator supported by a PC with the EPOS operating software.

EPOS 360 in portable housing

The software includes the Signal Editor module, which can be used to adjust parameters such as amplitude, phase angle and frequency for signal generation. Furthermore, the module offers many other functions for adjusting the basic parameters, such as offsets, overlays and harmonics.

The hardware and software functionality makes it very easy to perform the generation of diverse waveforms. The generation of the defined waveforms is provided by four voltage and three current output channels of the EPOS 360.
The three-phase signal generator EPOS 360 offers the possibility to apply signal waveforms to the test object and to analyze the effects. The overall EPOS 360 system with the EPOS operating software thus provides a useful mechanism for understanding and explaining mains phenomena without much effort.
The EPOS 360 signal generator is thus capable of simulating power quality disturbances in accordance with the EN 50160 standard. The described solution can be easily adapted to various practical requirements and can thus be used as a good and cost-effective alternative to expensive instruments for checking power quality meters and analyzers.