Three-phase signal generator for precise power network simulations

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Power quality monitoring is an important topic for energy suppliers and their customers. The operation of the power system can be improved and maintained by systematically analyzing the power quality.
Since it is difficult to generate power quality events in the real power supply environment, this paper presents a three-phase signal generator for generating and studying corresponding signals.

Power quality

The design of electrical equipment and components is becoming increasingly sophisticated and requires an uninterrupted and clean power supply. Electronic devices, such as computers and automated electronic equipment, used in industrial, commercial or residential environments are sensitive to many types of power quality disturbances.
In general, power quality disturbances are an important issue for electric utilities, electricity customers and consumers, but also for measurement equipment manufacturers.

The quality of supply is determined by the nature of supply voltages and currents. Furthermore, by network effects, which are introduced into the distribution network by the connected consumers and the decentralized energy generators. In order to reduce the influence of disturbances and equipment failures at the utility customers, the quality of the supplied voltages and currents must be continuously monitored and analyzed.
Reference values of the parameters to be monitored, including limit values and measurement intervals, are prescribed by the relevant national and international norms and PQ standards.
Information regarding the quality of voltages and currents in the distribution network can only be created by measuring and detailed processing of the measurement results in relation to the standardized PQ parameters.

Consequently, corresponding PQ data and signals are required for the development of measuring devices for the analysis and diagnosis of power quality. Due to the difficulty of recording real disturbances in the network, a signal generator that can simulate PQ signals is required for checking components.

Current and voltage source for network simulations

Conventional voltage sources cannot meet the requirements for complex signal generation. A conventional signal generator can only generate various types of general waveforms, but not PQ signals. However, the generation of typical power quality signals is an important requirement for scientific experiments, adjustments and calibrations.

Figure 1: EPOS 360 signal generator with EPPE CX power quality analyzer

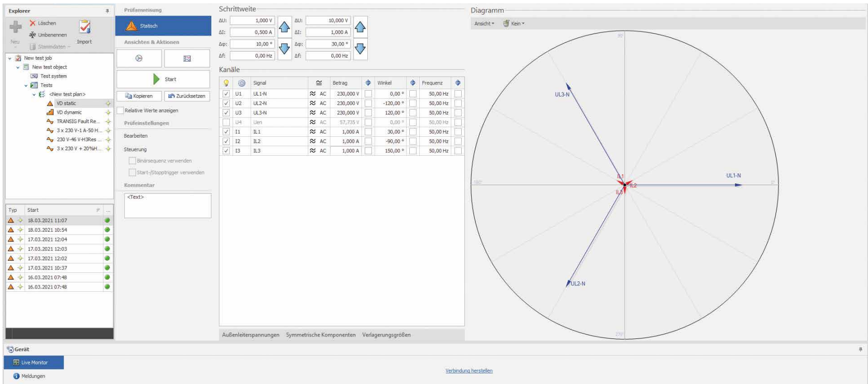
ELECTRONIC POWER SOURCE

A signal generator that meets this requirement is the EPOS 360 three-phase current and voltage source from KoCoS Messtechnik AG. In addition to the sinusoidal current and voltage waveforms of a single-phase or three-phase system, EPOS 360 can generate the various categories of PQ disturbances such as waveform distortion, undervoltages or overvoltages, voltage unbalances and transients. By using the EPOS 360 three-phase current and voltage source, the required waveforms can be generated easily and quickly.

EPOS 360 has four voltage and three current signal sources. The signal characteristics are calculated by a powerful signal processor and output via high-precision power amplifiers. The parameters amplitude, phase angle and frequency are separately and independently adjustable as well as overload and short-circuit protected and can be varied over a wide range during output.
The signals or waveforms can be used to check and calibrate measuring instruments and devices designed for monitoring, measuring and software-based processing of basic power quality parameters.

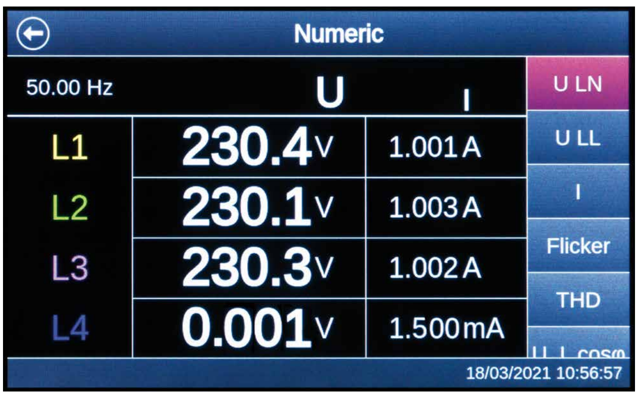
Operation and control

The EPOS 360 signal generator can be operated and controlled by means of the internal operating unit, via the EPOS operating software by a standard PC or a simple programming interface for integration into external test environments.
Different monitors are available in the software for parameterization and output of signals and test sequences.
One basic module is the VD-Monitor. This monitor enables the testing of any test objects by manually setting the voltage and current values. Furthermore, the output signals can ramp through a set range (linear or stepped).

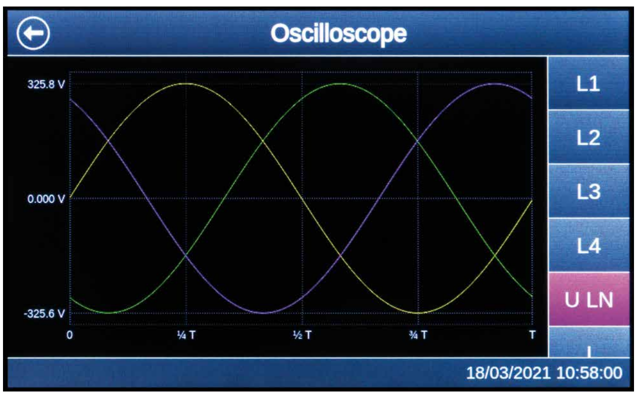


(a)

Figure 2: Generation of a three-phase AC voltage with EPOS 360 (a) and measurement with EPPE CX (b,c)



b)



c)

In addition, the software offers further adapted monitors. With the TRANSIG-Monitor module, the function of a DUT can be easily checked under real conditions. The TRANSIG-Monitor enables the graphical display and the output of recordings and signal curves via the signal generator EPOS 360. Signal curves can be e.g. recordings of disturbance detection systems or digital protection relays, which are available in the standardized COMTRADE format. During tests, the signal curves are replayed as a transient sequence via the hardware.

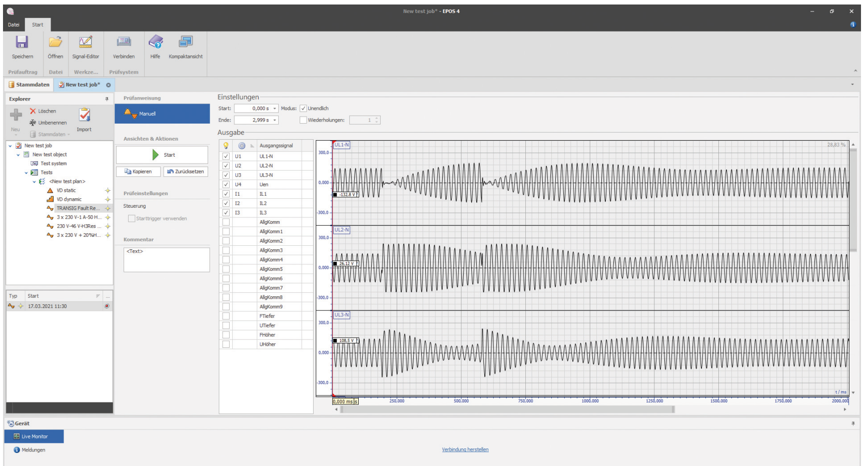


Figure 3: Visualization of a COMTRADE recording in the TRANSIG monitor of the EPOS operating software

Another component of the EPOS operating software is the signal editor. The signal editor enables the 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 individual channel. Each channel can in turn be divided into any number of time windows or time ranges of different lengths. Within the time windows, different function courses can be synthesized independently of each other. It is possible to generate the function curves from a basic function and its additive or multiplicative superposition with one or more superposition functions.

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Application example

As already described, voltages and currents in the network can show deviations from the sinusoidal shape. This can lead to disturbances in the operation of electrical components and also have an influence on the accuracy of measuring devices.

Curves whose shape deviate from the sinusoidal form can be generated from the superposition of a sinusoidal voltage or current and sinusoidal curves of a higher frequency. Depending on the network system, the fundamental wave is a sine wave of e.g. 16⅔, 50 or 60 Hz. The additional components with a higher frequency are called harmonics. These harmonics usually have a frequency 3, 5, 7, etc. times higher than the fundamental. Thus, at 50 Hz, the harmonics have frequencies of 150 Hz, 250 Hz, 350 Hz, etc. The peak values of the harmonics are usually smaller than the peak values of the fundamental.

To illustrate the generation of a distorted curve, in the following example a voltage with the fundamental is superimposed with a harmonic of three times the frequency (third harmonic). The harmonic has the same direction and passes through zero with the fundamental. The peak value of the harmonic is 20 % of the peak value of the fundamental. The addition of the instantaneous values of the fundamental and the harmonic gives the distorted curve.

Of interest may be the question, what is the RMS value of the voltage with a distorted curve. The RMS value of the voltage is calculated from

$$U = \sqrt{\frac{1}{2}(\hat{u}_1^2 + \hat{u}_3^2 + \hat{u}_5^2 + \ldots)}$$

$\hat{U}_N$: Peak values of the fundamental wave and the individual harmonics. Note: The above relationship applies equivalently to current curves.

The influence of the harmonics on the RMS value is less than would be expected from the ratio of the peak values of the harmonics to that of the fundamental.

Peak value of the fundamental wave: $\hat{u}_1 = 325{,}3\ \text{V}$
Peak value of the 3rd harmonic: $\hat{u}_3 = 65{,}1\ \text{V}$

For a pure sine wave, the peak values $\hat{u}_3$, $\hat{u}_5$ etc. are omitted and the relationship between RMS and peak value is obtained to:

$$U = \frac{\hat{u}}{\sqrt{2}}$$

From this, the RMS value of the fundamental wave is calculated to be

$$U = \frac{325{,}3\ \text{V}}{\sqrt{2}} = 230{,}0\ \text{V}$$

and the RMS value of the distorted curve

$$U = \sqrt{\frac{1}{2}((325{,}3\ \text{V})^2 + (65{,}1\ \text{V})^2)} = 234{,}6\ \text{V}$$

This value is only 1.98 % higher than the RMS value of the fundamental, although the peak value of the third harmonic is 20 % of the peak value of the fundamental.

Curves with the corresponding characteristics can be generated with the EPOS 360 signal generator by superimposing a second sine wave at 150 Hz on a fundamental wave at 50 Hz, where the peak value is 20% of the fundamental wave.

(a)

(b)

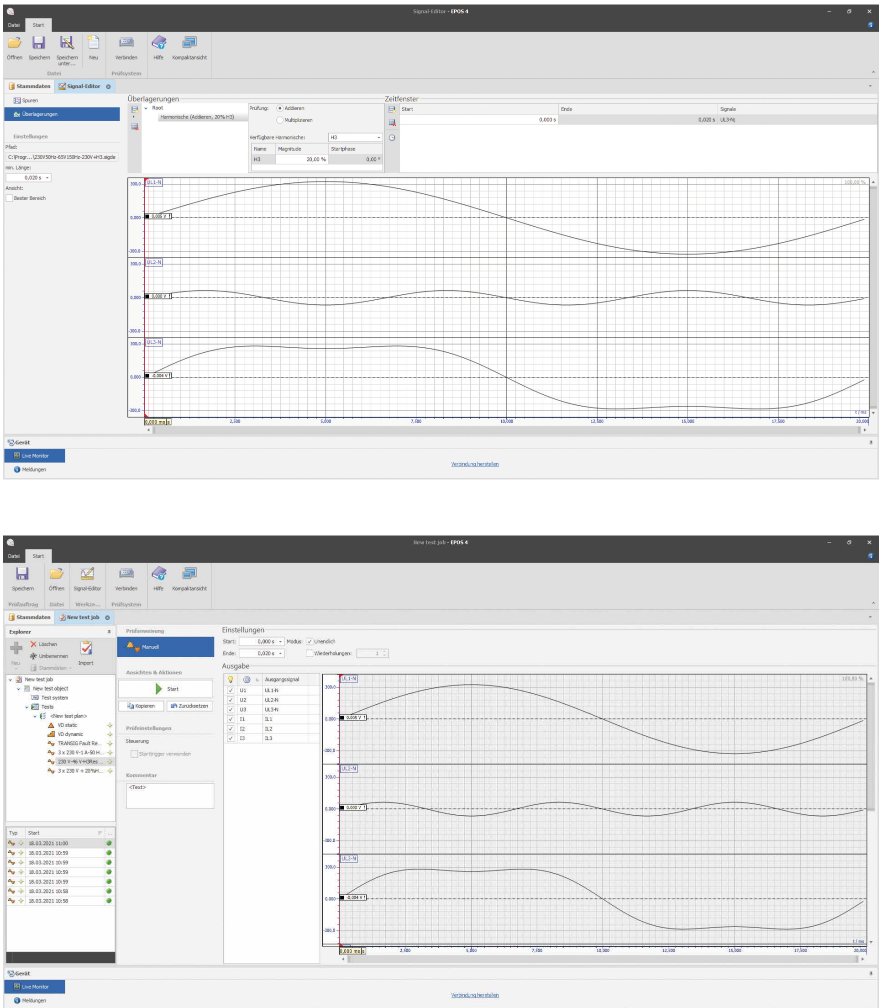
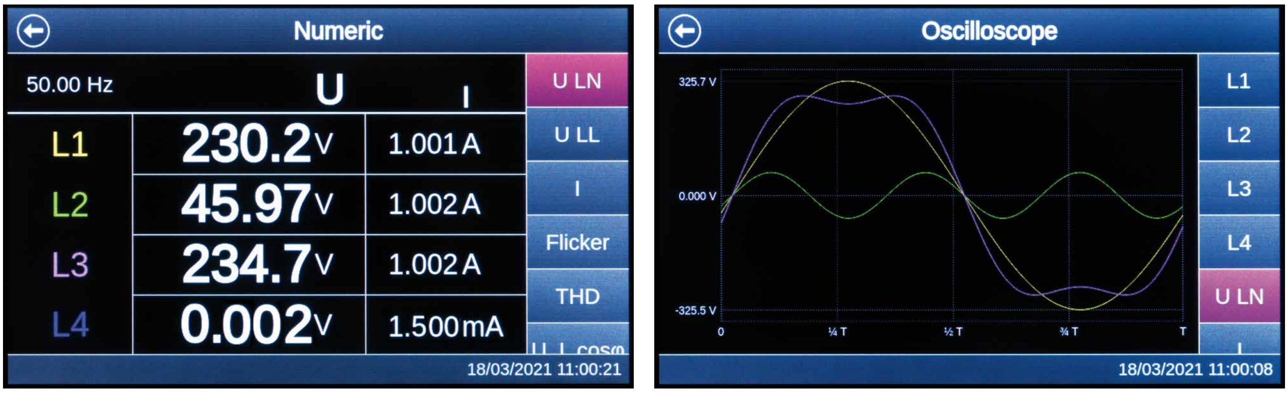


Figure 4: Creation of the signal waveforms via the Signal Editor module (a) and output of the waveforms via the TRANSIG monitor (b)



(a) (b)

Figure 5: Measurement of the defined voltages with 20 % share of the 3rd harmonic with power quality analyzer EPPE CX (a, b)
L1: fundamental wave, L2: third harmonic curve, L3: distorted curve

Conclusion

In the course of rising energy costs, increasing grid disturbances and the uncertainty of electricity customers, the testing of electrical components and measurement technology is becoming more and more important.
For the simulation and generation of grid signals and grid disturbances, EPOS 360 is an easy-to-use signal generator system. The system functionality is supported by professional software.

The signal generator system described can be used in procedures for developing instrumentation and electrical components to solve the problems of identification and mitigation in power system disturbances.

The signal generator also offers teachers and learners the possibility to analyze diverse signal characteristics, making it a useful tool in practical work for understanding and explaining power system phenomena.

In order to check the performance of electrical components and the plant, the use of the three-phase signal generator EPOS 360 thus has numerous advantages for manufacturers of measuring equipment, service providers, operators of electrical plants and energy suppliers. Corresponding test equipment thus offers a cost-effective, simple and fast option for on-site and also factory and laboratory testing.

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