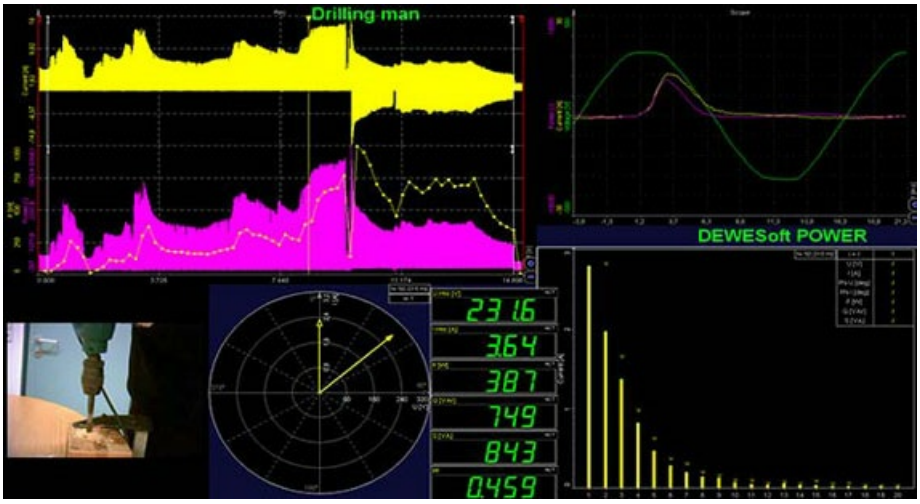
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Power Quality Analysis and Measurement



What is Power Quality?

The different Power Quality parameters describe the deviation of the voltage from its ideal sinusoidal waveform at a certain frequency. These deviations can lead to disturbances, outages or damages of electrical equipment connected to the grid. It is essential to permanently track these parameters: starting during the development phase (of the electrical equipment) up until the live operation and beyond: e.g. continuous monitoring of a couple of points in the electrical grid in order to prevent and correct quality disturbances.

The Dewesoft Power Quality Analyzer can measure all these parameters according to the IEC 61000-4-30 Class A Standard. In comparison to conventional Power Quality Analyzers it's possible to do more detailed analyses (e.g. raw data storing, behavior at faults, calculation of additional parameters etc.).

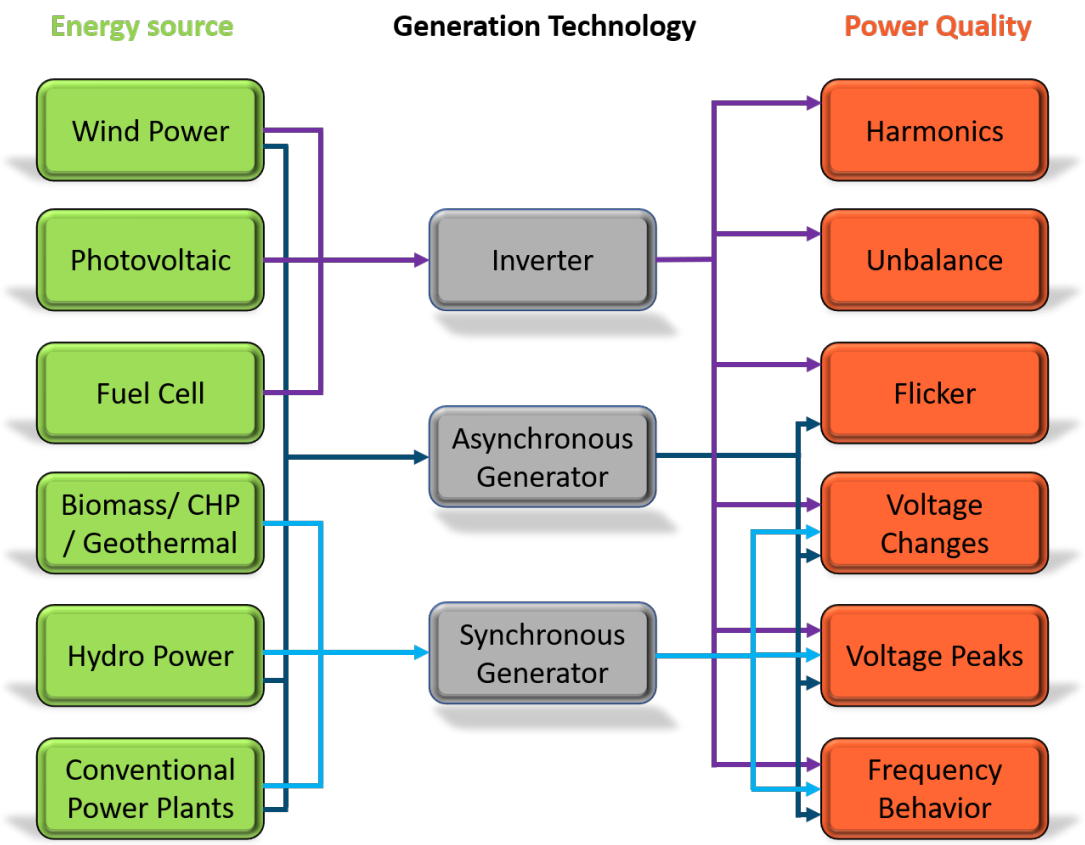


Image 1: Power quality application overview

The purpose of this chapter is to cover all Power Quality parameters which Dewesoft is able to calculate. After a short introduction and explanation of each parameter, a description on how the specific calculations are carried out and which variable names they are defined as in the Dewesoft X software.

To learn more about basic Power analysis and measurement, please visit our **POWER ANALYSIS** pro-training course.

What are Harmonics?

Harmonics are integer multiples of the fundamental frequency (e.g. 50 Hz for the grid in Europe) and cause a distortion in voltage and current of the original waveform. Harmonic voltages and currents caused by non-sinusoidal loads can affect the operation and lifetime of electrical equipment and devices. Harmonic frequencies in motors and generators can increase heating (iron & copper losses), can affect torque (pulsating or reduced torque), can create mechanical oscillations, and higher audible noise, it also causes aging of the shaft, insulation and mechanical parts and reduce the efficiency of the motor.

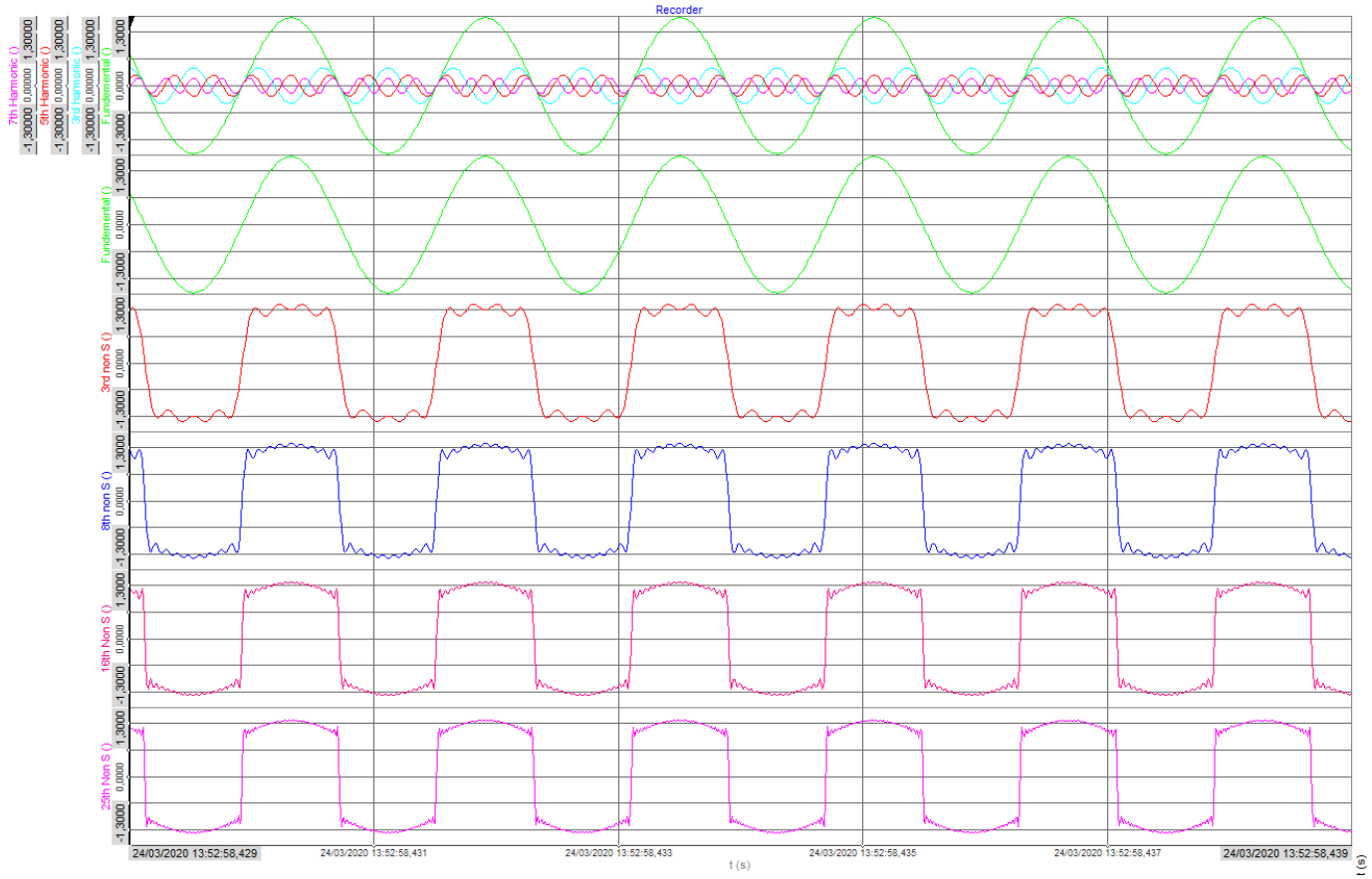


Image 2: Harmonic summation of sinusoidal waveforms

The image depicts such a case. In the first recorder, the fundamental frequency with the 3rd, 5th and 7th harmonic orders overlapping are depicted. So, what is the problem, they are all sinusoidal waveforms with different amplitudes, right? Well no, look at the second recorder this is the fundamental frequency, the perfect sinusoidal waveform would be perfect as all electrical equipment prefers receiving signals in this form as it is the ideal waveform to work with.

The problem with the harmonic orders is that they sum together with the fundamental frequency, causing non-sinusoidal waves to form. The recorders following the fundamental frequency depict what happens to the sinusoidal waveform as more and more harmonic orders are added. It is clearly visible that the higher the order goes the less sinusoidal the wave becomes. Already at the 25th harmonic order, it is visible how the waveform is changing onto a square wave. The higher the harmonic orders that are added to the waveform the squarer it will get. If there were infinitely many harmonics added to the waveform it would become a perfect square wave.

Overview

Current harmonics in transformers increase copper and stray flux losses. Voltage harmonics increase iron losses. The losses

are directly proportional to the frequency and, therefore, higher frequency harmonic components are more important than lower frequency components. Harmonics can also cause vibrations and higher noise. The effects on other electrical equipment and devices are very similar and are mainly: reduced efficiency and lifetime, increased heating, malfunction or even unpredictable behavior.

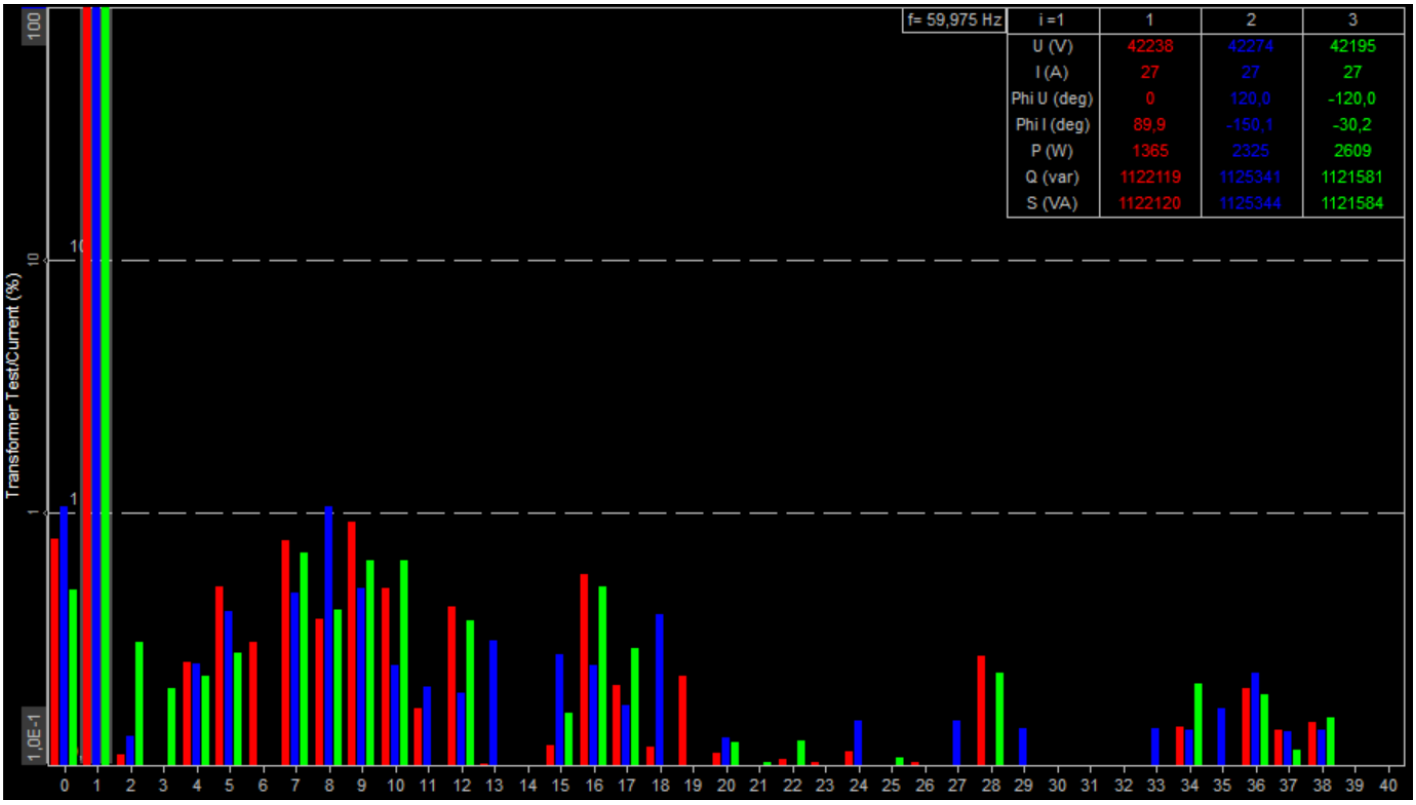


Image 3: Current harmonic measurement screen

Dewesoft measures harmonics for voltage and current as well as active and reactive power up to the 3000th order. All calculations are implemented according to IEC 61000-4-7 and can be selected in the power module according to the following image. In order to calculate higher harmonics, the sampling rate has to be adjusted accordingly, for instance at a sampling rate of 500 kS/sec or higher Dewesoft X can calculate up to the 3000th order.

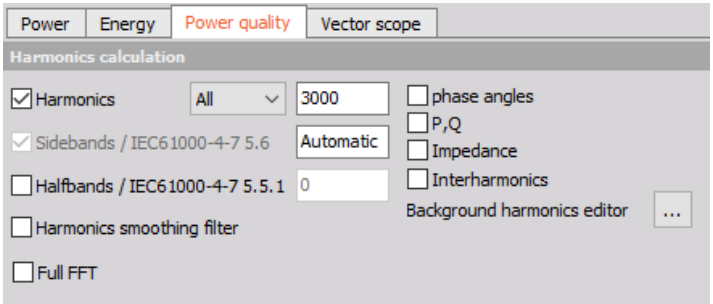


Image 4: Harmonic measurement options in the power module

Harmonics

Up to 500 harmonics can be calculated, in addition there is the option to choose all harmonics or just even or odd ones. If there are current channels used in the power module it is also possible to calculate phase angles, P, Q and the impedance.

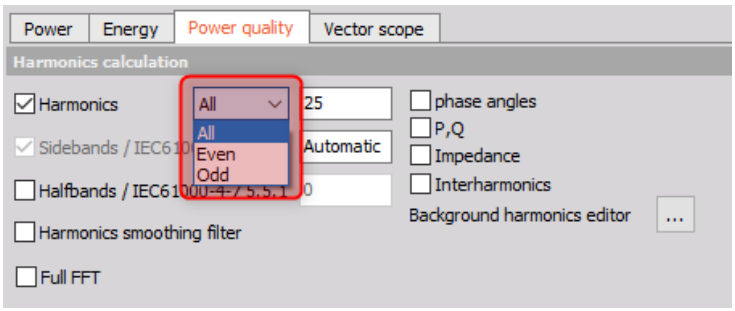


Image 5:Harmonic measurement calculation options in the power module

Number of sidebands

The basic idea of sidebands is that a certain frequency range is considered as one harmonic.

Example: 1 full sideband (equals +/-5Hz) at a frequency of 50 Hz means that a frequency range from 45-55 Hz is considered to be the first harmonic (it's the same for all other harmonics). If you select 2 sidebands the first harmonic will cover the frequency range 40 to 60 Hz.

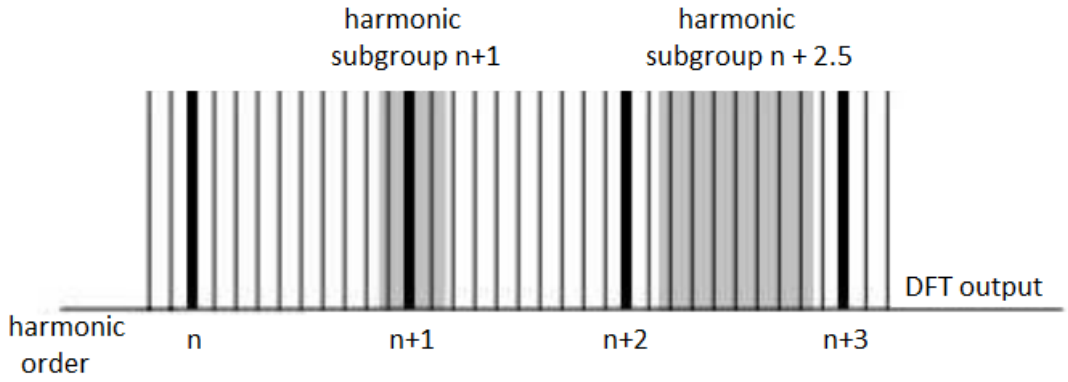


Image 6: Harmonic sidebands

Number of halfbands

The IEC 61000-4-7 (page 22) requires for the grouping of the harmonic sidebands where only the square root of the quadratic half should be added. This is required for the lowest and highest line and is defined as halfbands in Dewesoft.

Example I: 1 sideband and 1 halfband at a frequency of 50 Hz means that a frequency ranges from 45 to 55 Hz and the square root of the quadratic half of the 40 Hz to 60 Hz lines are considered to be the first harmonic.

Example II: 2 sidebands and 1 halfband at a frequency of 50 Hz mean that the lines from 40 Hz to 60 Hz have the full amplitude, while the lines at 35 Hz and 65 Hz are only considered with the square root of the quadratic half.

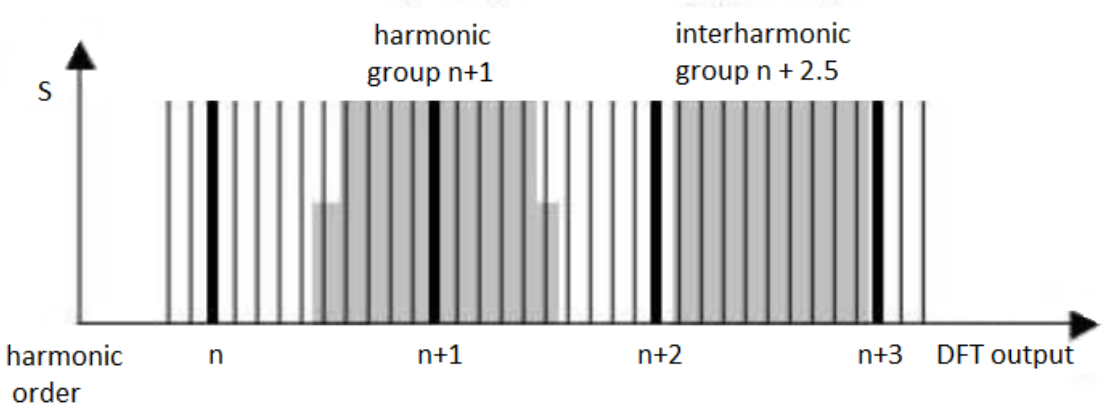


Image 7: Harmonic halfbands

Interharmonics

Interharmonics cover all lines not covered by the harmonics

Please refer to page 26 of IEC 61000-4-7

Example: 1 sideband and 1 halfband at a frequency of 50 Hz, the first interharmonic is the area between 0 Hz and 45Hz.

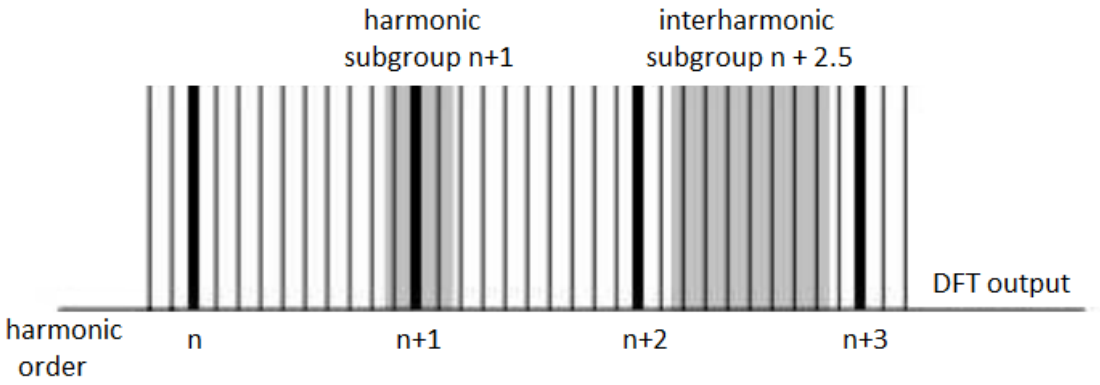


Image 8: Interharmonics

Group FFT lines

The higher frequency parts can be grouped in 200 Hz and in 2kHz bands up to 150 kHz.

Depending on which grouping the measurement might require. Dewesoft offers the possibility to select one or both of these harmonic groupings.

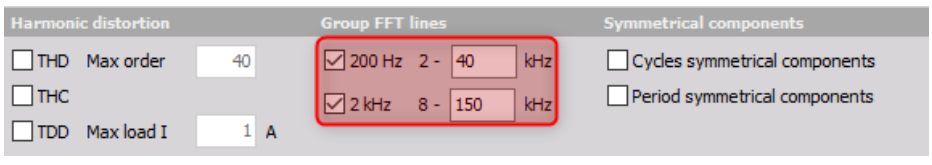


Image 9: Group FFT lines in the power module

Please be aware that according to page 29 of IEC 61000-4-7 these groups start at -95 Hz to +100 Hz around the middle frequency.

For 2.1 kHz, lines from 2005 Hz to 2200 Hz are considered to be one group.

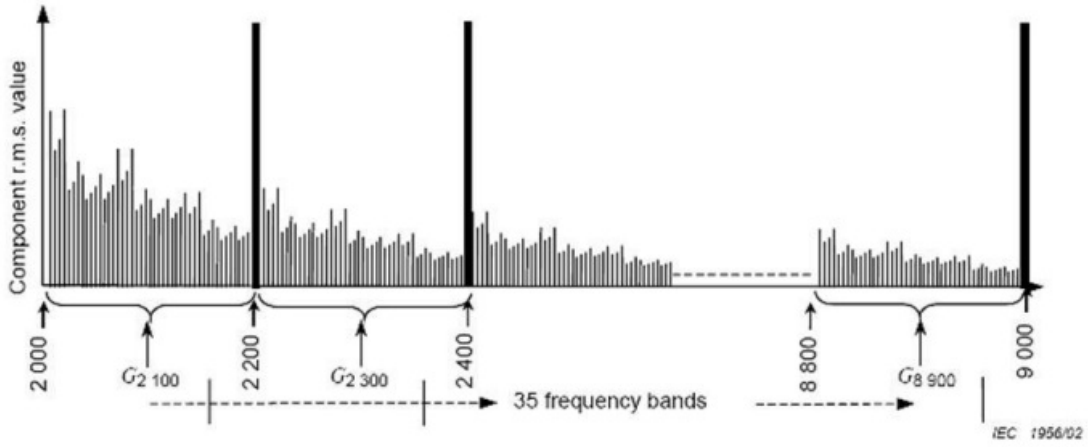


Image 10: Harmonic grouping according to the IEC 61000-4-7 standard

Full FFT

This option calculates a Full FFT which can then be exported to the database and displayed via a 2D-graph.



Image 11: Full FFT display options in the power module

Harmonics smoothing filter

This option enables the low-pass filter which is required according to the IEC 61000-4-7 standard, page 23.

Background harmonics

With this option it is possible to subtract an existing and known harmonic pattern (magnitude and phase) from measured values. This is a typical application for the commissioning of a powerful power converter in order to ascertain the noise of the converter.

This function is available for both voltage and/or current, and it can be selected from the background harmonics editor in Dewesoft X.

The only values that need to be entered for this calculation are the magnitude and the phase angle of the harmonic pattern as illustrated in the image of the input mask below.

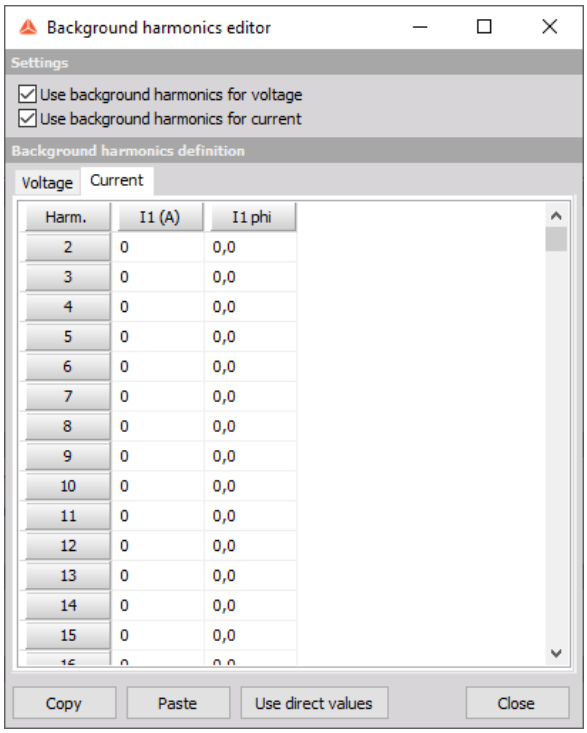


Image 12: Background harmonics editor

Example

The following images depict a certain harmonic pattern that was measured using Dewesoft DAQ devices. A harmonic filter was then applied to the same measurement in Dewesoft X, and it yielded an adjusted harmonic by subtracting the background harmonics.

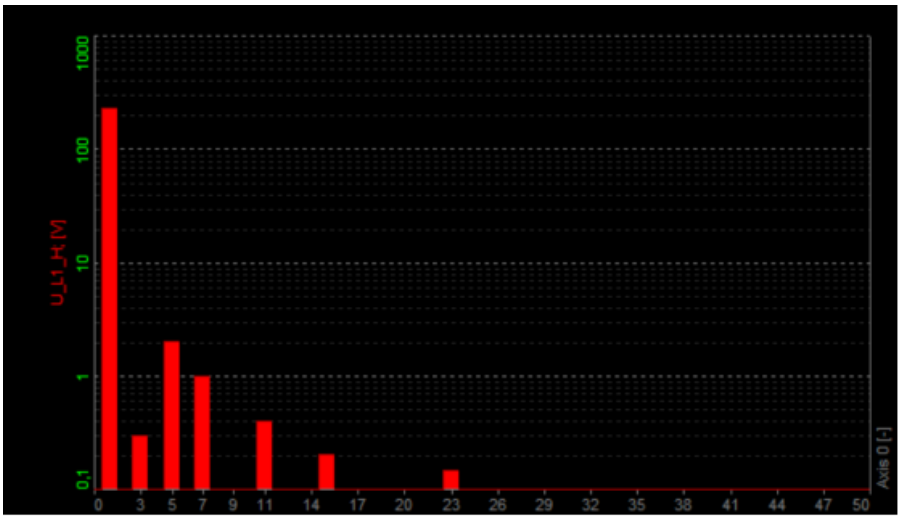


Image 13: Measurement screen without a harmonic filter applied

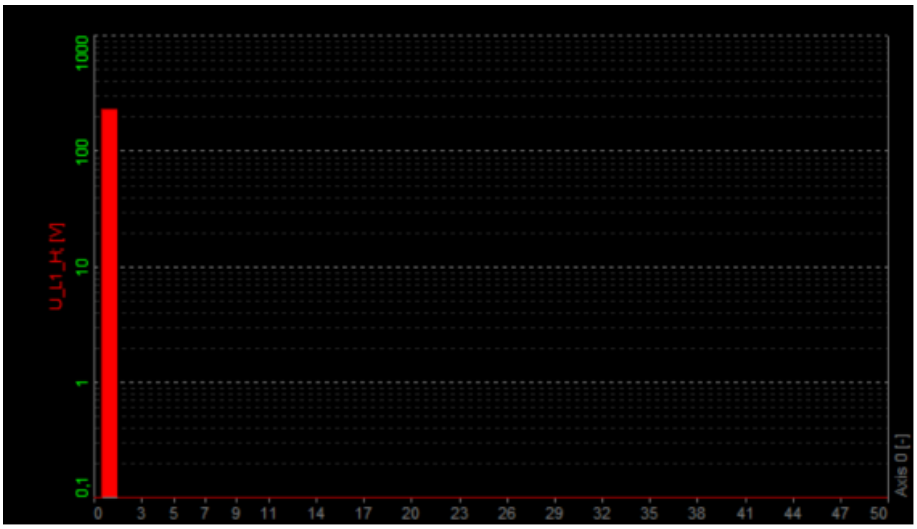


Image 14: Measurement screen with a harmonic filter applied

How to perform a Measurement with Dewesoft X?

Dewesoft X offers an array of display options for the following measurements: voltage, current, active and reactive power, phase angle, impedance, interharmonics, and higher frequencies, these can be displayed as Numeric Displays, on Recorders or as 2D-Graphs as the following image depicts. The user is absolutely free to configure the display as required.

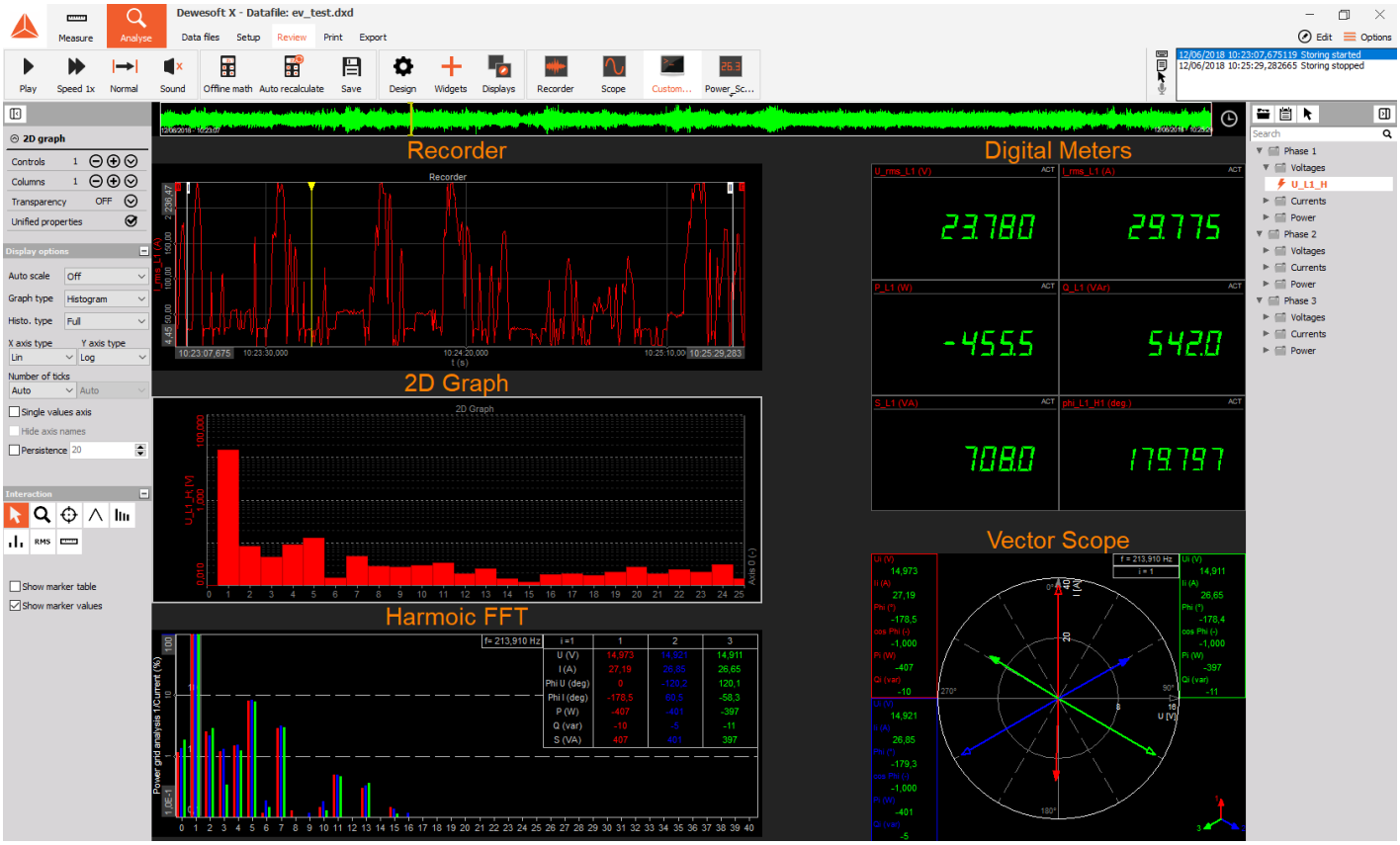


Image 15: Display options for the measurement screen in the power module

There are two possibilities for displaying harmonics in Dewesoft X. The available choices are the **Harmonic FFT** and the **2D graph**. The following image depicts the icons that are used for the two choices, left is the harmonic 2D Graph and right is the Harmonic FFT .

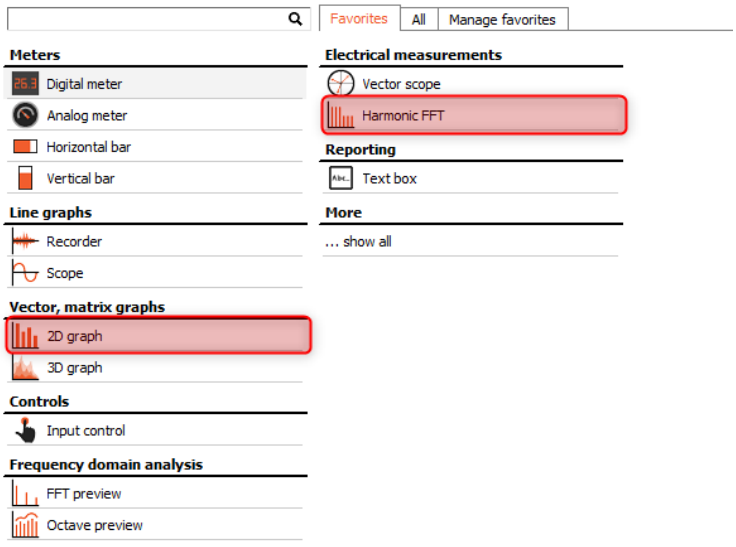


Image 16: Display options for harmonics in the power module

Harmonic FFT

In the Harmonic FFT the harmonics of the voltage, current, power and reactive power can be displayed. The following image depicts the voltage harmonics of a three-phase system.

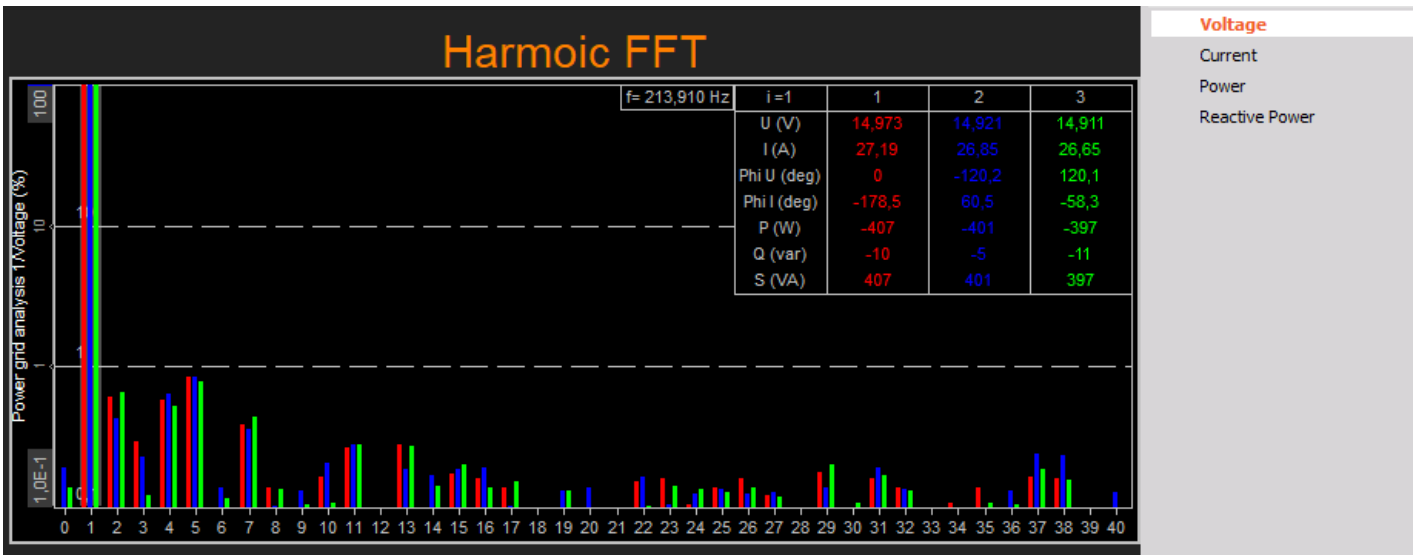


Image 17: Harmonic FFT measurement screen

2D Graph

With the 2D graph, it is possible to display voltages and currents of different phases in one graph. In addition to this there is a wide array of display options that the user can configure as needed for the specific application. The following figure displays the harmonics for the phase voltage of L1. On the right-hand side are the display options that are available for 2D graphs. Here the graph type can be chosen, whether line or histogram as well as the graph scale which can be either linear or logarithmic. The scaling of the graph axes can also be set independently.

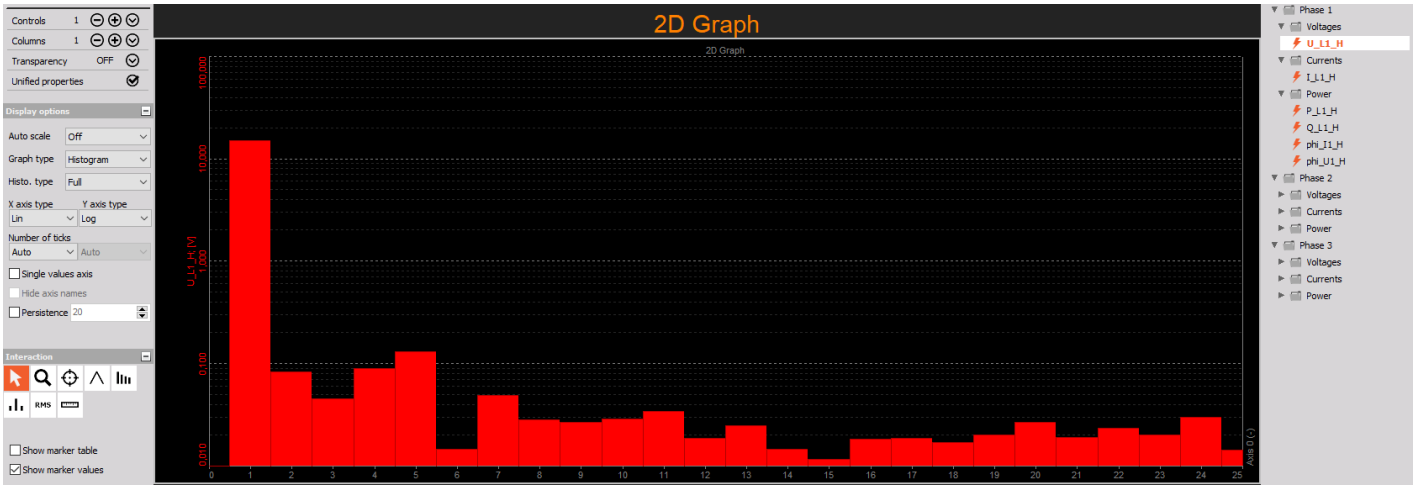


Image 18: Harmonic 2D graph measurement screen

Persistence

There is also the option available to depict the **Persistence** of the harmonics in the 2D Graph. This means that when the

harmonics change during a measurement, the changes are displayed blurred, as illustrated in the following figure.

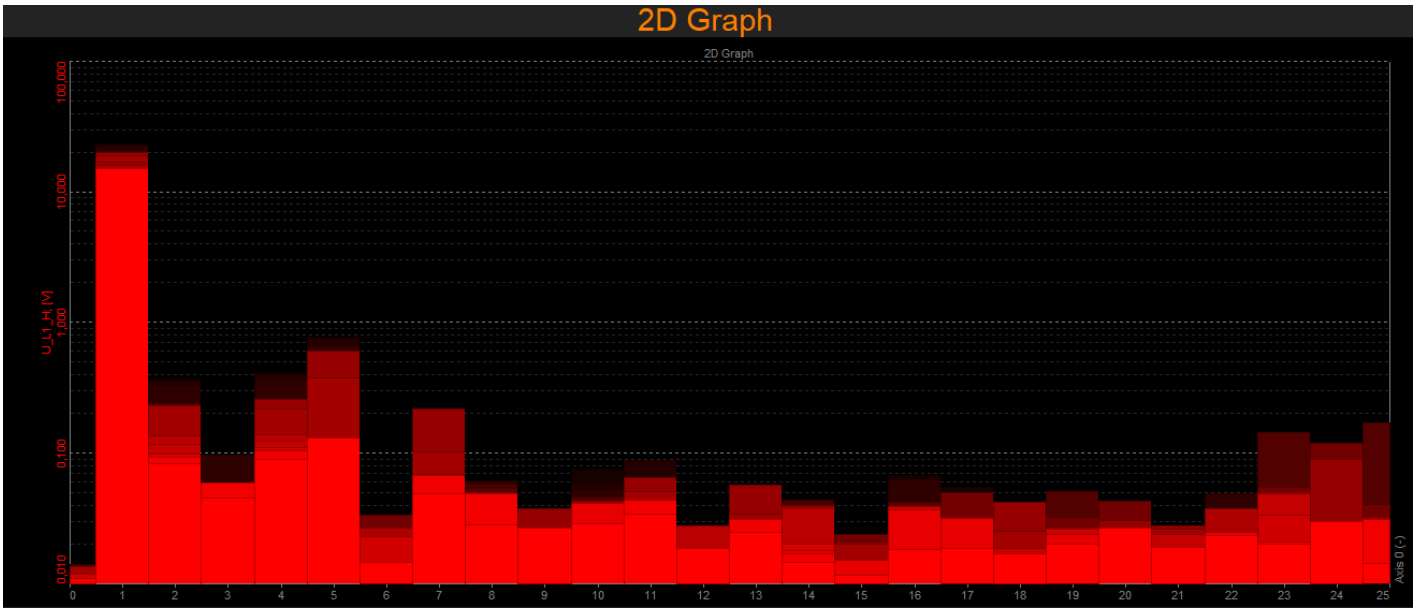


Image 19: Harmonic 2D graph measurement screen with persistence

Higher frequencies

Example: higher frequencies from 2 Hz up to 20 kHz shown in a 2D graph as histogram (application: HVDC converter station).

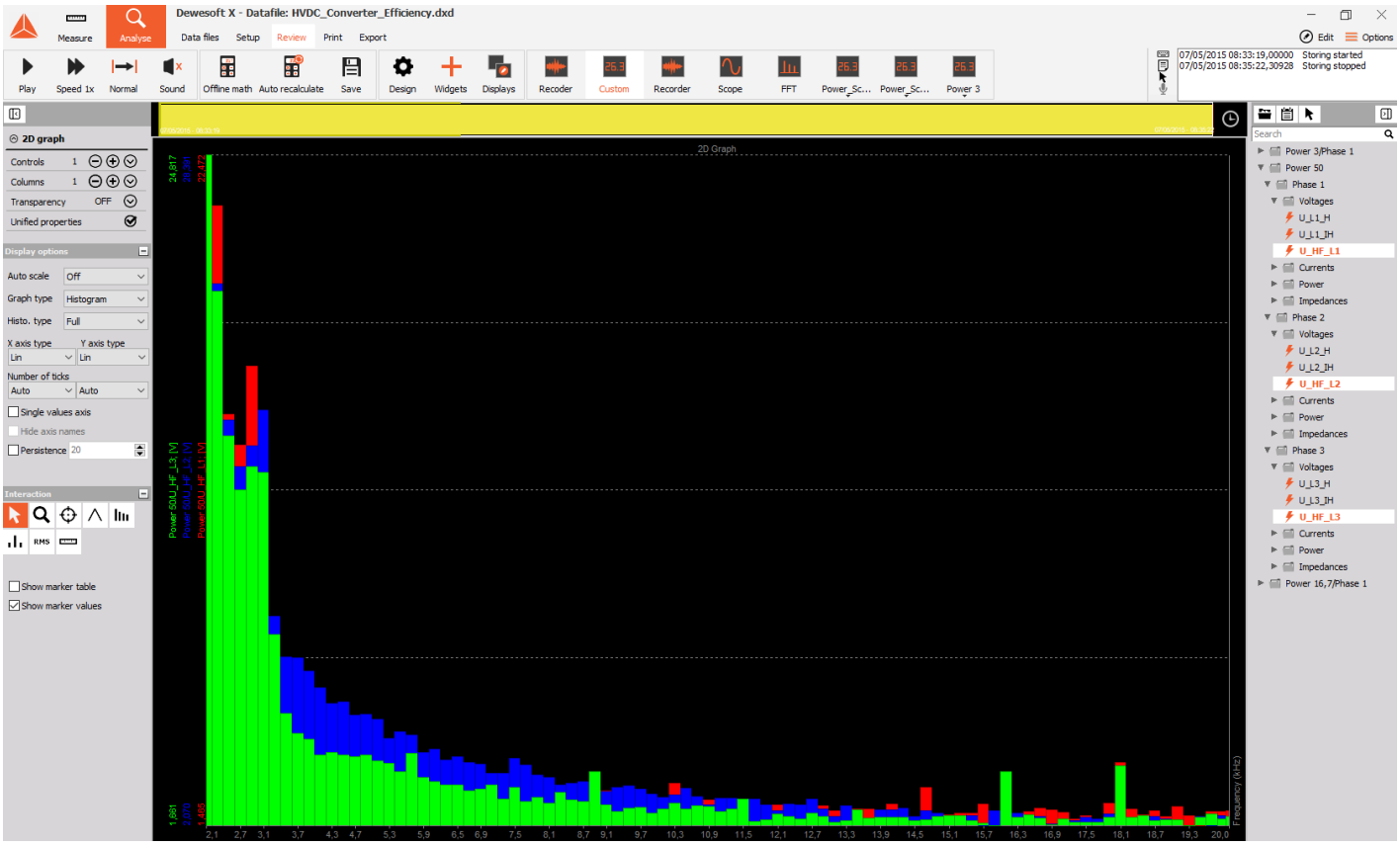


Image 20: Higher frequencies measurement screen in a 2D histogram

Interharmonics

Example: Interharmonics shown in 2D-Graph as Histogram. Peak at 900 Hz which is the switching frequency of a HVDC converter operated in the public grid.

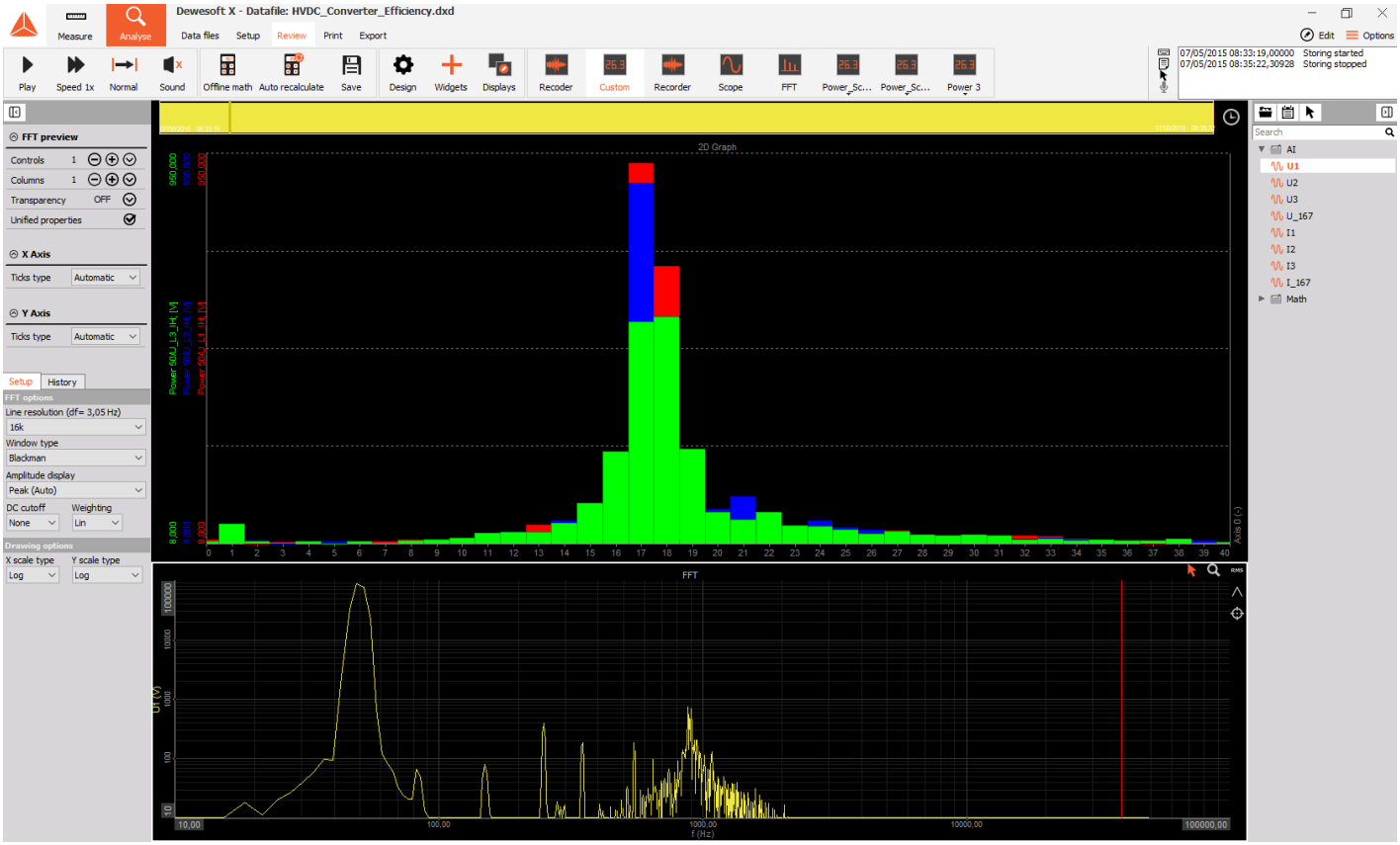


Image 21: Interharmonic measurement screen in a 2D graph and a FFT graph

Dewesoft Xcalculations for each harmonic/whole waveform

Channel name in DEWESoft	Calculation	Description
S_L1_H1	$S_h = U_h \cdot I_h$	Apparent, active and reactive power for a certain harmonic frequency (e.g. for L1 and h=1)
P_L1_H1	$P_h = U_h \cdot I_h \cdot cos(\varphi_h)$	
Q_L1_H1	$Q_h = U_h \cdot I_h \cdot sin(\varphi_h) = \sqrt{S_h^2 - P_h^2}$	
S_L1	$S = U_{1_{rms}} \cdot I_{1_{rms}}$	Three power parameters for the whole waveform (e.g. for L1)
P_L1	$P = \sum_{h=1}^{H} P_h$	
Q_L1	$Q = \sqrt{S^2 - P^2}$	
Z_L1	$Z_{L1} = \frac{U}{I}$	Impedance for the whole waveform (e.g. for L1)
Z_L1_H1	$Z_{L1} = \frac{U_H}{I_H}$	Impedance for a certain harmonic (e.g. for L1 and H1)
PF_L1	$PF = \frac{P}{S}$	Power factor (e.g. for L1)
D_L1	$D = \sqrt{Q^2 - Q_{h=1}^2}$	D_L1, distortion power of all harmonic components reactive powers (u and i have the same order but not equal 1 or have different order) (e.g. for L1)
QH_L1	$Q = \sum_{h=1}^{H} Q_h$	Reactive power of all harmonics where u and i have the same harmonics order (e.g. for L1)
DH_L1	$DH = \sqrt{Q^2 - QH^2}$	Distortion power of all harmonic components reactive powers where u and i have different harmonic orders (e.g. for L1)

Table 1: Calculations for each harmonic/whole waveform in the power module

Note: There are two definitions for reactive power included, because there is up to date no official definition that has been standardized. The formula of Q1_L1 loses sign, while QH_L1 does not. If there is a need to calculate the reactive power form only the harmonics (no fundamental included), the following simple math formula can be used: 'QH_L1' - 'Q_L1_H1'.

Dewesoft X calculations for a 3 phase system

Channel name in DEWESoft	Calculation	Description
S	$S_{3\sim} = S_{L1} + S_{L2} + S_{L3}$	Apparent, active and reactive power of a 3 phase system
P	$P_{3\sim} = P_{L1} + P_{L2} + P_{L3}$	
Q	$Q_{3\sim} = \sqrt{S_{3\sim}^2 - P_{3\sim}^2}$	
PF	$PF_{3\sim} = \frac{P_{3\sim}}{S_{3\sim}}$	Power factor

Table 2: 3-Phase system calculations in the power module

What is THD - Total Harmonic Distortion?

The Total Harmonic Distortion (THD) for voltage and current can be calculated up to the 3000th order. In general, it is defined as the sum of all harmonics relative to the fundamental frequency.

Channel name in DEWESoft	Calculation	Description
THD_U_L1, ...	$THD_U = \frac{\sqrt{\sum_{k=2}^{n} (U_k)^2}}{U_1}$	THD of the voltage
THDOdd_U_L1, ...	$THD_{Uodd} = \frac{\sqrt{(\sum_{k=1}^{n} (U_{2k+1})^2)}}{U_1}$	THD of the voltage for odd and even harmonics
THDEven_U_L1, ...	$THD_{Ueven} = \frac{\sqrt{(\sum_{k=1}^{n} (U_{2k})^2)}}{U_1}$	
THD_I_L1, ...	$THD_I = \frac{\sqrt{\sum_{k=2}^{n} (U_k)^2}}{I_1}$	THD of the current
THDOdd_I_L1, ...	$THD_{Iodd} = \frac{\sqrt{(\sum_{k=1}^{n} (I_{2k+1})^2)}}{I_1}$	THD of the current for odd and even harmonics
THDEven_I_L1, ...	$THD_{Ieven} = \frac{\sqrt{(\sum_{k=1}^{n} (I_{2k})^2)}}{I_1}$	

Table 3: Total harmonic distortion calculations in the power module

Channel name in DEWESoft	Calculation	Description
TIHD_U_L1, ...	$TIHD_U = \frac{\sqrt{\sum_{k=1}^{n} (U_k)^2}}{U_1}$	Total Interharmonic distortion of the voltage/current.
TIHD_I_L1, ...	$TIHD_I = \frac{\sqrt{\sum_{k=1}^{n} (I_k)^2}}{I_1}$	Equivalent to the THD, but defined for interharmonics
K_U_L1	$K_U = \frac{\sqrt{\sum_{k=2}^{n} (U_k)^2}}{U}$	K-factor for voltage and current. Refers to the full-spectrum, the THD only to the fundamental voltage
K_I_L1	$K_I = \frac{\sqrt{\sum_{k=2}^{n} (I_k)^2}}{I}$	

Table 4: Total interharmonic distortion and K factor calculations in the power module

The most important origins of harmonics are loads which are controlled by converters (diodes, thyristors, transistors). The following images depict a typical comparison of different light bulbs and the current waveforms that they produce (Blue). The green waveforms represent the Voltages. The Voltage, Current, THDI (Total harmonic distortion for current), power and power factor values that correspond to the individual light bulbs are also depicted

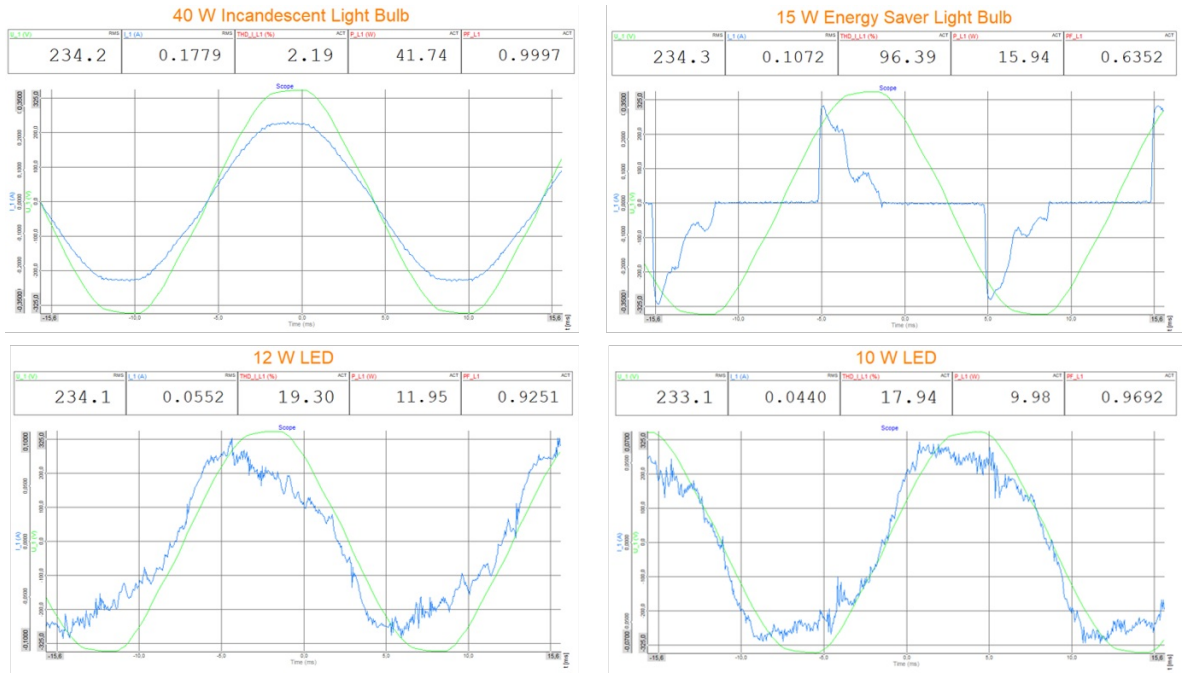


Image 22: Total harmonic distortion waveform for different light bulbs

Circuit	Curve shape	THD	Application
Single phase bridge rectifier with decoupling capacitor (2 pulse)		130 – 160 %	Switching power supply
6 pulse rectifiers with decoupling capacitor (voltage intermediate circuit, voltage inverter)		70 – 120 %	UPS facilities, frequency inverters for three-phase motors
6 pulse rectifiers with decoupling capacitor and ripple filter choke		40 – 70 %	(pumps, fans, paper machines, conveyors)
6 pulse rectifiers with ripple filter choke (current intermediate circuit, current inverter)		30 %	DC drives (ski lifts, extruders, bandsaws) Inverters for wind power plants
12 pulse rectifiers with ripple filter choke (current intermediate circuit, current inverter)		15 %	DC drives with high power (rolling mills, ropeways) DC electric arc furnaces, HVDC facilities
Active inverter (DC-voltage intermediate circuit, voltage inverter)		< 10 %	State of the art, RPM regulated 4-quadrant drives

Table 5: Total harmonic distortion curve shapes and % of distortion

How to calculate the Total Harmonic Current (THC) and current Total Demand Distortion (TDD)?

In addition to the THD calculation, it is now possible to add THC and TDD calculations as well.

Total Harmonic Current (THC) is the accumulated currents of the orders 2 to 40 that contribute to the distortion of the current waveform. This value is particularly useful in determining the required characteristics for the installation of modern active harmonic filters:

$$THC = \sqrt{\sum_{n=2}^{n=40} I_h^2}$$

Current Total Demand Distortion (TDD). This is defined as the ratio of the root-sum-square values of the harmonic current to the maximum demand load current times 100 to get the result in percentage. The maximum demand load current can be defined in the software with an input field.

$$I_{TDD} = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \cdots}}{I_L} \cdot 100$$

In the power module in Dewesoft X under power quality, the THC and TDD options can be selected, as shown in the image below.

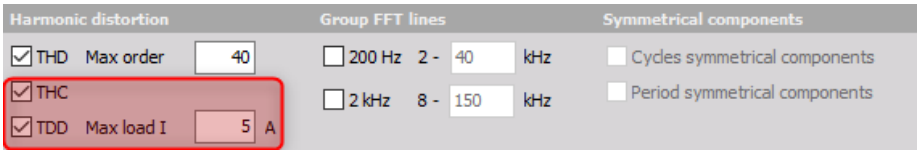


Image 23: Total harmonic current and Current total demand distortion

Fundamental symmetrical components

Normally an electric power system operates in a balanced three-phase sinusoidal steady-state mode. Disturbances, for example a fault or short circuit, lead to an unbalanced condition. As the following image depicts on the left-hand side is a balanced system with a symmetrical phase shift and equal vector distances. On the right-hand side is an unbalanced system with an unsymmetrical phase shift and uneven vector lengths.

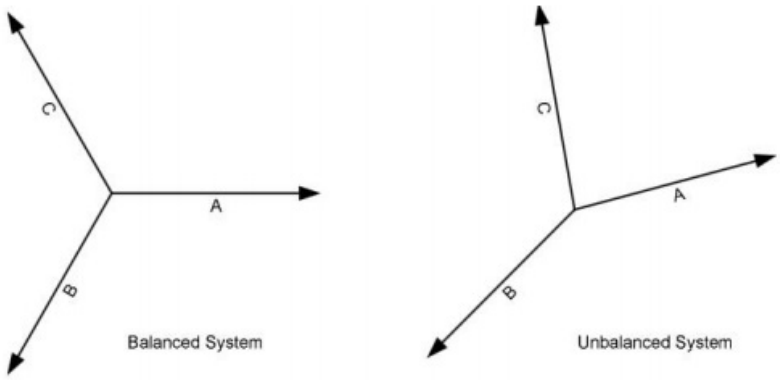


Image 24: Balanced system and an unbalanced system

By using the method of the symmetrical components, it is possible to transform any unbalanced 3-phase system into 3 separated sets of balanced three-phase components, the positive, negative and zero sequence.

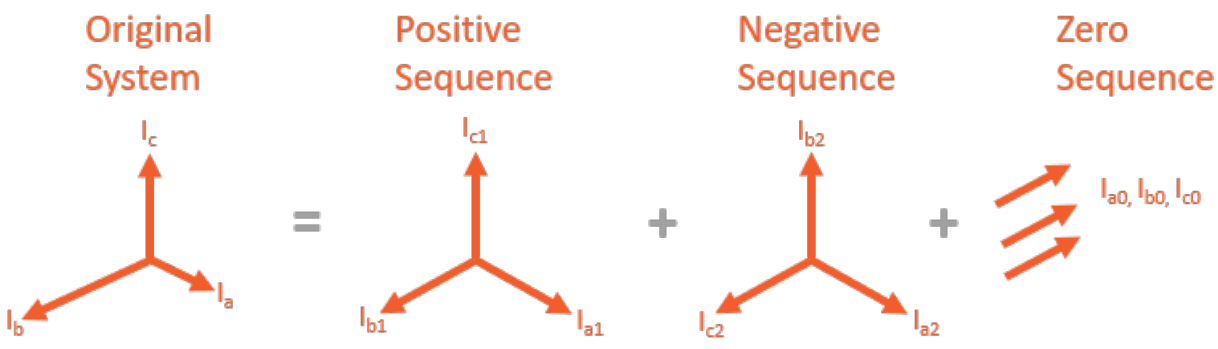


Image 25: Unbalanced system to balanced system transformation

The advantage of the symmetrical balanced system lies in that the calculations are simplified. Should a fault arise or there is a short circuit in the system, an unbalanced system can be transformed into a balanced system with symmetrical components, where the system calculations can be done with the normal formulas that would be used in a balanced system. The calculated values are then transformed back to the unsymmetrical system (real-scenario) phase voltages and currents. In general, a 3-phase system can be depicted and mathematically described as follows:

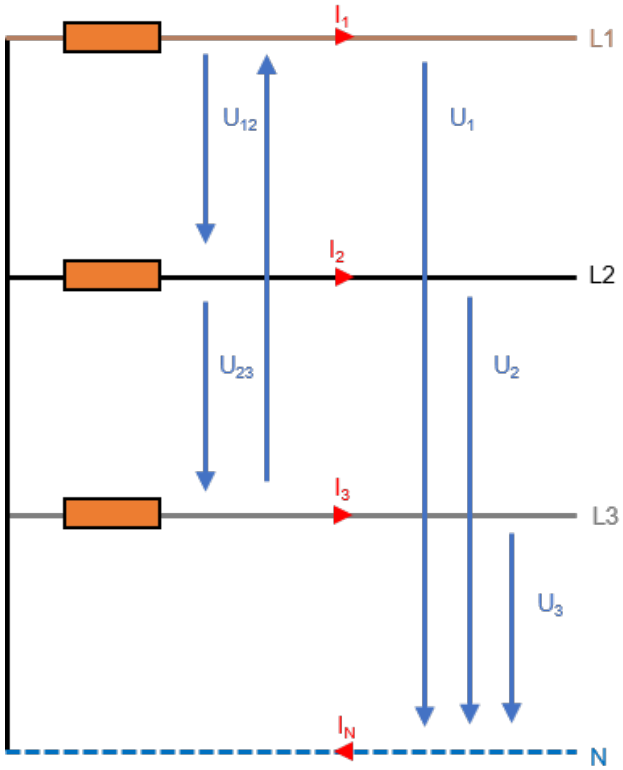


Image 26: Symmetrical system

$$U_{L1} = U_{L1_{RMS}} e^{j\varphi U_{L1}} \quad I_{L1} = I_{L1_{RMS}} e^{j\varphi I_{L1}}$$
$$U_{L2} = U_{L2_{RMS}} e^{j\varphi U_{L2}} \quad I_{L2} = I_{L2_{RMS}} e^{j\varphi I_{L2}}$$
$$U_{L3} = U_{L3_{RMS}} e^{j\varphi U_{L3}} \quad I_{L3} = I_{L3_{RMS}} e^{j\varphi I_{L3}}$$

A balanced 3-phase system looks like the image below with the same RMS-value for all line voltages and currents, and a 120Â° phase shift between each of them.

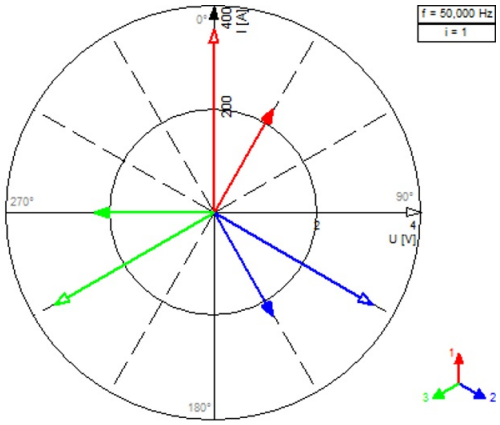


Image 27: Symmetrical balanced system vectorscope

$$U_{L1} = U_{Rms}e^{j0°} \qquad I_{L1} = I_{L1_{RMS}}e^{j\varphi}$$
$$U_{L2} = U_{L2_{RMS}}e^{j-120°} \qquad I_{L2} = I_{L2_{RMS}}e^{j(\varphi-70°)}$$
$$U_{L3} = U_{L3_{RMS}}e^{j\varphi-240°} \qquad I_{L3} = I_{L3_{RMS}}e^{j(\varphi-190°)}$$

In order to explain the basic idea of the symmetrical components, the first step would be to define the operator as a unit vector with an phase angle of 120Â° or 2*pi/3.

$$a = e^{\frac{j2\pi}{3}}$$

The voltages can be described mathematically in different ways as the table below shows:

Voltages	Complex view I	Complex view II	Angle view
U_{L1}	$\Re(U_{L1}) + \Im(U_{L1})$	$U_{L1} \cdot e^{j0°}$	U
U_{L2}	$\Re(U_{L2}) + \Im(U_{L2})$	$U_{L2} \cdot e^{j0°}$	$a^2 \cdot U$
U_{L3}	$\Re(U_{L3}) + \Im(U_{L3})$	$U_{L3} \cdot e^{j0°}$	$a \cdot U$

Table 6: Symmetrical components complex and angle calculations

Calculation of zero-sequence system

In an symmetrical system the following equation is valid:

$$U_{L1} + U_{L2} + U_{L3} = 0$$

In a real system the sum won't be zero. There will be a voltage difference as the following equation shows:

$$U_{L1} + U_{L2} + U_{L3} = \underline{\Delta} u$$

This voltage difference divided through 3 represents the so called zero-sequence system:

$$U_0 = \frac{1}{3} \cdot \underline{\Delta} u = u_{10} = u_{20} = u_{30}$$

The zero-sequence systems for the three phases (u_{10}, u_{20}, u_{30}) all have the same amplitude and phase. Therefore, only the value for the zero-sequence system â€žU_0â€œ will be shown.

The calculation of the zero-sequence current is analog to that of the voltage equation.



Hint: When the currents of the zero-sequence system are multiplied by three (=I_0 · 3) it will yield the current that is flowing in the neutral line U_N

Calculation of positive-sequence system

The positive sequence system has the same rotating direction as the original system (right). This means it will have the same rotating direction of an electrical machine connected to the grid.

$$\underline{\nu_{1m}} = \frac{1}{3}(\underline{\nu_1} + \underline{a\nu_2} + \underline{a^2\nu_3})$$

$$\underline{\nu_{2m}} = \underline{a^2\nu_{1m}} = \frac{1}{3}(\underline{\nu_1} + \underline{a\nu_2} + \underline{a^2\nu_3}) \cdot \underline{a^2}$$

$$\underline{\nu_{3m}} = \underline{a\nu_{1m}} = \frac{1}{3}(\underline{\nu_1} + \underline{a\nu_2} + \underline{a^2\nu_3}) \cdot \underline{a}$$

As the values of the positive-sequence system for all three phases have the same amplitude (now that they are symmetrical) and has a phase shift of exactly 120Â°, it's adequate to show only one value. The value for the positive-sequence system in Dewesoft X is called â€žU_1â€œ.

Calculation of negative-sequence system

The negative sequence system has the opposite rotating direction as the original system (left). This means it will rotate in opposite direction of an electrical machine connected to the grid.

$$\underline{\nu_{1g}} = \frac{1}{3}(\underline{\nu_1} + \underline{a^2\nu_2} + \underline{a\nu_3})$$

$$\underline{\nu_{2g}} = \underline{a\nu_{1g}} = \frac{1}{3}(\underline{a\nu_1} + \underline{\nu_2} + \underline{a^2\nu_3})$$

$$\underline{\nu_{3g}} = \underline{a^2\nu_{1g}} = \frac{1}{3}(\underline{a^2\nu_1} + \underline{a\nu_2} + \underline{\nu_3})$$

As the values of the negative-sequence system for all three phases have the same amplitude (now they are symmetrical) and has a phase shift of exactly 120Â°, it's adequate to show one value. The value for the negative-sequence system in Dewesoft X is called â€žU_2â€œ.

Matrix of zero, positive and negative-sequence system

According to the following equations the phase voltages and currents are transformed into the symmetrical components. The result are three balanced 3-phase systems, the positive (U_1, I_1), negative (U_2, I_2) and zero sequence (U_0, I_0).

Channel name in Dewesoft	Calculation
U_0, U_1, U_2	$\begin{bmatrix} \underline{U^0} \\ \underline{U^1} \\ \underline{U^2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \cdot \begin{bmatrix} \underline{U_{L1}} \\ \underline{U_{L2}} \\ \underline{U_{L3}} \end{bmatrix}$
I_0, I_1, I_2	$\begin{bmatrix} \underline{I^0} \\ \underline{I^1} \\ \underline{I^2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \cdot \begin{bmatrix} \underline{I_{L1}} \\ \underline{I_{L2}} \\ \underline{I_{L3}} \end{bmatrix}$

Table 7: Matrices of the zero-,positive-, and negative sequence system

Note: The basic values of symmetrical components (U_0, U_1, U_2, I_0, I_1, I_2) are calculated for each harmonic and added up geometrically

As illustrated in the following images, an unbalanced system can be rectified using the positive, negative and zero symmetrical components. The image below depicts an unsymmetrical system as a screen shot taken from Dewesoft X.

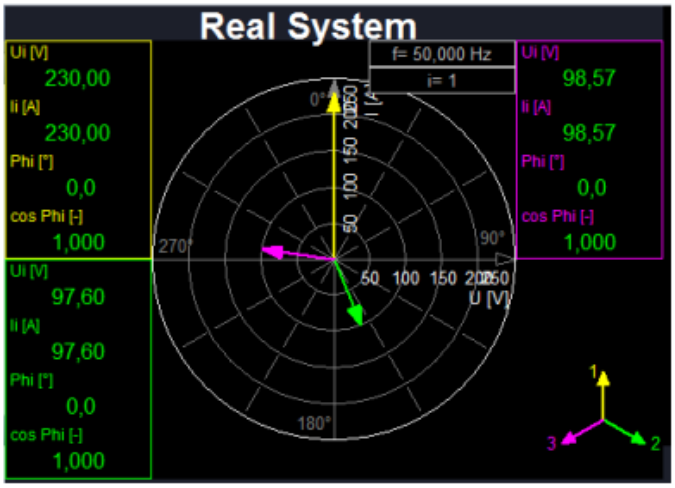


Image 28: Unbalanced system vectorscope in Dewesoft X

This screen was provided by Kurt STRANNER (KNG Netz GmbH)

The following image depicts a screen-shot showing the three systems (positive, negative and zero) of the symmetrical components in Dewesoft X:

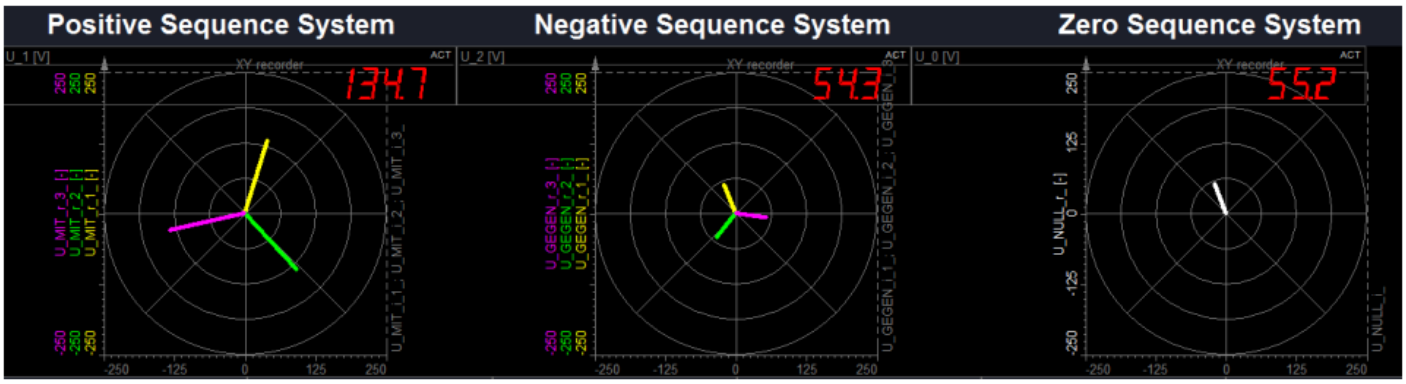


Image 29: Unbalanced system to balanced system transformation in Dewesoft X

This screen was provided by Kurt STRANNER (KNG Netz GmbH)

Out of the parameters of the symmetrical components (positive-, negative- and zero- sequence) the original system can be rebuilt easily, e.g.:

$$U_{L1} = U_0 + U_1 + U_2$$

The following variables are calculated in Dewesoft X and show the components of the zero- and negative-sequence system compared to the positive-sequence system (for the total and the fundamental harmonic).

Channel name in Dewesoft	Calculation	Description
u2,i2	$u_2 = \frac{U_1}{U_2} \cdot 100\ [\%]$ $i_2 = \frac{I_1}{I_2} \cdot 100\ [\%]$	Negative sequence component of the voltage / current of all harmonics **Note: This parameter is regulated in the EN 50160**
u0, i0	$u_0 = \frac{U_0}{U_1} \cdot 100\ [\%]$ $i_0 = \frac{I_0}{I_1} \cdot 100\ [\%]$	Zero sequence component of the voltage / current of all harmonics
u2_1, i2_1	$u_{2-1} = \frac{U_{2_{H1}}}{U_{1_{H1}}} \cdot 100\ [\%]$ $i_{2-1} = \frac{I_{2_{H1}}}{I_{1_{H1}}} \cdot 100\ [\%]$	Negative sequence component of the fundamental voltage / current in percent (unbalance factor according to EN50160)
u0_1, i0_1	$u_{0-1} = \frac{U_{0_{H1}}}{U_{1_{H1}}} \cdot 100\ [\%]$ $i_{0-1} = \frac{I_{0_{H1}}}{I_{1_{H1}}} \cdot 100\ [\%]$	Zero sequence component of the fundamental voltage / current in percent

Table 8: Zero-,positive-, and negative sequence system calculations in the power module

Extended positive sequence parameters (according to IEC 614000)

The following calculations are based on Annex C of IEC 61400-21.

Based on the measured phase voltages and currents, the fundamental's Fourier coefficients are calculated over one fundamental cycle T as first step.

$$u_a, cos = \frac{2}{T} \int_{t-T}^{t} u_a(t) cos(2\pi f_1 t) dt$$

$$u_a, sin = \frac{2}{T} \int_{t-T}^{t} u_a(t) sin(2\pi f_1 t) dt$$

It is important to mention that the index a stands for the line voltage L_1. The coefficients for L_2 (ub) and L_3 (uc) as well as the coefficients for the currents (ia, ib, ic) are calculated exactly the same. Furthermore f_1 is the frequency of the fundamental. The RMS value of the fundamental line voltage is:

$$U_{a1} = \sqrt{\frac{u_{a,cos}^2 + u_{a,sin}^2}{2}}$$

Channel name in Dewesoft	Calculation	Description
U_ap_cos_per	$U_{1+,cos} = \frac{1}{6}[2u_{a,cos} - u_{b,cos} - u_{c,cos} - \sqrt{3}(u_{c,sin} - u_{b,sin}]$	Voltage and current vector components of the positive sequence for the fundamental
U_ap_sin_per	$U_{1+,sin} = \frac{1}{6}[2u_{a,sin} - u_{b,sin} - u_{c,sin} - \sqrt{3}(u_{c,cos} - u_{b,cos}]$	
I_ap_cos_per	$i_{1+,cos} = \frac{1}{6}[2i_{a,cos} - i_{b,cos} - i_{c,cos} - \sqrt{3}(i_{c,sin} - i_{b,sin}]$	
I_ap_sin_per	$i_{1+,sin} = \frac{1}{6}[2i_{a,sin} - i_{b,sin} - i_{c,sin} - \sqrt{3}(i_{c,cos} - i_{b,cos}]$	
P_1p_per	$P_{1+} = \frac{3}{2}((u_{1+,cos} \cdot i_{1+,cos}) - (u_{1+,sin} \cdot i_{+,sin}))$	Active and reactive power from the fundamental positive sequence
Q_1p_per	$Q_{1+} = \frac{3}{2}((u_{1+,cos} \cdot i_{1+,sin}) - (u_{1+,sin} \cdot i_{+,cos}))$	
U_1p_per	$U_{1+} = \sqrt{\frac{3}{2}(U_{1+,sin}^2 + U_{1+,cos}^2}$	RMS value of the line voltage of the fundamental positive sequence
U_1p_per	$I_{P1+} = \frac{P_{1+}}{\sqrt{3} \cdot U_{1+}}$	RMS values of the active and reactive current from the fundamental positive sequence
I_q1p_per	$I_{Q1+} = \frac{Q_{1+}}{\sqrt{3} \cdot U_{1+}}$	
cos_phi_1p_per	$cos\varphi_{1+} = \frac{P_{1+}}{\sqrt{P_{1+}^2 + Q_{1+}^2}}$	Power factor of the fundamental positive sequence
S_1p_per	$S_{1+} = \sqrt{P_{1+}^2 + Q_{1+}^2}$	Further calculation
I_1p_per	$i_{1+} = \frac{S_{1+}}{\sqrt{3} \cdot U_{1+}}$	

Table 9: Extended positive sequence calculations in the power module

Extended negative sequence parameters (according to IEC 614000)

Channel name in Dewesoft	Calculation	Description
U_an_cos_per	$U_{1-,cos} = \frac{1}{6}[2u_{a,cos} - u_{b,cos} - u_{c,cos} + \sqrt{3}(u_{c,sin} - u_{b,sin}]$	Voltage and current vector components of the negative sequence for the fundamental
U_an_sin_per	$U_{1-,sin} = \frac{1}{6}[2u_{a,sin} - u_{b,sin} - u_{c,sin} + \sqrt{3}(u_{c,cos} - u_{b,cos}]$	
I_an_cos_per	$i_{1-,cos} = \frac{1}{6}[2i_{a,cos} - i_{b,cos} - i_{c,cos} + \sqrt{3}(i_{c,sin} - i_{b,sin}]$	
I_an_sin_per	$i_{1-,sin} = \frac{1}{6}[2i_{a,sin} - i_{b,sin} - i_{c,sin} + \sqrt{3}(i_{c,cos} - i_{b,cos}]$	
P_1n_per	$P_{1-} = \frac{3}{2}((u_{1-,cos} \cdot i_{1-,cos}) - (u_{1-,sin} \cdot i_{-,sin}))$	Active and reactive power from the fundamental negative sequence
Q_1n_per	$Q_{1-} = \frac{3}{2}((u_{1-,cos} \cdot i_{1-,sin}) - (u_{1-,sin} \cdot i_{-,cos}))$	
U_1n_per	$U_{1-} = \sqrt{\frac{3}{2}(U_{1-,sin}^2 + U_{1-+,cos}^2}$	RMS value of the line voltage of the fundamental negative sequence
S_1n_per	$S_{1-} = \sqrt{P_{1-}^2 + Q_{1-}^2}$	Further calculations
I_1n_per	$i_{1-} = \frac{S_{1-}}{\sqrt{3} \cdot U_{1-}}$	

Table 10: Extended negative sequence calculations in the power module

Extended zero sequence parameters (according to IEC 614000)

Channel name in Dewesoft	Calculation	Description
U_az_cos_per	$U_{1z,cos} = \frac{1}{3}[u_{a,cos} + u_{b,cos} + u_{c,cos}]$	Voltage and current vector components of the zero sequence for the fundamental
U_az_sin_per	$U_{1z,sin} = \frac{1}{3}[u_{a,sin} + u_{b,sin} + u_{c,sin}]$	
I_az_cos_per	$i_{1z,cos} = \frac{1}{3}[i_{a,cos} + i_{b,cos} + i_{c,cos}]$	
I_az_sin_per	$i_{1z,sin} = \frac{1}{3}[i_{a,sin} + i_{b,sin} + i_{c,sin}]$	
P_1z_per	$P_{1z} = \frac{3}{2}((u_{1z,cos} \cdot i_{1z,cos}) - (u_{1z,sin} \cdot i_{z,sin}))$	Active and reactive power from the fundamental negative sequence
Q_1z_per	$Q_{1z} = \frac{3}{2}((u_{1z,cos} \cdot i_{1z,sin}) - (u_{1z,sin} \cdot i_{z,cos}))$	
U_1z_per	$U_{1-} = \sqrt{\frac{3}{2}(U_{1z,sin}^2 + U_{1z+,cos}^2}$	RMS value of the line voltage of the fundamental negative sequence
S_1z_per	$S_{1z} = \sqrt{P_{1z}^2 + Q_{1z}^2}$	Further calculations
I_1z_per	$i_{1z} = \frac{S_{1z}}{\sqrt{3} \cdot U_{1z}}$	

Table 11: Extended zero sequence calculations in the power module

What is a Flicker?

Flicker is a term used to describe fluctuations (repetitive variations) of voltage. Flashing light bulbs are indicators of high flicker exposure. Flicker is especially present in grids with a low short-circuit resistance and is caused by the frequent connection and disconnection (e.g. heat pumps, rolling mills, etc.) of loads which affect the voltage. A high level of flicker is perceived as psychologically irritating and can be harmful to humans.

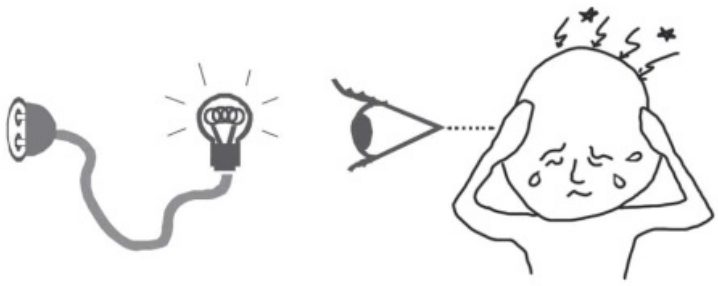


Image 30: Flicker impact on humans

The Dewesoft Power Analyzer can measure all the Flicker parameters according to the IEC 61000-4-15 standard. The Flicker emission calculation is implemented according to the IEC 61400-21 standard and allows for the evaluation of flicker emissions that are fed into the grid by wind power plants and other power generation units.

The flicker-meter architecture is depicted as a block diagram in the next image. It is divided into two parts, simulation of the response to the lamp-eye-brain chain and the on-line statistical analysis of the flicker signal leading to the known parameters. The blocks within the block diagram will be discussed briefly.

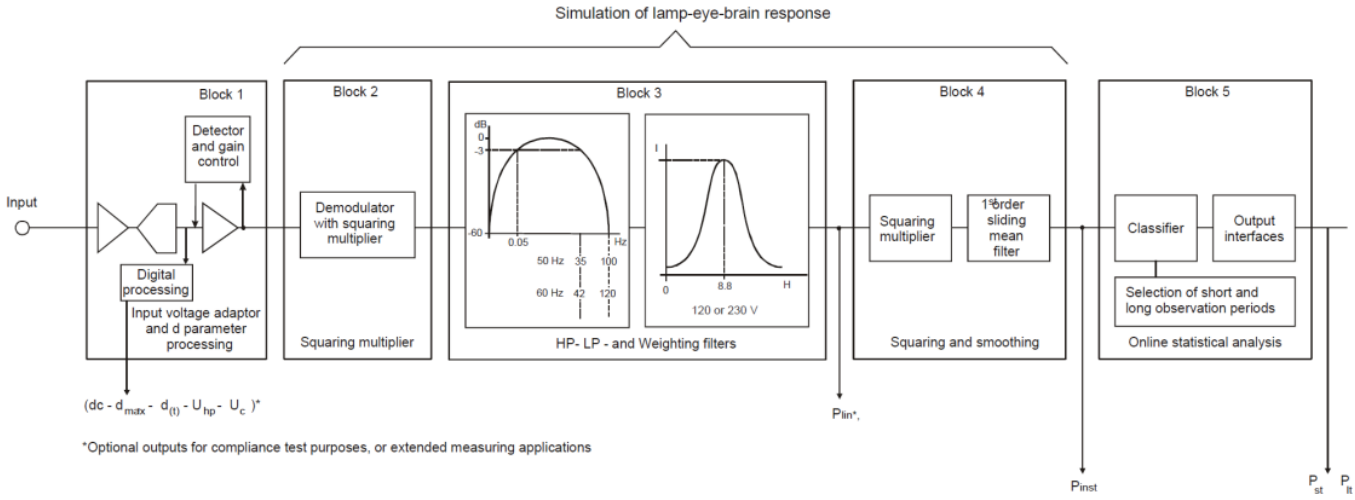


Image 31: Flicker-meter architecture

Block 1

The first block contains a voltage adapting circuit that scales the input mains frequency voltage to an internal reference level. This method permits flicker measurements to be made, independently of the actual input carrier voltage level and may be expressed as a percent ratio.

Block 2

The second block has the function of recovering the voltage fluctuation by squaring the input voltage scaled to the reference level, thus simulating the behavior of a lamp.

Block 3

The third block is composed of a cascade of two filters, which can precede or follow the selective filter circuit. The first low-pass filter eliminates the double mains frequency ripple components of the demodulated output.

The high pass filter can then be used to eliminate any DC voltage component. The second filter is a weighting filter block that simulates the frequency response of the human visual system to sinusoidal voltage fluctuations of a coiled filament gas-filled lamp (60 W/230 V and/or 60 W/120 V).

Block 4

The fourth block consists of a squaring multiplier and a first order low-pass filter. The human flicker perception, with an eye and brain combination, to voltage fluctuations applied to the reference lamp, is simulated by the combined non-linear response of the blocks 2,3 and 4.

Block 5

The last block of the chain performs an on-line analysis of the flicker level, thus allowing direct calculation of significant evaluation parameters.

The following image is an example of a rectangular voltage flicker.

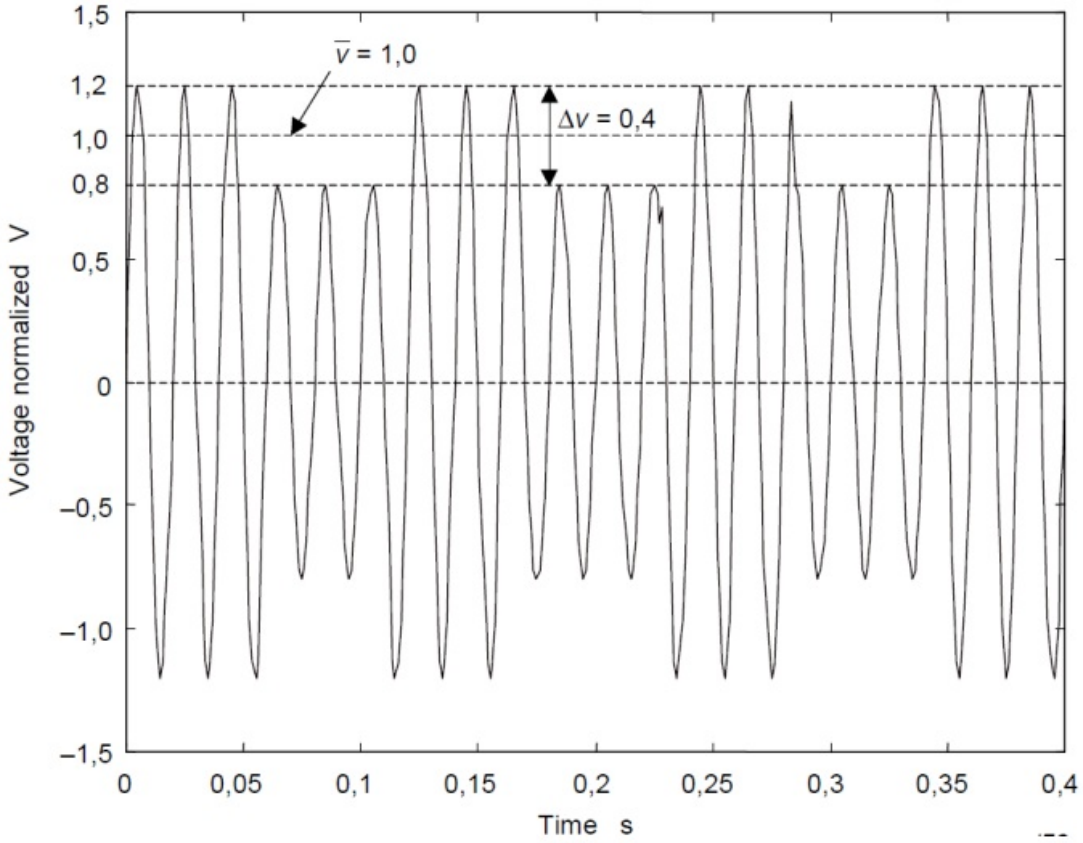


Image 32: Rectangular voltage flicker

Measurement with Dewesoft X: Flicker

With Dewesoft X the Short-Term Perceptibility (Pst) and Long-Term Perceptibility (Plt) values can be calculated according to the IEC standard, with a calculation time of 10 minutes and 120 minutes respectively. It is of course also possible to adapt the calculation time to the needs of the user, simply set a calculation overlap and filter.

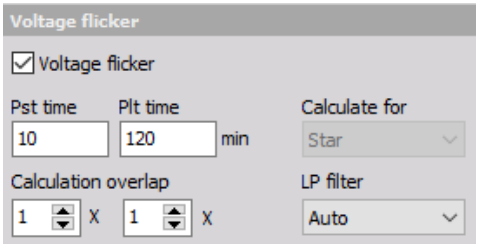


Image 33: Voltage flicker options in the power module

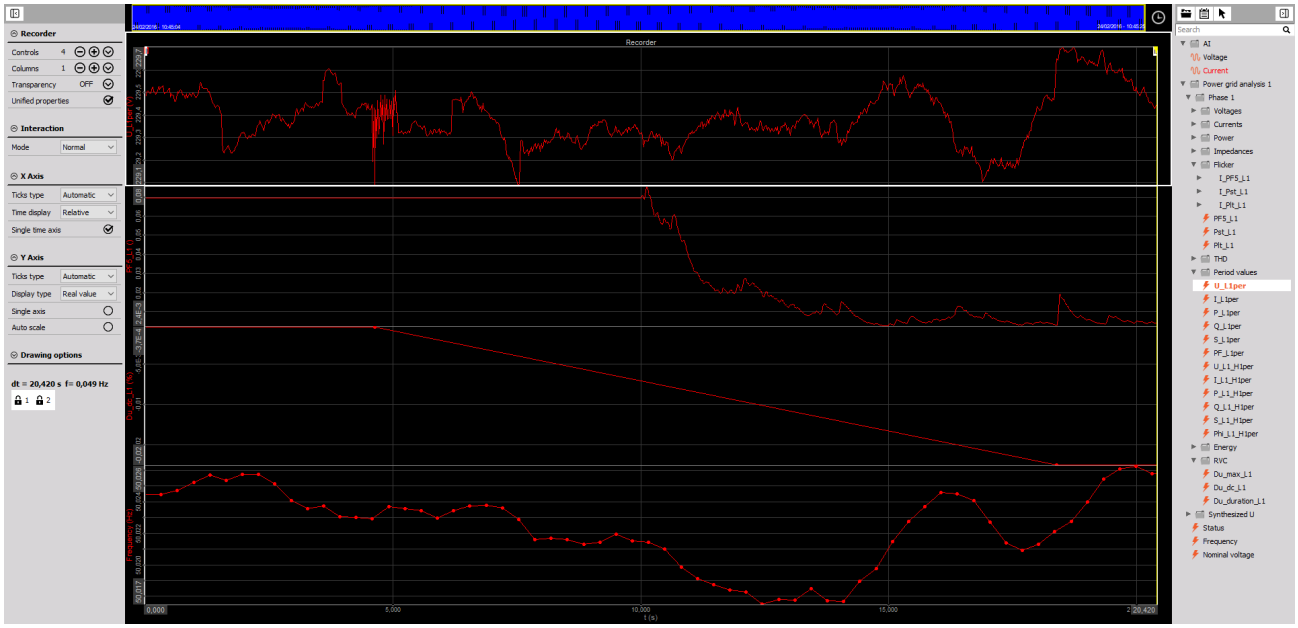


Image 34: Flicker measurement screen

Flicker emission

The flicker emission (also called current flicker) calculates the proportion of the flicker, which is added to the grid by a producer or a consumer. In addition, the internal voltage drop is calculated by the grid impedance of the current flow.

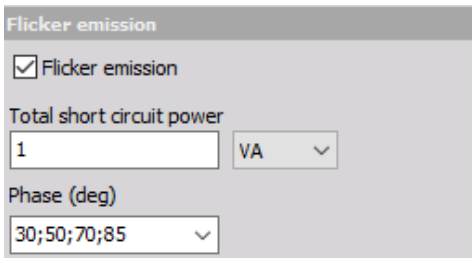


Image 35: Flicker emission options in the power module

The voltage drop is added to an idealized voltage source vectorially (U=Usim+Râˆ™I+Lâˆ™di/dt). Using the flicker algorithm and the new voltage, the current flicker values are calculated.

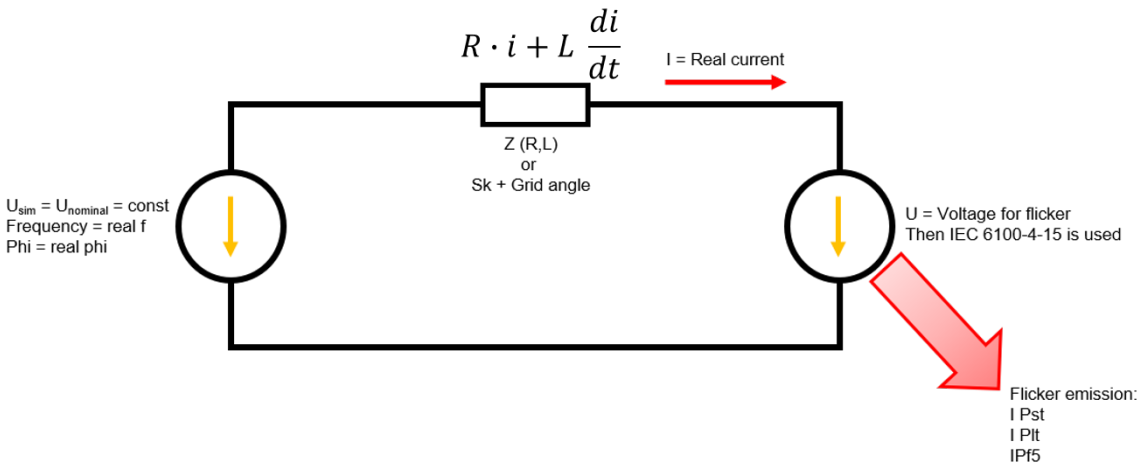
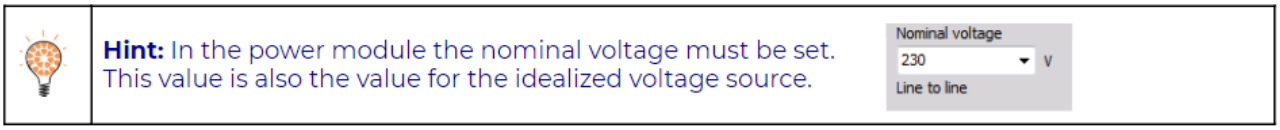


Image 36: Schematic illustration of the current flicker calculation

Enable "Flicker" and "Flicker emission" and add the grid parameters. The short circuit and the impedance of the grid can then also be added. The phase will be the impedance phase of the grid. The number of different phase angles can also be added (e.g. 30;50;70;85).



The following table expresses the channel names of the different parameters as they are presented in the Dewesoft X software. All the parameters are calculated using the IEC 61000-4-15 Standard's predefined calculation methods.

Channel name in Dewesoft	Calculation	Description
PF5_L1	According to IEC 61000-4-15	Represents the P_{inst} value from **IEC 61000-4-15**.
Pst_L1		Short time flicker value
Plt_L1		Long-time flicker value
I_PF5_L1		Represents the P_{inst} value from **IEC 61000-4-1**5 for the current
I_Pst_L1		Short time flicker value for the current
I_Plt_L1		Long-time flicker value for the current
I_PF5_L1_30; I_Pst_L1_30; I_Plt_L1_30		Flicker values for a certain phase angle

Table 12: Flicker calculations according to IEC 61000-4-15

What are the Rapid Voltage Changes?

Rapid Voltage Changes are parameters which are added as a supplement to the flicker standard. Rapid Voltage Changes describe all voltage changes that change the voltage for more than 3% at a certain time interval. These voltage changes can afterwards be analyzed with different parameters (depth of voltage change, duration, steady state deviation, etc.).

The Rapid Voltage Changes (RVC) are special calculations in Dewesoft X which allows the calculation of the maximal voltage drop (d_{max}), the stationary deviation after the voltage drop (dc) and the time where the voltage drops below 3,3% of U_n. All values are calculated according to the IEC 61000-4-15. Analysis can be done for example for IEC 61000-3-3 and IEC 61000-3-11. The following image shows the calculated parameters (IEC 61000-4-15 page 35).

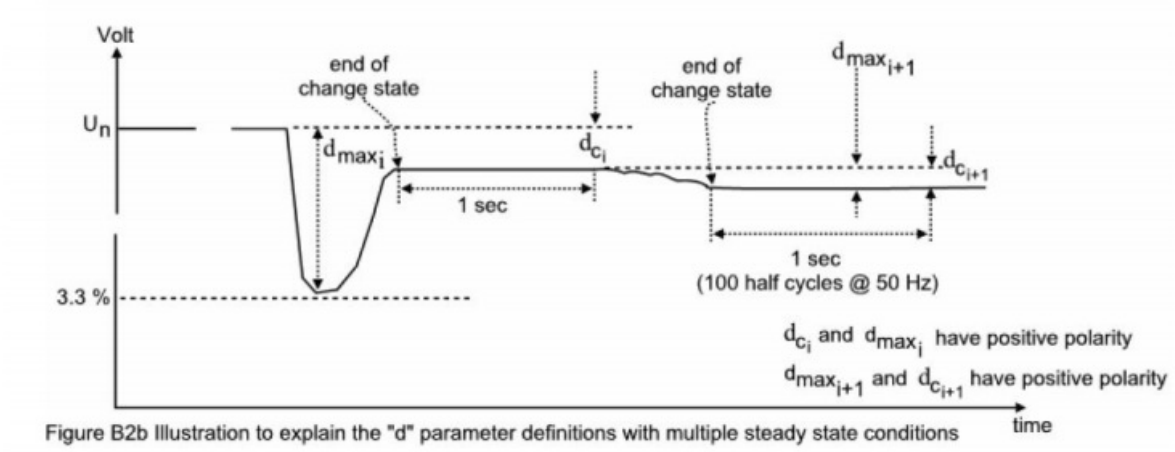


Image 37: Rapid voltage changes according to the IEC 61000-4-15 standard

Measurements with Dewesoft X

RVCs measurements with Dewesoft X:

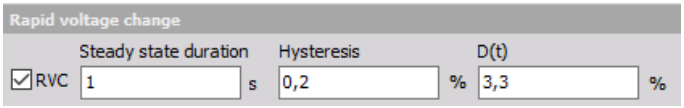


Image 38: Rapid voltage change options in the power module

Steady state duration: This defines the duration of the steady state defined in seconds.

Hysteresis: This is the condition for the stationary deviation (d_u_d_c) defined in percentage, see IEC 61000-4-15 page 8.

Example: If a hysteresis of 0,2% and a steady state duration of 1s is defined, the stationary condition is reached if the voltage doesn't deviate more than +- 0,2% for 1 second.

Hint: The Rapid Voltage Change values ($d_{u(max)}$, $d_{u(duration)}$ and $d_{u(dc)}$) are calculated from the defined settings for period values (Number of periods and overlap). Please ensure that the correct settings are used for analysis according to the related standards (½ period values for RVC determination according to IEC 61000-4-15)

Channel name in Dewesoft	Calculation	Description
Du_max_L1	According to IEC 61000-4-15	Maximum absolute voltage changes during an observation period
Du_dc_L1		Stationary deviation after the voltage drop
Du_duration_L1		time where the voltage drop is below 3,3% of Un

Table 13: Additional flicker calculations according to IEC 61000-4-15

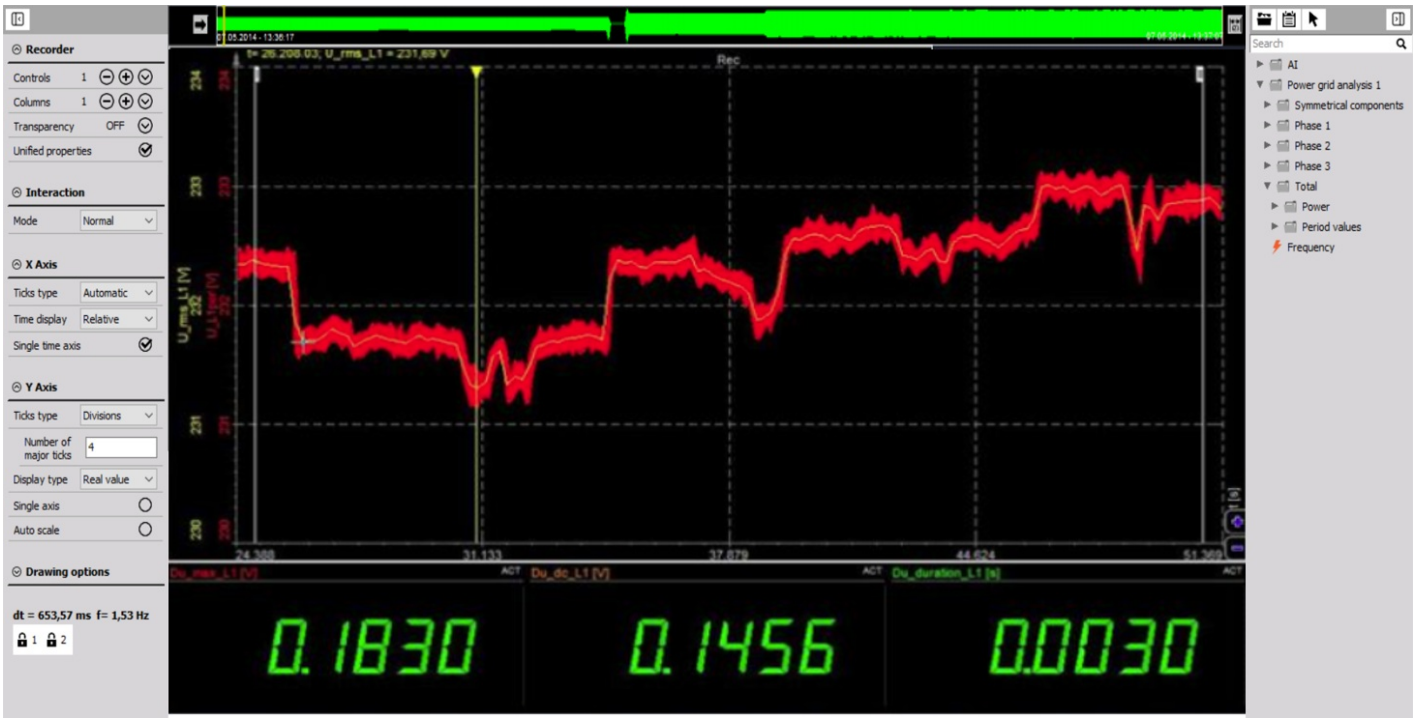


Image 39: Rapid voltage change measurement screen

How the Channel list is defined in Dewesoft X?

DEWESoft has created a special FFT algorithm (software PLL) to determine the periodic time (frequency). The algorithm determines the periodic time of the signal via a special FFT algorithm at a sampling window of multiple periods (typically 10 periods, definable in power module). The calculated frequency is highly accurate (mHz) and works for all applications (motor, inverter, grid, etc.).

How Dewesoft X calculates the power of an AC system

While other power analyses calculate the power in the time domain, in Dewesoft X calculates in the frequency domain. With the predetermined period time, an FFT analysis for voltage and current is done for a definable number of periods (typically 10, with electrical applications) and a definable sampling rate. The FFT yields an amplitude for the voltage, current, and the cos phi for each harmonic. One major benefit of this FFT transformation is that the behavior of amplifiers, current or voltage transducers in amplitude and phase for the whole frequency range (using the Sensor XML) can now be corrected. This way of power analysis has the highest possible accuracy. Another benefit is that harmonic analysis and other power quality analysis can be done completely synchronized to the fundamental frequency.

With the FFT corrected values, the RMS voltages and currents are calculated out of the RMS values of each harmonic.

$$U_{rms_{total}} = \sqrt{U_0^2 + U_1^2 + U_2^2 + \cdots + U_n^2}$$

$$I_{rms_{total}} = \sqrt{I_0^2 + I_1^2 + I_2^2 + \cdots + I_n^2}$$

The rectified mean is the average of the rectified signal. In terms of an AC signal, it's the average of the absolute value of voltage or current.

$$U_{RECT} = \frac{1}{T}\int_{t=0}^{T} |u|(t)dt$$

$$I_{RECT} = \frac{1}{T}\int_{t=0}^{T} |i|(t)dt$$

The rectified mean is used e.g. for transformer testing as the rectified mean is proportional to the magnetic flux.

The power values for each harmonic and the total values are calculated with the following formulas:

	n-Harmonic	Total
Apparent Power	$S_h = U_h \cdot I_h$	$S = U_{rms_{total}} \cdot I_{rms_{total}}$
Active Power	$P_h = U_h \cdot I_h \cdot \cos(\varphi_h)$	$P = \sum_{h=1}^{H} P_h$
Reactive Power	$Q_h = U_h \cdot I_h * \sin(\varphi_h) = \sqrt{S_h^2 - P_h^2}$	$Q = \sqrt{S^2 - P^2}$

Channel name in DEWESoft	Calculation	Description
S_L1_H1	$S_h = U_h \cdot I_h$	Apparent, active and reactive power for a certain harmonic frequency (e.g. for L1 and h=1)
P_L1_H1	$P_h = U_h \cdot I_h \cdot \cos(\varphi_h)$	
Q_L1_H1	$Q_h = U_h \cdot I_h \cdot \sin(\varphi_h) = \sqrt{(S_h^2 - P_h^2)}$	
S_L1	$S = U_{rms} * I_{rms}$	Three power parameters for the whole waveform (e.g. for L1)
P_L1	$P = \sum_{h=1}^{H} P_h$	
Q_L1	$Q = \sqrt{(S^2 - P^2)}$	
Z_L1	$Z_{L1} = \frac{U}{I}$	Impedance for the whole waveform (e.g. for L1)
Z_L1_H1	$Z_{L1} = \frac{U_H}{I_H}$	Impedance for a certain harmonic (e.g. for L1 and H1)
PF_L1	$PF = \frac{P}{S}$	Power factor (e.g. for L1)
D_L1	$D = \sqrt{(Q^2 - Q_{h=1}^2)}$	D_L1, distortion power of all harmonic components' reactive powers (u and i have the same order but not equal 1 or have different order) (e.g. for L1)
QH_L1	$QH = \sum_{h=1}^{H} Q_h$	Reactive power of all harmonics where u and i have the same harmonics order (e.g. for L1)
DH_L1	$DH = \sqrt{(Q^2 - QH^2)}$	Distortion power of all harmonic components' reactive powers where u and i have different harmonic orders (e.g. for L1)

There are two definitions for reactive power included, because there is up to date no official definition that has been standardized. The formula of Q1_L1 loses sign, while QH_L1 does not. If there is a need to calculate the reactive power form only the harmonics (no fundamental included) the following simple math formula can be used: â€˜QH_L1â€™ â€“ â€˜Q_L1_H1â€™

Channel name in DEWESoft	Calculation	Description
THD_U_L1, ...	$THD_U = \frac{\sqrt{(\sum_{h=2}^{n}(U_h)^2)}}{U_1}$	THD of the voltage
THDOdd_U_L1, ...	$THD_{Uodd} = \frac{\sqrt{(\sum_{h=1}^{n}(U_{2h+1})^2)}}{U_1}$	THD of the voltage for odd and even harmonics
THDEven_U_L1, ...	$THD_{Ueven} = \frac{\sqrt{(\sum_{h=1}^{n}(U_{2h})^2)}}{U_1}$	
THD_I_L1, ...	$THD_I = \frac{\sqrt{(\sum_{h=2}^{n}(I_h)^2)}}{I_1}$	THD of the current
THDOdd_I_L1, ...	$THD_{Iodd} = \frac{\sqrt{(\sum_{h=1}^{n}(I_{2h+1})^2)}}{I_1}$	THD of the current for odd and even harmonics
THDEven_I_L1, ...	$THD_{Ieven} = \frac{\sqrt{(\sum_{h=1}^{n}(I_{2h})^2)}}{I_1}$	
TIHD_U_L1, ...	$TIHD_U = \frac{\sqrt{(\sum_{k=1}^{n}(U_k)^2)}}{U_1}$	Total Interharmonic distortion of the voltage/current. Equivalent to the THD, but defined for interharmonics
TIHD_I_L1, ...	$TIHD_I = \frac{\sqrt{(\sum_{k=1}^{n}(I_k)^2)}}{I_1}$	
K_U_L1	$K_U = \frac{\sqrt{(\sum_{h=2}^{n}(U_h)^2)}}{U}$	K-factor for voltage and current. Refers to the full-spectrum, the THD only to the fundamental voltage
K_I_L1	$K_I = \frac{\sqrt{(\sum_{h=2}^{n}(I_h)^2)}}{I}$	
THC	$THC = \sqrt{\sum_{n=2}^{n=40} I_h^2}$	THC (Total Harmonics Current) for distortion of current waveform of the orders 2 to 40.
TDD	$I_{TDD} = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \ldots}}{I_L} * 100$	TDD (Total Demand Distortion) ratio of the root-sum-square value of the harmonic current to the maximum demand load current in percentage.

Channel name in DEWESoft	Calculation
U_0, U_1, U_2; I_0, I_1, I_2	$\begin{bmatrix} \underline{U}^0 \\ \underline{U}^1 \\ \underline{U}^2 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \cdot \begin{bmatrix} \underline{U}_{L1} \\ \underline{U}_{L2} \\ \underline{U}_{L3} \end{bmatrix} \begin{bmatrix} \underline{I}^0 \\ \underline{I}^1 \\ \underline{I}^2 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \cdot \begin{bmatrix} \underline{I}_{L1} \\ \underline{I}_{L2} \\ \underline{I}_{L3} \end{bmatrix}$

Channel name in DEWESoft	Calculation	Description
u2, i2	$u_2 = \frac{\underline{U}^2}{\underline{U}^1} \cdot 100\%$ $\quad i_2 = \frac{\underline{I}^2}{\underline{I}^1} \cdot 100\%$	Negative sequence component of the voltage/current
u0, i0	$u_0 = \frac{\underline{U}^0}{\underline{U}^1} \cdot 100\%$ $\quad i_0 = \frac{\underline{I}^0}{\underline{I}^1} \cdot 100\%$	Zero sequence component of the voltage/current
u2_1, i2_1	$u_{2_1} = \frac{\underline{U}_{H1}^2}{\underline{U}_{H1}^1} \cdot 100\%$ $\quad i_{2_1} = \frac{\underline{I}_{H1}^2}{\underline{I}_{H1}^1} \cdot 100\%$	Negative sequence component of the fundamental voltage/current in per cent (unbalance factor according to EN50160)
u0_1, i0_1	$u_{0_1} = \frac{\underline{U}_{H1}^0}{\underline{U}_{H1}^1} \cdot 100\%$ $\quad i_{0_1} = \frac{\underline{I}_{H1}^0}{\underline{I}_{H1}^1} \cdot 100\%$	Zero sequence component of the fundamental voltage/current in per cent

Channel name in DEWESoft	Calculation	Description
U_ap_cos_per	$U_{1+,\cos} = \frac{1}{6}[2u_{a,\cos} - u_{b,\cos} - u_{c,\cos} - \sqrt{3}(u_{c,\sin} - u_{b,\sin})]$	Voltage and current vector components of the positive sequence for the fundamental
U_ap_sin_per	$U_{1+,\sin} = \frac{1}{6}[2u_{a,\sin} - u_{b,\sin} - u_{c,\sin} - \sqrt{3}(u_{c,\cos} - u_{b,\cos})]$	
I_ap_cos_per	$i_{1+,\cos} = \frac{1}{6}[2i_{a,\cos} - i_{b,\cos} - i_{c,\cos} - \sqrt{3}(i_{c,\sin} - i_{b,\sin})]$	
I_ap_sin_per	$i_{1+,\sin} = \frac{1}{6}[2i_{a,\sin} - i_{b,\sin} - i_{c,\sin} - \sqrt{3}(i_{b,\cos} - i_{c,\cos})]$	
P_1p_per	$P_{1+} = \frac{3}{2}(u_{1+,\cos}i_{1+,\cos} - u_{1+,\sin}i_{1+,\sin})$	Active and reactive power from the fundamental positive sequence
Q_1p_per	$Q_{1+} = \frac{3}{2}(u_{1+,\cos}i_{1+,\sin} - u_{1+,\sin}i_{1+,\cos})$	
U_1p_per	$U_{1+} = \sqrt{\frac{3}{2}(U_{1+,\sin}^2 + U_{1+,\cos}^2)}$	RMS value of the line voltage of the fundamental positive sequence
I_p1p_per	$I_{P1+} = \frac{P_{1+}}{\sqrt{3}U_{1+}}$	RMS values of the active and reactive current from the fundamental positive sequence
I_q1p_per	$I_{Q1+} = \frac{Q_{1+}}{\sqrt{3}U_{1+}}$	

Channel name in DEWESoft	Calculation	Description
cos_phi_1p_per	$\cos\varphi_{1+} = \frac{P_{1+}}{\sqrt{P_{1+}^{(2)} + Q_{1+}^{(2)}}}$	Power factor of the fundamental positive sequence
S_1p_per	$S_{1+} = \sqrt{P_{1+}^{(2)} + Q_{1+}^{(2)}}$	Further calculation
I_1p_per	$i_{1+} = \frac{S_{1+}}{\sqrt{3}U_{1+}}$	

Channel name in DEWESoft	Calculation	Description
U_an_cos_per	$U_{1-,\cos} = \frac{1}{6}[2u_{a,\cos} - u_{b,\cos} - u_{c,\cos} + \sqrt{3}(u_{c,\sin} - u_{b,\sin})]$	Voltage and current vector components of the negative sequence for the fundamental
U_an_sin_per	$U_{1-,\sin} = \frac{1}{6}[2u_{a,\sin} - u_{b,\sin} - u_{c,\sin} + \sqrt{3}(u_{b,\cos} - u_{c,\cos})]$	
I_an_cos_per	$i_{1-,\cos} = \frac{1}{6}[2i_{a,\cos} - i_{b,\cos} - i_{c,\cos} + \sqrt{3}(i_{c,\sin} - i_{b,\sin})]$	
I_an_sin_per	$i_{1-,\sin} = \frac{1}{6}[2i_{a,\sin} - i_{b,\sin} - i_{c,\sin} + \sqrt{3}(i_{b,\cos} - i_{c,\cos})]$	
P_1n_per	$P_{1-} = \frac{3}{2}(u_{1-,\cos}i_{1-,\cos} - u_{1-,\sin}i_{1-,\sin})$	Active and reactive power from the fundamental negative sequence
Q_1n_per	$Q_{1-} = \frac{3}{2}(u_{1-,\cos}i_{1-,\sin} - u_{1-,\sin}i_{1-,\cos})$	
U_1n_per	$U_{1-} = \sqrt{\frac{3}{2}(U_{1-,\sin}^2 + U_{1-,\cos}^2)}$	RMS value of the line voltage of the fundamental negative sequence
S_1n_per	$S_{1-} = \sqrt{P_{1-}^{(2)} + Q_{1-}^{(2)}}$	Further calculations
I_1n_per	$i_{1-} = \frac{S_{1-}}{\sqrt{3}U_{1-}}$	

Channel name in DEWESoft	Calculation	Description
U_az_cos_per	$U_{1z,\cos} = \frac{1}{3}[u_{a,\cos} + u_{b,\cos} + u_{c,\cos}]$	Voltage and current vector components of the zero sequence for the fundamental
U_az_sin_per	$U_{1z,\sin} = \frac{1}{3}[u_{a,\sin} + u_{b,\sin} + u_{c,\sin}]$	
I_az_cos_per	$i_{1z,\cos} = \frac{1}{3}[i_{a,\cos} + i_{b,\cos} + i_{c,\cos}]$	
I_az_sin_per	$i_{1z,\sin} = \frac{1}{3}[i_{a,\sin} + i_{b,\sin} + i_{c,\sin}]$	
P_1z_per	$P_{1z} = \frac{3}{2}(u_{1z,\cos}i_{1z,\cos} - u_{1z,\sin}i_{1z,\sin})$	Active and reactive power from the fundamental zero sequence
Q_1z_per	$Q_{1z} = \frac{3}{2}(u_{1z,\cos}i_{1z,\sin} - u_{1z,\sin}i_{1z,\cos})$	
U_1z_per	$U_{1z} = \sqrt{\frac{3}{2}(U_{1z,\sin}^2 + U_{1z,\cos}^2)}$	RMS value of the line voltage of the fundamental zero sequence
S_1z_per	$S_{1z} = \sqrt{P_{1z}^{(2)} + Q_{1z}^{(2)}}$	Further calculations
I_1z_per	$i_{1z} = \frac{S_{1z}}{\sqrt{3}U_{1z}}$	

Description	Calculation
Total Energy	$E = \frac{1}{T}\int_{t=0}^{T} p(t)dt$
Positive Energy	$E_{mot} = \frac{1}{T}\int_{t=0}^{T} p_{mot}(t)dt$ if $p_{mot}(t) > 0$
Negative Energy	$E_{recup} = \frac{1}{T}\int_{t=0}^{T} p_{mot}(t)dt$ if $p_{mot}(t) < 0$

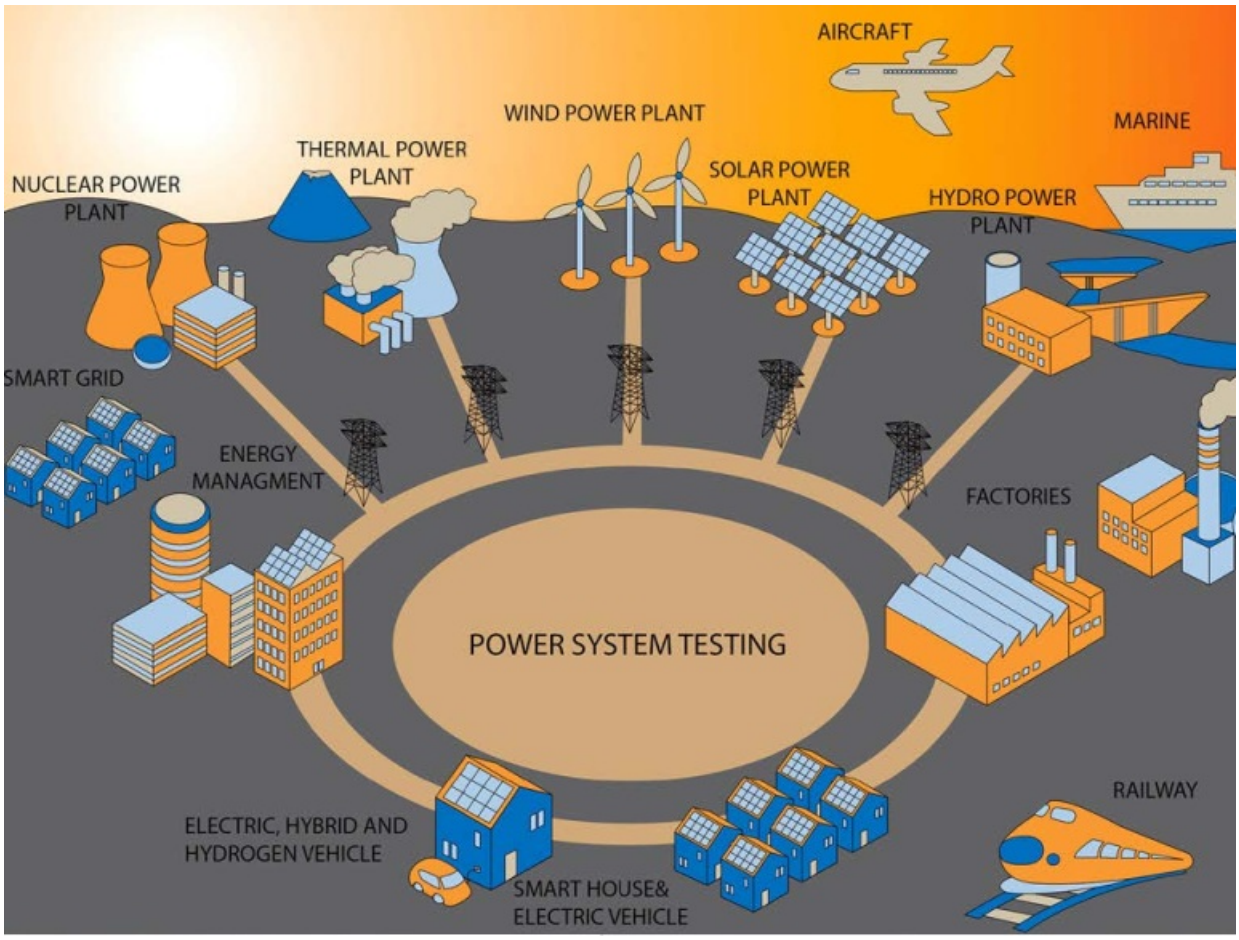
Channel name in DEWESoft	Calculation	Description
PF5_L1	According to IEC 61000-4-15	Represents the P_{inst} value from IEC 61000-4-15.
Pst_L1		Short time flicker value
Plt_L1		Long time flicker value
I_PF5_L1		Represents the P_{inst} value from IEC 61000-4-15 for the current
I_Pst_L1		Short time flicker value for the current
I_Plt_L1		Long time flicker value for the current
I_PF5_L1_30; I_Pst_L1_30; I_Plt_L1_30		Flicker values for a certain phase angle

Channel name in DEWESoft	Calculation	Description
Du_max_L1	According to IEC 61000-4-15	maximum absolute voltage change during an observation period
Du_dc_L1		stationary deviation after the voltage drop
Du_duration_L1		time where the voltage drop is below 3,3% of Un

Period values for each phase	
Channel name in DEWESoft	Description
U_L1per	phase-to-earth voltage
U_L12per	phase-to-phase voltage
U_L1_H1per	fundamental phase-to-earth voltage
I_L1per	phase current
I_L1_H1per	fundamental phase current
P_L1per	active power of phase
P_L1_H1per	active power of the fundamental of the phase
Q_L1per	reactive power of phase
Q_L1_H1per	reactive power of the fundamental of the phase
S_L1per	apparent power of phase
S_L1_H1per	apparent power of the fundamental of the phase
PF_L1per	power factor of the phase
phi_L1_H1per	period value of phi

Power values total	
Channel name in DEWESoft	Description
Uper	Average voltage of all phases
U_H1per	Average voltage of all phases for the fundamental
Iper	Cumulative current of all phases
I_H1per	Cumulative current of all phases for the fundamental
Pper	Active power
P_H1per	Active power of the fundamental
Qper	Reactive power
Q_H1per	Reactive power of the fundamental
Sper	Apparent power
S_H1per	Apparent power of the fundamental
PFper	Power factor
phi_H1_per	Average phi of the fundamental

Where the Power Quality can be Applied?



Power grid

- fault and transient recording
- power quality analysis (IEEE 1159, EN50160)

Transformer

- efficiency analysis (IEC 60076-1)
- no-load and short circuit testing
- vibration, noise

Wind, solar and CHP

- power performance (IEC 61400-12)
- power quality (IEC 61400-21 / FGW-TR3)
- active and reactive power (FGW-TR3)
- behavior at faults (FGW-TR3)

Nuclear power plant

- turbine and generator
- testing rod drop
- castor testing

Turbine and generator

- modal analysis
- order tracking
- balancing
- rotational vibration
- efficiency measurement

Smart grid and energy management

- power system testing
- load profile
- demand-side management

Aircraft

- power system testing
- fault and transient recording
- hybrid testing
- harmonics analysis

Marine

- power system testing
- fault and transient recording
- hybrid testing

Railway

- power system testing (AC and DC rails)
- power quality analysis
- fault and transient recording
- short-circuit analysis

- pantograph and current shoe testing

E-mobility

- electric two-wheeler
- electric vehicle
- hybrid vehicle (series and parallel)
- hydrogen vehicle

Equipment testing

- fans and pumps testing
- circuit breaker testing
- filter analysis
- harmonics analysis according to IEC 61000-3-2/-12
- voltage changes according to IEC 61000-3-3/-11
- CE conformity of electrical devices (harmonics, flicker) and a lot more

To learn more about POWER APPLICATION please download our POWER BROCHURE.

Dewesoft's power Instruments

OVERVIEW	DEWESoft® DS-R8D POWER	DEWESoft® DS-R3 POWER	DEWESoft® DS-R2DB POWER	DEWESoft® SIRIUS POWER
				
Max. isolated ChnNo.	64	24	16	8
Sample Rate/Res. - 1	1MS / 16 Bit	1MS / 16 Bit	1MS / 16 Bit	1MS / 16 Bit
Bandwidth	2MHz	2MHz	2MHz	2MHz
Sample Rate/Res. - 2	200 kS/s / 24 Bit	200 kS/s / 24 Bit	200 kS/s / 24 Bit	200 kS/s / 24 Bit
Bandwidth	75 kHz	75 kHz	75 kHz	75 kHz
Base accuracy	0.03%	0.03%	0.03%	0.03%
Max. Range	1600V DC	1600V DC	1600V DC	1600V DC
3 PHASE SYSTEMS	8	3	2	1
Tacho / Counter	16	4	4	2
CAN	up to 8	up to 3	up to 2	optional (SBOX up to 2)
Option Fanless	–	–	–	✓
Digital Inputs	192	72	48	24
Digital Outputs	64	24	16	8
Analogue Outputs	64 (optional)	–	16 (optional)	8 (optional)
Time Synchronisation	IRIG, GPS, NTP	IRIG, GPS, NTP	IRIG, GPS, NTP	IRIG, GPS, NTP

NOTE: Bandwidth at 1MS/16Bit depends on selected input: HS-LV has **1MHz** and HS-HV has **2MHz**.

HIGH VOLTAGE INPUT	
ADC type	16 bit SAR with 100 kHz 5th order analog AAF filter or bypass (2 MHz)
Sampling rate	Simultaneous 1 MS/s
Ranges	±1600 V, ±800 V, ±400 V, ±200 V, ±100 V, ±50 V, ±20 V
Typ. SNR @ 100 kHz	85 dB
Input coupling	DC
Input impedance	10 MΩ in parallel 2pF
Overvoltage protection	In+ to In-: 4 kVpk-pk , Inx to GND: 2 kVpk-pk , CAT II 1000V, CATIII 600V

LOW VOLTAGE INPUT	
ADC type	16 bit SAR with 100 kHz 5th order analog AAF filter or bypass
Sampling rate	Simultaneous 1 MS/s
Ranges	±100V, ±50V, ±20V, ±10V, ±5V, ±2V, ±1V, ± 500mV, ±200mV, ±100mV and 50mV
Br ranges @ 10 Vexc	1000 mV/V, 100 mV/V, 10 mV/V
Input coupling	DC, AC 1 Hz (3 Hz, 10 Hz per SW)
Input impedance (100 V range)	10 (1) MΩ between IN+ or In- and GND
Bridge modes	Full bridge
TEDS	Standard + MSI adapters, only on DSUB 9 version
Sensor Excitation	2 to 30 V bipolar / 0 to 24 V unipolar, sw programmable (16 bit DAC), max 0,2 A / 2 W
Overvoltage protection	Range < 10 V: 100V (200 V peak for 10msec); Range ≥ 10 V: 300 V cont.; 1000V with banana plug
Connector	BNC, DSUB 9, Banana, Screw Connector