Mobile damping analyser

DA-Box 2000

- **Enables mobile analysis of network dynamics - to improve security of supply**
- **Disturbance analysis to solve integration problems of renewables, distributed generation**
- **Captures harmful oscillation modes caused by generators and loads (5 mHz to 98 Hz)**
- **Highly accurate measurement of frequency, drift processes (U, f) and oscillation damping**

1. Application

The DA-Box 2000 is primarily designed for use in distribution networks. It allows network stability analyses to be carried out that were previously not possible with conventional measurement technology.

The new requirements placed on distribution networks, resulting for example from regulators and decentralised infeeds, are the stimulus behind such analyses. Interesting measuring points are infeed points and transfer points to customer systems.

The DA-Box 2000 can help to identify damping weak spots in the network and provide a new form of network service.

Frequencies from 5 mHz to 98 Hz are used for this analysis. Information which shows the stability status of the network without the use of a network model is obtained from these frequencies.

The DA-Box 2000 is designed for mobile use and features a sturdy mechanical construction. This is achieved through the use of passively cooled components and static memory.

Since continuous measurements of at least three months are recommended for network analyses, the device is equipped with its own industry PC and a sufficiently large 16 GB memory. If failure in the voltage supply to the DA-Box 2000 should occur during measurement, the last measurements will be saved via an internal backup system with a buffer battery and the industry PC safely shut down. Once the voltage supply is resumed, the system will automatically restart and continue the measurement.

All recorded data are saved in a MySQL database, which means that they can be easily processed later on. The system can be accessed on site at all times via external keyboard and screen connections. The DA-Box 2000 is also equipped with a network interface, which allows connections to be made via remote desktop.

The system provides the preinstalled software GDAView for simple offline analysis and even online monitoring purposes. A direct connection to an existing WinPQ installation with MySQL database is possible.

Time synchronisation can be implemented with the usual standards right up to NTP. DCF 77, GPS and IRIG receivers are available as accessories..

The area of application for the DA-Box 2000 is not just limited to networks in which a measuring voltage of 100 V is available.

Measurements can be carried out directly at 100 V, 400 V and even 690 V by switching the measuring range. The measurement input is separated by an optical cable, ensuring complete safety.

1.1 Consequences of unstable networks

The following example shows the possible effects in distribution networks

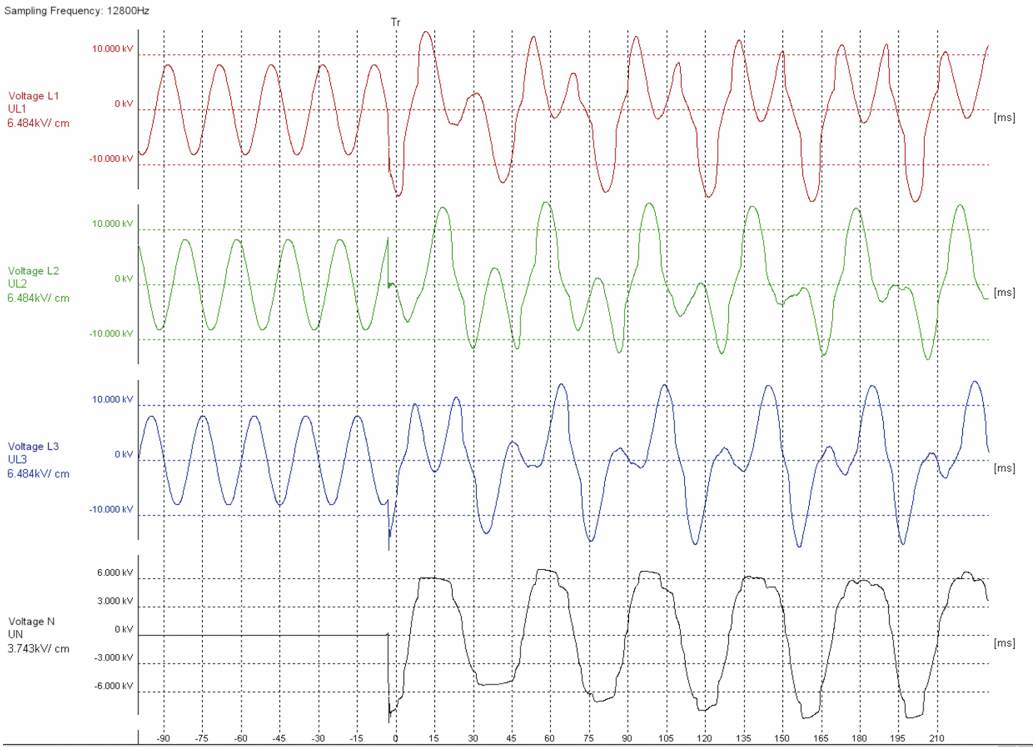


Figure 1: Earth fault as an excitation of the system

Figure 2 shows the increase in the neutral earth voltage over an extended period of time.

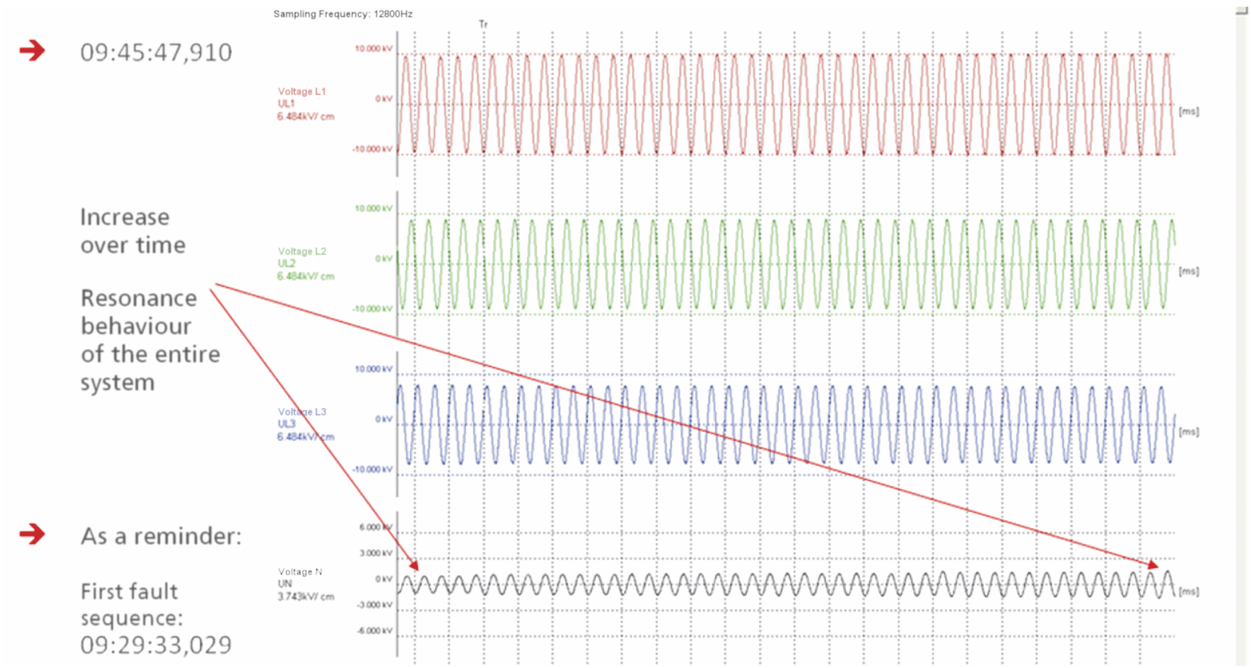


Figure 2: Increase in the neutral earth voltage

The following figure shows possible results:

Figure 3: Transformers destroyed by undamped oscillations in the network

In this case, the earth fault causes oscillations in the affected medium-voltage network. Figure 1: shows so-called double amplitudes in the three conductor voltages. Figure 2: additionally displays the influence on the neutral earth voltage over several periods. In this case then, an excitation in the neutral earth voltage range also occurs in addition to the double amplitudes. The progressive increase is visible. The frequency of this development is very low and cannot be derived from the frequency of the double amplitudes.

The DA-Box 2000 helps to identify these frequencies.

1.2 Easy operation

The DA-Box 2000 is parameterised in the factory in such a way that all trigger values are set for common medium-voltage networks. For initial measurements, only the reference voltage value must be parameterised. Only the voltage supply and the two external conductor voltages (100 V measurement inputs) must be connected). The Start button is then used to begin and end the measurement.

Date can be read out directly from the device using a standard USB stick. Pressing the "Copy USB" button saves all data recorded up to that point. Measurement can continue while this is happening.

This means that no additional computer technology is required on site.

However, a monitor and a keyboard can be connected for direct operation at any time.

1.3 Options for analysis and installation

The following steps are necessary:

- Measurement value recording in your transformer station for at least three months
- It often makes sense to carry out measurements at several points in the network **simultaneously**
- Analysis and report then follows
- Information such as important switching operations, load situations and particular events during the measurement time is provided by you

1.4 Discussion of the results with our experts

- Support during the implementation of improvement measures

We always rely on your support in order to carry out a successful analysis.

We require the **Operating log** from you, as this contains the switching operations for the measurement period. Additionally, you are mostly already familiar with the probable weak points in the network. It therefore makes sense to define the measurement locations with you before and during measurement.

1.5 Examples of calculated measurement values:

Various monitoring periods / recorders are used to calculate the properties of the network.

The familiar instantaneous value fault recorder is shown in Figure 4.

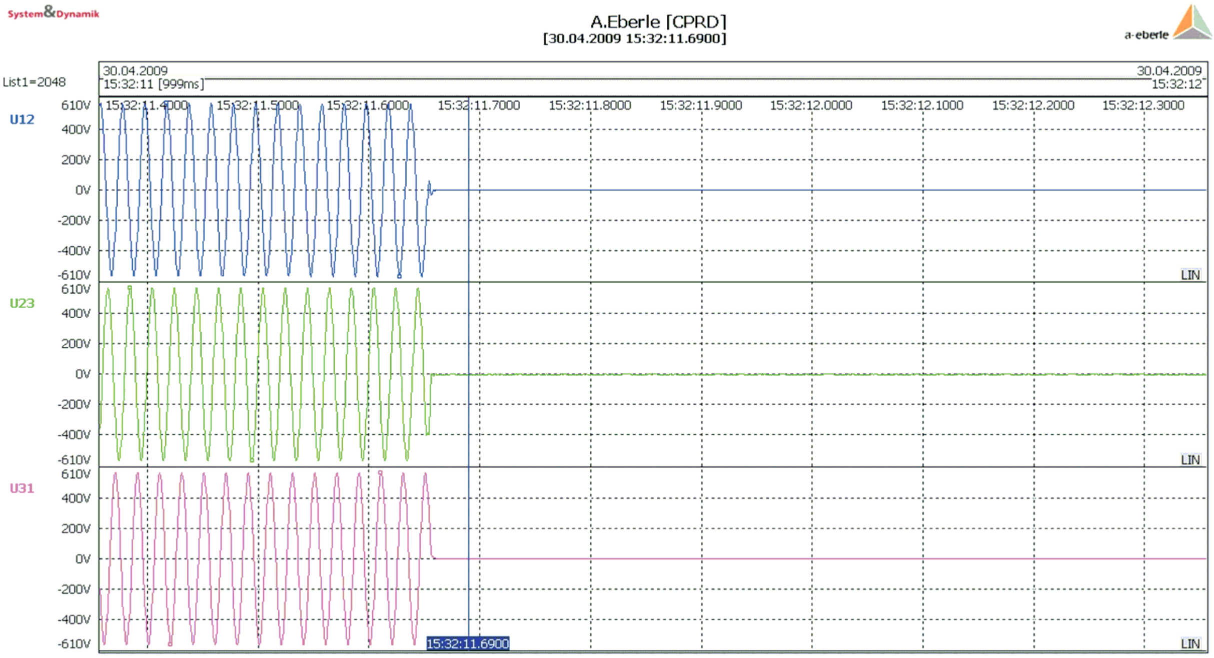


Figure 4: High-resolution instantaneous value fault record (recorder A) 100 µs

The average value fault records span from the 10 ms fault record in Figure 5...

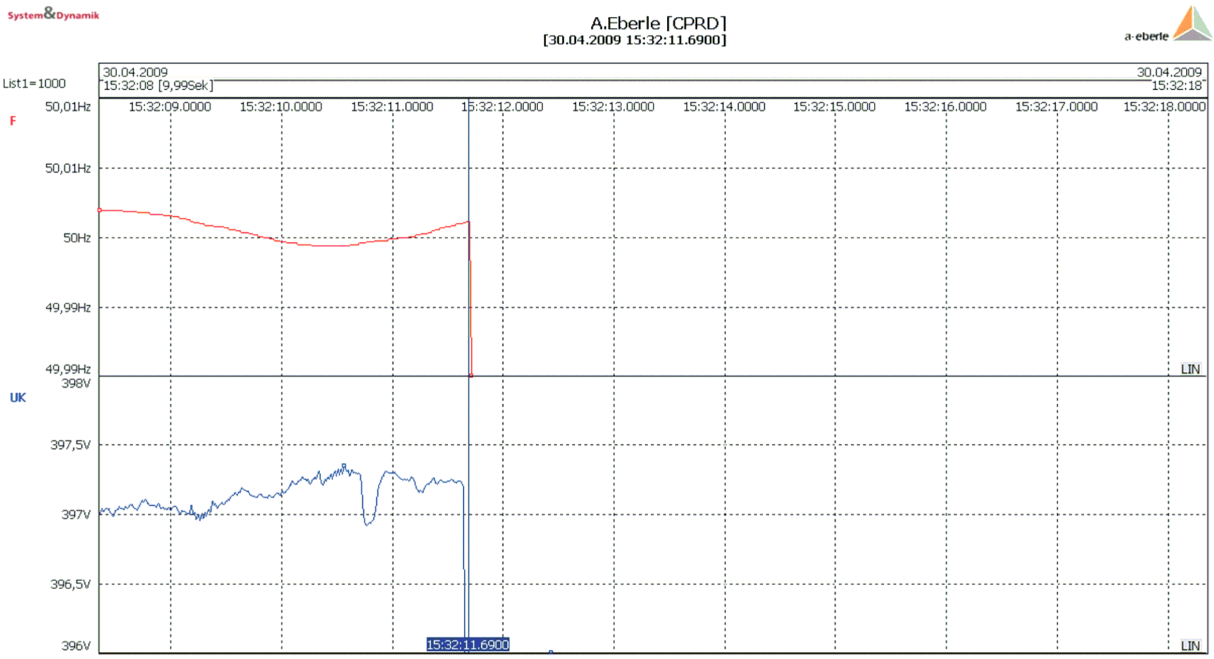


Figure 5: High-resolution average value fault record (recorder B) 10 ms

… through 5-second fault record in Figure 6 to …

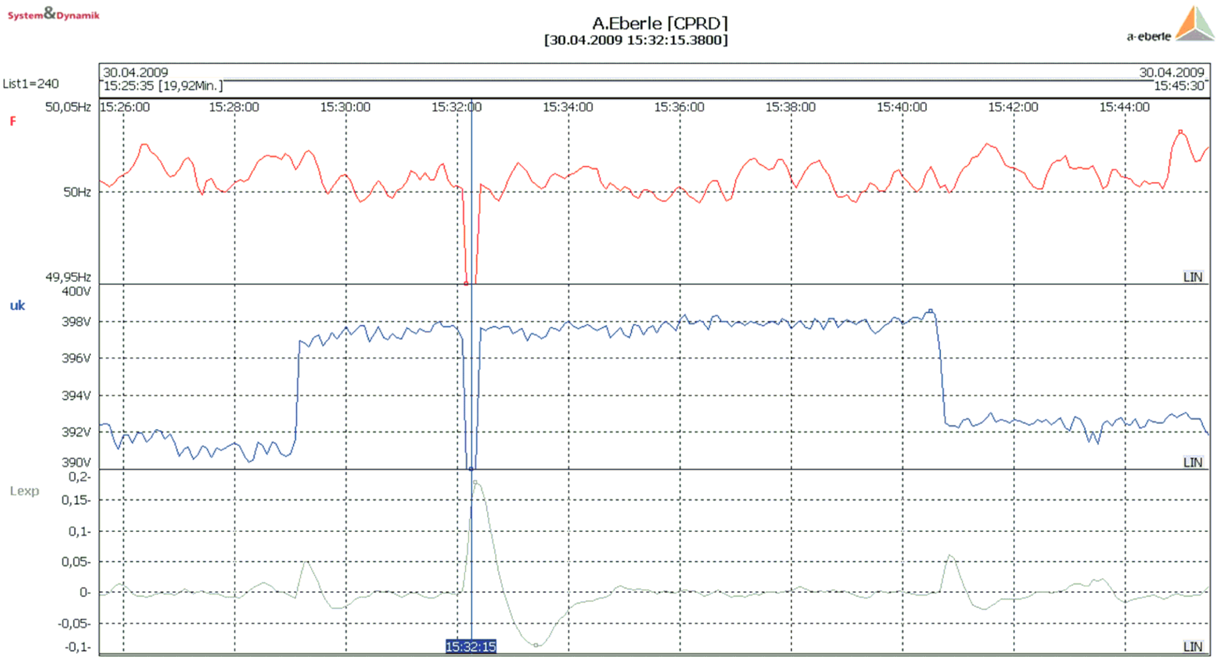


Figure 6: Average value fault record (recorder C) 5 s

… 50-second long-term fault records that are displayed in Figure 7.

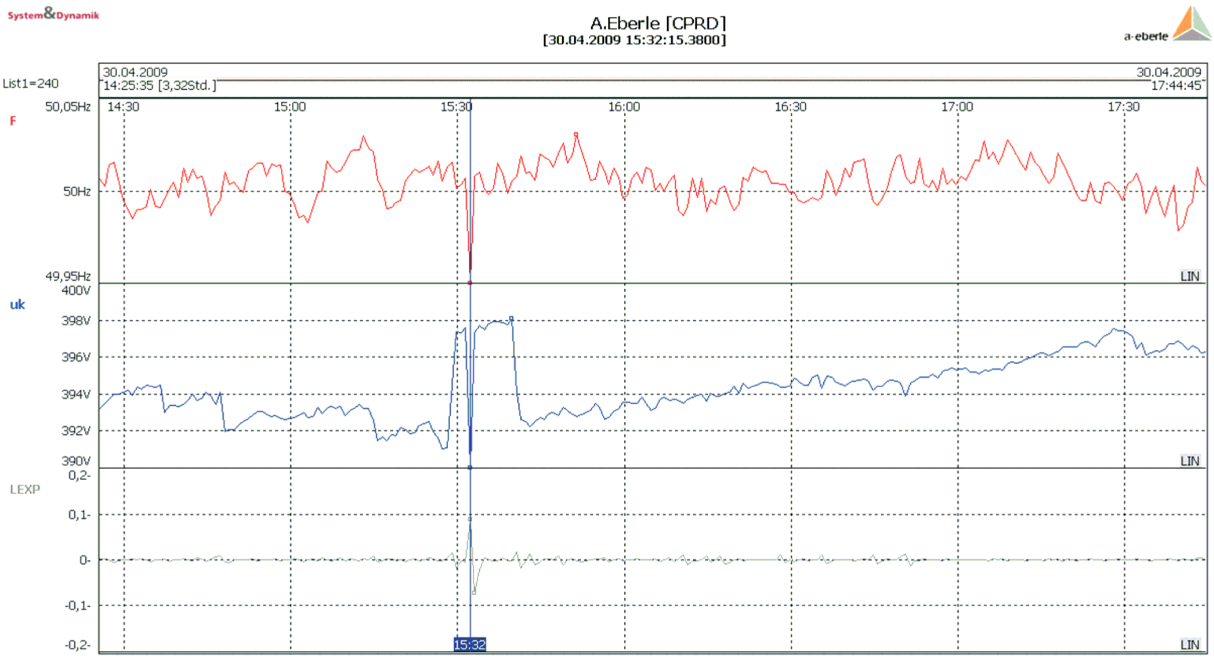


Figure 7: Long-term average value fault record (recorder D) 50 s

Since we concentrate on frequencies below 50 Hz in dynamic analysis, the long-term measurement values are of great significance. The 5-second and 50-second average values are therefore permanently recorded and used to carry out the analysis.

The following criteria for the stability of the network are thus determined:

- Spectral analysis of variations in grid voltage and frequency with a high frequency resolution
- Analysis / monitoring of the damping profile of the network, split into typical frequency modes
- Online determination of the Lyapunov exponent (index for the stability of a system)

The following figures give an impression of typical analysis procedures:

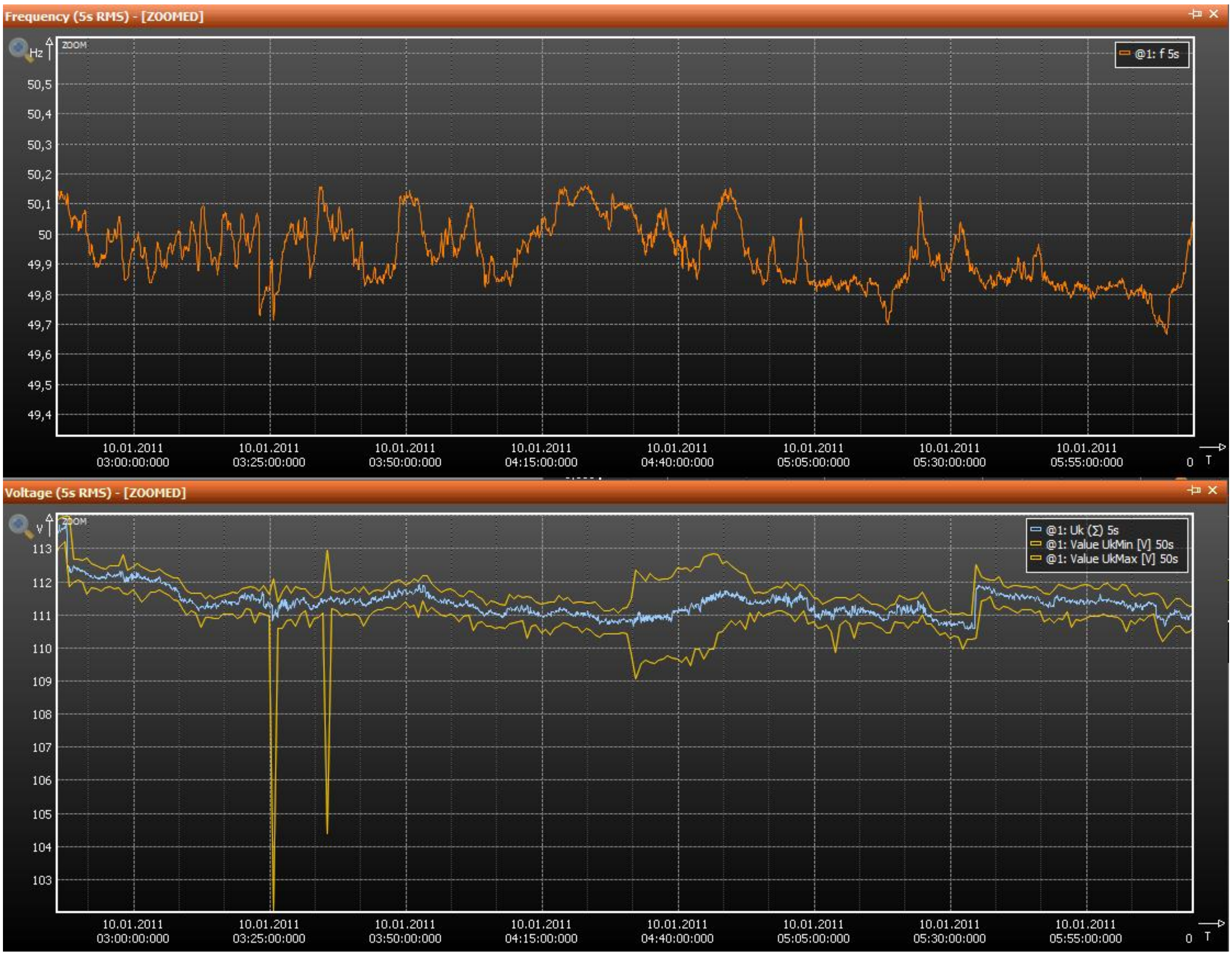


Figure 8: Inconspicuous plot of grid frequency (upper panel) and at the same time some very obvious short time voltage dips and deviations at the same point of measurement (lower panel)

Figure 8 shows some basic measurement quantities captured during a major disturbance in a transmission network. Grid frequency - being a comparably stable, rather global state variable of the complete grid - shows no obvious indication of trouble (upper panel). The lower panel shows 5s-RMS average values of the collective voltage Uka t the measurement site. Also shown are "fast" 10ms extreme values of voltage (Ukmin, Ukmax). In the left half of this plot, some very deep short time voltage dips are visible. Slightly right of the middle one can clearly see a longer term broadening of the extreme values - a deviation from the mean value. This is always a clear indication of local voltage variations - usually originating from dynamic effects.

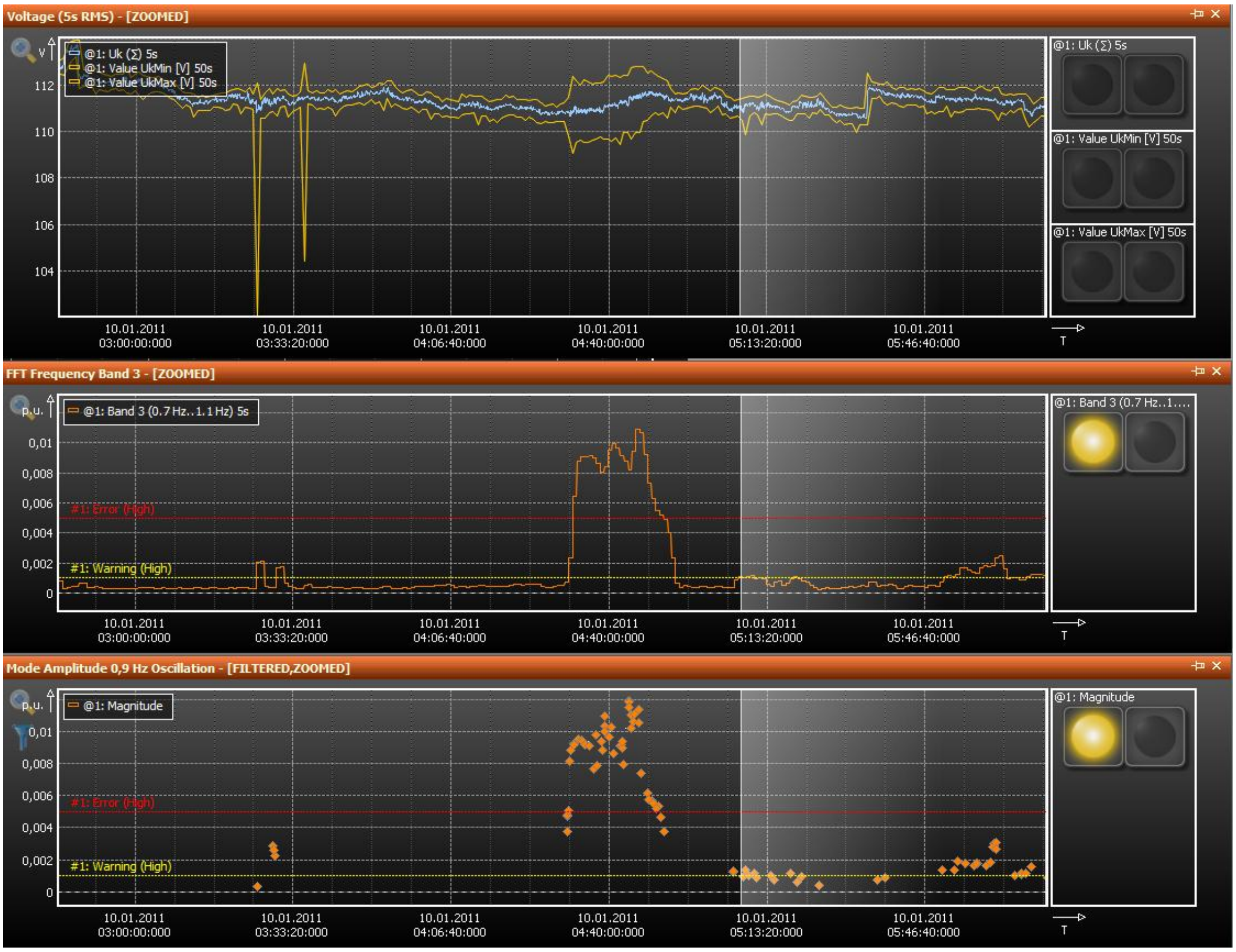


Figure 9: *Voltage at the measurement site (upper panel). FFT frequency band 3 as well as oscillation amplitudes in damping monitor - both with the threshold monitoring feature activated (middle and lower panel).*

Figure 9 once again shows the plot of voltage, this time combined with two measurement quantities useful for oscillation analysis. The comparison clearly shows that the short time voltage dips as well as the broadening coincide with dynamic oscillations in the electrical grid. FFT and Wavelet analysis in the lower two panels are in very good qualitative agreement. While the excitation of frequency band 3 shows that there is a strong oscillation somewhere within the relatively wide band of 0,7 Hz to 1,1 Hz, damping monitor allows to pinpoint the dominant oscillation frequency with mHz accuracy (it is a 0,9 Hz mode). This frequency is usually a revealing characteristic of the disturbing network element (in this case a large generator). The corresponding criticality is most easily assessed by activating the monitoring of freely adjustable thresholds. Visualization in GDAView is realized with an easy to understand "traffic light" scheme. In this case the voltage dips are related to faults in the grid. As a consequence some large generators were affected and were driven to dynamic instability - this is seen from the strong 0,9 Hz oscillation mode. During this specific incidence there was a relatively long early warning time - the time elapsing between the first warning signal (short term dips plus 0,9 Hz oscillation mode) and the occurrence of the large instability near the middle of the panel.

These kinds of measurements enable a large number of applicable use cases. In the following, one representative example shall be given for the transmission level as well as another one for the distribution level.

Transmission level

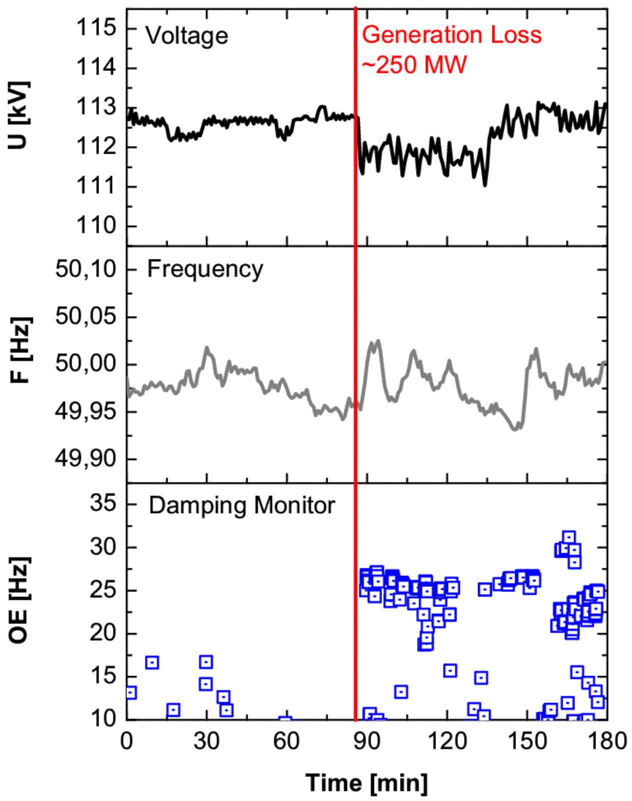


Figure 10: Loss of generation capacity (250 MW).

Switching events in electric power networks are everyday occurrences. No matter whether they are scheduled or occur due to a failure of a transmission system element - it is necessary to be wary of unexpected consequences all the time. Figure 10 shows measurements taken in a genuine high voltage level power transmission system. The red vertical line in the middle of the measurement interval marks an event in which 250 MW of power generation were lost. To assess the impact of this loss, it is interesting to follow the development of average system voltage and frequency, as displayed in the upper and middle panels.

As one would expect, the system voltage visibly drops to a lower value immediately after the loss happens. However, the old voltage level is already restored not much later, due to an abrupt transformer step up. The features in the system frequency are even less pronounced. The only thing to be seen is that immediately after switching, the frequency undergoes a few temporary deviations. As stated above, such a times series analysis of voltage and frequency represents the conventional way of approaching this problem. It should be noted that from the analysis of the upper two panels alone, one might easily conclude that the stability of the net did not significantly change before and after the loss of 250 MW of generated power.

The picture changes however, when taking into account the output of the damping monitor. Here it can be easily seen that immediately after the switching event, dynamical oscillations occur in the range of 20 to 30 Hz. Most importantly these frequencies are still clearly visible at times when average voltage and frequency seem to have returned to a normal behavior.

If in such a case, additional oscillations are accompanied by poor damping and large oscillation amplitude, this is a certain warning sign for poor system stability.

Distribution level

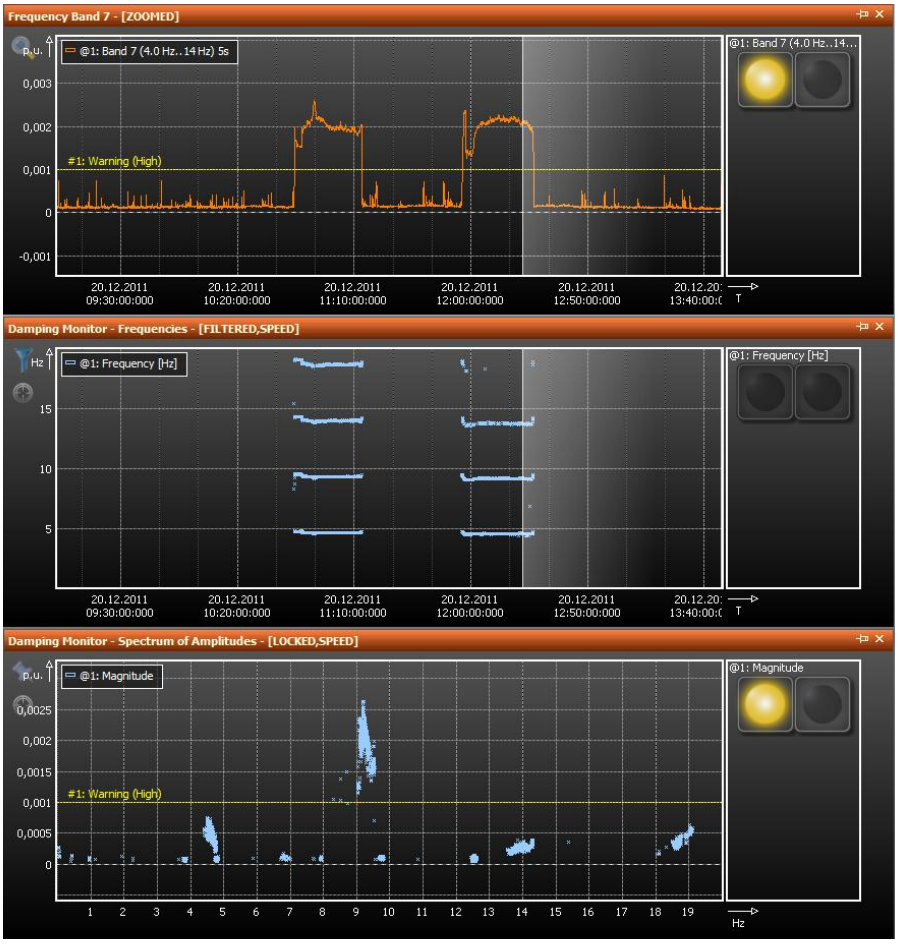


Figure 11: Analysis of oscillations triggered by feed-in problems of a photovoltaic generator.

Figure 11 shows measurements of a grid dynamic effect in a rural distribution grid where multiple photovoltaic generators are connected to the same line. The owner of one of the PV generators had massively complained because his inverters had regularly dropped of the grid, without obvious reasons. At the same time, the utility had measured high Flicker levels using an additional PQ Box 100. In the DA-Box 2000 data (upper panel) one sees a strongly excited frequency band 7 (4Hz to 14 Hz). This is a band which is critical for Flickers. In the middle panel, multiple oscillation events in damping monitor happening simultaneously. A look at the amplitude spectrum in the lower panel reveals that the 9Hz oscillation has the highest amplitudes by far and is directly responsible for the high Flicker levels. A correlation with power flow measurements furthermore revealed that the 9 Hz oscillation occured during load flow reversal, i.e. times of net feed-in. Also, feed-in broke down whenever large 9 Hz oscillation amplitudes occurred, indicating that these oscillations are also responsible for the feed-in problems. After realizing this, the utility simply cut the electrical connection between the affected and a neighboring photovoltaic generation site. The outcome of this was that the 9 Hz oscillation disappeared - and the PV generator started to work flawlessly. In summary, significant evidence pointed towards a harmful controller interaction between two competing PV inverters on the same distribution line. DA-Box 2000 with its high frequency resolution enabled the detailed analysis as well as the elimination of this integration problem of PV generators.

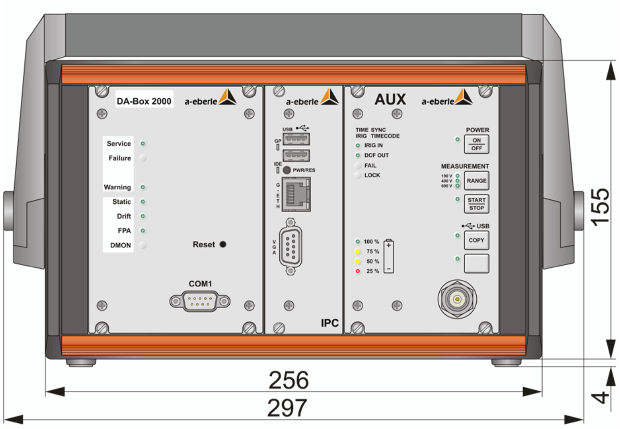
2. Features

- 2 voltage inputs switchable for 100 V, 400 V conductor-conductor or 690 V conductor-conductor; 0.1% error
- 10.24 kHz sampling frequency
- 24 bit A/D converter
- Automatic synchronisation to network frequency
- 4 freely programmable inputs (230 V)
- 4 (including status) freely programmable inputs (250 V; 5 A)
- 4 freely programmable mA outputs
  (-20 vmA..20 mA)
- Start button for starting and stopping measurement
- Button for reading out data via USB stick
- 5-minute internal UPS via NiMH battery in the event of a power failure
- **IPC with 600 MHz processor (passively cooled) and 16 GB memory (flash)**
- 3 USB interfaces
  - Data readout via any USB stick
  - USB connection for GSM modem, analogue modem,
- Ethernet interface (RJ45)
- RGB connection for monitor
- Windows XP Embedded operating system for IPC

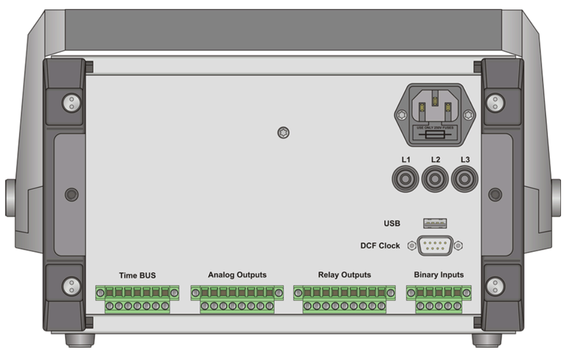
3. Dimensions

Dimensions

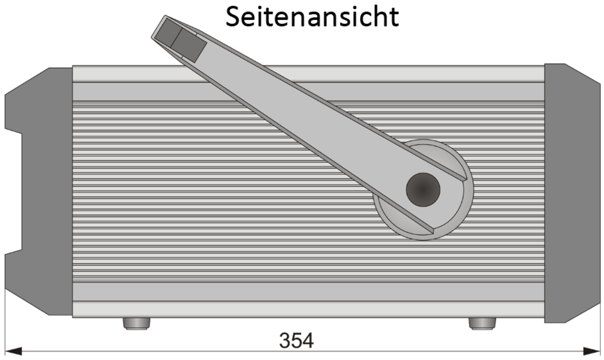
Frontansicht



Rückansicht

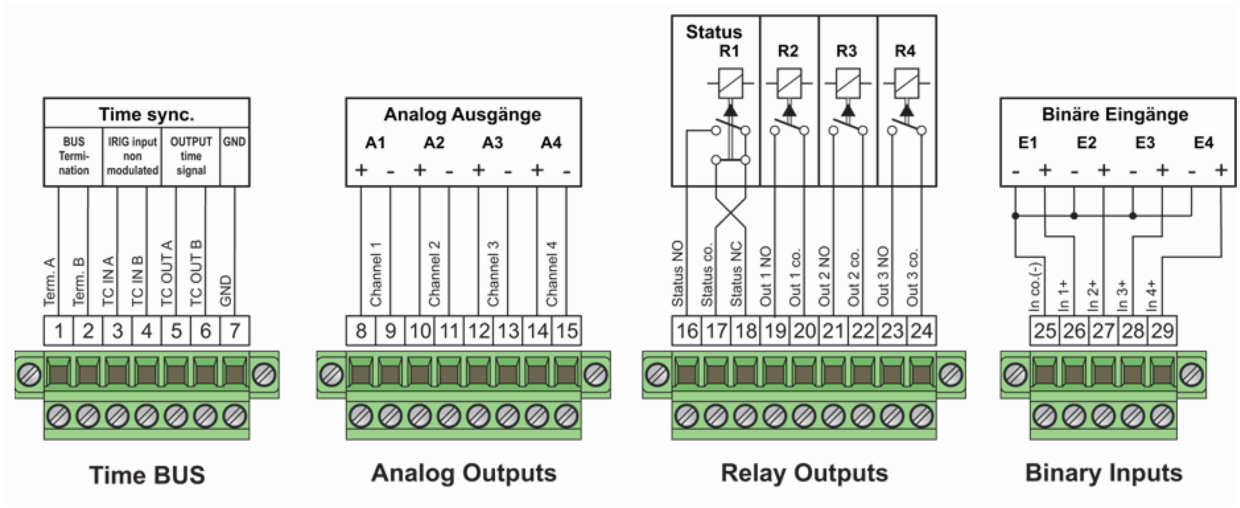


Seitenansicht



Height:	159 mm
Width:	297 mm
Depth:	354 mm
Weight:	8.5 kg

4. Terminal assignment



Designation			Function	Terminal	Assignment
Time sync.	BUS termination	Term A		1	External termination channel A (only for optional IRIG time synchronisation)
		Term B		2	External termination channel B (only for optional IRIG time synchronisation)
	IRIG input Non-modulated	TC in A		3	Connection of an external, non-modulated IRIG time signal, channel A
		TC in B		4	Connection of an external, non-modulated IRIG time signal, channel B
	OUTPUT time signal	TC out A		5	Connection of an external, non-modulated IRIG time signal, channel A
		TC out B		6	Connection of an external, non-modulated IRIG time signal, channel B
	GND	GND	GND	7	Earth (ground) connection for time signal
Analogue outputs	A1		+ -	8 9	Freely programmable with measurement values from all data classes
	A2		+ -	10 11	Freely programmable with measurement values from all data classes
	A3		+ -	12 13	Freely programmable with measurement values from all data classes
	A4		+ -	14 15	Freely programmable with measurement values from all data classes
Binary outputs 230 V (relay outputs)	Status R1		NC contact Pole NO contact	16 17 18	Status relay with NO contact and NC contact
	R2		NO contact Pole	19 20	Freely programmable

	R3	NO contact Pole	21 22	Freely programmable
	R4	NO contact Pole	23 24	Freely programmable
Binary inputs 230 V	E1...E4	GND	25	Earth (common earth) of the four binary inputs
	E1	+	26	Freely programmable
	E2	+	27	Freely programmable
	E3	+	28	Freely programmable
	E4	+	29	Freely programmable

5. Serial interfaces

RS232 interfaces

The DA-Box 2000 is equipped with a serial RS232 interface. The COM1 can be accessed via a D-Sub socket on the front of the device.

A further interface in RS232 format is the DCF77 interface. This is located on the rear of the housing. A DCF77 receiver or a GPS receiver with an RS232 output can be connected here. These are available as accessories.

Connection elements

COM1	Pin strip, Sub Min D on the front of the device, pin assignment the same as on PC
Connection possibilities	PC, terminal, modem, PLC
Number of data bits / protocol	Parity 8, even, off, odd
Transfer rate bit/s	1200, 2400, 4800, 9600, 19200, 38400, 57600, 76800, 115200
Handshake	RTS / CTS or X_{ON} / X_{OFF}
DCF77	Direct connection of a DCF77 receiver or GPS clock with RS232 output (accessories)

6. Electrical data

Power consumption: < 35 VA

Supply: 88 V …. 264 V AC
124 V ….370 V DC

In the event of a power failure, the integrated battery will supply power to the measurement device for several minutes. Thereafter, the DA-Box 2000 will switch itself off and, when power is resumed, will continue with the previous settings still intact.

Regulations and standards

IEC 61010-1 / DIN EN 61010-1
IEC 60255-4 / DIN EN 60255-4
IEC 61326-1 / DIN EN 61326-1
IEC 60529 / DIN EN 60529
IEC 60068-1 / DIN EN 60068-1
IEC 60688 / DIN EN 60688
IEC 61000-6-2 / DIN EN 61000-6-2
IEC 61000-6-4 / DIN EN 61000-6-4

CE

Voltage inputs			
Measurement range	**100 V**	**400 V**	**690 V**
Nominal voltage	100 V	400 V	690 V
Voltage end range	200 V	460 V	800 V
Input resistance	1.4 MΩ		
Measurement fault	< ±0.1% of U_{din} range 10% ... 150% of U_{din}		
Bandwidth	DC...3 kHz		
Insulation category	CAT III / 1000 V CAT IV / 600 V		
Frequency error	0.01%		

Transmission behaviour	
Error limit – Voltage: – Frequency:	 0,1 % 0.01 % of all errors compared to Y2
Measurement cycle times	10 ms, 5 s, 50 s, 10 min
Sampling rate	2.048 kHz

Binary inputs (BI)	
Number	4
Control signals U_{st}	in the range 45 V...230 V AC/DC
Curve shapes – H – Level – L – Level	Rectangular, sinusoidal ≥ 48 V < 10 V
Signal frequency	DC ... 50 Hz
Switching delay	selectable in the range of 1..999 s
Input resistance	108 kΩ
Electrical isolation	All inputs earthed on one side

Binary outputs (BO)	
Number	4
Max. switching frequency	≤ 1 Hz
Electrical isolation	Isolated from all device-internal potentials
Contact load	AC: 250 V, 5 A $(\cos\varphi = 1{,}0)$ AC: 250 V, 3 A $(\cos\varphi = 0{,}4)$ DC: 220 V, 150 W
No. of switching operations	≥ $1{\cdot}10^4$ electrical

Analogue outputs (AO)	
Number	4
Output range – Y1...Y2	-20 mA...0...20 mA -20 mA...0...20 mA
Electrical isolation	Optocoupler
Load range	0 ≤ R ≤ 8 V / Y2
Alternating component	<0.5 % of Y2

The outputs can be continuously short-circuited or operated open. All output connections are galvanically isolated from all other circuits.

Electromagnetic compatibility

CE conformity • Interference immunity – EN 61326 – EN 61000-6-2 • Emitted interference – EN 61326 – EN 61000-6-4	
ESD – IEC 61000-4-2 – IEC 60 255-22-2	8 kV / 16 kV
Electromagnetic fields – IEC 61000-4-3 – IEC 60 255-22-3	10 V/m
Burst – IEC 61000-4-4 – IEC 60 255-22-4	4 kV / 2 kV
Surge – IEC 61000-4-5 – IEC 61000-4-12 – IEC 60 255-22-1	4 kV / 2 kV 2.5 kV, Class III
Conducted high frequencies – IEC 61000-4-6 Magnetic fields – IEC 61000-4-8 – All positions	10 V, 150 kHz ... 80 MHz 100 A/m continuous 1000 A/m 1 s
Voltage dips – IEC 61000-4-11	100 % 5 min
Emitted interference – EN 61326 – EN 61000-6-4 • Housing at a distance of 10 m • AC power supply connection at a distance of 10 m	30...230 MHz, 40 dB 230...1000 MHz, 47 dB 0.15...0.5 MHz, 79 dB 0.5...5 MHz, 73 dB 5...30 MHz, 73 dB

Storage of measurement values

Storage of measurement values

Measurement plug-in memory	64 MB
IPC memory	16 GB

Electrical safety

Degree of pollution	2
Degree of protection	I
Degree of protection	IP30

Reference conditions

Reference temperature	23 °C ± 1 K
Input parameters	U_E = 90 ... 110 V
Auxiliary voltage	H = Hn ± 10 %
Frequency	50 Hz...60 Hz

Operating voltages

50 V	300 V	300 V
E-LAN, COM1 ... COM3 analogue outputs time / trigger bus	Additional inputs and outputs	Auxiliary voltage

Test voltages

Auxiliary voltage	3 kV
COMs, E-LAN, time/trigger bus	0.35 kV
Binary outputs	1.8 kV
Binary inputs (250 V)	1.8 kV
Analogue outputs	0.35 kV
Input voltage	7 kV

Note: All test voltages are AC voltages in kV, which may be applied for 1 minute.

7. Ordering information

Feature	ID
Mobile damping analyser - DA-Box 2000 for recording the damping and stability ratios on medium-voltage busbars Portable housing equipped with a DMR-D and an IPC with 16 GB flash	**101.3602**
Mobile damping analyser - DA-Box 2000 IRIG for recording the damping and stability ratios on medium-voltage busbars with an IRIG-B plug-in for time synchronisation via IRIG-B	**101.3603**
Damping analysis with the DA-Box 2000 for recording the damping and frequency ratios in medium-voltage networks in the range below 50 Hz **Service:** Set-up of the measurement by the customer, at least 3 months' measurement time, evaluation and presentation of the results (valid only within Germany)	**Service**

Accessories for the DA-Box 2000	ID
GPS NIS Time radio clock **Supply voltage H1 85 V...264 V AC/DC** **Supply voltage H2 18 V...72 V DC**	 111.9024.47 111.9024.48
DCF 77 radio clock in IP65 housing	111.9024.01
RS 232 extension cable (10 m)	582.2040.10
Operating manual German English	 G1 G2

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Software version:

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