Combined Earth Fault and Short Circuit Indicator

EOR-3D

- **Panel mount housing (B01)**
- **DIN rail housing (B02)**

1. Application

The EOR-3D combines earth fault and short circuit detection in a compact device. In particular, the advantages of different locating methods can be combined. For the first time, prioritization and thus weighting of the locating procedure is possible. The device is designed for the detection of a single discharge. By combining the methods, it is particularly suitable for substations. Of course, the advantages of the following methods can also be used directly in the transformer station.

1.1 Location method for use in compensated networks

- **Transient earth fault detection** using the **qu2 and qui** algorithms for
  - single faults
  - intermittent faults (qui)
  - faults in loops with large circulating currents (qu2)
- **Active power direction** and cos(φ), suitable transducers required
- **Harmonics method** with measurement of the associated reactive power direction for a user selectable frequency
- **Pulse location**: traditional and using the new high power-current injection method (HPCI). With the EOR-3D, overcompensation is no longer mandatory
- **Directional short-circuit indicator**
- **Non-directional short-circuit indicator** with configurable reset time

1.2 Location method for use in isolated networks

- **Transient earth fault detection** using the **qu2 and qui** algorithms for
  - single faults
  - restriking faults (qui)
  - faults in loops with large circulating currents (qu2)
- **Reactive power direction** and sin(φ) method
- **Directional short-circuit indicator**
- **Non-directional short-circuit indicator** with configurable reset time

1.3 General Features

- **4 GB** memory for event recorder and log book
- Extra long fault recording
- Logbook for events
- Network interface for configuration and log book and fault record data transfer via **PC or network**
- USB 2.0 interface for the transfer of log book, fault records and firmware updates
- Local connection of the device via network
- Data acquisition with traditional **transducers** or **sensors** possible
- Signalling of faults via
  - GSM as SMS
  - GPRS / UMTS
  - WLAN
  - Modem
- Control system connection:
  - IEC 60870-5-104
  - IEC 60870-5-103 **including fault log**
  - EC 60870-5-101
  - Modbus RTU (RS232, RS485, TCP/IP)

2. Characteristics

2.1 qu2 algorithm (transient)

With the new qu2 algorithm, transient earth faults can be selectively detected to a few kΩ. In the null system the healthy outputs can be considered as capacitors. To obtain a voltage shift $u_{0(t)}$, these capacitors have to be charged. This charge is created with the null current $i_{0(t)}$ and results in the charge $q_{0(t).}$ With healthy outputs this yields the equation $q0(t) = C_0\ u_{0(t).}$ When $u_{0(t)}$ is plotted on the x-axis and $q_{0(t)}$ on the y-axis of the qu-graph, this gives a straight line for healthy outputs. This behavior does not apply for faulty outputs. Figure 1 shows this behavior for a low impedance earth fault.

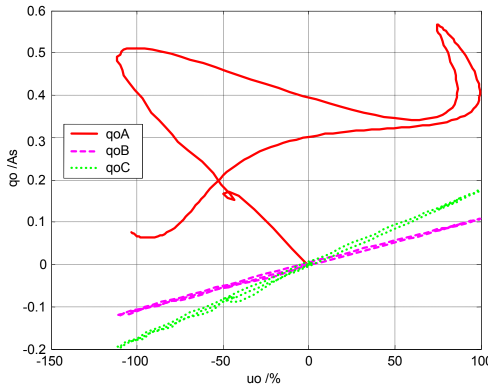


Figure 1: qu-graph for a low impedance earth fault

In parallel lines and meshed networks, circulating currents occur that can lead to an erroneous display. The new improved qu2 algorithm eliminates this influence through linearization to the operating point and a downstream, non-linear filter. This algorithm is thus the first algorithm that really works in a meshed network and performs a successful, directional evaluation

This results in the following properties for the qu2 algorithm:

- Suitable for earth faults up to several kilo-ohms
- The triggering threshold of the voltage shift u_{NE} is configurable
- The triggering current can be configured as an equivalent phase-earth capacitance
- Suppression of the earth fault in response to a selectable minimum duration of the earth fault (continuous earthing message)
- Suppression of the earth fault indication in the direction of the busbar is possible
- Reset of the indication by an external signal: automatically after a specified period or at the end of the earth fault (selectable and can be combined)
- For the evaluation, either the measured or calculated u_{NE} from the three phase-earth voltages can be used
- Recording of the transient events in the logbook
- Recording of the associated fault record with 10 periods of pre-event history and an adjustable post-event history length (several seconds)
- Errors due to higher-frequency signals are greatly reduced by integral evaluation
- The qu2 algorithm, in comparison with the standard transient method, uses a much larger time range for the evaluation of the fault direction

2.2 qui algorithm for the detection of restriking and intermittent earth faults

Restriking faults occur especially in cable networks. Figure 2 shows the change in the voltage of the faulty phase and Figure 3 shows the corresponding change in the voltage shift. In the measurement, a mean value of the voltage over 10 periods is usually taken. As a result, this restriking fault is interpreted as a high-impedance fault and the failure location starts in the transmission line network, rather than in the area of the cable section. A further complication is that the usual stationary location methods, such as the cos (φ) method of stationary conditions would lead to the fault location and this non-linear method for the restriking cannot be properly evaluated. The corresponding directional indications are arbitrary and do not help with the fault location.

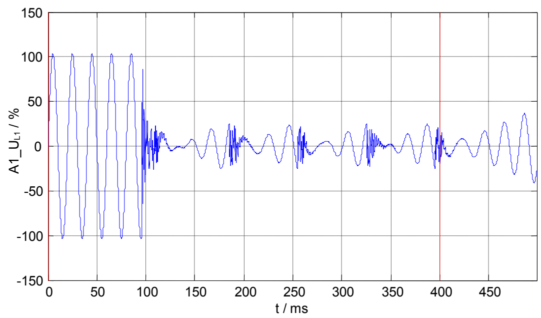


Figure 2: Voltage of the faulty conductors

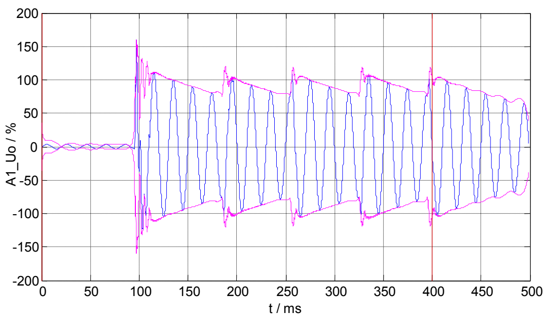


Figure 3: $u_0(t)$ with a restriking fault

The qui algorithm is based on the proven qu algorithm and is adapted to the intermittent fault only in terms of the parameter. A modified parameter set is required when, for example, the shift voltage no longer falls below the threshold value for the earth fault detection.

This results in the following essential properties for the qui algorithm:

- Directional indication also during restriking and intermittent earth faults
- The indication tracks the fault, i.e. if the faulty segment changes while creating the open connection in the circuit to the other output, with the qui method the indication also changes
- Fault location can already be performed during the restriking error
- Fault location can already be started on the faulty cable output because there is no misinterpretation of a high-impedance fault
- The recording of the events in the log book (coming, going) is configurable
- A cyclic record of the measured values in the log book during the fault can be configured for subsequent evaluation

2.3 Reactive power direction method for isolated networks: sin(φ)

- The trigger thresholds for the voltage shift U_{NE} and the total current $3I_0$ are configurable
- For the evaluation, either the measured or calculated U_{NE} from the three phase-earth voltages can be selected. The same applies for the total current $3I_0$
- In the reactive power direction method, the requirements for the accuracy of the angle between current and voltage transformers are less
- Suppression of the earth fault indication in the direction of the busbar is possible
- The recording of the events in the log book (coming, going) is configurable
- A cyclic record of the measured values in the log book during the fault can be configured. Thus, a more detailed analysis of the fault is possible

2.4 Active power direction method for compensated networks: cos(φ)

- The trigger thresholds for the voltage shift U_{NE} and the total current $3I_0$ are configurable
- Selectable operating modes:
  - Fault tracking indication of the direction of the active power in the null system
  - Stored indication of the active residual current increase
- Reset of the indication by an external signal: automatically after a specified period or at the end of the earth fault can be selected and combined
- Suppression of the earth fault indication in the direction of the busbar is possible
- The recording of the events in the log book (coming, going) is configurable
- A cyclic record of the measured values in the log book during the fault can be parameterized for subsequent evaluation
- When using the active power direction method, the accuracy of the angle between current and voltage transformers must be monitored

2.5 Harmonics method sin(φ)

- The evaluation is made using the sin(φ) method, however the frequency can be freely selected
- The method can be used in both isolated and compensated networks
- The recording of the events in the log book (coming, going) is configurable
- A cyclic record of the measured values in the log book during the fault can be configured for subsequent evaluation

2.6 Pulse location - Standard

- The trigger threshold of the pulse amplitude of the total current $3I_0$ is configurable
- The stationary part of the null current is removed automatically during the recognition of the pulse pattern

- Reset of the indication by an external signal or automatically after a specified period can be selected and combined
- A simple depth positioning is possible due to the pulse location
- Symmetrical and asymmetrical pulsing can be configured

2.7 Pulse location combined with high-power current injection (HPCI)

- In normal operation, the high-power current injection (HPCI) from the Petersen-coil controller REG-DP(A) can be used to tune the Petersen coil. The HPCI is used to locate the fault during the earth fault. Due to the simultaneous injection of two frequencies, considerably faster "pulse location" is possible
- Overcompensation is no longer mandatory for this method

2.8 Non-directional short circuit indication

- Adjustable activation threshold
- Automatic indication reset after a set time or via a digital input

2.9 Directional short circuit indication

- Directional indication through evaluation of the phase-earth voltages
- Adjustable activation threshold
- Adjustable direction plot
- Automatic indication reset after a set time or via a digital input
- Timing of LED and relay separately adjustable

2.10 Digital inputs can be used as additional analog voltage measurement

The digital inputs are configured as additional analog inputs.

- The digital inputs can be used for additional voltage measurements
- The trigger thresholds are adjustable by software

2.11 Applicability of the methods

The following table shows the possible use of EOR-3D, depending on the placement of the Analog Input board.

No.	Conventional transformer				Transient: qu2	sin(φ)	cos(φ)	OV	Pulse	Double earth fault	Short circuit
	I_0	I_L	U_0	U_L							
1	1								x		
2	1		1		x	x	x	x	x		
3	1	3						x	x	x	x
4		3							x	x	x
5		3		3	x	x			x	x	x
6		3	1		x	x			x	x	x
7		3	1	3	x	x			x	x	x
8	1	3		3	x	x	x	x	x	x	x
9	1	3	1		x	x	x	x	x	x	x
10	1	3	1	3	x	x	x	x	x	x	x
	Sensors										
	I_{0S}	I_{LS}	U_{0S}	U_{LS}							
11	1								x		
12	1		1		x	x		x	x		
13	1	3							x	x	x
14		3							x	x	x
15		3		3	x	x			x	x	x
16		3	1		x	x			x	x	x
17		3	1	3	x	x			x	x	x
18	1	3		3	x	x		x	x	x	x
19	1	3	1		x	x		x	x	x	x
20	1	3	1	3	x	x		x	x	x	x

2.12 Digital outputs (relay)

- Signals can be inverted by software
- Multiple signals can be combined by software (OR-operation, invertible)

2.12.1 Industrial housing

- 2 relays with changeover, monostable contacts
- 6 relays with normally open, bistable contacts

2.12.2 DIN rail housing

- 1 relay with changeover, monostable contacts
- 5 relays with normally open, monostable contacts

2.13 Fault recorder

- Recording with a sampling frequency ≥ 2 kHz
- Recording of all analog channels, all digital inputs and relay outputs as well as all internal digital process decisions
- Due to 4 GB internal memory, very long periods can be monitored
- The recording is made in CSV format (Comma-Separated Values), and can be read directly
- The recordings can be converted using the operating software into COMTRADE format

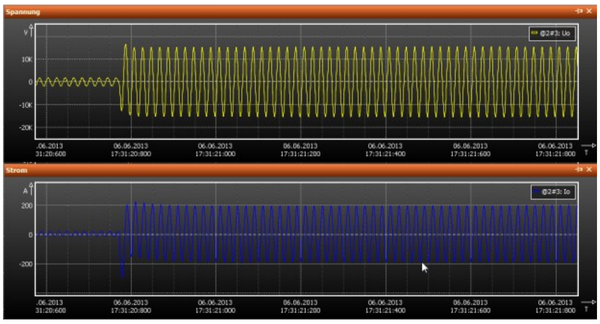


Figure 4: Fault record example Uo and Io

- The binary signals can be displayed as well

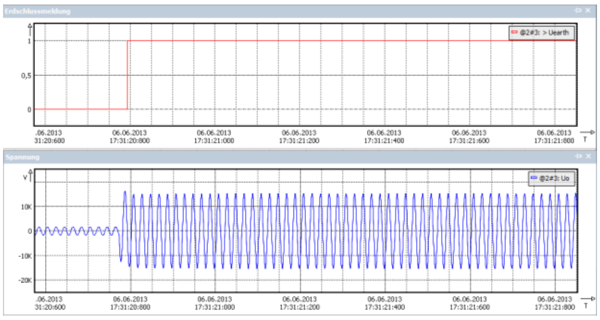
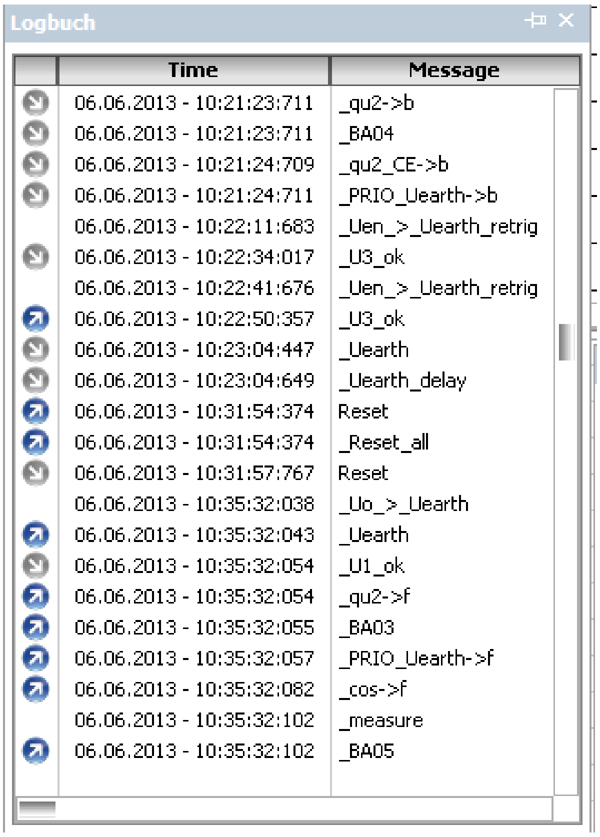


Figure 5: Fault record view incl. binary signal

- View the fault records directly in the software
- Comtrade file import via drag and drop

2.14 Log book

- Fast display of important signal directly at the EOR-3D
- Detailed recording can be read via operating software
- The recording is done in ASCII format and can be read directly
- The events to be recorded in the log book can be configured
- Cyclic input of measurement values can be activated during the fault
- Results of calculations are also entered, e.g. I_{CE} at the ouputs
- Parameterized mapping of the relay is entered in plain text



Logbuch

Time	Message
06.06.2013 - 10:21:23:711	_qu2->b
06.06.2013 - 10:21:23:711	_BA04
06.06.2013 - 10:21:24:709	_qu2_CE->b
06.06.2013 - 10:21:24:711	_PRIO_Uearth->b
06.06.2013 - 10:22:11:683	_Uen_>_Uearth_retrig
06.06.2013 - 10:22:34:017	_U3_ok
06.06.2013 - 10:22:41:676	_Uen_>_Uearth_retrig
06.06.2013 - 10:22:50:357	_U3_ok
06.06.2013 - 10:23:04:447	_Uearth
06.06.2013 - 10:23:04:649	_Uearth_delay
06.06.2013 - 10:31:54:374	Reset
06.06.2013 - 10:31:54:374	_Reset_all
06.06.2013 - 10:31:57:767	Reset
06.06.2013 - 10:35:32:038	_Uo_>_Uearth
06.06.2013 - 10:35:32:043	_Uearth
06.06.2013 - 10:35:32:054	_U1_ok
06.06.2013 - 10:35:32:054	_qu2->f
06.06.2013 - 10:35:32:055	_BA03
06.06.2013 - 10:35:32:057	_PRIO_Uearth->f
06.06.2013 - 10:35:32:082	_cos->f
06.06.2013 - 10:35:32:102	_measure
06.06.2013 - 10:35:32:102	_BA05

Figure 6: EOR-3D Logfile

2.15 Data logger

- Recording of measured operating values with adjustable sampling period
- The following are recorded: U, I, P, Q, S, 50 Hz

3. EOR-3D application software

The following functions are available in the application software

3.1 Configuring the relay

- System configuration
- Comparison of the parameterization and creation of difference lists
- Activation of the various detection methods
- Setting the trigger levels
- Configuration of the signalling (LEDs, relays and combined signalling)
- Configuration of the sequence of the displays on the EOR-3D

3.2 Support for easy commissioning

- Online service page
- Digital input and output testing
- Simulation of all input, output functions and analog values for simple control system commissioning
- Display of all measurements:
  - U, I, P, Q, S, φ
- Graphic display of the measured values in a vector diagram

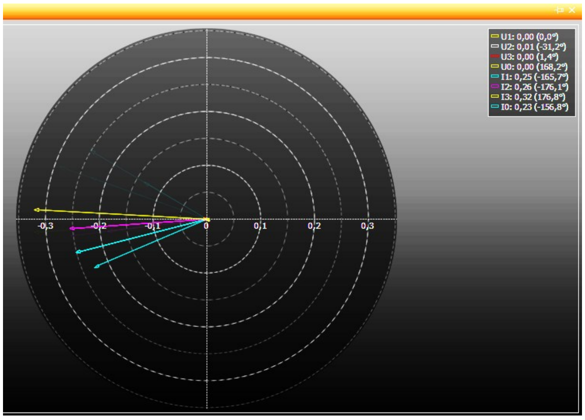


Figure 7: Vector diagram of the measurement values

- Primary examination of the direction of the power transformer in a healthy network with earth fault compensation during normal operation This test requires no additional accessories.

Figure 8: EOR-3D programming software

3.3 Fault analysis

- Log book download and display
- Time synchronization of multiple log books
- Presentation of the events in digital traces
- Download of the recorded fault records
- Conversion of the fault records into COMTRADE format
- In the fault record, events are represented as binary traces

3.4 Network analysis

- Calculation of the capacitance of each output. Either by adjustment of the Petersen coil or by evaluation of the multi-frequency current injection signals of the E-coil control

The EOR-3D configuration software can be connected to the EOR-3D directly or via a network. Connections via WLAN and UMTS are configurable.

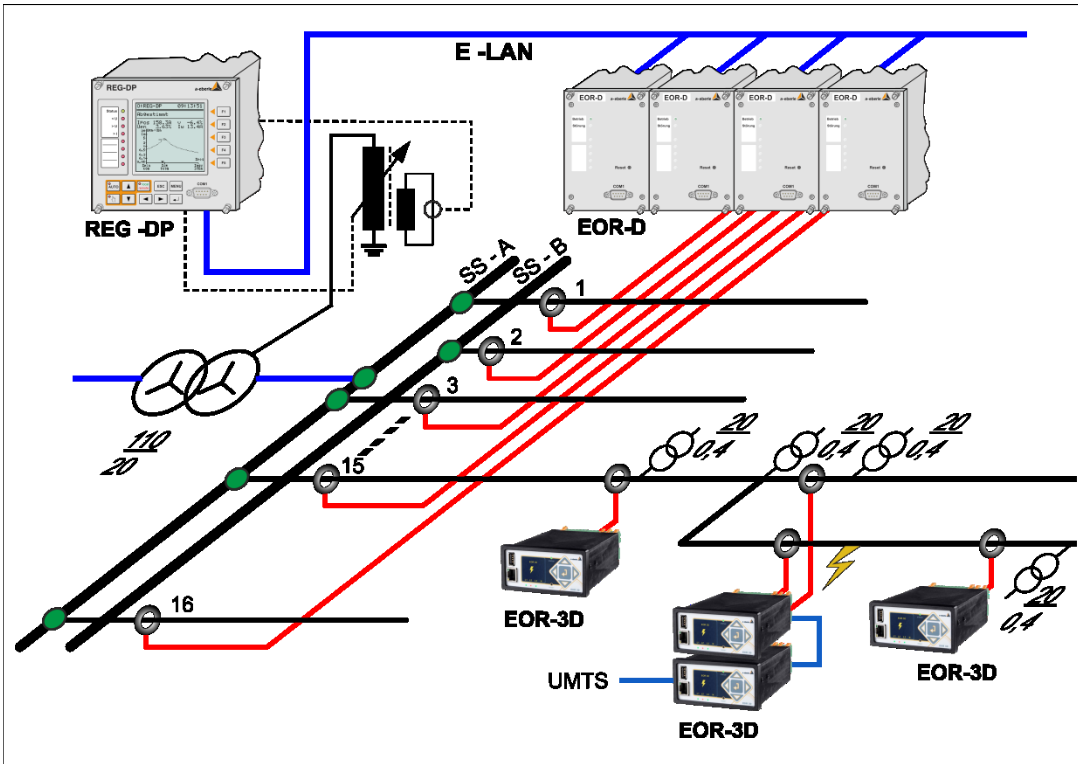


Figure 9: EOR-3D system, Petersen-coil controller REG-DP and EOR-D (4 outputs)

The base unit is, as shown in Figure 7, also designed for installation on a tee-off. Through the selectable analog inputs, conventional current and voltage transducers or sensors can also be used, depending on the configuration. Therefore, multiple connection options for the installation location are possible.

The connection of multiple EOR-3D units is possible via a network. Serial interfaces enable the connection to a control system with protocols that require an RS232 or RS485 transfer level.

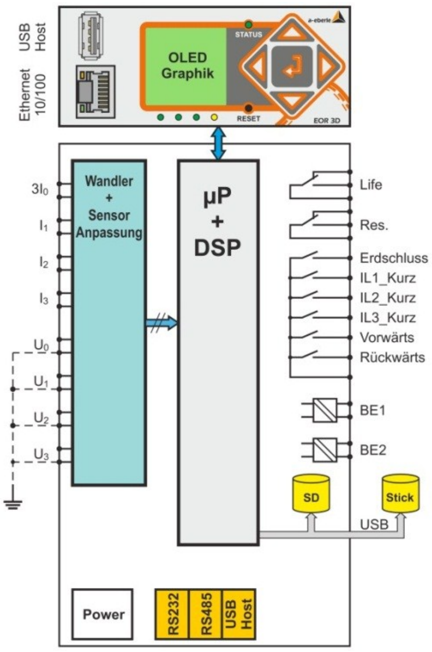


Figure 10: Hardware architecture of the EOR-3D industrial housing

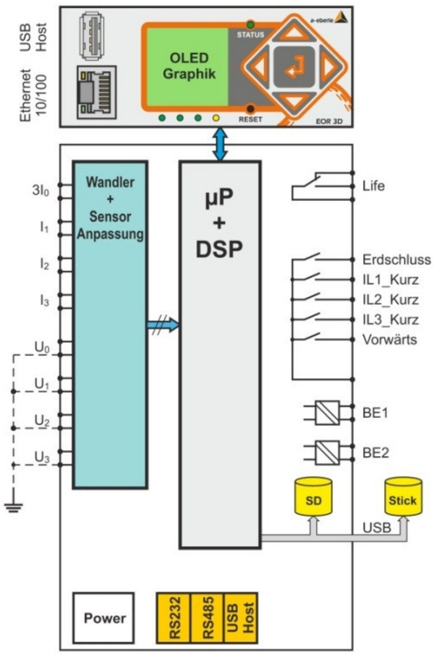


Figure 11: Hardware architecture of the EOR-3D DIN rail housing

4. Technical specifications

4.1 Regulations and standards

IEC 61010-1
IEC 60255-22-1
IEC 60529
IEC 60068-2-70
IEC 60688
IEC 61000-6-2
IEC 61000-6-4

4.2 AC input (conventional transformer)

Measuring voltage	0.1 V ... 120 V
Shape of the curve	Sine
Frequency range of the fundamental wave	45....50....60....65 Hz
Internal consumption	$\leq U_{nom}^2$ / 1 MΩ
Overload capacity	U_{nom} *1.2

4.3 AC voltage input (sensors)

Measuring voltage	0.1 V ... 120 V
Shape of the curve	Sine
Frequency range of the fundamental wave	45....50....60....65 Hz
Internal consumption	$\leq U_{nom}^2$ / 30 MΩ
Overload capacity	U_{nom} *1.2

4.4 AC current input (sensors)

Measuring voltage	0.5 V
Shape of the curve	Sine
Frequency range	45....50....60....65 Hz
Internal consumption	≤ 0.01 VA
Overload capacity	U_{nom} *1.2

4.5 Digital inputs

Inputs BE1 ... BE2

Input voltage	AC/DC 40 V...260 V
Shape of the curve, permissible	Rectangular, sinusoidal
H - Level	Programmable
L - Level	Programmable
AC Filter	Programmable
Wobble hold-off	Programmable
Signal frequency fs	DC ≤ fs ≤ 60 Hz
Input resistance	≥ 100 kΩ
Potential isolation	Optocoupler

4.6 Industrial housing B01

4.7 DIN rail housing B02

4.8 Supply voltage

Characteristic		Power B01	Power B02
H1:	AC: 90 230 264 V 50/60 Hz DC: 120 220... 300 V	4.2 VA	12.7 VA
H2:	DC: 18 24 60 V protected against polarity reversal	3.8 VA	9.2 VA
H3:	DC: 36 48 ...150 V protected against polarity reversal	3.9 VA	9.4 VA

4.9 Digital outputs (signal relay)

4.9.1 DO for industry housing

Relay BA1 .. BA8

max. switching frequency	≤ 1 Hz
Potential isolation	Isolated from all device-internal potentials
Contact load	AC 250 V, 30 W (cosφ =1.0) DC 220 V, 30 W
Switching operations	> 10^6 electrical
BA1, BA2	Relay with changeover, monostable contacts
BA3 … BA8	bistable relay

4.9.2 DO for DIN rail housing

Relay BA1, BA3 .. BA7

max. switching frequency	≤ 1 Hz
Potential isolation	Isolated from all device-internal potentials
Contact load	AC 240 V, 6 A (cosφ =1.0) DC: (resistive load) 300 V, 0.15 A 220 V, 0.17 A 110 V, 0.20 A 60 V, 0.30 A 28V, 6 A
Switching operations	> 10^6 electrical
BA1	Relay with changeover, monostable contacts
BA3 … BA7	monostable relay

4.10 Limit-value monitoring

Limit values	programmable
Response times	programmable
Alarm indicators	programmable: LED; Display

4.11 Reference conditions

Reference temperature	23°C ± 1 K
Input quantities	U_E = 90…110 V
Auxiliary voltage	H = Hn ± 10%
Frequency	50 Hz...60 Hz with AC
Other	IEC 60688 - Part 1

4.12 Measurement value recording

non-volatile	≤ 4 GB

4.13 Electrical safety

Degree of protection	IP 30
Protection class	I
Degree of pollution	2
Measurement category	III/150 V
Measurement category	II/300 V
Overvoltage category	II

Operating voltages

50 V	120 V	230 V
COMs USB Ethernet	Voltage inputs	Auxiliary voltage digital inputs relay outputs

4.14 Electromagnetic compatibility

Interference emissions

Limit class A according to IEC 61000-6-4

Disturbance immunity

Electrostatic discharge Air discharge: Contact discharge:	according to IEC 61000-4-2 8 kV 4 kV
Electromagnetic fields 80 - 2000 MHz:	according to IEC 61000-4-3 10 V/m
Fast transient Interference (bursts)	according to IEC 61000-4-4
Supply voltage AC 230 V: Data connections:	 2 kV 1 kV
Conducted interference 0.15 - 80 MHz:	according to IEC 61000-4-6 10 Veff
50 Hz magnetic field	according to EN 61000-4-8 100 A/m

4.15 Climatic conditions

Temperature range	
Operation (industrial housing)	-20 °C...+50 °C
Operation (DIN rail)	-20 °C...+50 °C
Transport and storage	-25 °C...+65 °C
Humidity	5 %..95 % Non-condensing
Air-pressure	Up to 2000 meters

4.16 EOR-3D industrial housing

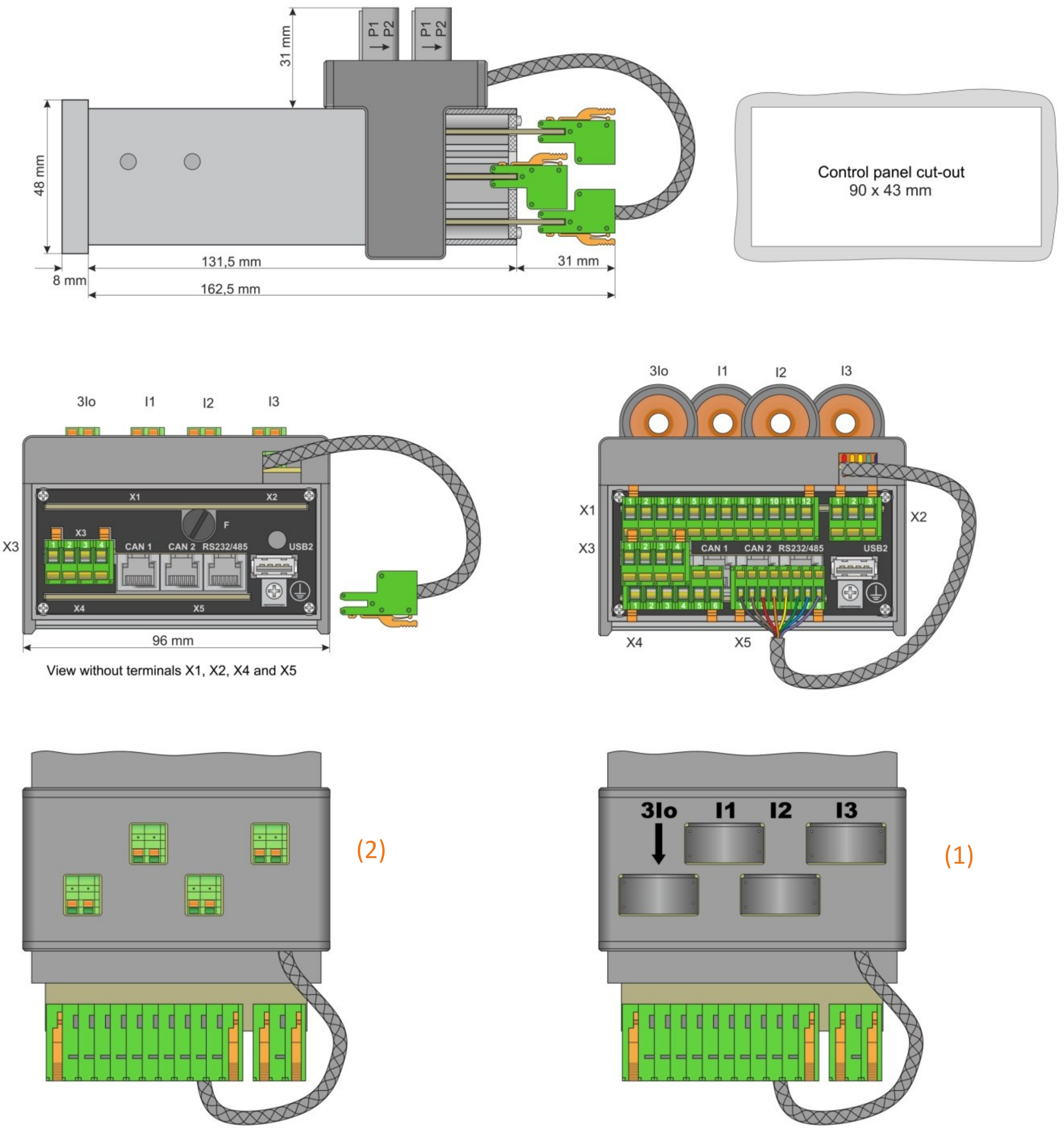


Figure 12: EOR-3D industrial housing dimensions and top view with conventional transformer (1) and sensors (2)

4.16.1 EOR-3D industrial housing: Connection for conventional transformer

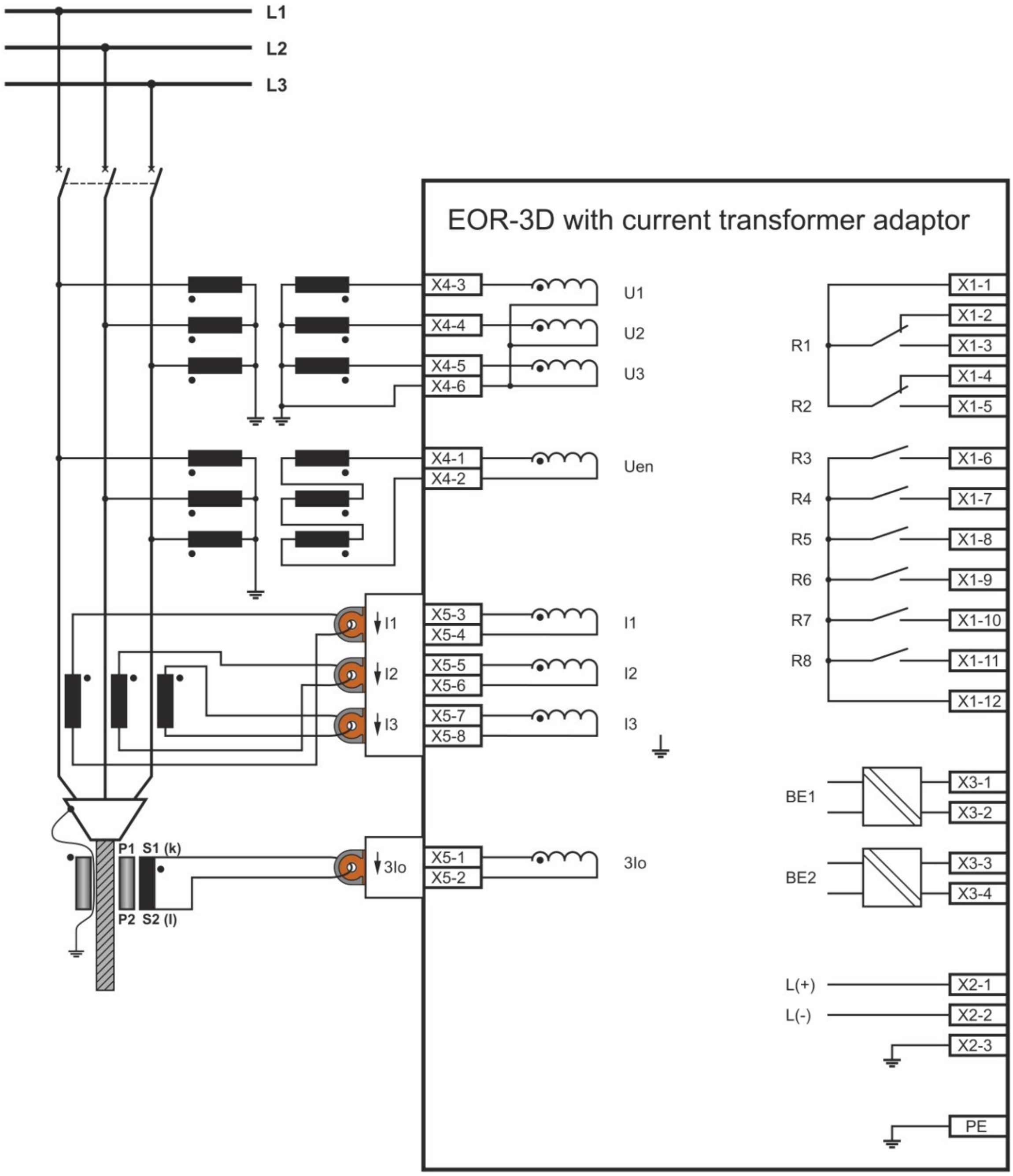


Figure 13: EOR-3D in industrial housing for use with traditional instrument transformer

4.17 EOR-3D DIN rail version

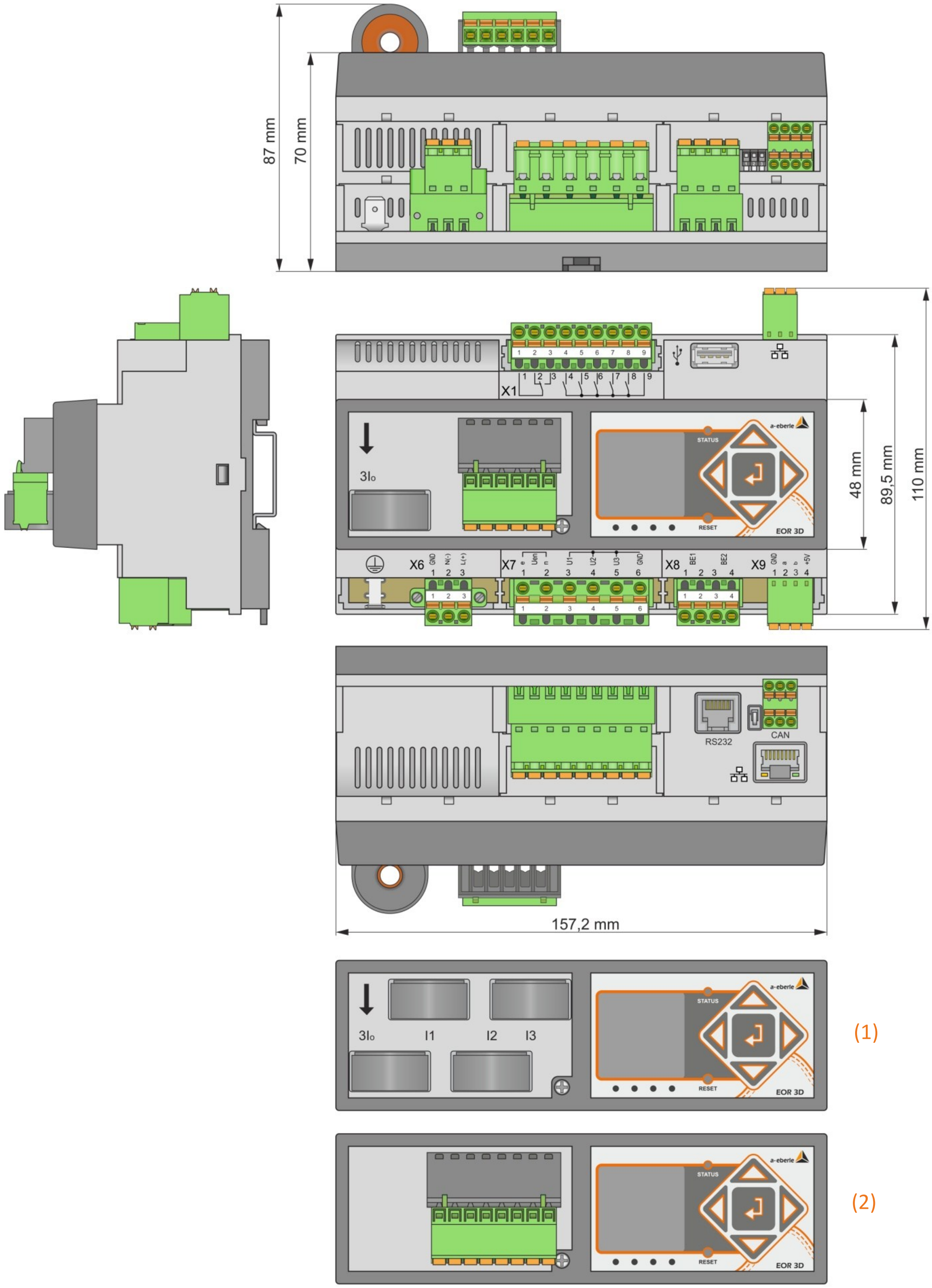


Figure 14: DIN rail housing dimensions and top view with conventional transformer (1) and sensors (2)

4.17.1 EOR-3D DIN rail housing connection for conventional transformer

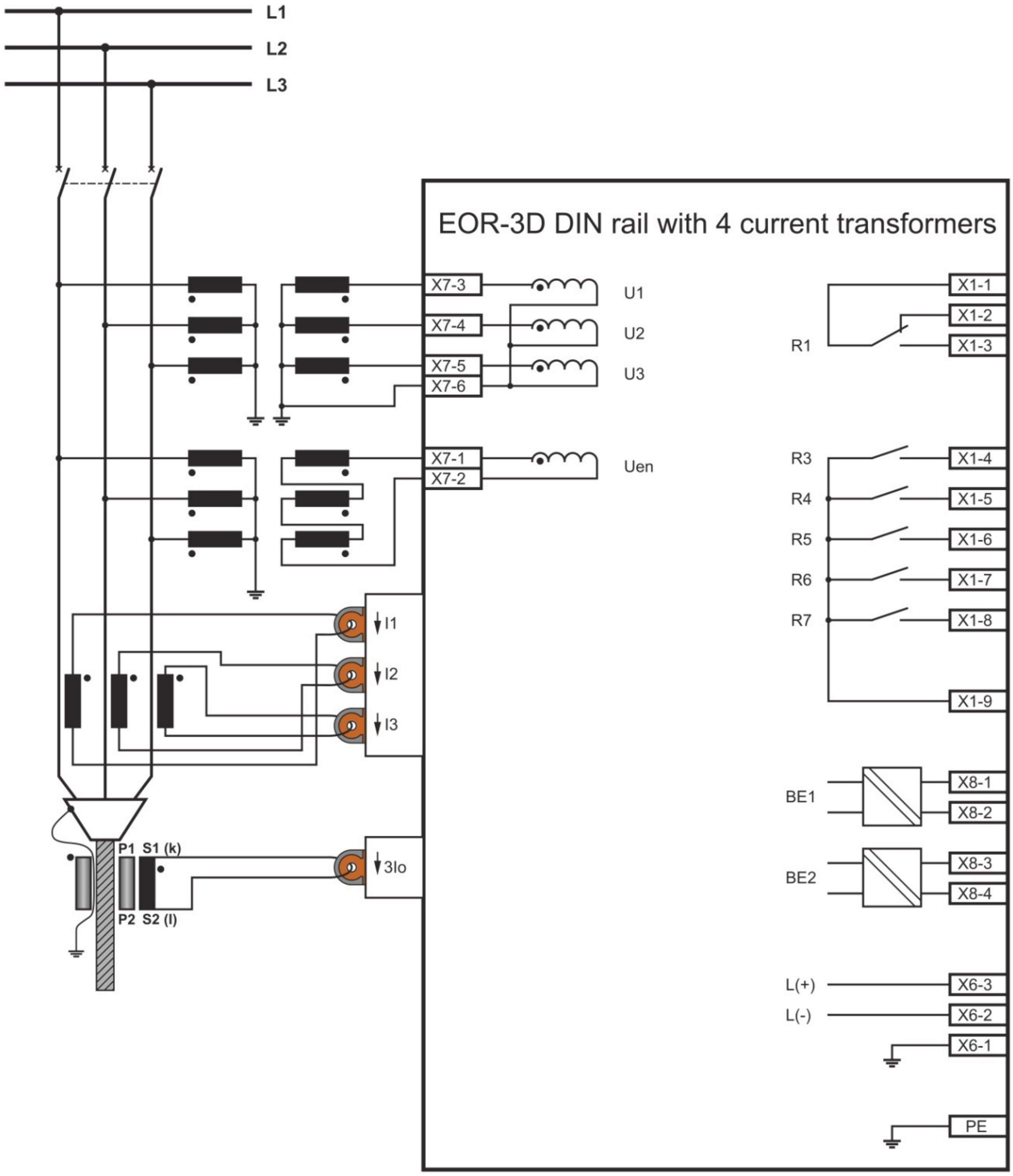


Figure 15: EOR-3D for use with traditional instrument transformer

4.18 EOR-3D connection designation

4.18.1 Industrial housing

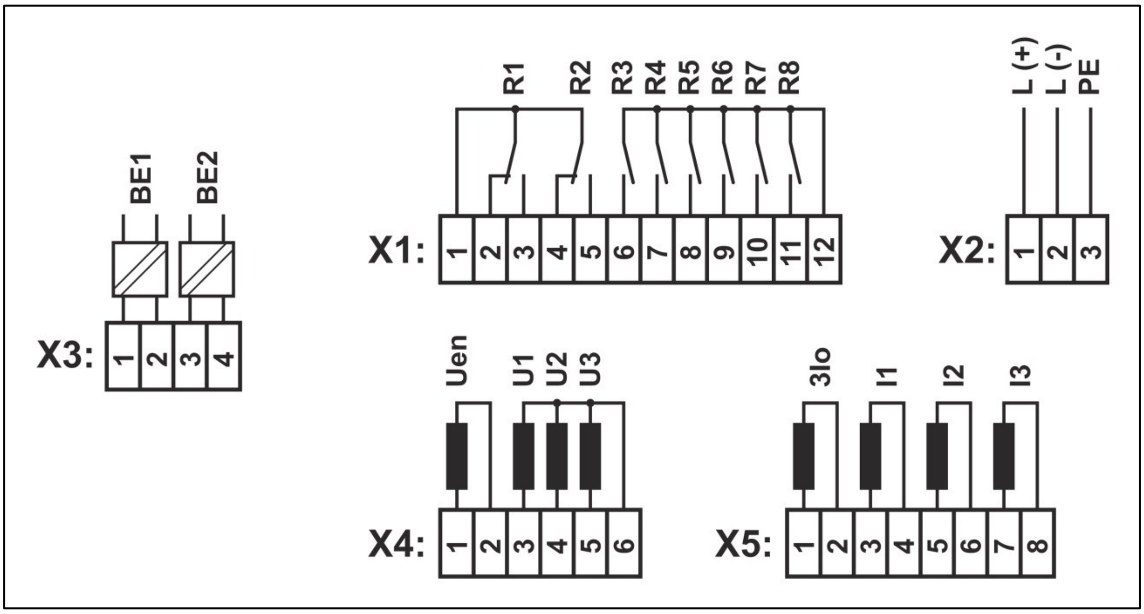


Figure 16: Terminal designation EOR-3D industrial housing

4.18.2 DIN rail housing

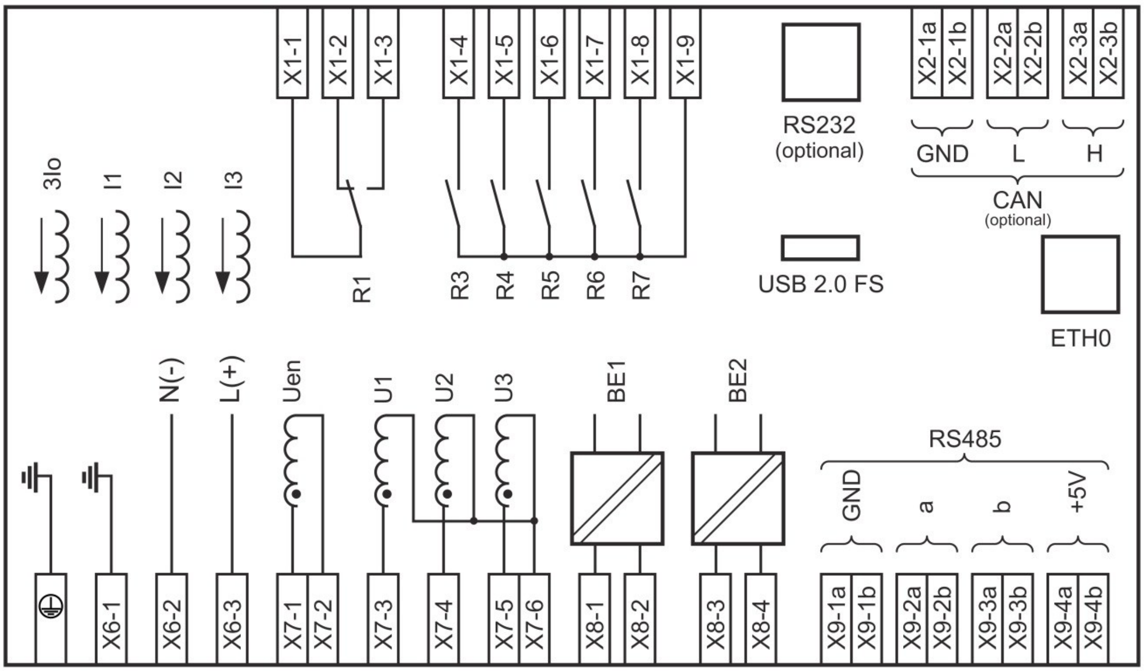


Figure 17: Terminal designation EOR-3D DIN rail housing

5. EOR-3D accessories

5.1 Current transformer with low nominal load

Figure 18: Current transformer for short circuit detection 2200/1 A

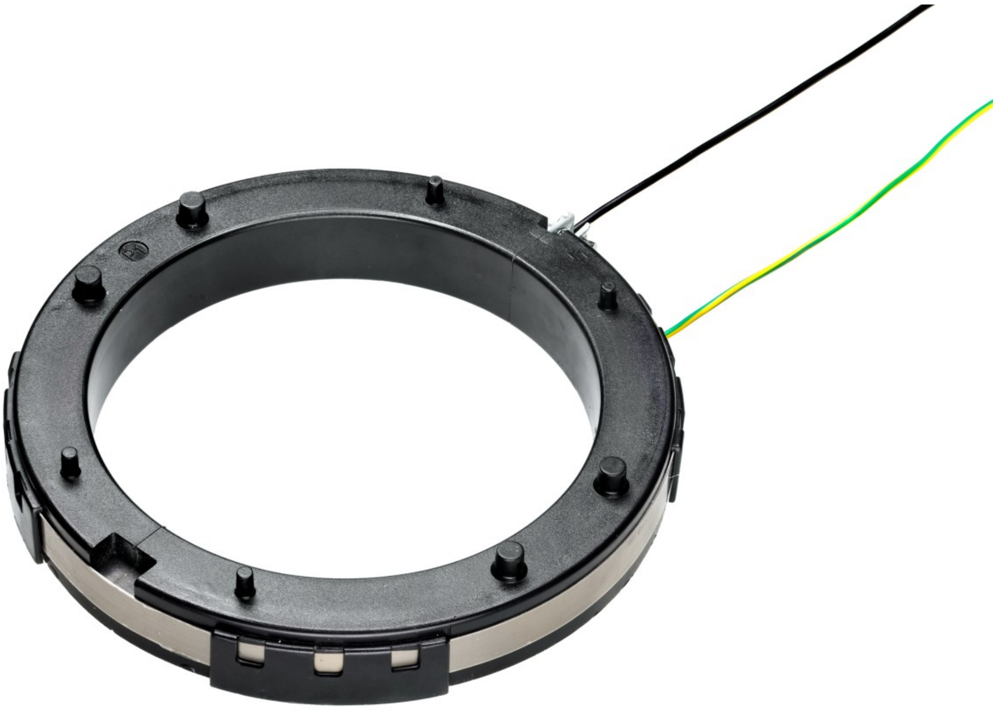


Figure 19: Ring-type current transformer for 3Io measurement with transmission ratio 100/1 A and nominal load 0.05 VA

6. Order specifications

For determining the order details:

- Only one unit can be ordered for codes with the same capital letter.
- When a code's capital letter is followed only by zeros, the code may be omitted.

Characteristic	CODE
Earth fault detection and short circuit indicator - EOR-3D	EOR-3D
• 4GB internal memory • with two programmable inputs (digital, analog) • equipped with 2 x USB host for USB stick, USB⇔Ethernet, USB modem • equipped with Ethernet 10/100 MBits/s • Log book and fault recorder for easy fault analysis • Clock for logbook and fault recorder protected by SuperCap and battery • including PC software and Ethernet cable	
Model	
• Industrial housing 96 x 48 mm – with programmable relay (6 x bistable contacts, 2x changeover contacts)	B01
• DIN rail version – with programmable relay (5 x monostable contacts, 1x changeover contact)	B02
Supply voltage	
• external AC 85 ... 230 ... 264 V / DC 120 ... 220 ... 300 V	H1
• external DC 18 ... 24 ... 48 ... 60 V	H2
• external DC 36 ... 48 ... 60 ... 110 ... 150 V	H3
Firmware	
• Standard: qu2,qui, cos(φ), sin(φ), sin(φ)_cos(φ), harm_250, harm_fx, Puls_50, non-directional short circuit, P, Q, S, transformer direction test	S000
• in addition: Puls_HPCI	S001
• in addition: directional short circuit	S010
Note: The Sxx1, Sx1x and S1xx features are also all selectable in the basic software. The feature is the sum of the individual features selected. Example: Standard + Puls_HPCI + directional short circuit = S011.	
Communication	
• None	T000
• Signalling via GSM (using separate modem)	T001
• Signalling via GPRS / UMTS (using separate modem)	T002
• Modbus RTU RS232/RS485, 2-wire	T005
• Modbus TCP/IP	T006
• IEC60870-5-103 with fault recorder supply	T103
• IEC60870-5-101	T101
• IEC60870-5-104	T104
Current input configuration (does not include sensors or transformer)	
• Adaptor for 4 x current transformer for 1 A / 5 A (1 x $3I_0$, 3 x I_{Lx})	C21
• Adaptor for 1 x current sensor ($3I_0$) + 3 x current transformer for 1 A / 5 A (3 x I_{Lx})	C22
• Adaptor for 1 x current transformer 1 A / 5 A ($3I_0$) + 3 x current sensors (3 x I_{Lx})	C23
• Adaptor for 4 x current sensors (1 x $3I_0$, 3 x I_{Lx})	C24
• Adaptor for 1 x current transformer (1 x $3I_0$) **EWR22 replacement**	C25
• Adaptor for 3x current sensor and 1x3Io transformer, version 330.1700 – 3M (cable!)/**B02 only**	C26
• Adaptor for 3x current sensor and 1x3Io transformer, version 330.1600 – SGE (overhead line!)/**B02 only**	C27

Characteristic	CODE
Voltage input configuration (does not include sensors or transformer)	
• 1 x voltage transformer 100 V (2 MΩ) Uo	U01
• 4 x voltage transformers 100 V (2 MΩ) (also suitable for single connection to capacitive acquisition with 2 MΩ nominal load) **Please select U04 if C26 or C27 is choosen**	U04
• 4 x voltage transformers 100 V (40 MΩ), HRM and LRM	U24
• Digital input as analog voltage input 100 V	U51
Serial Interface (only for DIN rail version B02)	
• None	R0
• RS232 1 including 30 cm connecting cable and adaptor with 9 pin SubminD-ML	R1
• RS232 1 including 30 cm connecting cable and adaptor with 3 pin bus connector	R2
Operating instructions	
• German	G1
• English	G2
• French	G3

ACCESSORIES	Code
Transformer and sensors	
• Current transformer $3I_0$, 0.05 VA (Inside ϕ: 150 mm), length of connecting cable 3.5 m	
– 100/1 A	
• Short circuit transformer (Inside ϕ: 30 mm)	
– 2200/1 A	
• Current sensors	
– Current sensor for I_L	
– Current sensor for $3I_0$	
• Voltage sensors	
– capacitative voltage divider	
Cables and Modules	
• Adaptor cable for connecting to CAPDIS, WEGA	
• Network cable	
• Cable for Time Bus	
• USB⇔Ethernet converter for 2. Ethernet interface e.g. IEC 60870-5-104 to industrial housing	
• USB-WLAN Stick	
• USB-UMTS-Modem	
• USB Flash memory stick	
• Radio-controlled clock DCF77, including adaptor cable	
• GPS clock NIS Time, Uh:H1, with accessories	
• GPS clock NIS Time, Uh:H2, with accessories	

Notes

Notes

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