Operating manual

EOR-1D

Directional earth fault and short circuit indicator

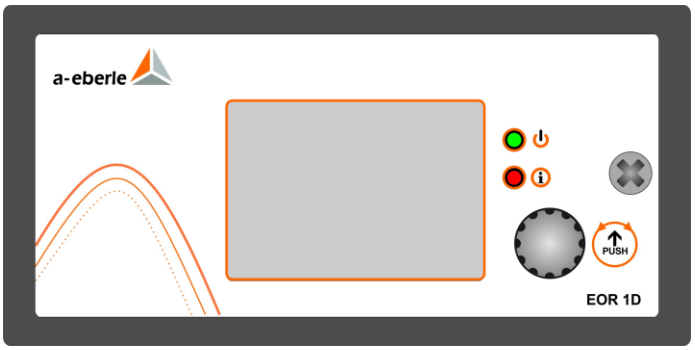

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Table of Contents

1. User guidance

This User Manual is a summary of the information needed for the installation, commissioning and operation of the EOR-1D.

Read the User Manual in its entirety and do not use the product unless you have understood the User Manual.

1.1 Target group

The User Manual is intended for skilled technicians as well trained and certified operators.

The contents of this User Manual must be accessible to people tasked with the installation and operation of the system.

1.2 Warnings

Structure of the warnings

Warnings are structured as follows:

⚠ SIGNAL WORD	**Nature and source of the danger.** Consequences of non-compliance. ➲ Actions to avoid the danger.

Types of warnings

Warnings are distinguished by the type of danger they are warning against:

⚠ DANGER!	Warns of imminent danger that can result in death or serious injuries if not avoided.

⚠ WARNING!	Warns of a potentially dangerous situation that can result in death or serious injuries when not avoided.

⚠ CAUTION!	Warns of a potentially dangerous situation that can result in fairly serious or minor injuries when not avoided.

NOTICE:	Warns of a potentially dangerous situation that if not avoided could result in material or environmental damage.

1.3 Tips

Tips on the appropriate device use and recommendations.

1.4 Other symbols

Instructions

Structure of the instructions:

➲ Instructions for an action.

↳ Indication of an outcome, if necessary.

Lists

Structure of unnumbered lists:

- List level 1
  - List level 2

Structure of numbered lists:

1) List level 1
2) List level 1
   1. List level 2
   2. List level 2

1.5 Applicable documentation

For the safe and correct use of the product, observe the additional documentation delivered with the system as well as the relevant standards and laws.

1.6 Keeping

Keep the user manual, including the supplied documentation, readily accessible near the system.

1.7 Updated documentation

The latest version of the documentation can be dowloaded from https://www.a-eberle.de/de/downloads..

2. Scope of Delivery

The scope of delivery contains the displaying unit (EOR-1D) for detection of earth faults and short circuits. Depending on the chosen order code additionally a current adaptor for conventional current transducers or three SR55-sensors (rogowski coils) for current measurement are included. The following options are available:

Article-Nr.	Included components
119.9004.00	EOR-1D incl. LRM port without current sensor
119.9004.21	EOR-1D incl. LRM port with adaptor for conventional current transformer
119.9005.00	EOR-1D incl. LRM port with current sensor (rogowski coil SR55)

A backup battery (Li-battery 3,6 V, 2600 mAh, AA) for operation without external power supply is included in the delivery, but has to be activated at first (see chapter 7.1).

The adaptor cable for connection of the voltage measurement to the LRM-port is not included in the delivery (optional adapters see chapter 7.3).

3. Safety instructions

- Observe the operating instructions
- Always keep the operating instructions with the unit.
- Make sure that the device is never operated in a damaged or compromised condition.
- Make sure that only specialized personnel operate the unit.
- The device must be connected according to the manufacturer's installation instructions.
- Make sure that the device is never operated beyond its stated ratings
- Do not operate the unit in any hazardous environment where explosive gases, dust or fumes occur.
- Ensure that protective covers are always in place and are functional
- Ensure that the five safety regulations according to DIN VDE 0105 are always observed.

➲ Clean the appliance only with commercially available detergents.

4. Technical Data

The earth-fault and short circuit indicator EOR-1D can be used in compensated, isolated or solidly earthed grids. The device consists of the indication unit and three rogowski sensors (SR55) or the adaptor for the conventional current transducers, respectively. A core balanced current transformer (CBCT) is not necessary. The sensors have to be installed on shielded cables.

In operation the indicator has to be connected to a AC/DC power suplply which may fail in the case of a fault. In case of power fail the device switches to energy-saving mode and operates with the help of the internal battery. In energy-saving mode the current and voltage measurements are disabled. Already detected earth faults or short circuits (via modbus or relays) remain indicated. The modbus interface switches to sleep mode and is active in a restricted way. Detailed information can be found in chapter 9.1. The function of the SD-card is switched off in energy-save mode. The Comtrade log however is written on the SD-card, in the case that the power supply fails with a detected fault.

4.1 Indication unit

Subject	Description
Indicator	● LC display (backlit) Multilingual: German, English (other languages possible) ● LEDs for status control
Configuration	● Menu-driven (push/turn control) ● Via Modbus ● Copy of configuration files via MicroSD card from another EOR-1D
Current measurement	● Indication of operating current via Display ● Indication of operating current via Modbus ● 24 Bit A/D-converter, 2kHz sampling frequency
Voltage measurement	● Indication of operating voltage via Display ● Indication of operating voltage via Modbus ● 24 Bit A/D-converter, 2kHz sampling frequency, accuracy +/-3% ● LRM-interface (4 pin AMP-socket, 10 MΩ ohmic resistance) ● Maximum permitted voltage: 55VAC
Power supply	● Input 1: 18-75 VDC, 18-53 VAC (isolated) ● Input 2: 100-240 V DC+AC (isolated) ● Power consumption AC: 0,3 VA (max. 0,6 VA) ● Power consumption DC: 0,4 VA (max. 0,7 VA) ● Easy changeable battery (3,6 V, 2600 mAh, AA) ● Battery lifetime: ○ 20 years if disconnector is not removed (delivery state) ○ 15 years operation with power supply + 1000 h indication operation without power supply (without Modbus polling in case of power supply fail) ○ 2 years in standby operation (without indication, without power supply, without Modbus polling) ○ Without power supply the battery lifetime is reduced by the Modbus polling interval (worse case lifetime: 3 days)

SCADA terminals	• Two freely configurable relays (changeover contact) • Permanent/Immediate or wipe contact (time adjustable) • Indication of short circuit, earth fault, permanent fault, exceed of earth fault threshold, battery status • max. 230 V AC / max. 2 A / max. 30 W
Test/Reset	• Via menu navigation • Via external binary inputs reset and test • Via Modbus
Communication	• Transmission mode: Modus RTU • Adress range: 1 to 247 • Parity: no, odd, even • Baudrate: 9600 - 38400 • Interface: RS485 (2-wire + GND)
Fault recorder	• Saved on removeable MicroSD card • Fault records of current and voltage of phases 1,2 and 3 • Support of FAT16/FAT32 MicroSD cards with 2 - 32 GB and one partition • Fault record can be triggered manually • Up to 65535 fault record per SD card • Time stamp • Log file of events and parameter changes in readable text file
Real time clock	• Adjustable via Modbus • Adjustable via menu navigation • Precision 12 ppm (corresponds to 3,15 minutes/year)
Fault detection short circuit	• Adjustable to 20-2500 A • Suppression of wrong indications through settable response delay • Function disengageable
Fault detection Pulse location method	• Reliable detection with symmetrical pulse (Suppression of false indication through phase selective pulse location) • Reliable detection with unsymmetrical pulse • No continuous over-compensation necessary for reliable pulse location in the network, because of amplitude and phase evaluation of every phase! • Pulse detection with distributed Petersen coils possible • Minimum current amplitude of pulse settable (1A - 100A) • Tolerance of pulse ratio settable: x of y pulses detected correctly
Fault detection qu2 Transient Algorithm	• Reliable detection and location of earth faults for isolated as well as for compensated networks • Fault detection also possible in meshed networks • Detection of high impedance faults (up to kΩ-range) possible • Additional indication of permanent earth-faults possible • Thresholds for total current (Ice min) and zero sequence voltage (Ue) freely adjustable
External flashing light	• Connection of external flashing light possible (type BL4.1 or type BL6)
Operating temperature range	• from -20°C up to +65°C

Dimensions	● 97 mm x 48 mm x 86 mm (WxHxD) ● Dimensions for panel cutout: 92+0.8 x 45+0.6 mm ● IEC 61554 / DIN 43700
Protection class	● IP40

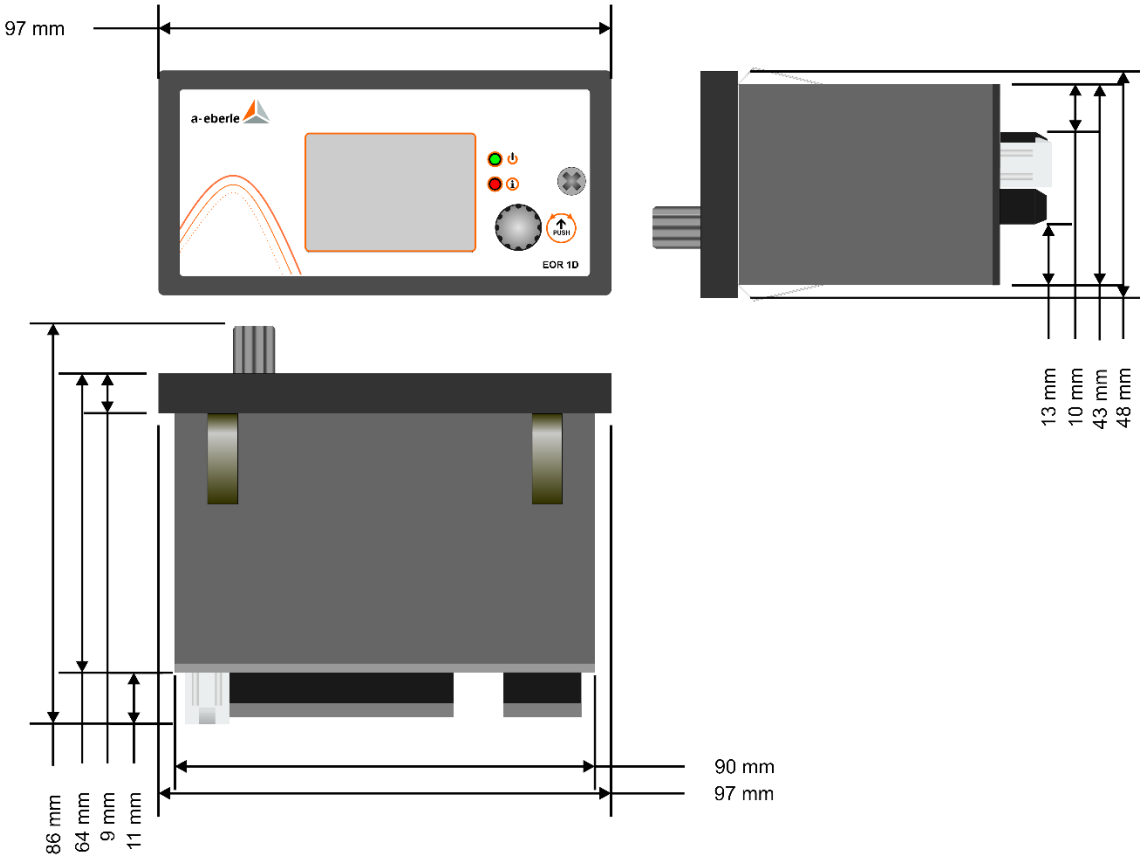


Figure 1: Dimensioned drawing EOR-1D

4.2 Sensors for current measurement

4.2.1 SR55

Subject	Description
Type	 • SR55
Conductor diameter	• 13-55 mm
Cable Length	• 8 m
Mounting	• Cable ties
Measurement range	• 0 A to 2500 A
Accuracy	• +/- 5 %
Cable type	• Only for shielded cables • Cable shield (ground) must be passed through each sensor back for elimination of currents on the cable shield

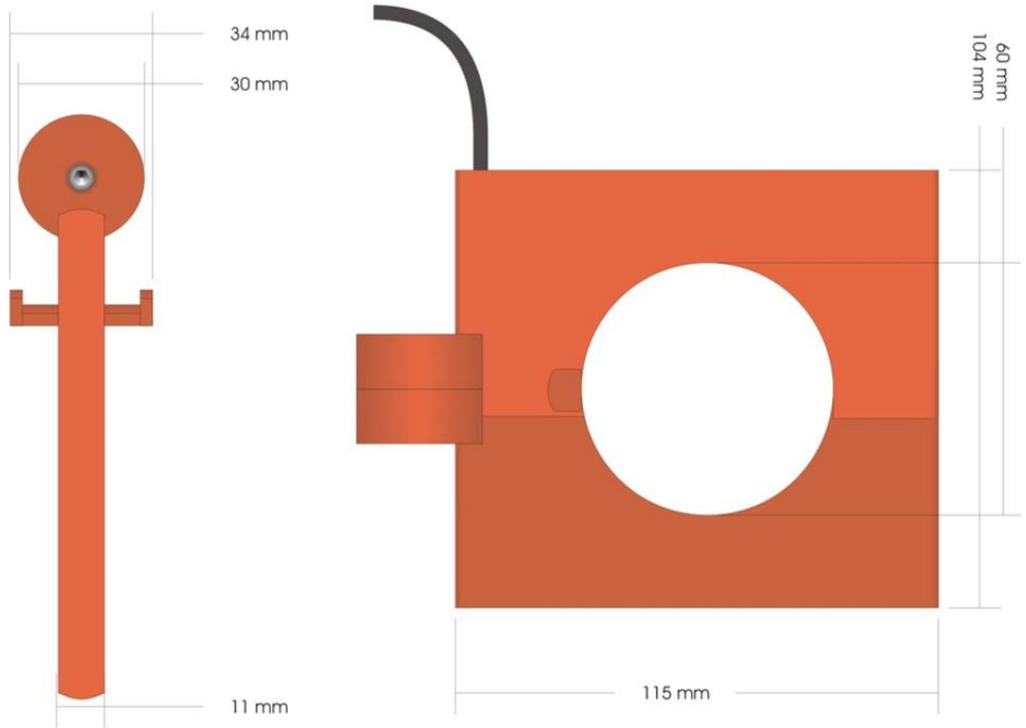


Figure 2: Dimensioned drawing SR55

4.2.2 Plug-on current transducer

Subject	Description
Type	 ● Plug-on-current transducer
Conductor diameter	● Max. 6 mm
Mounting	● Is put onto device
Rated current	● 1 A / 5 A
Measurement range	● 0 A to 12.5 A
Accuracy	● +/- 1 %

Currently the input for zero sequence current is not used internally in the device.

4.3 Optional external blinking light

Optional the external blinking light type BL4.1 and blinking light type BL6 are available on request.

Blinking light BL4.1 without directional indication for wall mounting, cable length 6 m

Article-No. 119.9100.06

Blinking light BL6 without directional indication for surface mounting, cable length 6 m

Article-No. 119.9102.06

5. Intended use

The earth fault and short circuit indicator EOR-1D is provided for fixed installation and permanent measurement, control and evaluation of voltages and currents.

This product is designed exclusively for use in power engineering installations in which the required work is performed by trained and qualified engineers. Qualified engineers are people who are familiar with the installation, assembly, commissioning and operation of such products and have the appropriate qualifications.

6. Transport and storage

The devices shall be stored in dry and clean rooms.

For storage of the device or related spare parts a temperature range from 20 °C to +65 °C is valid.

The relativ humidity must not cause condensation or icing.

It is recommended to connect the devices to a power supply before fielding. Especially when the devices shall be applied in extreme climate conditions (e.g. tropical conditions) by this pre-heating condensation can be prevented.

Before the device is connected to power supply for the first time it is recommended to store the device at minimum two hours in the operating room to achieve a temperature balance and to prevent humidity and condensation.

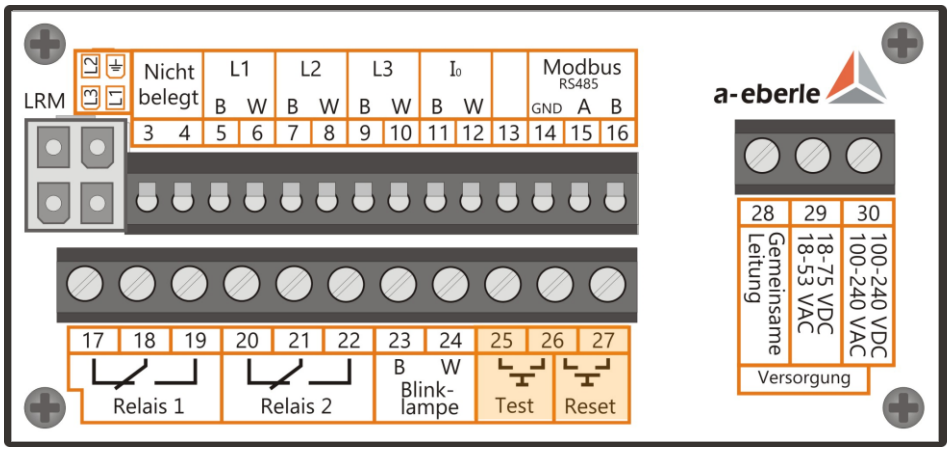
7. Installation/Commissioning

7.1 Indication unit

For the first use of the device the backup battery of the device has to be activated. Therefore the screw (cross-head) on the front cover has to be screwed out and the front cover has to be removed. The paper between the battery and the retainer has to be removed so that the battery circuit is closed.

Figure 3: Removing the protection-paper between the contact and the battery

The housing is an IEC 61554 / DIN43700 standard housing.
On the backside of the device the following screw terminals can be found.



Caution! The terminals 25-27 must be used potential-free

Figure 4: Backplane EOR-1D with terminal layout

LRM:	4 pole jack for LRM system (voltage measurement)
Terminals 3 - 4:	*not used*
Terminals 5 - 6:	current sensor L1 (SR55 or plug-on current transducer)
Terminals 7 - 8:	current sensor L2 (SR55 or plug-on current transducer)
Terminals 9 - 10:	current sensor L3 (SR55 or plug-on current transducer)
Terminals 11 - 12:	zero sequence current (currently not supported by the device)
Terminal 13:	*not used*
Terminals 14 - 16:	serial connection (RS485) for Modbus protocol
Terminals 17 - 19:	relay 1
Terminals 20 - 22:	relay 2
Terminals 23 - 24:	blinking light (max. 30 mA)
Terminals 25 - 26:	test (only use potential-free!)
Terminals 26 - 27:	reset (only use potential-free!)
Terminal 8:	common ground power supply
Terminal 29:	18 - 75 V DC / 18 - 53 V AC
Terminal 30:	100 - 240 V DC / V AC

7.2 Sensors and mounting

⚠ DANGER!	**Danger to life because of electric shock!**
	➲ EOR-1D indicator and current sensors must not be mounted in energized state
	➲ Ensure that the five safety rules are observed

The sensors can be installed on one-phase cables with a diameter from 13 to 55 mm. The sensors are fixed with cable ties. The installation only requires a few steps and normally can be done very easily in less than a minute.

Please note: the cable shield has to be passed through the sensor back again, per phase respectively.

Please note: the cable shield has to be passed through the sensor back again, per phase respectively.

Step 1:

➲ For easy mounting it is recommended to fix a cable tie to the cable first.

Step 2:

➲ The sensor can be opened on the joint and therefore laid around the cable afterwards.

Step 3:

➲ The already installed cable tie is laid around the upper bracket of the sensor and is then tightened.

Step 4:

➲ A second cable tie is mounted on the bottom side of the sensor and tightened as described before.

Step 5:

➲ Cut off the protruding parts of the cable ties.

Completely mounted sensor!

For high measurement accuracy the sensor should be vertical to the cable. If only one cable tie is used this criterion is not necessarily fulfilled.

By using a second cable tie the sensor is vertical to the cable. Furthermore an accidental opening of the sensor is prevented.

7.3 LRM-interface for voltage measurement

For measuring of voltage the EOR-1D can be coupled with a LRM-system, which means it can be connected in parallel to a voltage indicator (e.g. Capdis or WEGA). The burden of the LRM input of the EOR-1D is 10 MΩ.

The EOR-1D does not provide a second capacity for measurement of the voltage on a capacitive voltage divider. An appropriate device has to be used that provides a capacity corresponding to the capacitive voltage divider (e.g. Capdis or WEGA system). The EOR-1D can only be connected in parallel to such a device with a LRM – adapter cable.

The EOR-1D is equipped with a 4-pole AMP-socket. If an appropriate cable is not already available the following connection cables for connection of the voltage from a LRM-system to the AMP-socket of the EOR-1D are available as accessories:

LRM adapter: 4 pole AMP-plug on both sides

Article-No. 582.8114.03

LRM Y-adapter: 3x flat plug / socket to 4 pole AMP-connector

Article-No. 582.8113.03

8. Description and function range

In the following chapters the functions and parameters of the device are explained based on the menu structure. Furthermore the algorithms used by the device are explained by giving background information.

8.1 Menu navigation

The display is normally in standby-mode. By pushing the push/turn button on the front panel of the device the display gets activated.

On the very first page possibly detected short circuits and earth faults are displayed.

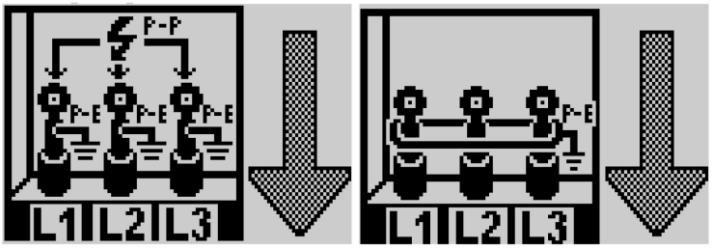


Figure 5: Three-phase short circuit (left) and qu2 earth fault in cable direction (right)

After pushing the push/turn button again the following overview pages are available. Via scrolling with the button it can be switched between the different overview pages.

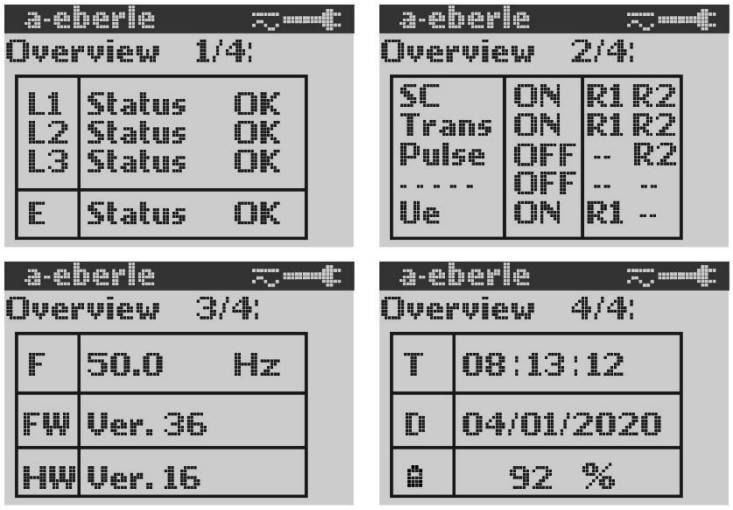


Figure 6:
Overview page 1 – Status of the three phases and ground,
Overview page 2 – Overview of activated algorithms and relay assignments
Overview page 3 – network frequency, firmware and hardware version
Overview page 4 – time, date and battery condition

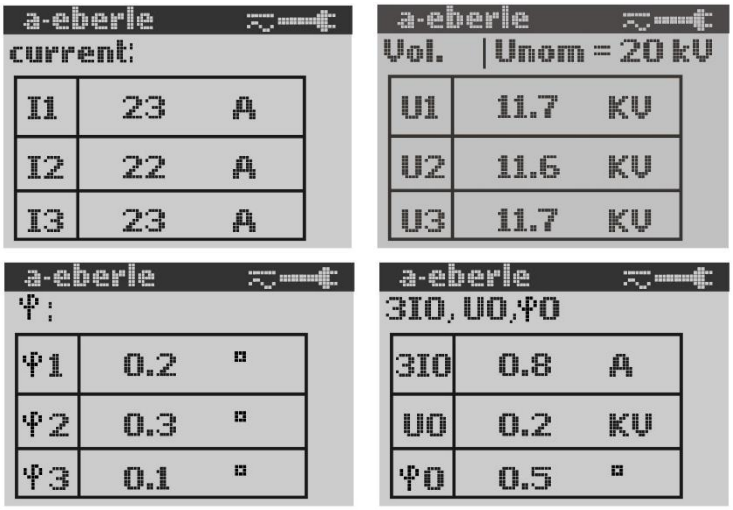


Figure 7: Overview pages for current, voltage, phase angle and zero sequence system

By pushing the button another time the main menu is activated. The main menu in detail is explained in chapter 8.2. The path of the actual menu is indicated by the numerical sequence in the headline of the submenu. By turning the push/turn button it can be chosen between one of maximum six options. By pushing the button the chosen option is confirmed.

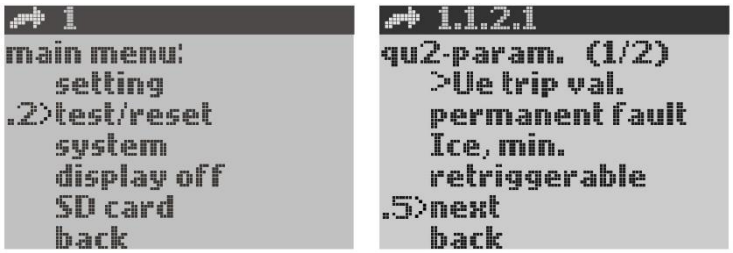


Figure 8: Main menu and submenu qu2-param.

In the parametrization menu of the actual parameter the current value of the parameter is shown in the bottom part of the display. By pushing the button a parameter change is confirmed.

Via „back“ it is always possible to switch back to the next higher level of the menu. Furthermore on parametrization pages where parameters can be changed it is possible to cancel the current process by pushing the button for at least 3 s.

8.2 Settings

8.2.1 Short circuit detection

The EOR-1D is able to perform undirected as well as directed short circuit detection. For the undirected short circuit detection only the fault current is evaluated. For the directed short circuit detection the fault angle between fault current and fault voltage is evaluated, provided that the configured current threshold and configured threshold time are exceeded.

The angle for triggering a directed short circuit indication can be parametrized freely. The trigger angle α sets the area for forward indication from α to α + 180°. For α = -90° a fault in forward direction (in direction of the cable) would be detected for example in the 1st and the 4th quadrant (assumed that no dead band is parametrized). A fault in backwards direction (busbar direction) would then be detected in the 2nd and 3rd quadrant. (see Figure 9)

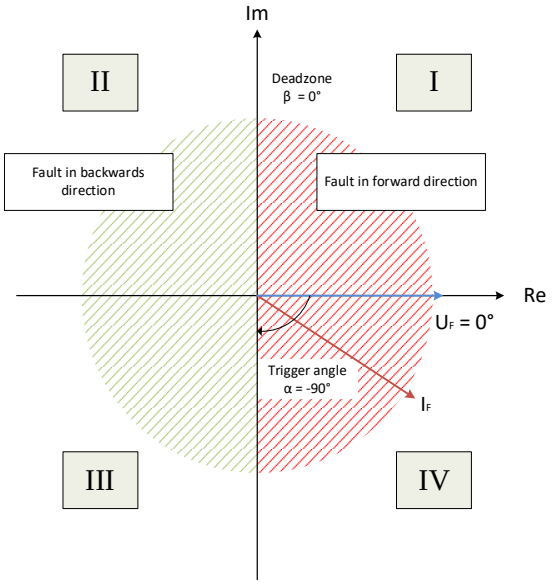


Figure 9: Definition of areas for the directional short circuit indication of the EOR-1D without dead band and α = -90°

For suppression of a back and forth in the directional indication in borderline cases additionally a deadband is implemented. In the dead band area no direction is indicated. All short circuits in this area are evaluated as undirected. The dead band is defined by the angle β which has its starting point at the angle α. The following areas exist for the directed short circuit detection:

Area	Lower limit	Upper limit
Indication forward	α	α+180°+ β
Dead zone	α+180°+ β	α+180
Indication backward	α+180	α+β
Dead zone	α+β	α

In Figure 10 the definition of the areas for the directed evaluation is shown for two examples to facilitate the understanding:

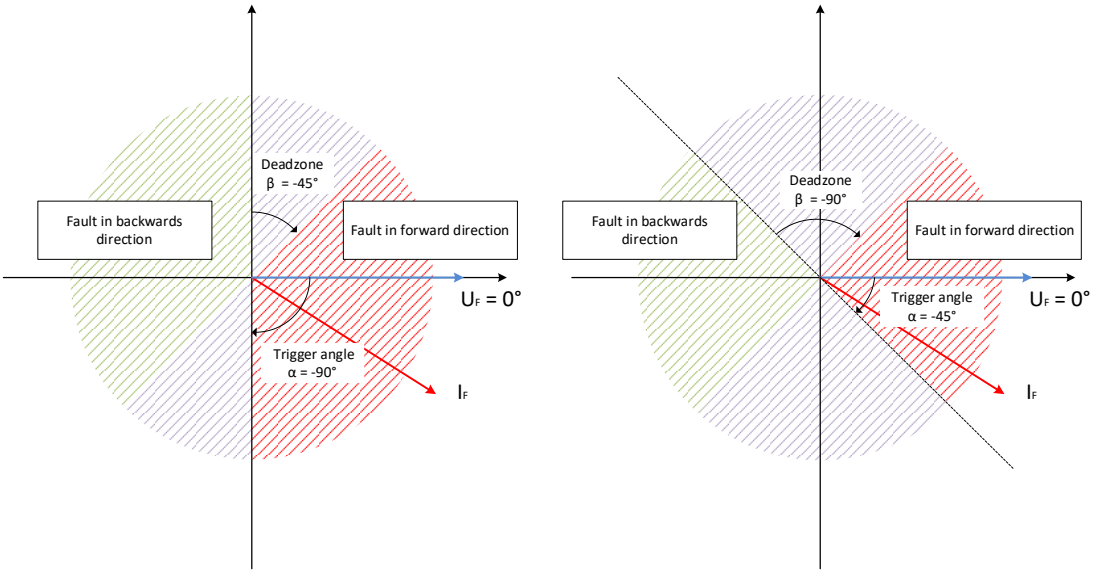


Figure 10: Definition of areas for the directional short circuit indication of the EOR-1D for case a) α = -90° and β = -45° (equivalent to default parameters)
case b) α = -45° und β = -90°

In the EOR-1D for evaluation of the short circuit the voltage *U* is placed on the real and therefore the angle of the current *I* is considered (analogue to the calculation of the angle $\varphi = \varphi_I - \varphi_U$ in the EOR-1D). Electrical lines behave ohmic-inductive in case of a short circuit, which means for fault in cable direction (forward indication) the current lags compared to the voltage. Therefore the forward fault referring to the chosen angle definition in the EOR-1D is found in the 4th quadrant and the backward fault in the 2nd quadrant. Accordingly the 2nd and 4th quadrant should normally be completely covered during parameterization of α and β. This is accomplished by the default settings α=-90° and β = -45°.

Additionally to the detection of single short circuits the EOR-1D is able to detect a second short circuit separately as long as the first short circuit is hold by the device. The second detected short circuit is display with 2.P-P instead of P-P.

Trip current				
Submenu	[Start page → main menu → settings → short circuit → trip current]			
Description	With this parameter the current threshold for triggering the short circuit indication is defined. The mean value is calculated over 2 periods. For the configuration with a plug-on-current transducer the threshold values are depending on the chosen transformer ratio kni.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
Trip current	20	2500	10	A

Response delay				
Submenu	[Start page → main menu → settings → short circuit → response delay]			
Description	When the trip current is exceeded for the parametrized response delay a corresponding short circuit is indicated by the device.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
Response delay	20	3000	20	ms

Reset time short circuit				
Submenu	[Start page → main menu → settings → short circuit → reset SC → Reset time SC]			
Description	Time for automatic reset of the short circuit indication. The timer starts on the detected short circuit occurrence.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
Resettime SC	5 s	18 h	1 s	HH:MM:SS

Current reset				
Submenu	[Start page → main menu → settings → short circuit → reset SC→ current reset]			
Description	With the automatic current reset only short circuit messages are reset, as soon as the current on the conductor L1, L2 or L3 is higher than the chosen limit. This function as an example can be used for a reconnection after a short circuit to reset the short circuit message before the normal short circuit reset time, so that when another short circuit occurs the evaluation starts again.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
Current reset	OFF or 3	50	1	A

The parameters directional indication and trigger angle are only visible in the display when voltage via LRM is activated, see chapter 0.

Directional indication		
Submenu	[Start page → main menu → settings → short circuit → directional]	
Description	This parameter enables the directional short circuit detection. When deactivated all short circuits are indicated as undirected. The directed short circuit detection is only possible for a response time up to 1000 ms. For higher values of the parameter response time the directional detection is automatically deactivated.	
Depending parameters	Trigger angle	
Shortcut	**Value**	
Directional ind.	On/Off	

Trigger angle				
Shortcut	[Start page → main menu → settings → short circuit → trigger angle]			
Shortcut	Via trigger angle the offset α and the dead band β as described above can be parametrized.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
Offset α	-180	180	1	°
Deadz. β	α -45°	α+45°	1	°

8.2.2 Earth fault detection

Depending on the neutral point treatment of the grid two different algorithms for earth fault detection can be used: Pulse detection or qu2-algorithm (transient method). For better understanding of the earth fault detection methods the general theory and processes of an earth fault event are explained in the following section.

8.2.2.1 Processes of an earth fault event

The earth fault is characterised by one phase of the three-phase system being shorted to earth. Therefore the voltage of the faulty phase collapses. In the healthy phases the voltage increases in compensated and isolated grids. In solidly and low ohmic earthed grids the earth fault becomes an earth short circuit where high currents over earth occur. In all cases and types of neutral point treatment a zero sequence voltage (vectorial sum of phase voltages $\underline{U}_0 = \underline{U}_{1E} + \underline{U}_{2E} + \underline{U}_{3E}$) due to the imbalance occurs. Hence the zero sequence voltage often is used as the basic criterion for earth fault detection. The following three overlapping processes are distinguished:

- Discharging of the defective line via earth
- Charging of the healthy lines via earth
- Steady-state

In the following section these processes are discussed shortly at the example of an isolated grid with three feeders.

Discharging process of the faulty phase

First the capcities to ground of the faulty phase (in the faulty feeder as well as in the healthy feeders) are discharged.

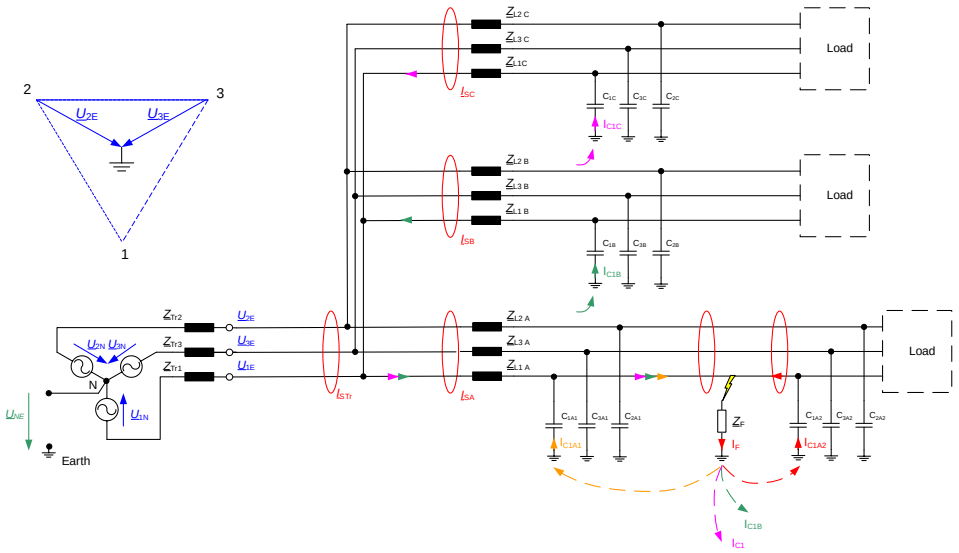


Figure 11: Discharging process for an isolated grid with three feeders

Important for the discharge process are:

- Capacity of faulty phase to earth
- Charging state of the capacity of faulty phase
- Line impedance to and in the other outgoing feeders
- Impedance of the faulty section itself or the earthing

The discharging process affects only the faulty phase and is independent of the neutral point treatment of the grid. The very high-frequency transient process depends on the length of the cables and its frequency gets higher as the cables get shorter. It is usually in the range of >10 kHz. Therefore the discharging process is not evaluated for the earth fault location.

Charging process of the healthy phases

In the second process the healthy phases are charged over earth. Caused by the charging the phase voltages of the healthy phases increase at maximum up to the value of the line-to-line voltage (depending on the fault impedance). This causes a netral point shift.

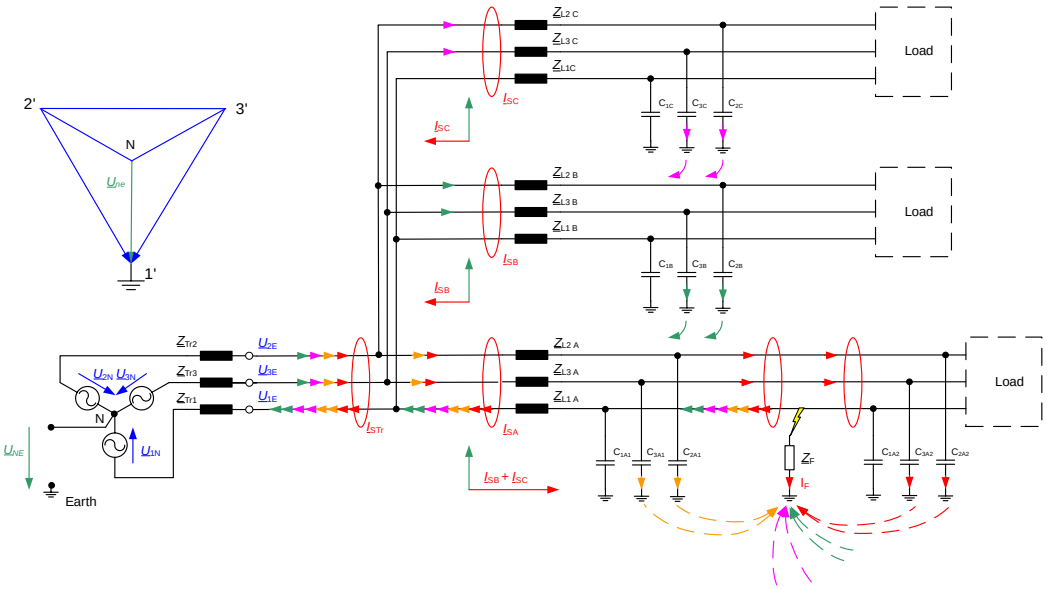


Figure 12: Charging process for an isolated grid with three feeders

Key for the charging process are:

- Capacitance of healthy phases to earth
- Charging state of the phases' capacitance
- Charging voltage
- Leakage inductance from the injecting transformer
- Line impedance from the faulty feeder to the injecting transformer
- Impedance of the fault itself or the earthing

The distribution transformers or the loads are only considered with a high impedance and can be neglected in the first approximation. The charge oscillation's limiting element remains the injecting transformer's relatively low impedance leakage inductance, and, if the faults are very far away, the transformer's inductance to the faulty section.

The charging process for the wye connection is displayed in the equivalent circuit in Figure 13. A possible transformer delta connection can be converted to the equivalent wye connection.

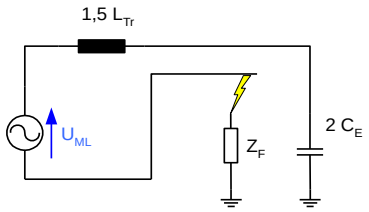


Figure 13: Equivalent circuit for the charging process

The frequency of the charge oscillation is calculated from

$$f_A = \frac{1}{2\pi}\sqrt{\frac{1}{L_{ers}C_{ers}}} = \frac{1}{2\pi}\sqrt{\frac{1}{3\,L_{Tr}C_E}} \qquad (0.1)$$

This formula for the charge oscillation frequency also applies when the inductance of the transformer L_{Tr} is added to the inductance of the line from the faulty section to the transformer. It reduces the frequency. An earth fault that is very far away delivers a lower charge frequency than an earth fault that is closer to a bus bar.

Estimation of the leakage impedance over the impedance voltage and the transformer's rated apparent power:

$$X_{Tr} = \omega\, L_{Tr} = \frac{u_s\, U_n^2}{100\, S_{Tr\,n}} \approx \frac{u_k\, U_n^2}{100\, S_{Tr\,n}} \qquad (0.2)$$

The initial amplitude of the charging current is given by:

$$\hat{I}_{ZA} = 2\,\omega\, C_E\, \hat{U}_{ML}\; c_\phi = \frac{2}{3}\hat{I}_{CE}\; c_\phi \qquad (0.3)$$

The impact of the switching moment (angle φ) is taken into account by the amplitude factor (in the formula, f = 50 Hz):

$$c_\phi = \sqrt{\cos^2\varphi + \left(\frac{f_A}{f}\right)^2 \sin^2\varphi} \qquad (0.4)$$

In the maximum of the earth-line voltage of the faulty line (φ = 90°)

$\hat{I}_{ZA} = 0{,}667\;\hat{I}_{CE}\;\frac{f_A}{f}$ an the zero point of the earth-line voltage of the faulty line (φ = 0°) $c_\phi = 1$ and $\hat{I}_{ZA} = 0{,}667\;\hat{I}_{CE}$.

The above derivations have shown that the peak value of the charging current takes on at least the value $0{,}667\;\hat{I}_{CE}$ of the remaining grid (total grid minus faulty feeder).

Transient relays evaluate the charging process. The high frequency discharge oscillations are filtered out.

Steady state

In the steady state, the 50 Hz component of an isolated grid's capacitive current flows across the faulty section. The faulty voltage of the faulty phase remains zero while the voltages of the healthy phases remain on the increaed value of the phase to phase voltage (in case of a low ohmic fault). The steady state corresponds to the conditions in the charging process without charging osillation as shown in Figure 12. In an isolated grid the capacitive earth fault current I_{CE} flows on the fault location.

8.2.2.2 The basics of resonant earthing

In medium and high voltage grids, Petersen coils are used to compensate the capacitive current across the faulty section by a similarly large counter-flowing inductive current when a single pole-to-earth fault occurs. This is done by setting the coil (in the grid's healthy state) to an inductive reactance X_L that corresponds approximately to the grid's capacitive reactance X_C. A real compensation coil additionally to the inductivity L_P shows an ohmic component G_P.

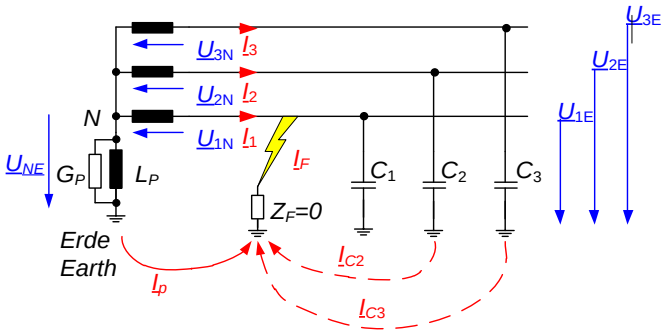


Figure 14: Equivalent circuit of a compensated grid (with only one feeder) with compensation coil und one-pole earth fault

When X_L equals exactly X_C only the so-called wattmetric residual current flows over the fault location. Normally the compensation coil is not exactly tuned to the resonance point (full compensation), but is slightly overcompensated.

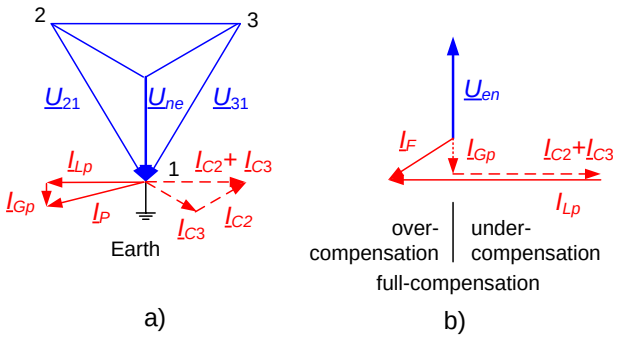


Figure 15: a) Vector diagram with earth fault in phase L1 (fault impedance = 0 Ω)
b) Influence of different positions of the compensation coil on the fault current I_F

In compensated grids the zero sequence currents are significatly reduced compared to the isolated grid. Hence other methods for locating of earth faults have to be used. For the evaluation of the steady state in compensated grids the pulse detection can be used. The evaluation of the transient charging process via qu2-method can be used for both isolated and compensated grids and is therefore very flexible.

8.2.2.3 General

The erath fault detection algorithms qu2 transient method and pulse detection method are generally started, as soon as the Uearth trip value is exceeded. If the voltage falls below the treshold of Uearth the indication is delayed in addtion by the parameter >Ue reset time.

>Uearth trip value				
Submenu	[Start page → main menu → settings → earth fault → general →>Ue trip val.]			
Description	With this parameter the trigger value for earth fault detection in general is defined. When the zero sequence voltage exceeds this threshold the evaluation of the qu2-method is started.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
>Ue trip value	1	90	1	%

>Ue reset time				
Submenu	[Start page → main menu → settings → earth fault → general → >Ue resettime]			
Description	Time for an automatic reset of the >Ue indication. The timer starts when the zero sequence voltage deceeds the >Ue threshold (when there is no earth fault any more).			
Shortcut	**Min. value**	**Max. value**	**Stepsize**	**Unit**
Resettime >Ue	5 s	18 h	1 s	HH:MM:SS

8.2.2.4 Qu2 transient method

The qu2-method (transient method) evaluates the recharging process (see also chapter 8.2.2.1) of the two healthy phases when an earth fault occurs.

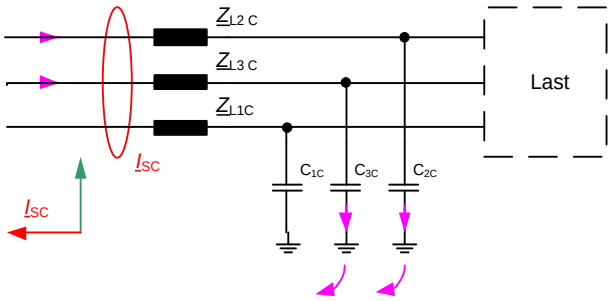


Figure 16: Recharging process of healthy feeder

The curve of the zero sequence voltage can be described in a simplified manner by the following equation: $u_0(t) = \frac{1}{C}\int_o^t i_o(\tau)d\tau$. It shows that the voltage does not occur until a current flows on the line-to-earth capacitance. This creates a current that leads the voltage by 90°. The integrated value of the current can be interpreted here as the applied charge q. This means that the voltage in a fault-free feeder is proportional to the charge. Plotting u_0 and q against in a diagram will always yield a straight line with a positive gradient for the fault-free feeder.

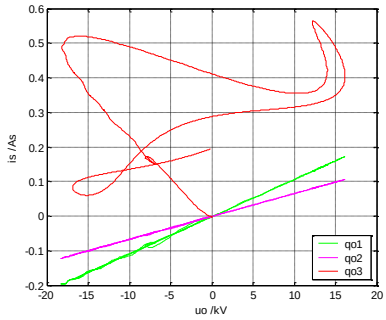


Figure 17: Direction evaluation qu2-methode (faulty feeder qo3)

Based on the fault resistance, the faulty feeder will yield a straight line with a negative gradient or the direction evaluation will be based on the rotation (corresponds to the surface or the curvature of the curve).

Fault-free feeder: Straight line with positive gradient

Faulty feeder:Straight line with negative gradient or rotation

The qu2-method compared to the conventional qu-method is additionally using a lineraization on the operating point and nonlinear filters. Therefore a reliable earth fault detection is also possible in meshed grids.

The folder “transient detection“, which contains all parameters for the qu2-method, is hidden in the menu when “voltage over LRM” is switched off, see chapter 0.

Current threshold Ice min	
Submenu	[Start page → main menu → settings → earth fault → transient det. →Ice, min.]
Description	For triggering the qu2-signal in addition to the Uearth threshold a current threshold has to be exceeded. This parameter correlates to the minimal residual healthy grid (primary value). The current threshold can be estimated from the capacitive earth fault current I_{CE} of the uncompensated grid. $$I_{ce,min} = I_{CE} \cdot 0.05$$ With a plug-on current transducer for the configuration the minimum and maximum values for this parameter are depending on the chosen transformer ratio kni.

Shortcut	Min. value	Max. value	Step size	Unit
Ice min	0	100	1	A

Reset time transient method	
Submenu	[Start page → main menu → settings → earth fault → transient det. → resettime tran.]
Description	Time for an automatic reset of the qu2-transient method indication. The timer starts when the qu2 indication gets active (when the earth fault is detected).

Shortcut	Min. value	Max. value	Stepsize	Unit
Resettime trans.	5 s	18 h	1 s	HH:MM:SS

Permanent fault				
Submenu	[Start page → main menu → settings → earth fault → transient det. → permanent fault]			
Description	● When the zero sequence voltage exceeds the Uearth trip value for a longer time than the parametrized permanent fault time the device detects a permanent earth fault. In addition to the normal Uearth indication “Ue” the device also sets a corresponding message “Ue_PE”.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
Permanent fault	0	60	1	s

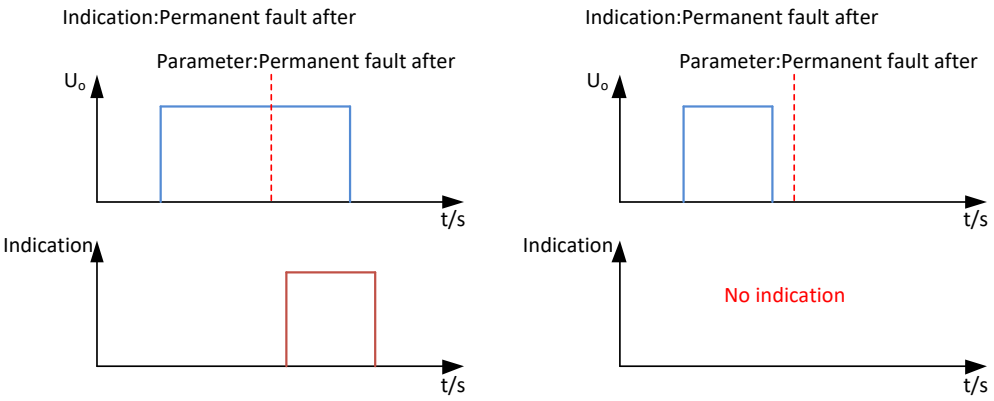


Figure 18: Earth fault indication in case of permanent earth fault

Type of signal/ retriggerable		
Submenu	[Start page → main menu → settings → earth fault → transient det. → retriggerable]	
Description	With this parameter it can be chosen between two types of qu2-message: ● Retriggerable (always the latest fault detected by the qu2 is indicated) ● Not retriggerable (the first earth fault detected by the qu2 is saved and indicated until it is reset).	
Shortcut	**Unit**	
Retriggerable	ON/OFF	

Direction filter	
Submenu	[Start page → main menu → settings → earth fault → transient det. → direct. filter]
Description	Only the qu2 indication in forward direction is indicated when this parameter this set to “On”. Qu2 indications in backward direction are suppressed in that case.
Shortcut	**Unit**
Direction filter	ON/OFF

Rot./Grad.				
Submenu	[Start page → main menu → settings → earth fault → transient det. → rot./grad.]			
Description	With this parameter it can be defined when rotation and when the gradient is used as criterio for the direction of the signal in the qu2-algorithm. When the ratio of the calculated values for rotation/gradient < parameter Rot./Grad. then the gradient is used for evaluation, otherwise the rotaion is used.  The parameter is set to 50 per default and normally has not to be adapted. Changes in this parameter should only be performed in consultation with A. Eberle GmbH & Co. KG.			
Shortcut	**Min. value**	**Max. value**	**Stepsize**	**Unit**
Rot./Grad.	0	360	1	-

8.2.2.5 Pulse detection

For pulse detection a pulsing device is necessary, that is normally connected to the power auxiliary winding of the arc suppression coil. The pulsing device generates a pulsing current that can be measured only up to the fault location . By swithing on and off a capacity (or inductance) the detuning of the compensated grid and therefore the zero sequence current changes. When condensators are switched on for pulsing the overcompensation is reduced, which causes a shift on the resonance curve to full compensation.

For **low-ohmic faults** the generated zero-sequence current can only flow over the fault location. The voltages of the healthy phases are not influenced by the pulsing. The capacitive currents in the healthy feeders therefore also remain constant. A pulsing zero-sequence current can therefore be only detected in the faulty feeder.

For **high-ohmic faults** a coupling to the healthy feeders occurs. The pulsing on the fault location now causes a change of the zero-sequence voltage because of the fault impedance. Therefore the voltages of the healthy phases also change, which in consequence causes the capacitive currents in the healthy feeders to change with the pulse.

For **classic pulse detection relays**, that only evaluate the amplitude of the current, this leads to the problem that with a symmetrical pulse for high-ohmic faults the healthy and faulty feeders can not be differentiated from each other. Therefore an unsymmetrical pulse (e.g. pulse/pause-ratio 1,5/1) must be used for conventional relays. Furthermore for distributed arc suppression coils in the grid an overcompensation over the complete lenght of the lines has to be taken into acocunt , see Figure 19. The grade of overcompensation in the substation is not constant over the line but decreases with increasing distance from the substation because of the I_{CE} of the line.

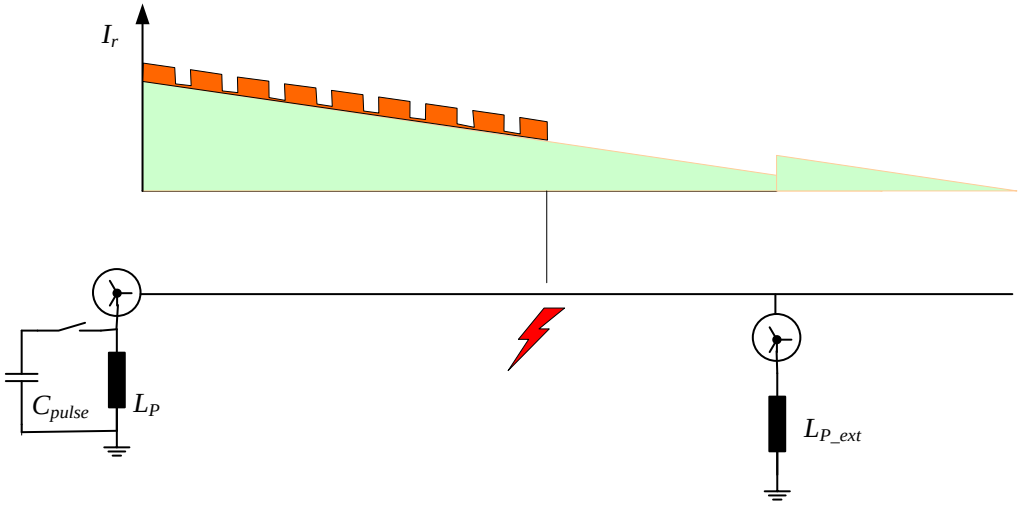


Figure 19: Classic pulse detection relay – Overcompensation requirements with and without distributed arc suppression coils in the grid

The **pulse detection algorithm of EOR-1D** by contrast evaluates not only the amplitude of the current but also the phase information of the currents. Therefore the faulty feeder can be detected correctly both with unsymmetrical and with symmetrical pulse. Furthermore there is no strict need for overcompensation as shown in Figure 19. This means that the pulse detection of the EOR-1D is independent from the detuning of the arc suppression coil and also from distance depending detuning of the line, see Figure 20.

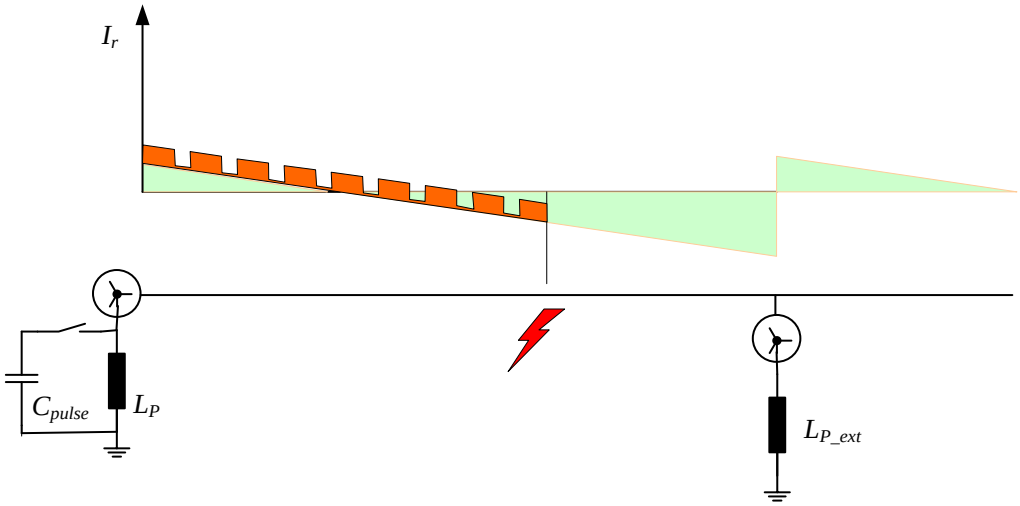


Figure 20: Pulse detection algorithm of the EOR-1D – no overcompensation requirement with and without distributed arc suppresion coils in the grid

Minimum current amplitude				
Submenu	[Start page → main menu → settings → earth fault → pulse location → min cur. ampli.]			
Description	This parameter sets the minimal current amplitude of the pulsed signal. The active and reactive current are calculated automatically to determine the value of ΔI_c. The mean value of the current is made over 5 periods. The minimum and maximum values for plug-on current transducers depend on the chosen current transmission kni.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
Min cur. ampl.	1	100	1	A

Setting pulse

Submenu	[Start page → main menu → settings → earth fault → pulse location → setting pulse]
Description:	The earth fault indicator first asks for the switch on time and then automatically the switch off time. By pushing the push/turn button the selected value is saved. For a correct parameterization of the pulse location method the sum of "swi. on time" and "swi. off time" has to be equal to the sum of switching on and off time of the pulse device (pulse source). Thereby it is not important whether the parameter "swi. on time" or "swi. off time" corresponds to the real switch on time of the pulse device, because an increase of the current (switching on a capacitance in an undercompensated network or switching on an inductance in an overcompensated network) as well as a decrease of the current (switching on a capacitance in an overcompensated network or switching on an inductance in an undercompensated network) gets interpreted from the algorithm as "pulse on". Hereby accidentally wrong setups by mixing up the "swi. on time" and "swi. off time" are automatically prevented. Example: Unsymmetrical pulse: 1,5 s to 1 s = ∑2,5s Symmetrical pulse: 1,25s to 1,25s = ∑ 2,5s The parameterisation for the last case must be set to 1,3s to 1,2s.

Shortcut	Min. value	Max. value	Step size	Unit
Swi. on time	500	2000	100	ms
Swi. off time	500	2000	100	ms

Pulse quota

Submenu	[Start page → main menu → settings → earth fault → pulse location → Pulse quota]
Description	The parameter pulse quota defines how many pulses have to be recognized in a pulse sequence. Example: 3 form 5. This means that a pulse sequence of 5 x (switch on time + switch off time) is checked and at least 3 pulses have to be recognized correctly. First it is asked in the settings for the total amount of pulses, second for the minimum amount of correct recognized pulses.

Shortcut	Min. value	Max. value	Step size	Unit
Pulse sequence	1	10	1	-
Min. of correct recognized pulses	1	10	1	-

Reset time pulse detection				
Submenu	[Start page → main menu → settings → earth fault → pulse location → reset-time pulse]			
Description	Time for the automatic reset of the pulse detection indication.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
Resettime pulse	5 s	18 h	1 s	HH:MM:SS

8.2.3 Remote indication

8.2.3.1 Relay function

Relay 1 / Relay 2	
Submenu	[Start page → main menu → settings → remote ind. → relay function → relay 1 / relay 2]
Description	The earth fault indicator EOR-1D has two relays, each of them can be assigned with a different function. The menu leads the user through the different settings by asking the needed parameters. The chosen functions are logically connected with an "OR". The parameter "wipe time" is only visible when "wipe contact" is chosen for the specific relay and can be used to parametrize a defined time for the relay signal.

Shortcut	Options
relay 1 / relay 2	• >Uearth permanent earth fault (PE) • >Uearth • Transient PE towards busbar ↑ • Transient PE towards line ↓ • Transient towards busbar ↑ • Transient towards line ↓ • Short circuit towards busbar ↑ • Short circuit towards line ↓ • Short circuit undirected ↓↑ • Battery Status • Reserved (not choosable) • pulse detection

Contact type (available for relay 1 and relay 2)	
Submenu	[Start page → main menu → settings → remote ind. → relay function → contact type]
Description	Here the contact type for relay 1+2 is chosen. Permanent contact: By the contact type permanent contact the relays are switched on, until the reset. Wipe contact: By the contact type wipe contact the relays switch on for a defined time from the occurrence of the event and after that the relays switch off again. The wipe time can be parametrized in the menu directly after wipe contact was chosen for the specific relay. Immediate mode: In immediate mode the relays switch on as long as the event occurs. After the event the relays switch off immediately. (<100ms)

Shortcut	Options
Contact type relay 1 / relay 2	• permanent contact • wipe contact • immediate

8.2.3.2 Modbus RS485

Address				
Submenu	[Start page → main menu → settings → remote ind. → Modbus RS485 → address]			
Description	Slave address of the EOR-1D in Modbus RS485 protocol.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
MODBUS address	1	247	1	-

Baud rate		
Submenu	[Start page → main menu → settings → remote ind. → Modbus RS485 → baud rate]	
Description	Transmission rate of the Modbus RS485 interface.	
Shortcut	**Value**	**Unit**
MODBUS baud rate	• 9600 • 19200 • 38400	Baud

Parity bit	
Submenu	[Start page → main menu → settings → remote ind. → Modbus RS485 → parity bit]
Description	Parity bit of the Modbus RS485 interface.
Shortcut	**Value**
Parity bit	• none (2 stop bits) • even (1 stop bit) • odd (1 stop bit)

Register mapping	
Submenu	[Start page → main menu → settings → remote ind. → Modbus RS485 → Reg. mapping]
Description	Selection of different register mapping (data point lists), also see chapter 9.3 and 0.
Shortcut	**Value**
Register mapping	• Standard • SNH 1.4

Modbus mode	
Submenu	[Start page → main menu → settings → remote ind. → Modbus RS485 → modbus mode]
Description	In the 'auto on/off' mode the Modbus interface is put into sleep mode 30 s after the supply voltage is lost. If a Modbus command arrives, it wakes up the Modbus interface, but the first command is missed. All subsequent commands are processed directly again. After 30 seconds without a new command the Modbus, the interface is switched off again. In the 'perm. off' mode, the Modbus interface is permanently disabled. In 'batt. mode off' the Modbus interface is put into sleep mode 30 s after the supply voltage is lost and it is not possible to wake it up again until the supply voltage is available again. Only one mode can be active at once.
Shortcut	**Value**
Modbus mode	• Auto on/off • Perm. off • Batt. mode off

Debug mode	
Submenu	[Start page → main menu → settings → remote ind. → Modbus RS485 → modbus mode → Debug mode]
Description	The logbook entries, which are normally written on the SD-card, can be alternatively sent online via the RS485 interface. A Modbus RS485 communication is not possible when the debug mode is activated. The communication parameters of the RS485 port in debug mode comply with the chosen Modbus settings. The debug mode will be disabled after 3 hours automatically.
Shortcut	**Value**
Debug mode	ON/OFF

8.2.4 Voltage Measurement

For detection of power flow direction and fault direction the device can be connected to LRM system for voltage measurement, see also chapter 7.3.

The EOR-1D does not provide a second capacity for measurement of the voltage on a capacitive voltage divider. An appropriate device has to be used that provides a capacity corresponding to the capacitive voltage divider (e.g. Capdis or WEGA system). The EOR-1D can only be connected in parallel to such a device with a LRM – adapter cable.

When the voltage measurement is activated a voltage measurement must be connected. If no voltage measurement is connected while the function is activated this may cause deviations in the current measurement. In addition the red LED of the EOR-1D is blinking, in case no voltage is being measured and the EOR-1D has power supply.

Voltage measurement activation	
Submenu	[Start page → main menu → settings → voltage → volt. over LRM]
Description	When the voltage measurement is activated, the direction of the current flow will be shown with a sign in the main menu. Also the directed short circuit and the qu2 transient method are shown in the settings menu and can be used.
Shortcut	**Value**
Volt. over LRM	ON/OFF

Rated voltage				
Submenu	[Start page → main menu → settings → volateg → rated voltage]			
Description	The rated voltage (phase - phase) is shown on the overview page of the voltage and is used for the adjustment of the conductors L1/L2/L3 as reference value.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
Rated volt. P-P	0,4	36	0,1	kV

Voltage record adjustment				
Submenu	[Start page → main menu → settings → voltage → adj. voltage Lx]			
Description	To measure the phase voltage with the EOR-1D as exact as possible, all phase voltages can be calibrated separately. For this process a voltage must be applied on the LRM socket. Then it is possible to adjust on every conductor the present primary voltage which is measured with a reference device.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
Adj. voltage L1/L2/L3	0,5	36	0,1	kV

8.3 Test and reset

Test function short circuit backward	
Submenu	[Start page → main menu → test/reset → short cir. test → test direct. ↑]
Description	With this menu the fault indication can be simulated. A short circuit on all three phases in reverse direction and an undirected short circuit are signalled.

Test function short circuit forward	
Submenu	[Start page → main menu → test/reset → short cir. test → test direct. ↓]
Description	With this menu the fault indication can be simulated. A short circuit on all three phases in forward direction and an undirected short circuit are signalled.

Test function earth fault backward	
Submenu	[Start page → main menu → test/reset → earth fault test→ test direct. ↑]
Description	With this menu the fault indication can be simulated. An earth fault on all three phases in backward direction and an undirected earth fault are signalled. The indications >Ue and permanent earth fault are not simulated.

Test function earth fault forward	
Submenu	[Start page → main menu → test/reset → earth fault test→ test direct. ↓]
Description	With this menu the fault indication can be simulated. An earth fault on all three phases in forward direction and an undirected earth fault are signalled. The indications >Ue and permanent earth fault are not simulated.

Reset function	
Submenu	[Start page → main menu → test/reset → reset]
Description	When a fault is displayed, it is possible to reset the indication with this menu step. Alternatively the fault display can be reset via Modbus, the binary input 'reset' or the corresponding reset time.

CT log at test	
Submenu	[Start page → main menu → test/reset → CT log at test]
Description	In this menu it can be selected whether a Comtrade log is created for simulated fault indications or not.

Self test	
Submenu	[Start page → main menu → test/reset → Self test]
Description	The device performs a self test. In this process also the battery voltage is checked outside of the interval (daily at 09:00 o´clock) ant the result is shown on the display.

8.4 System

8.4.1 General

Info/factory reset	
Submenu	[Start page → main menu → system → info/fac. reset]
Description	This menu shows information about the hardware version, firmware version and the production date. By pushing the button for 5 s in this menu the device is reset to factory settings. When a factory reset is performed also the chosen current transformer type is reset to "SR55". If the plug-on current transducer is used, the transformer ratio kni afterwards also has to be set again.

Language	
Submenu	[Start page → main menu → system → language]
Description	In this menu the display language can be changed. Depending on the firmware version there are different languages available.
Shortcut	**Value**
language	• Deutsch • English

8.4.2 Date and time

Time				
Submenu	[Start page → main menu → system → date/time → change time]			
Description	In this menu the time is set and saved in the real-time clock. It always uses the 24h format. The time is used in the Comtrade and log function.  There is no change between summer and winter time (DST).			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
hours	0	23	1	hours
minutes	0	59	1	minutes
seconds	0	59	1	seconds

Date				
Submenu	[Start page → main menu → system → date/time → date]			
Description	In this menu the date is set and saved in the real-time clock. First the month is set, then the day and the year. The date is used in the Comtrade and log function.			
Shortcut	**Min. value**	**Max. value**	**Step size**	**Unit**
month	1	12	1	month
day	1	28,30,31	1	day
year	[20]00	[20]99	1	year

8.4.3 Other settings

8.4.3.1 Settings code

Change settings code			
Submenu	[Start page → main menu → system → other settings → settings code]		
Description	All settings are protected against accidental changes by the settings code. This code can be changed at the device. **The device is delivered with the code '111'.**  The new code must be confirmed with a second input.		
Shortcut	**Min. value**	**Max. value**	**Step size**
code	0	999	1

8.4.3.2 LCD

Change contrast			
Submenu	[Start page → main menu → system → other settings → LCD contrast]		
Description	If the visibility of the display is not optimal, the contrast can be adapted here.		
Shortcut	**Min. value**	**Max. value**	**Step size**
contrast	0	18	1

8.4.3.3 Current transformer selection

Current transformer selection	
Submenu	[Start page → main menu → system → other settings → ct selection]
Description	With this parameter the used current transformer is chosen. For the plug-on current transducer the transformer ratio kni has to be set in the next step according to the used current transformer. For a kni of 1 (default value) the measured values are shown as secondary values in mA.
Shortcut	**Value**
ct selection	• SR55 • clip on ct

8.4.3.4 Battery

Battery alert	
Submenu	[Start page → main menu → system → other settings → battery alert]
Description	With this parameter the point of a battery alert is set. The parameter shows the battery charge in percent. When the message battery reset is set on a relay, the relay signals at 09:00 o´clock.

Battery reset/status	
Submenu	[Start page → main menu → system → other settings → battery reset]
Description	With this parameter the battery counter must be reset after a battery change. There is the present status and the battery charge shown. The battery charge is calculated on different parameters and the state of charge is saved.  When the battery is changed the counter must be reset. The battery reset can be achieved when the operating button is pushed longer. A counter shows the remaining time to press the button.

8.4.4 Operating manual

Manual	
Submenu	[Start page → main menu → system → manual]
Description	By clicking on this submenu a QR-code is visualized on the display. By scanning the QR-code a link to the latest version of the operating manual for the device is opened.

8.5 Switch display off

Display off	
Submenu	[Start page → main menu → display off]
Description	By clicking on this menu the display is switched off. All other functions of the device are unaffected. The display gets active again when the button is pushed again.

8.6 SD card

The SD card function is only available when a power supply is connected.

8.6.1 Copy and save parameter configuration on the SD card

Load parameter configuration from SD card to EOR-1D	
Submenu	[Start page → main menu → SD card → „Conf. SD --> EOR“]
Description	To make a fast and safe configuration possible, the EOR-1D can copy all settings on a SD card. This configuration can be read in by any other EOR-1D. By choosing this menu point the current parameterization from the SD card is read into the device.

Write parameter configuration of EOR-1D to SD card	
Submenu	[Start page → main menu → SD card → „Conf. EOR --> SD“]
Description	To make a fast and safe configuration possible, the EOR-1D can copy all settings on a SD card. This configuration can be read in by other EOR-1D. By choosing this menu point the current parameterization is written onto the SD card from the device.

8.6.2 Save fault record on a SD card in Comtrade format

Comtrade Log	
Submenu	[Start page → main menu → SD card → COMTRADE Log]
Description	When a fault is detected a Comtrade log is written on the SD card. With this function a fault record is created on the SD card when the push/turn button is pushed.

8.6.3 Firmware update with SD card

NOTICE!	**Undefined firmware state!** When the power supply is interrupted during a firmware update an undefined firmware state occurs and the device must be send in for repair. ➲ Make sure that during a firmware update the power supply is not interrupted.

NOTICE!	**Existing parameter file on SD card will be overwritten during firmware update!** During a firmware update a pre-existing parameter file on the SD card will be overwritten with the current parameter setup at the time of the firmware update. ➲ Use two SD cards for the firmware update file and a customer specific parameter file.

Firmware update	
Submenu	[Start page → main menu → SD card → FW update]
Description	With an SD card the firmware of the device can be updated. For this process it is necessary to copy the new firmware (image.hex) in the root directory of the SD card. In the menu point 'FW update' the current and new firmware version are shown. To perform a firmware update the operation button must be pressed for 5 seconds in the 'FW update' menu. A counter shows the remaining time to press the button. The display turns off and the red and green LEDs start to blink. After a successful update the device restarts automatically. During the firmware update the parameters remain unchanged and are not reset.

9. Modbus protocol

The EOR-1D offers a serial Modbus interfache, which can be also used for parameterizing the device.

9.1 Modbus mode

The different Modbus modes are explained in chapter 8.2.3.2.

9.2 Technical data Modbus interface

Subject	Description
Type	• Two wire RS485 connection (not isolated) • Modbus RTU mode
Baud rate	• 9600 • 19200 • 38400
Mode	• 1 start / 8 bits / even parity / 1 stop: total 11 bits • 1 start / 8 bits / odd parity / 1 stop: total 11 bits • 1 start / 8 bits / none parity / 2 stop: total 11 bits
Address range	• 1 to 247
Function	• Function 03 (0x03): read register • Function 06 (0x06): write register • Function 08 (0x08): diagnosis (only echo)
Byte structure	• HI-Byte: 0bX15X14X13X12X11X10X09X08 • LO-Byte: 0bX07X06X05X04X03X02X01X00 • reserved bits are reported back with '0'

9.3 datapoint list - register mapping – 'Standard'

Register dec	Register hex	R/W	Unit	Values	Description	Firmware Version
Trip value configuration (Register 1 to 100)						
1	0x0001	R/W	A	20 to 2500* Step: 10	Short-circuit: Trip current 0 = OFF *Rogowski coil; with plug-on current transformer depending on kni	8
9	0x0009	R/W	ms	20 to 3000 Step: 20	Short-circuit: response time	28
13	0x000D	R/W	A	0 to 30*	Pulse locating: Minimum current deviation 0 = OFF *Rogowski coil; with plug-on current transformer depending on kni	28
14	0x000E	R/W	ms	500 to 2000 Step: 100	Pulse method: Switch on time of the detuning	28
15	0x000F	R/W	ms	500 to 2000 Step: 100	Pulse method: Switch off time of the detuning	8
16	0x0010	R/W		1 to 10	Pulse method: Pulse window (observation window)	8
17	0x0011	R/W		1 to 10	Pulse method: Minimum successfully detected pulses in observation window	8
18	0x0012	R/W	ON/ OFF	0 or 1	Voltage detection by LRM interface	22
19	0x0013	R/W	ON/ OFF	0 or 1	Directional fault indication (earth-fault and short-circuit)	22
20	0x0014	R/W	°	-180 to +180	Short-circuit: Trigger angle forward/backward	34
21	0x0015	R/W	°	-90 to +90	Short-circuit: dead zone angle (1,2 and 3-phase fault)	34
32	0x0020	R/W	A	1 to 100 * 0 = OFF	Transient detection (qu2): Current trip value $I_{CE,min}$ 0 = OFF *Rogowski coil; with plug-on current transformer depending on kni	36
33	0x0021	R/W	%	1 to 90	Transient detection (qu2): Voltage trip value $>U_e$	38
34	0x0022	R/W	ON/ OFF	0 or 1	Transient detection (qu2): Direction filter	36
35	0x0023	R/W	ON/ OFF	0 or 1	Transient detection (qu2): Retrigger ability	36
36	0x0024	R/W	ms	0 to 60000 Step: 100	Transient detection (qu2): Permanent Earth-fault 0 = OFF	36
37	0x0025	R/W		0 to 360 Step: 1	Transient detection (qu2): Rot./Grad. 0 = OFF	36

40	0x0028	R/W	V	500 to 36000 Step: 100	Rated voltage (phase-phase)	36
Reset configuration (Registers 101 to 200)						
102	0x0066	R/W	A	2 to 50	Reset by recovering operating current on conductor L1 2 = disabled	20
106	0x006A	R/W	s	5 to 64799	Short-circuit: reset time	10
107	0x006B	R/W	s	5 to 64799	Earth-fault: reset time	36
108	0x006C	R/W	s	5 to 64799	Earth-fault: reset time Pulse location	36
110	0x006E	R/W	s	5 to 64799	Earth-fault: reset time transient detection	36
111	0x006F	R/W	s	5 to 64799	>U earth detection: reset time	36
Indicator status (Register 201 to 300)						
201	0x00C9	R	%	0 to 100	Battery charge in percent (0% = empty or battery not installed)	8
202	0x00CA	R/W	%	10 to 90 (step of 5)	Low battery alert level (value of residual charge)	34
203	0x00CB	R	-	0 to 65535	Indicator status summery 1: X_{00} = short-circuit (1=yes/ 0=no) X_{01} = short-circuit phase 1 (1=yes / 0=no) X_{02} = short-circuit phase 2 (1=yes / 0=no) X_{03} = short-circuit phase 3 (1=yes / 0=no) X_{04} = earth-fault (1=yes / 0=no) X_{05} = earth-fault phase 1 (1=yes / 0=no) X_{06} = earth-fault phase 2 (1=yes / 0=no) X_{07} = earth-fault phase 3 (1=yes / 0=no) X_{08} = reserved X_{09} = battery charge <20% (1=yes / 0=no) X_{10} = external power supply (1=yes / 0=no) X_{11} to X_{14} = reserved X_{15} = mode (1=indicating / 0=standby)	 8 8 8 8 8 38 38 38 - 34 8 - 8
204	0x00CC	R/W	-	0 or 1	Set indicator into standby or indication status: 0 = reset indicator into standby mode 1 = test indicator / set indicator into indication mode	8
206	0x00CE	R	-	10 or 65535	Firmware Version of indicator	8

221	0x00DD	R	-	0 to 15	Short-circuit fault status and direction on conductor 1: X_{00} = fault current detected, direction unknown (1=yes / 0=no) X_{01} = fault current in bus bar direction detected (1=yes / 0=no) X_{02} = fault current in cable direction detected (1=yes / 0=no) X_{03} = second short-circuit detected (within reset time) (1=yes / 0=no)	28
222	0x00DE	R	-	0 to 15	Short-circuit fault status and direction on conductor 2 *analogous to register 221*	28
223	0x00DF	R	-	0 to 15	Short-circuit fault status and direction on conductor 3 *analogous to register 221*	28
224	0x00E0	R	-	0 to 15	Earth-fault status and direction on conductor 1 X_{00} = fault detected, direction unknown X_{01} = fault in busbar direktion detected X_{02} = fault in cable direction detectedt X_{03} bis X_{07} = reserved X_{08} = detection by pulse method X_{09} = reserved X_{10} = detection by transient method X_{11} = detection by transient method PE	 36 38 38 - 36 - 38 38
225	0x00E1	R	-	0 to 15	Earth-fault status and direction on conductor 2 *analogous to register 224*	36/38
226	0x00E2	R	-	0 to 15	Earth-fault status and direction on conductor 3 *analogous to register 224*	36/38
227	0x00E3	R		0 to 65535	Earth-fault fault status and direction of all conductors: X_{00} = fault detected, direction unknown X_{01} = fault in bus bar direction detected X_{02} = fault in cable direction detected X_{03} = reserved X_{08} = pulse detection X_{09} = reserved X_{10} = transient detection X_{11} = transient detection (permanent fault) X_{12} = >Ue X_{13} = >Ue (permanent earth fault)	36
230	0x00E6	R	°	+/- 180	Angle between voltage and current L1	28
231	0x00E7	R	°	+/- 180	Angle between voltage and current L2	28
232	0x00E8	R	°	+/- 180	Angle between voltage and current L3	28
233	0x00E9	R	°	+/- 180	Angle between voltage U0 and current I0	36
240	0x00F0	R	V	0 to 65535	Voltage level L1	28
241	0x00F1	R	V	0 to 65535	Voltage level L2	28
242	0x00F2	R	V	0 to 65535	Voltage level L3	28
243	0x00F3	R	V	0 to 65535	Zero-Sequence Voltage U0	36
245	0x00F5	R	A	0 to *	Current Phase L1	34

246	0x00F6	R	A	0 to *	Current Phase L2	34
247	0x00F7	R	A	0 to *	Current Phase L3	34
248	0x00F8	R	A	0 to *	Current read-out: Phase I0 (EOR-1D starting from Rev. 22: two's comple-ment -2500 to 2500A)	36
250	0x00FA	W	-	0 or 1	Reset indicator into standby mode: 0 = no change 1 = Reset After reset, the register will be cleared auto-matically	34
251	0x00FB	W	-	0 or 1	Set indicator into indication mode: 0 = no change 1 = Set indicator to indication mode After switching to indication mode, the register will be cleared automatically X_{00} = set all activated fault detection methods in cable direction* X_{01} = set short circuit in bus bar direction* X_{02} = set short circuit in cable direction* X_{03} = set earth fault in bus bar direction* X_{04} = set earth fault cable direction* X_{05} to X_{15} = reserved *Note: undirected fault simulation, if voltage detection is switched off.	36
MODBUS configuration (Register 301 to 419)						
301	0x012D	R/W	-	1 to 247	MODBUS Address	8
302	0x012E	R/W	-	0,1 or 2	Parity bit configuration 0 = no parity (two stop bits) (default) 1 = odd parity (one stop bit) 2 = even parity (one stop bit)	8
303	0x012F	R/W	bps	9600, 19200, 38400	Baud rate configuration	34
408	0x0198	-	-	-	*Please refer to register 245*	8
409	0x0199	-	-	-	*Please refer to register 246*	8
410	0x019A	-	-	-	*Please refer to register 247*	8
MODBUS configuration (Register 420 to 500)						
424	0x01A8	R/W	time	0 to 23	Real time clock: Hours Format: 24h	8
425	0x01A9	R/W	time	0 to 59	Real time clock: minutes	8
426	0x01AA	R/W	time	0 to 59	Real time clock: seconds	8
427	0x01AB	R/W	date	1 to 31	Real time clock: Day (Invalid days, like 31 st of February, will cause unspecific behaviour!)	8
428	0x01AC	R/W	date	1 to 12	Real time clock: month	8
429	0x01AD	R/W	date	2014 to 2099	Real time clock: year	8

450	0x01C2	R/W	-	0 to 255	Relay 1 function: X_{00} = >Uearth permanent fault (PE) X_{01} = >Uearth X_{02} = Transient PE towards busbar X_{03} = Transient PE towards line X_{04} = Transient towards busbar X_{05} = Transient towards line X_{06} = Short circuit towards busbar X_{07} = Short circuit towards line X_{08} = Short circuit undirected X_{09} = Battery Status X_{10} = reserved X_{11} = Pulse detection X_{12} to X_{15} = reserved	38
451	0x01C3	R/W	-	0 to 255	Relay 2 function: X_{00} = >Uearth permanent fault (PE) X_{01} = >Uearth X_{02} = Transient PE towards busbar X_{03} = Transient PE towards line X_{04} = Transient towards busbar X_{05} = Transient towards line X_{06} = Short circuit towards busbar X_{07} = Short circuit towards line X_{08} = Short circuit undirected X_{09} = Battery Status X_{10} = reserved X_{11} = Pulse detection X_{12} to X_{15} = reserved	38
452	0x01C4	R/W	-	1,2 or 4	Relay 1+2 contact type (both relay settings are changed): X_{00} = permanent contact X_{01} = wipe contact (please refer to register 453) X_{02} = immediate mode (resets as soon as fault current stops) X_{03} to X_{15} = reserved	28
453	0x01C5	R/W	ms	20 to 500 Step: 10	Relay 1 wipe time	36
454	0x01C6	R/W	ms	20 to 500 Step: 10	Relay 2 wipe time	36
455	0x01C7	R/W	-	1,2 or 4	Relay 1 contact type: *analogous to register 452*	34
456	0x01C8	R/W	-	1,2 or 4	Relay 2 contact type: *analogous to register 452*	34
460	0x01CC	-	-	-	*Please refer to register 20*	28
461	0x01CD	-	-	-	*Please refer to register 21*	28

Customer registers (Register 501 to 600)						
501	0x01F5	R/W	-	0 to 65535	Registers for Customer Values will be saved in internal EEPROM (16-Bit value) Registers can be used e.g. to write: - customer inventory number - location code - last battery exchange information (like 1012 for October 2012) - date of installation (like 1012 for October 2012)	8
502	0x01F6	R/W	-	0 to 65535	*analogous to register 501*	8
503	0x01F7	R/W	-	0 to 65535	*analogous to register 501*	8

9.4 datapoint list - register mapping “SNH”

Register dec	Register hex	R/W	Function Code	Values	Description	Firm-ware Version
2	0x0002	W	0x05	1	Reset all short circuit and earth fault indications	32
10	0x000A	R	0x02	0 or 1	Earth fault status on any phase: 0 = no fault detected, 1 = fault detected	32
11	0x000B	R	0x02	0 or 1	Short circuit or earth fault on phase 1: 0 = no fault detected, 1 = fault detected	38
12	0x000C	R	0x02	0 or 1	Short circuit or earth fault on phase 2: 0 = no fault detected, 1 = fault detected	38
13	0x000D	R	0x02	0 or 1	Short circuit or earth fault on phase 3: 0 = no fault detected, 1 = fault detected	38
16	0x0010	R	0x02	0 or 1	Short circuit in bus bar direction	40
17	0x0011	R	0x02	0 or 1	Short circuit in cable direction	40
18	0x0012	R	0x02	0 or 1	Earth fault (only qu2) and short circuit to earth (with priority) in bus bar direction	32
19	0x0013	R	0x02	0 or 1	Earth fault (only qu2) and short circuit to earth (with priority) in cable direction	32
8000	0x1F40	W	0x06	15395	Set fault on L1, L2 and L3 (short circuit and pulse)	38
20000	0x4E20	R	0x03	float32	Current measurement L1 (amount)	36
20002	0x4E22	R	0x03	float32	Current measurement L2 (amount)	36
20004	0x4E24	R	0x03	float32	Current measurement L3 (amount)	36
21100	0x526C	R	0x03	float32	Current measurement L1 (with sign)	36
21102	0x526E	R	0x03	float32	Current measurement L2 (with sign)	36
21104	0x5270	R	0x03	float32	Current measurement L3 (with sign)	36
22000	0x55F0	R	0x03		Indicator status summery: X_{00} to X_{03} = reserved X_{04} = self test result not ok (internal fault present) X_{05} = self test result ok X_{06} = self test running (1=yes / 0=no) X_{07} = external power supply (1=yes / 0=no) X_{08} to X_{12} = reserved X_{13} = Error, e.g. battery empty X_{14} to X_{15} = reserved	 -- 36 36 36 32 -- 32 --
22100	0x5654	W	0x06	1	Start self test (Result in Register 22000)	36
22105 to 22108	0x5659 to 0x565C	R/W	Read:0x03 Write:0x10		Set time and date: Register 22105: milliseconds Register 22106: hours: $X_{12}X_{11}X_{10}X_{09}X_{08}$ minutes: $X_{06}X_{05}X_{04}X_{03}X_{02}X_{01}X_{00}$ Register 22107: month: $X_{11}X_{10}X_{09}X_{08}$ day of week: $X_{07}X_{06}X_{05}$ (Mo=1,…) day: $X_{04}X_{03}X_{02}X_{01}X_{00}$ Register 22108: year: $X_{06}X_{05}X_{04}X_{03}X_{02}X_{01}X_{00}$ (only last two digits, e.g. „19“ for 2019)	34

10. Servicing/Cleaning/Spare parts

The service interval depends on the operating and environmental conditions. The service interval can be determined by the customer himself. An interval of 5 years is recommended. In service cases please use our service documentation from the download center of our homepage www.a-eberle.de.

10.1 Battery change

When the battery is changed the counter must be reset. The battery reset can be achieved when the operating button is pushed longer in the menu “info”. A counter shows the remaining time to press the button.

For the battery change the front plate of the EOR-1D must be dismounted. Detailed information to set the battery charge to 99% can be found in chapter 8.4.3.4.

10.2 Firmware update

For the firmware update a power supply must be connected. The firmware update is performed via the internal SD card of the device. To copy the new firmware on the SD card, first the front plate of the EOR-1D must be dismounted, then the SD card has to be taken out and with the help of a computer the new firmware (“image.hex”) has to be copied in the root folder of the SD card. The current firmware version is available in the download center on our homepage www.a-eberle.de.

The detailed process to update the firmware in the menu of the EOR-1D is explained in chapter 8.6.3.

10.3 Cold start

On the EOR-1D a cold start can be performed, when the operating button is pushed continuously for at least 30 seconds. The green LED (if a voltage source is provided) turns off. As soon as the operating button is released the green LED shows through a short flash that the cold start is performed. During this the firmware restarts,the parameterization and the real time clock remain unchanged.

10.4 Spare parts

Spare parts can be requested from A. Eberle GmbH & Co. KG. A periodic change of parts is only needed for the backup battery.

10.5 Cleaning

Use a soft, lightly wet and fuss-free cloth. Pay attention that no humidity enters the case. Use no window cleaner, sprays, household cleaners, solvents, alcoholic cleaners, ammonia solution or scouring agent for cleaning.

If there is high staining in the inside caused by incorrect usage it is recommended to send the device back to the producer. If there is a large amount of dust on the circuit boards the insulation coordination could fail.

Dusts are generally hygroscobic and can bypass creepage distances. By this reason it is recommanded to operate the device, if possible, with closed case door.

NOTICE!	**Cleaning the device with the wrong cleaning agent!** Damaging the surface of the device and detaching of labels ➲ Pay attention to the above listed mediums

11. Standards and Laws

- EMC 2014/35/EU Low Voltage Directive
- EMC 2014/30/EU Electromagnetic Compatibility (EMC)
- IEC 61000-4-4:2004 + Cor. 1:2006 + Cor. 2:2007 + A1:2010 Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test
- IEC 61000-4-5:2005 Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test
- IEC 61000-4-8:2009 Electromagnetic compatibility (EMC) - Part 4-8: Testing and measurement techniques - Power frequency magnetic field immunity test
- IEC 61000-4-9:1993 + A1:2001 Electromagnetic compatibility (EMC) - Part 4-9: Testing and measurement techniques - Impulse magnetic field immunity test
- IEC 61000-4-11:2004 Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase
- DIN EN 82079-1 1 Preparation of instructions for use - Structuring, content and presentation – Part 1: General principles and detailed requirements

12. Disassembly & disposal

DANGER!	**Danger of electric shock!**
	➲ Only disassemble the EOR-1D indication unit and the current sensors when the system is de-energised
	➲ Comply with the 5 rules of safety

- ➲ Disconnect transformers / sensors from the power grid
- ➲ Disconnect the device from power supply
- ➲ Ensure that EOR-1D is de-energized
  - ↳ All other connections can be seperated from the devices and the device can be disassembled

The disposal of the EOR-1D is carried out by A. Eberle GmbH & Co. KG.

- ➲ Send all components to:

A. Eberle GmbH & Co. KG

Frankenstraße 160

D-90461 Nuremberg

13. Warranty

A. Eberle GmbH & Co. KG. warrants that this product and accessories will be free from defects in materials and workmanship for a period of three years from the date of purchase.

Warranty does not apply to damage caused by:

- Accidents
- Misuse
- Abnormal operating conditions

To make a warranty claim, please contact your local A. Eberle distributor or alternatively contact A. Eberle GmbH & Co KG in Nuremberg, Germany.

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