# RELEMATIKA

**TOR 300 SERIES
PROTECTION AND AUTOMATION
INTELLIGENT ELECTRONIC DEVICE**

**Operation Manual. General technical requirements**

AIPB.656122.011 OM1

# IMPORTANT PREFACE

## Copyright

## Purpose of this manual

The manual describes the technical data, functionality, operation, installation and commissioning procedure for the TOR 300 Intelligent Electronic Devices.

## Targeted audience

Protection engineers, mechatronic engineers, commissioning engineers, personnel concerned with setting, monitoring and service of protection equipment, industrial automatic and control facilities within the electrical power systems.

## Applicability

This manual is valid for TOR 300 multifunctional Intelligent Electronic Devices; software version 2.16.

## Liability statement

All responsible specialists have checked the contents of this document to ensure the description of both, hardware and software are as accurate as possible. However, deviations from the description cannot be completely ruled out, so that no liability can be accepted for any errors or failures contained in the given document, which content is reviewed regularly. Corrections will be included in following editions. Any suggested improvements are highly appreciated. Relematika, LLC reserves the right to make technical improvements without notice.

# Safety symbols and messages

The warnings and notes contained in this manual serve for your own safety as well as safety of people and property around you. Please observe them!

The following indicators and standard definitions are used:

**DANGER**

Indicates an imminently hazardous situation which, if not avoided, will result in death, serious injury or property damage.

**CAUTION**

Indicates a potentially hazardous situation which, if not avoided, could result in minor or moderate injury or property damage.

**WARNING**

Indicates a potentially hazardous situation which, if not avoided, could result in death, serious injury or property damage.

**NOTE**

Indicates information about the device or respective part of instruction manual which is essential to highlight.

# Warning

Only qualified personnel can work on this device. Certain parts of the device inevitably have dangerous voltage. Thorough familiarity with all warnings and safety notices of this manual along with applicable safety regulations is required. Failure to observe these precautions can result in fatality, personal injury or extensive material damage. The successful and safe operation of this device is dependent on proper handling, installation, operation and maintenance by qualified personnel.

QUALIFIED PERSONNEL

For the purpose of this manual and product, a qualified person is one who is familiar with the installation, construction and operation of the equipment and hazards involved. Following qualifications are needed:

- knowledge to energize, de-energize, clear, ground and tag circuits and equipment in accordance with established safety practices;

- knowledge of proper care and use of protective equipment in accordance with established safety practices;

proficiency in rendering first aid;

- proficiency in rendering first aid.

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## PLEASE READ THIS MANUAL BEFORE ENERGIZING TOR 300 IED!

This operation manual applies to microprocessor based protection, automation, control and signalling Intelligent Electronic Devices (IEDs) of **TOR 300** series (hereinafter referred to as "IED", "Device" or "Relay") and contains all the necessary information about their technical characteristics as well as it determines the operation, maintenance, storage and transportation requirements.

This operation manual covers TOR 300 IEDs with software version 2.16.

The operation manual is divided into the following documents: AIPB.656122.011 OM1 and AIPB.656122.011-XXX OM2. The first one – OM1 – contains information relating to all the device functional versions: technical data, existing IED design descriptions, structure and function of IED modules, operation and maintenance guidelines. The second document – OM2 – is prepared for the TOR 300 functional versions, composed by protection and automation functions and describes operating principles of different protection and automation functions.

TOR 300 is a microprocessor-based IED and composed by different standardized modules. The corresponding application software is downloaded to each device depending on the power system element to be protected, providing the performance of all required functionality. Free programmable logic of TOR 300, allows adjusting the typical functional and logic schemes to specific requirements of particular application.

Implementation of various communication protocols, such as IEC 61850-8-1 (MMS, GOOSE), ensures integration of the IEDs into substation/station control systems (in further text also SCS). Applied IEC 61850-9-2 protocol allows connection of IEDs to digital voltage and current converters.

Reliability and lifetime of TOR 300 IEDs are provided with both the product quality and the compliance with operation conditions, transportation, storage, installation requirements. Therefore, meeting of all the requirements specified herein is obligatory.

Taking into account that Relematika, LLC (in further text Relematika) is continuously developing functionality and design of the IEDs, this operation manual cannot cover all the changes, improving parameters and quality of the product. The company reserves the right to make changes and IED improvements without prior notice to the customer.

## 1 APPLICATION

TOR 300 series IEDs are microprocessor-based devices intended for protection, control, automation and monitoring purposes in 6-750 kV power networks. The units are intended for installation in the relay protection switchgears, such as indoor and outdoor switchgears, on the relay protection panels, in the cubicles and on control boards of power plants and substations.

The IEDs can be applied in utilities with AC, rectified AC and DC auxiliary voltage.

The IEDs are freely programmable. Functional logical diagrams are developed by PCAP graphical programming tool, which enables the user to configure binary inputs and outputs, analog inputs, control buttons, LEDs, disturbance recorder, event recorder, user interface, etc. Freely programmable logic allows modifying and additionally developing typical functional logical diagrams, taking into account the special needs of the protected object.

The main application functionality of the IED is represented in the ordering code structure shown in Appendix A.

An example of ordering code for:

- TOR 300 (IED type);
- DP (main application function: line distance protection and breaker control IED with phase-selection functionality for 110-220 kV power lines);
- 512 (standard application version);
- 133 (standard hardware version);
- D1 (alphanumerical HMI with 6.9 cm display diagonal);
- =220 (rated auxiliary DC voltage 220 V);
- RS-485 (two communication ports RS-485);
- Eth-T (two copper wire Ethernet communication ports), looks as follows:

**TOR 300 DP 512 133, D1, =220 V, RS-485, Eth-T.**

A number of optional functions, which are not covered by the present manual, can be implemented on special request. All deviations (concerning design and algorithm) from the standard version are described in the project specific documentation.

## 1.1 General technical specifications and characteristics

### 1.1.1 Auxiliary power supply

Table 1.1: Auxiliary power supply – basic data

| Parameter | Value | | |
|---|---|---|---|
| $U_{aux}$ nominal ($U_n$) | Standard | On request | |
| | (110 – 220) V DC<br>(110 – 220) V AC<br>(110 – 220) V rectified AC | (24 – 48) V DC | |
| $U_{aux}$ variation | (80 – 110) % of specified range | | |
| Current pulse at power up[1] | 20 A for 0.5 ms | | |
| Maximum load at DC/AC supply circuits | Number of binary IO modules (casing) | Normal operation | 50 % of relays energized |
| | 1 module (1/4 x 19") | 9 W | 14 W |
| | 4 modules (1/2 x 19") | 10 W | 16 W |
| | 6 modules (3/4 x 19") | 13 W | 25 W |
| | 11 modules (1 x 19") | 17 W | 35 W |
| Power consumption of single binary input | max. 0.6 W continuously at 220 V DC/AC<br>max. 0.3 W continuously at 110 V DC / 100 V AC | | |
| Start-up time | max. 10 s at first power-up after the configuration has been changed<br>max. 1.5 s at the following power-ups | | |
| Interruption time (at $U_n$, normal operation) | max. 200 ms without restarting the IED<br>max. 100 ms without restarting the IED for 110 V<br>max. 500 ms without restarting the IED when special filter SF-02-01 is applied | | |
| $U_{aux}$ connection | No damage occurs to IED when power supply connected with reverse polarity | | |
| [1] It is recommended to protect auxiliary power supply circuit with 15 A rated current automatic fuse. | | | |

Table 1.2: Auxiliary power supply – immunity tests

| Immunity tests | Value | Corresponding standard |
|---|---|---|
| Harmonics and interharmonics including mains signalling at AC power supply voltage | Up to 12 % | IEC 61000-4-13:2015 |
| Voltage fluctuation for equipment with input current not exceeding 16 A per phase | Within ±20 % | IEC 61000-4-14:2009<br>Severity – special<br>Performance criteria – A |
| Ripple on DC input power port | ±10 % at $U_n$ (100 Hz) | IEC 61000-4-17:2008, SL=3, PC=A |
| Variations of power frequency | Frequency range ±15 % | IEC 61000-4-28:2009, SL=3, PC=A |
| Voltage dips, short interruptions and voltage variations on DC input power port | Voltage dips, interruptions and variations | IEC 61000-4-29:2000 |

Abbreviations: SL = Severity Level and PC = Performance Criteria.

## 1.1.2 Transformer energizing inputs

Table 1.3: AC current energizing inputs

| Description | Value | | |
|---|---|---|---|
| Type designation | CT1 | CT2 | CT3 |
| Rated AC current $I_r$ | (1/5) A [1] | 0.2 A [2] | 0.02 A [2] |
| Burden at $I_r$ (per phase) | max. 0.2 VA at Ir=1 A<br>max. 0.5 VA at Ir=5 A | max. 0.5 VA at Ir=0.02 A<br>max. 0.1 VA at Ir=0.2 A | |
| Thermal withstand capability | | | |
| At $I_r$= 1 A or 5 A<br>At $I_r$ = 0.02 A or 0.2 A | $4 \cdot I_r$ continuously<br>5 A continuously | $100 \cdot I_r$ for 1 s<br>30 A for 10 s | |
| Current operating range | | | |
| $I_r$=1 A or 5 A<br>$I_r$=0.2 A<br>$I_r$=0.02 A | $(0.01-60) \cdot I_r$<br>$(0.002-12)$ A<br>$(0.0005-1.5)$ A | | |
| Measuring accuracy | | | |
| At measured current range | Amplitude (relative error) | Angle (absolute error) | |
| $(0.01-0.2) \cdot I_r$<br>$(0.2-1.0) \cdot I_r$<br>$(1-60) \cdot I_r$ | ±3 %<br>±1 %<br>±1 % | ±5 deg<br>±2 deg<br>±1 deg | |
| Additional relative error at: | | | |
| $U_{aux}$=(80 – 110) % of $U_r$ | $(0.5-1)$ V | max. ±3 % of value measured at Ur | |
| | $(1-280)$ V | max. ±1 % of value measured at Ur | |
| Ambient temperature between (–40..55) $^O$C | ±5 % of mean value measured at (20 ± 5) $^O$C | | |
| Frequency range $(0.9-1.1) \cdot f_r$ | ±5 % of mean value measured at $f_r$ | | |

[1] Phase or residual currents.
[2] Residual current circuits.

Table 1.4: AC voltage energizing inputs

| Description | Value | |
|---|---|---|
| Type designation | VT1 | VT2 |
| Rated AC voltage $U_r$ | 100 V (110 V) | 220 V |
| Burden at $U_r$ (per phase) | max. 0.1 VA | |

| Description | Value | |
|---|---|---|
| Thermal withstand capability | 2·$U_r$ continuously | 280 V continuously |
| | 2.5·$U_r$ for 10 s | 1.5·$U_r$ for 10 s |
| Voltage operating range | (0.001 – 1.5)·$U_r$ | (0.00227 – 1.27)·$U_r$ |
| Measuring accuracy: | | |
| At measured voltage range: | Amplitude (relative error) | Angle (absolute error) |
| (0.5 – 1) V<br>(1 – 3) V<br>(3 – 150) V | ±1.5 %<br>±1 %<br>±0.5 % | ±1 deg<br>±1 deg<br>±1 deg |
| Additional relative error at: | | |

| | | | |
|---|---|---|---|
| $U_{aux}$=(80 – 110) % of $U_r$ | (0.5 – 1) V | max. ±3 % of value measured at Ur | |
| | (1 – 280) V | max. ±1 % of value measured at Ur | |
| Ambient temperature between (–40..55) °C | ±5 % of mean value measured at (20 ± 5) °C | | |
| Frequency range (0.9 – 1.1)·$f_r$ | ±5 % of mean value measured at $f_r$ | | |

Table 1.5: 150 mA AC energizing inputs

| Description | Value | |
|---|---|---|
| Type designation | TCVD | |
| Rated AC current $I_{rC}$ | 150 mA | |
| Burden at $I_{rC}$ (per phase) | max. 0.5 VA | |
| Thermal withstand capability | 600 mA continuously | |
| Current operating range | (1 – 300) mA | |
| Measuring accuracy: | | |
| At measured current range (10 – 150) mA | Amplitude (relative error) | Angle (absolute error) |
| | ±2 % | ±2 deg |
| Additional relative error at: | | |

| | | | |
|---|---|---|---|
| $U_{aux}$=(80 – 110) % of $U_r$ | (0.5 – 1) V | max. ±3 % of value measured at Ur | |
| | (1 – 280) V | max. ±1 % of value measured at Ur | |
| Ambient temperature between (–40..55) °C | ±5 % of mean value measured at (20 ± 5) °C | | |
| Frequency range (0.9 – 1.1)·$f_r$ | ±5 % of mean value measured at $f_r$ | | |

## 1.1.3 DC electronic inputs

Table 1.6: DC current electronic inputs (electronic transformers)

| Description | Value | | | |
|---|---|---|---|---|
| Type designation | CTE1_1 | CTE1_2 | CTE2 | CTE3 |
| Rated DC current $I_{rDC}$ | 20 mA | | | |
| Power consumption (per channel) | 0.1 W | | | |
| Thermal withstand capability | 100 mA continuously | | | |
| Current operating range | AC circuits from 0.05 to 2 A; for DC circuits from 0.05 to 2.5 A | AC and DC circuits from minus 30 to plus 30 mA in amplitude values | DC circuits from minus 25 to plus 25 mA | DC circuits from minus 20 to plus 20 mA |
| Measuring accuracy (reduced) | max 1 % | max 1 % | max 1 % | max 0,1 % |
| Additional relative error at: | | | | |
| $U_{aux}$=(80 – 110) % of $U_r$ | max. ±0.1 % of value measured at Ur | | | |

| Description | Value |
|---|---|
| Ambient temperature between (–40..+55) $^{\circ}$C | ±0.1 % of AC current(voltage) mean value measured at (20 ± 5) $^{\circ}$C per every 10 $^{\circ}$C change |
| | ±0.2 % of phase and total power mean value measured at (20 ± 5) $^{\circ}$C per every 10 $^{\circ}$C change |
| | ±0.2 % of power factor measured at (20 ± 5) $^{\circ}$C per every 10 $^{\circ}$C change |
| | ±0.2 % of DC power from -5 to +5 mA , from 0 to 5 mA measured at (20 ± 5) $^{\circ}$C per every 10 $^{\circ}$C change |
| | ±0.05 % of DC power from -20 to +20 mA , from 0 to 20 mA, from 4 to 20 mA measured at (20 ± 5) $^{\circ}$C per every 10 $^{\circ}$C change |

CTE1 can be used for measuring AC current. The current operating range can be specified within ±1 A on request.

Table 1.7: DC voltage electronic inputs (electronic transformers)

| Description | Value | |
|---|---|---|
| Type designation | VTE1 | VTE2 |
| Voltage operating range | AC and DC: (1 – 350) V | AC and DC: (1 – 330) V |
| Thermal withstand capability | 1.5·$U_{rDC}$ | |
| Measuring accuracy (reduced) | max 1 % | max 1 % |
| Additional relative error at: | | |
| $U_{aux}$=(80 – 110) % of $U_r$ | max. ±0.1 % of value measured at Ur | |
| Ambient temperature between (–40..+55) $^{\circ}$C | ±0.1 % of mean value measured at (20 ± 5) $^{\circ}$C per every 10 $^{\circ}$C change | |

Can be used for measuring AC voltage. The voltage operating range can be specified within ±220 V on request.

## 1.1.4 TWFL Inputs and Outputs

TWFL voltage inputs are galvanically connected to each other. TWFL current inputs are galvanically isolated from internal circuits using intermediate current transformers.

AC voltage measurement operating range is from 0.005 to 1.05 $U_{TWFL}$. The operating range for measuring AC current is from 0.005 to 1.0 $I_{TWFL}$.

Operating frequency range is from 10Hz to 0.1MHz.

AC circuits withstand maximum 4 $I_{TWFL}$ continuously and 100 $I_{TWFL}$ for 1 s.

Thermal resistance of voltage circuits connected to the voltage transformer windings is provided at a voltage of 2.0 $U_{TWFL}$ continuously and 2.5 $U_{TWFL}$ for 10 s.

Relative mean measurement error is given in Table 1. 8.

Table 1. 8 – Measurement accuracy in AC current and voltage circuits

| Characteristic name | AC frequency, Hz | Range | Amplitude value, %, no more |
|---|---|---|---|
| Mean relative error of measuring the effective value of the AC voltage | 50 | $(0,005 - 0,05)\ U_{TWFL}$ | ±1,5 |
| | | $(0,05 - 1,05)\ U_{TWFL}$ | ±0,5 |
| | $10^3$ | $(0,005 - 0,05)\ U_{TWFL}$ | ±1,5 |
| | | $(0,05 - 1,05)\ U_{TWFL}$ | ±0,5 |
| | $10^4$ | $(0,005 - 0,05)\ U_{TWFL}$ | ±1,6 |
| | | $(0,05 - 1,05)\ U_{TWFL}$ | ±0,6 |
| | $10^5$ | $(0,005 - 0,05)\ U_{TWFL}$ | ±15 |
| | | $(0,05 - 1,05)\ U_{TWFL}$ | ±5 |
| Mean relative error of measuring the effective value of the AC current | 50 | $(0,005 - 0,05)\ I_{TWFL}$ | ±1,5 |
| | | $(0,05 - 1,0)\ I_{TWFL}$ | ±0,5 |
| | $10^3$ | $(0,005 - 0,05)\ I_{TWFL}$ | ±1,5 |
| | | $(0,05 - 1,0)\ I_{TWFL}$ | ±0,5 |
| | $10^4$ | $(0,005 - 0,05)\ I_{TWFL}$ | ±2,1 |
| | | $(0,05 - 1,0)\ I_{TWFL}$ | ±0,7 |
| | $10^5$ | $(0,005 - 0,05)\ I_{TWFL}$ | ±30 |
| | | $(0,05 - 1,0)\ I_{TWFL}$ | ±10 |

Additional relative measurement error of AC current and voltage when operating current voltage changes from 0.8 to 1.1 Uaux does not exceed ±1% relative to measurement of values at rated operating current voltage.

## 1.1.5 Binary inputs

Table 1.9: Binary inputs

| Description | Value | |
|---|---|---|
| Type designation | BI_DC | BI_AC |
| Rated input voltage $U_{rBI}$ | (110 or 220) V DC [1] | (110 or 220) V AC [1] |
| Contact oxide burning current | min. 30 mA for (15 – 25) ms | |
| Continuous binary input current | max. 2 mA ($U_{RBI}$=110 V) max. 2.5 mA ($U_{RBI}$=220 V) | max. 2 mA rms ($U_{RBI}$=110 V) max. 2.5 mA rms ($U_{RBI}$=220 V) |
| Continues permited voltage | max. 300 V | max. 250 V |
| Reliable operate voltage | max. 0.75·$U_{rBI}$ | max. 0.6·$U_{rBI}$ |
| Reliable non-operate voltage | min. 0.65·$U_{rBI}$ | min. 0.55·$U_{rBI}$ |
| Setting ranges of operate/reset timers | (0 – 30) ms, step 1 ms [2] | max. 25/40 ms [3] |

[1] Rating and DC/AC type are to be specified at ordering.
[2] Default settings on each DC binary input are: operate time 10 ms, reset time-5 ms.
[3] AC binary input has no adjustable timer setting, operate time - max. 25 ms, reset time - max. 40 ms.

## 1.1.6 Binary outputs

Table 1.10: Output relays with increased inter-contact gap on Power supply module S3021

| Description | Value |
|---|---|
| Type designation | REL_IG |
| Rated contact DC voltage $U_{rCON}$ | 220 V DC |
| Maximum commutated DC voltage | 250 V |
| Maximum continuous current | 10 A |

| Description | Value |
|---|---|
| Commutation ability (220 V DC, inductive load, time constant 50 ms) | 2000 cycles |
| Breaking capacity | 0.25 A (220 V DC, inductive load, time constant 50 ms) |
| | 1 A (230 V DC, resistive load, 1 min interval, max. 10 times) |
| Making capacity | 40 A for 0.03 s |
| | 30 A for 0.2 s |
| | 15 A for 0.3 s |
| | 10 A for 1 s |
| Operate / Reset time | max. 10 ms |
| Commutation wear resistance | min. 10000 cycles at resistive load |

Table 1.11: Bistable output relays on Power supply module S3021

| Description | Value |
|---|---|
| Type designation | REL_BS |
| Rated contact DC voltage $U_{rCON}$ | 220 V DC |
| Maximum commutated DC voltage | 250 V |
| Maximum continuous current | 2 A |
| Maximum making current | 3 A |
| Breaking capacity | 0.2 A (220 V DC, active-inductive load, time constant 7 ms) |
| Operate / Reset time | max. 20 ms |
| Commutation wear resistance | min. 50000 cycles at resistive load |

Table 1.12: Double contact output relays on Power supply module S3021

| Description | Value |
|---|---|
| Type designation | REL_S2 |
| Rated contact DC voltage $U_{rCON}$ | 220 V DC |
| Maximum commutated DC voltage | 250 V |
| Maximum continuous current | 8 A |
| Maximum making current | 14 A for 4 s at pulse ratio of 10 % |
| Breaking capacity | 0.6 A (220 V DC, resistive load) |
| Operate / Reset time | max. 9 ms |
| Commutation wear resistance | min. 50000 cycles at resistive load |

Table 1.13: Output relays on binary IO modules B3021 and B3023

| Description | Value |
|---|---|
| Type designation | REL_S1 |
| Rated contact DC voltage $U_{rCON}$ | 220 V DC |
| Maximum commutated DC voltage | 250 V |
| Maximum continuous current | 8 A |
| Maximum making current | 10 A |
| Breaking capacity | 30 W (250 V DC, inductive load, time constant 20 ms) |
| Operate / Reset time | max. 10/5 ms |
| Commutation wear resistance | min. 10000 cycles at inductive load |

Table 1.14: High-speed bistable relays on module B3028

| Description | Value |
|---|---|
| Type designation | REL_SS |
| Rated contact DC voltage $U_{rCON}$ | 220 V DC |
| Maximum commutated DC voltage | 418 V |
| Maximum commutated AC voltage | 295 V |
| Maximum continuous current | 2 A |
| Maximum making current | 20 A |
| Breaking capacity | Breaking capacity in DC circuits at 220 V with resistive load with an unlimited number of switching operations is 40 A with a current pulse duration of not more than 10 s |
| Operate / Reset time | max. 70 μs |
| Commutation wear resistance | min. 10000 cycles at inductive load |

## 1.1.7 Electromagnetic compatibility

TOR 300 remains operative and functional without performance derating under the influence of the following factors, presented in the Table 1.15 below. Abbreviations: SL corresponds to "Severity Level" and PC corresponds to "Performance Criteria".

Table 1.15: Electromagnetic compatibility

| Type of test | Type test values | Related reference standards |
|---|---|---|
| Electrostatic discharge immunity test:<br>- contact discharge<br>- air discharge | <br>6 kV, 150 pF<br>8 kV, 150 pF | IEC 61000-4-2:2008, SL=3, PC=B |
| Radio frequency electromagnetic field immunity test | 10 V/m | IEC 61000-4-3:2010, SL=3, PC=A |
| Power frequency (50/60 Hz) magnetic field immunity test:<br>- continuous<br>- transient (for 3 s) | <br>100 A/m<br>1000 A/m | IEC 61000-4-8:2009, SL=5, PC=A |
| Pulse magnetic field immunity test | 1000 A/m | IEC 61000-4-9:2016, SL=5, PC=A |
| Damped oscillatory magnetic field immunity test | 100 A/m | IEC 61000-4-10:2016, SL=5, PC=A |
| Electrical fast transient/burst immunity test:<br>- communication ports<br>- other ports | <br>4 kV pulse (5/50 ns)<br>4 kV pulse (5/50 ns) | IEC 61000-4-4:2012, SL=4, PC=A |
| Surge immunity test with 1/50μs and 6.4/16μs pulses:<br>- power supply<br>- communication<br>- other ports | <br>4 kV line-to-earth and 2 kV line-to-line<br>4 kV line-to-earth<br>4 kV line-to-earth and 2 kV line-to-line | IEC 61000-4-5:2014<br>SL=4, PC=A<br>SL=3, PC=A<br>SL=1, PC=A |
| Immunity to conducted disturbances, induced by radio-frequency fields | 10 V, f = (0.15 – 80) MHz | IEC 61000-4-6:2013, SL=3, PC=A |
| Voltage dips, short interruptions and voltage variations: | ≤ 0,2 $U_{aux}$ ($t_{pf}$ = 5000 ms);<br>≤ 0,3 $U_{aux}$ ($t_{pf}$ = 500 ms);<br>≤ 0,6 $U_{aux}$ ($t_{pf}$ = 200 ms);<br>≤ $U_{aux}$ ($t_{pf}$ = 20 ms);<br>min $t_{inter}$= 500 ms | IEC 61000-4-11:2004, PC=A |
| Ring wave immunity test:<br>- single oscillations<br>- repeating oscillations | <br>4 kV line-to-earth; 2 kV line-to-line<br>2,5 kV line-to-earth; 1 kV line-to-line | IEC 61000-4-12:2006, SL=3, PC=A |
| Harmonics and interharmonics including mains signalling at AC power port, low frequency immunity tests | ≤ 12% | IEC 61000-4-13:2002 |

| Type of test | Type test values | Related reference standards |
|---|---|---|
| Voltage fluctuation immunity test for equipment with input current not exceeding 16 A per phase | $U_{aux}$ ± 20% | IEC 61000-4-14:2009, SL=X, PC=A |
| Conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz:<br>- continuously<br>- for 1 s | <br><br>30 V<br>300 V | IEC 61000-4-16:2009, SL=4, PC=A |
| Ripple on DC input power port immunity test | $U_{aux}$ ± 10% | IEC 61000-4-17:2001, SL=3, PC=A |
| Immunity to variation of power frequency | fr ± 15 % | IEC 61000-4-28:2001, SL=4, PC=A |
| Voltage dips, short interruptions and voltage variations on DC input power port immunity tests | ≤ 0,3 Uaux (tpf = 1000 ms);<br>≤ 0,6 Uaux (tpf = 100 ms);<br>min $t_{inter}$= 500 ms | IEC 61000-4-29:2000, SL=3, PC=A |
| Radio-frequency disturbance characteristics | Class A | IEC CISPR 11:2004, IEC CISPR 22:2006 |

## 1.1.8 Insulation resistance

Unless otherwise specified, all the below values refer to following: ambient temperature within (20±5) $^{\circ}$C, relative humidity within (45 – 80) %, rated AC voltage frequency of 50 Hz.

Table 1.16: Insulation tests

| Type of test | Type test values | Related reference standards |
|---|---|---|
| Insulation resistance of not connected IED:<br>- between independent circuits<br>- between circuits and earth | <br>> 100 MΩ, 500 V DC<br>> 100 MΩ, 500 V DC | IEC 60255-5:2000 |
| Dielectric test[1]:<br>- communication circuits<br>- all other circuits | <br>0.5 kV, 50 Hz, 1 min<br>2 kV, 50 Hz, 1 min | IEC 60255-5:2000 |
| Impulse voltage withstand test: Between independent circuits and between circuits and the case:<br>- communication circuits<br>- other circuits | Three positive and three negative impulses (1.2±0.36)/(50±10) µs<br>1 kV, source energy 0.5 J<br>5 kV, source energy 0.5 J | IEC 60255-5:2000 |
| [1] At repeated tests a test voltage should not exceed 85 % of the specified value. | | |

## 1.1.9 Required environmental conditions

TOR 300 IEDs are designed for operation in the environmental conditions according to Table 1.17 and Table 1.18. Place of installation should be protected against water, oil, emulsion splashes and direct solar radiation.

Table 1.17: Required environmental conditions

| Parameter description | Value (range) |
|---|---|
| Maximum altitude above the sea level | up to 2000 m |
| Maximum permitted ambient temperature | +55 $^{\circ}$C |
| Minimum permitted ambient temperature | -40 $^{\circ}$C, (no frost and condensed moisture) |
| Maximum permitted relative humidity | 98 % at 25 $^{\circ}$C, non-condensing |
| Required environmental conditions | non-explosive, free from current-conducting dust, corrosive gases and fumes in concentrations, which could be disruptive for insulation and metals |
| Pollution degree | degree 1, i.e. no pollution, only dry, non-conductive pollution may occur |

Table 1.18: Vibration, shock, bump and seismic tests

| Type of test | Type test values | Related reference standards |
|---|---|---|
| Vibration response (sinusoidal) | Class 1 | IEC 60255-21-1:1988 |
| Vibration endurance | Class 1 | IEC 60255-21-1:1988 |
| Shocks response | Class 1 | IEC 60255-21-2:1988 |
| Shocks withstand | Class 1 | IEC 60255-21-2:1988 |
| Bump | Class 1 | IEC 60255-21-2:1988 |
| Seismic | Class 1 | IEC 60255-21-3:1993 |
| IP code (ingress protection) [1]:<br> - front part<br> - other parts | <br>IP40<br>IP20 | IEC 60529:2013 |
| [1] The device should be mounted in relay cubicles with IP54 protection degree. | | |

### 1.1.10 Reliability parameters

Specially implemented software and hardware back-up methods secure correct performance of implemented functionality. Self-supervision system continuously monitors software and hardware with available parameter checkout. In case a persistent failure is detected the IED generates a failure signal indicating the cause of a failure.

Table 1.19: Reliability parameters

| Parameter description | Value (range) | Note |
|---|---|---|
| Mean time between failures (MTBF) | $\geq$ 125.000 hours | - |
| Average unit repair time | 0.5 h | Considering that all spare parts are available |
| Service life time | At least 25 years | Considering that all operating conditions and maintenance procedures are followed |
| Average module service time | At least 10 years | - |
| Probability of failure to operate | $< 3 \cdot 10^{-4}$/year | - |
| Probability of false operation | $< 10^{-6}$ hour | - |

### 1.1.11 Data communication interfaces

Table 1.20: Ethernet 100Base-TX port technical data

| Parameter description | Value (range) |
|---|---|
| Connector type | RJ45 |
| Maximum transmission segment distance | Up to 100 m |

Table 1.21: Ethernet 100Base-FX connector technical data

| Parameter description | Value |
|---|---|
| Connector type | LC type, for glass optic fiber |
| Optic fiber type | Multimode |
| Optic fiber diameter | 62,5/125 µm at NA = 0,275<br>50/125 µm at NA = 0,2 |
| Wave length | (1270 – 1380) nm |
| Transmitter power | –20 dBm |
| Receiver sensitivity | –31 dBm |
| Communication distance | max. 2000 m |

Table 1.22: RS-485 port technical data

| Parameter description | Value |
|---|---|
| Connector type | Plug MSTB 2,5 (PHOENIX) |
| Insulation strength | 1500 V RMS (1 min) |
| The number of IEDs in the line | max. 32 |
| Total length of a communication line | max. 1200 m |

Typical connection scheme is based on parallel connection of devices with the limitations specified in Table 1.32 technical data are specified in Table 1.22.

Table 1.23: Technical data for built-in fiber optical port

| Parameter description | Value |
|---|---|
| Connector type | Type ST, for a glass optical fiber |
| Optic fiber type | Multimode |
| Diameter of an optical fiber | 62.5/125 µm |
| Radiation wavelength | (792 – 865) nm |
| Transmitter power | –16 dBm |
| Receiver sensitivity | –24 dBm |
| Communication range | max. 1500 m with attenuation coefficient in optical fiber not more than 3 dB/km |

Table 1.24: Power Line Carrier (PLC) port technical data

| Channel | Characteristic parameter of the channel | Value |
|---|---|---|
| Autocontrol inhibit | Maximum permissible switching current | 50 mA |
| HF start | Maximum permissible switching current | 50 mA |
| HF reception | Power of current-limiting resistor | 0,25 W |

Table 1.25: Technical data of the built-in optical fiber port

| Parameter description | Value |
|---|---|
| Connector type | Type SC, for a glass optical fiber |
| Optic fiber type | Single-mode |
| Diameter of an optical fiber | 9/125 µm |
| Radiation wavelength | (1260-1360) nm |
| Transmitter power, min | 0 dBm |
| Receiver sensitivity | - 37 dBm |
| Maximum allowable receiver input power | - 5 dBm * |
| Communication range | with attenuation coefficient in optical fiber not more than 0,35 dB/km |
| * Higher input power requires the use of 10 dB attenuator. | |

## 1.2 TOR 300 hardware design and operating characteristics

TOR 300 IED is designed as a programmable logic controller having a central processing unit as a core, which provides interaction between all units included into the device. A structural diagram is shown in Figure 1.1.

Depending on the intended installation location, two versions with different mounting methods are provided: flush and hinged.

Flush mounting is used when the IED is placed on a door or in a hole in the mounting plate of a relay cubicle with rear connection of secondary circuit conductors.

Surface (hinged) mounting of the IED with rear connection of conductors (using a mounting kit) is used when placed on a wall or mounting plate without a mounting hole. To access the connectors, rotate the IED 90°.

Surface mounting of the IED with front connection of conductors (without display unit) is also used when placed on a wall or mounting plate without a mounting hole. The remote control panel is placed on the door of the relay cubicle or in any convenient place and is connected to the IED using the supplied cable.

TOR 300 IED is housed within a standard euro rack with different modules installed to the front or rear panels. Depending on the number of installed hardware modules, four case overall dimensions are available. Overall, mounting dimensions, weight, layout and control elements arrangement on the front panel are shown in Appendix B.

TOR 300 IED contains the following HW modules:

- power supply module;

- input transformer module(s);

- binary input/output module(s);

- central processing module with communication modules;

- front panel local human-machine interface (HMI) module;

- TWFL module;

- combined backplane modules.

Each TOR 300 unit includes different number of specified modules, depending on project specific requirements. Their number and type is determined by the corresponding HW and SW version. Modules are electrically connected by a backplane board.

The front panel (local HMI) contains:

- LED indicators;

- alphanumeric or graphical display;

- push-buttons;

- USB port connector for connection to local PC.

Quantity of installed LED indicators and push-buttons depends on indication unit version.
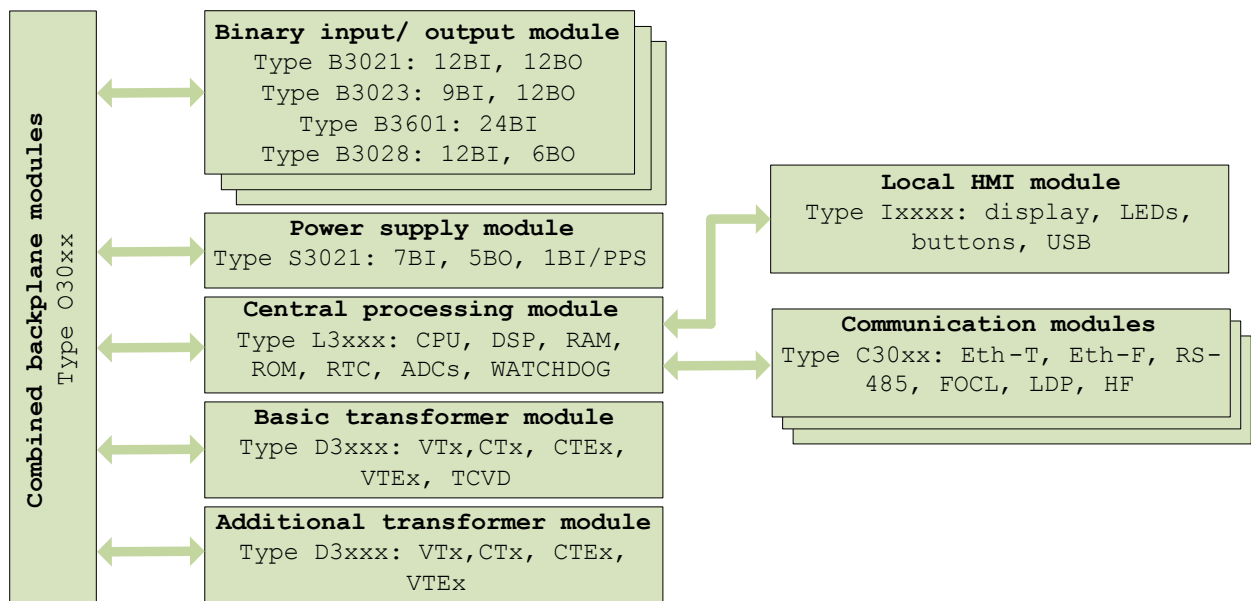


Figure 1.1: Structural diagram of TOR 300 hardware design

A rear panel accommodates terminal blocks for connection to measuring, power supply, and signalling circuits together with communication ports for connection to different communication systems as well as grounding bolt (screw).

Terminal blocks ensure connection of external conductors:

- terminal blocks provide screw connection of one or two identical conductors with a cross section of not more than 3 mm$^2$ each and a cross section of at least 0.5 mm$^2$ each.

- plug-in connectors provide screw connection possibility for one rigid (flexible) cable with maximum 2.5 mm$^2$ cross section, or two identical cables with maximum cross section area 1 mm$^2$ (rigid) or 1.5 mm$^2$ (flexible) each with a cross section not less than 0.5 mm$^2$.

IED design provides air gaps and insulation distance between the contact pins and the housing not less than 3 mm over the air and 4 mm over the surface.

Protective earth continuity is ensured in compliance with the Standard (IEC 60439-1). Electrical resistance measured between the ground screw and any grounded metal part does not exceed 0.1 Ω.

## 1.2.1 Power supply module

Power supply module operates on both AC and DC auxiliary power supply. Depending on a device version power supply can be 110 V or 220 V. Auxiliary voltage is supplied to the IED via input terminals X2:1 and X2:2. Besides, the module S3021 incorporates 8 binary inputs and 5 output relays terminated on connectors X2 and X1, correspondingly. Binary input No. 8 (input terminals X2:17, X2:18) can be used as 1PPS type time synchronization input[1]. Power supply inputs and outputs are schematically presented in Appendix C (Figure Ca).

Power supply module S3021 incorporates 5 output relays:

- two relays with increased contact gap (relay 1.1, relay 1.2);
- one bistable relay (relay 1.3, relay 1.4 – command latched relay, which fixes the latest control command sent to the circuit breaker (breaker position) and stores the information in the absence of control and/or power supply;
- two signalling double-pole relays with switched contacts (relay 1.5, relay "Failure"). The "Failure" relay is controlled by internal signal from a CP module. When relay is energized and under normal operation conditions, it is in a tripped state (the contact is closed). Relay releases when persistent failure detected by self-supervision system occurs or auxiliary power supply of the IED is lost.

## 1.2.2 Binary input/output (IO) module

Binary input/output modules are used for receiving and transmitting binary signals and issuing relay commands. Each channel is intended for acceptance (input) or transmission (output) of one binary signal. See block-diagram in Appendix C (Figure C).

IO modules are available in three versions:

- B3021 module has 12 input and 12 output binary signals (Figure C.1a);
- B3023 module has 9 input and 12 output binary signals (Figure C.1b);
- B3601 module has 24 input signals (Figure C.1c);
- B3028 module has 12 input and 6 high-speed binary signals (Figure C.1d).

Depending on the implementation version, binary input channels are divided to:

- two galvanically isolated groups with six channels per one common point (Figure C.1a);
- four galvanically isolated groups with two channels per one common point and one group with one channel (figure C.1b);
- eight channels and one group with 16 channels with two common points (Figure C.1c);
- five channels (Figure C.1d)

Binary inputs and outputs are linked via X3-X24 connectors.

Number of binary input/output modules in IED is determined by its version: one module can be in ¼ of 19" case, four modules in ½ of 19" case, six modules in ¾ of 19" case and 11 modules in full 19" case.

General technical data and characteristics of binary inputs are given in sector 1.1.4 and for binary outputs – in sector 1.1.6.

> For commutation of the currents, exceeding the output relay switching capacity it is necessary to use intermediate relays. The same applies also in cases when several independent circuits are to be simultaneously commutated, i.e. for contact multiplication. Relay should be selected on the basis of resulting operation time. When intermediate relays are used it is recommended to apply quenching circuit with intermediate relay coil shunted by resistor and diode (see Figure 1.2 below).
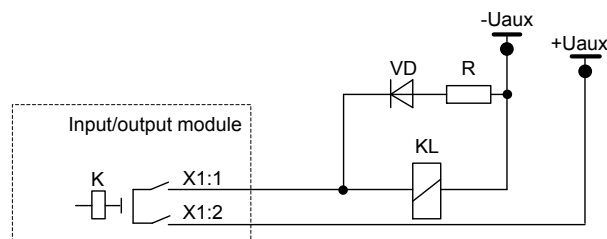


Figure 1.2: Connection of external auxiliary relay to TOR 300 output contacts, when required

Resistor in a quenching circuit is to be selected according to the following condition

$$R = 0.1\ R_{KL},$$

where $R_{KL}$ [Ω] is intermediate relay coil resistance.

---

[1] It is not permitted to use binary input No 8 as an ordinary binary input.

Its corresponding power shall be selected according to expected short-term current flow (at least 2 W).

The diode shall have the parameters with triple current and reverse voltage margin

$$I_{VD}=3\ U_{aux}/R;\ U_{VD}=3\ U_{aux},$$

where $I_{VD}$ [A] is direct current through the diode in forward direction; and $U_{VD}$ [V] is a DC voltage applied to the diode in reverse direction.

### 1.2.3 Input transformer module

TOR 300 generally contains one basic input transformer modules of D3xxx type. The device can also contain one more additional input transformer module of D3xxx type. Number of transformer modules in TOR 300 depends on its version: one module in ¼ rack, two modules in ½ and ¾ of 19" rack and two or four modules in a full 19" rack.

The block of transformers can contain up to 12 intermediate current and voltage transformers, the circuits of which are wired respectively to the XA1-XA12 connectors. The terminal, depending on the type, can contain up to 48 intermediate current and voltage transformers in various combinations. For more information on available D30xx modules, input combination and their correspondence with CP modules refer to Table 1.26. The layout of D30xx modules is shown in Appendix D.

Energizing inputs in general case are connected via XA1-XA8 terminal blocks.

Current transformer inputs of CT1 type are used for measuring phase and residual currents and have separate taps for connection to primary CTs with rated secondary current ($I_r$) of both 1 A and 5 A. Current transformer inputs of CT2 and CT3 type have rated secondary current ($I_r$) of 0.2 A and 0.02 A correspondingly. They are typically used for measuring of the residual current.

Voltage transformer inputs of VT type are used for measuring both phase-to-ground and phase-to-phase voltages and have rated secondary voltage ($U_r$) of 100 V.

Transformer module can have 150 mA current input of TCVD type. Usage of this input is application specific. In some applications it is used for measuring of the voltage value from the power line, using capacitive voltage divider or shunt resistor in VT circuits.

Basic transformer module can contain up to 12 DC current and/or voltage electronic transformers (CTEx and VTEx types) intended for connection to 20 mA DC sensors, static current measuring transformers with rated value up to 1 A and static voltage measuring transformers with rated value up to 220 V. These inputs can measure both DC and AC signals. They are generally situated on the basic transformer module.

Table 1.26: Available transformer modules and their correspondence with CP modules

| Type | Used types of inputs | L3101 | L3102 | L3103 | L3104 | L3105 | L3106 | L3107 | L3108 | L3109 | L3110 | L3111 | L3112 | L3113 | L3114 | L3115 | L3116 | L3117 | L3119 | L3121 | L3122 | L3124 | L3125 | L3128 | L3130 | L3134 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Basic transformer modules | | | | | | | | | | | | | | | | | | | | | | | | | | |
| D3101 | 3 VT, 9 CT1 | | | | | | | √ | √ | | √ | | | | | | | | | | | | | | | |
| D3102 | 4 VT, 4 CT1 | | √ | | | | | | | | | | | | | √ | √ | | | | | | | | | |
| D3105 | 4 VT, 9 CT1 1) | | √ | | | | | | | | | | | | | | | | | | | | | | | |
| D3106 | 5 VT, 4 CT1, TCVD | √ | | | | | | | | | | | | | | | | | | | | | | | | |
| D3107 | 5 VT, 6 CT1, TCVD | √ | | | | | | | | | | | | | | | | | | | | | | | | |
| D3008 | 5 VT, 6 CT1, CT2, CT3 1) | | | | | | | | | | | | | | √ | | | | | | | | | | | |
| D3109 | 5 VT, 7 CT1 | √ | | | | | | | | | | | | | | | | | | | | | | | | |
| D3112 | 8 VT, 4 CT1 | | | | | | | | | | | | | | | | | | | | | √ | | | √ | |
| D3113 | 12 VT | | | | | | | | | | | √ | | | √ | | | | | | √ | | | | | |
| D3114 | 12 CT1 | | | | √ | | | | | | | | √ | | | | | | | | | | | | | |
| D3121 | 6 VT, 7 CT1 1) | | | √ | | | | | | | | | | | | | | | | | | | | | | |
| D3123 | 3 CT2, 9 CT1 | | | | √ | | | | | | | | | | | | | | | | | | | | | |
| D3125 | 4 VT, 6 CT1, 2 CTE1 | | | | | | | | | | | | | | | | √ | | √ | | | | | | | |
| D3132 | 4 VT, 6 CT1, 3 CT2 1) | | √ | | | | | | | | | | | | | | | | | | | | | | | |
| D3133 | 6 VT, 1 CT1 | | | √ | | √ | | | | | | | √ | | | | | | | | | | | | | |

| Type | Used types of inputs | L3101 | L3102 | L3103 | L3104 | L3105 | L3106 | L3107 | L3108 | L3109 | L3110 | L3111 | L3112 | L3113 | L3114 | L3115 | L3116 | L3117 | L3119 | L3121 | L3122 | L3124 | L3125 | L3128 | L3130 | L3134 |
|------|---------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| D3134 | 6 VT, 4 CT1, 1 CT2 | | | √ | | | | | | | | | | | | | | | | | | | | | | |
| D3135 | 4 VT, 4 CT2 | | | | | | | | | | | | | | | | | | | √ | | | | | | |
| Additional transformer modules | | | | | | | | | | | | | | | | | | | | | | | | | | |
| D3103 | 4 VT, 4 CT1, 4 CT2 | | | | | | | | | | | | | | | | | | | | | | | | | |
| D3104 | 4 VT, 8 CT1 | | | | | | | | √ | | √ | | √ | | | | | | | | | | | | | |
| D3115 | 12 CT1 | √ | √ | | √ | | √ | √ | | √ | | | | | | | √ | √ | | | | | √ | | √ | |
| D3116 | 3 VT, 9 CT1 | | | | | | | | | | √ | | | | | √ | | | | | √ | | | | | |
| D3118 | 3 CT2, 9 CT1 | √ | | | √ | √ | √ | | | | | | | | | | | | | | | | | | | |
| D3124 | 6 VT, 6 CT1 | | | | | | | | | | | | | √ | | | | | | | √ | √ | | | | |
| D3136 | 4 VT, 4 CT2 | | | | | | | | | | | | | | | | | | | √ | | | | | | |

[1] Not to be combined with additional transformer modules.

## 1.2.4 Central Processing Module

Central Processing (CP) module is a central module within TOR 300 IED, incorporating the following components:

- central microprocessor;
- digital signal processor (DSP);
- random-access memory (RAM);
- non-volatile memory (ROM);
- real-time clock;
- analog-digital converter (maximum 48 analog signals can be processed, provided that additional transformer module is installed);
- communication modules of C0xx type, see 1.2.6.

CP module serves to acquisition and final processing of analog and digital signals, delivery of control commands to output relays and other IEDs via digital communication channels. The module can also perform the following functions:

- real-time clock;
- GPS/GLONASS time synchronization;
- disturbance and event recording and storage;
- human-machine interface;
- device self-supervision;
- communication with station control system.

Protection algorithms, functional settings and IED configuration are stored in a non-volatile flash memory.

Events are registered with a real time tag. Real-time clock accuracy is ±0.3 s per day at the permitted temperature range. A redundant power supply is used for a real-time clock at de-energizing of CP module.

The list of available CP modules and their correspondence with transformer modules is given in Table 1.26.

## 1.2.5 Local Human Machine Interface (HMI)

Local HMI module on the front panel of TOR 300 IED, incorporates LEDs, display (OLED or TFT), push-buttons and USB communication port.

Display has two implementations:

- OLED alphanumeric version with 6 rows by 21 characters each;
- TFT graphical version with possibility of mnemonic diagram presentation.

Number of LEDs and control buttons depends on the IED version and is given in .Control buttons assignment is given in 2.5.2. USB-port is described in 1.2.8.

Table 1.27: Number of LEDs and push buttons on different versions of TOR 300

| Case | LED quantity (without button LEDs) | HMI control buttons, **RESET** button | Switching devices control buttons (L/R, I, O) | Number of programmable control buttons (**K1**, **K2** …**K50**) [2] |
|---|---|---|---|---|
| 1/4 | 19[1] | + | − | 6 |
| 1/2 | 27 or 35[1] | + | + | 13 or 16 |
| 3/4 | 51[1] | + | + | 36 |
| 1/1 | 83[1] | + | + | 50 |
| [1] Three LEDs are used to indicate the device status, others – for the protection and failure status indication. The latter can be recorded in non-volatile memory and restored after power supply interruption. [2] Each programmable control button has LED indication of its internal state, which is stored in non-volatile memory. | | | | |

### 1.2.6 TWFL module

The TWFL module contains three own voltage sensors and three own intermediate current transformers, connected to XA30 and XA31 connectors, respectively.

The current inputs of TWFL (XA31) can be connected to one of the following types of PSU:

- electromagnetic type current transformers with a rated current value of 1 A or 5 A (intermediate current transformers are designed for both ratings);
- high-frequency voltage or current sensors with current outputs.

TWFL voltage inputs (XA30) can be connected to one of the following types of PSU:

- voltage transformers of electromagnetic type with nominal voltage value of 100 V;
- high-frequency voltage or current sensors with potential type outputs;
- high-frequency bays to the power lines

TWFL voltage sensors are assembled in a "star with zero" circuit inside the terminal, "zero" is connected to the terminal's ground, therefore a special voltage connection scheme must be used without connecting the neutral conductor. Phase voltages are applied to the terminals XA30:1 – XA30:3, terminal XA30:4 is earthed. In Figure 1.3 an example of connecting the secondary windings of PSU in a "star" with phase B grounding is shown. It is allowed to connect the MVT windings into a "delta".
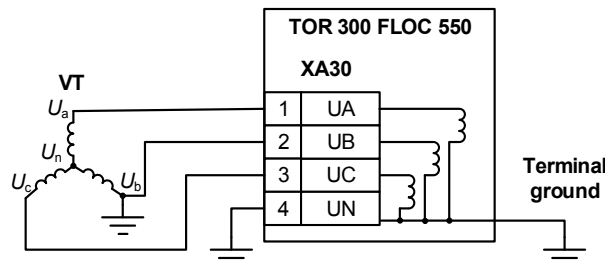


Figure 1.3: Connection diagram of MVT to TWFL voltage sensors

AC current and voltages circuit characteristics are given in 1.1.4.

### 1.2.7 Connector for GPS/GLONASS antenna connection

The TWFL block has a built-in global time source synchronized from GPS/GLONASS systems. Connector **XW1** is used to connect the antenna. Technical characteristics of the synchronization unit and the GPS/GLONASS antenna are given in Table 1.7.

Table 1.28: Technical characteristics of the synchronization unit and GPS/GLONASS antenna

| Parameter | Value |
|---|---|
| Connector type XW1 | SMA-F |
| Type of connector on the cable on the terminal side | SMA-M |
| Type of connector on the cable from the antenna side | TNC-M |
| Antenna connector type | TNC-F |
| Cable type | RG-58 |

| Parameter | Value |
|---|---|
| Maximum antenna cable length, m | 50 |
| Time synchronization accuracy, ns | ±300 |

The antenna should be installed in an open area with the best viewing radius of the sky. Installation on the roof of a building is preferred. If it is not possible to mount on the roof, install the antenna on the south side of the building. The overlap angle of the sky view relative to the horizon should not exceed 10°. Before mounting the antenna, it is recommended to first turn on the IED with the antenna, locate the antenna in the place of the intended installation and make sure that the time of TWFL module is synchronized (2.5.13).

The delivery set of the IED with TWFL function includes GPS/GLONASS antenna, connecting cable, bracket for outdoor installation of the antenna and a set of fasteners. One antenna is used only for one IED.

## 1.2.8 Data communication ports

General on communication ports

Communication to the substation control system (SCS) and substation monitoring system (SMS) is provided in accordance with the following standards:

- IEC 60870-5-103:1997 "Telecontrol equipment and systems. Part 5-103. Transmission protocols – Companion standard for the informative interface of protection equipment";
- IEC 60870-5-104:2006 "Telecontrol equipment and systems. Part 5-104. Transmission protocols – Network access for IEC 60870-5-101:2015 using standard transport profiles";
- MODBUS – set of standards: "Modbus Application Protocol" containing specification of an application layer and "Modbus over serial line" specifying channel and physical layers;
- IEC 61850 is a set of standards including peer-to-peer and client-server communication standard, standard for the design and configuration of electrical substation automation, standard for test procedure, environmental and engineering standard. The standard defines object-oriented programming (approach to analysis) of data and services. The standard enables interoperation of Intelligent Electronic Devices (IEDs) from different vendors bypassing SCS and simplifies its design.

Synchronization of the real time clock of the IEDs is carried out by means of GOST R IEC 60870-5-103-2005, GOST R IEC 60870-5-104-2004, GOST R IEC 60870-5-101-2006, ModBus, SPA-Bus, NTP/SNTP, NMEA0183, PPS, IEEE 1588 PTPv2.

USB-port installed on the front panel is intended for connection to the PC via USB 2.0 A-B cable. The port is used for local configuration and parameterization of a device as well as for software update.[2]

Communication ports on the rear panel (RS-485 or Ethernet, copper or fiber-optic) are available for connection of TOR 300 to the SCS and/or SMS. Configuration and setting of the IED is possible via these ports. Physical interfaces of communication ports, quantity and their type are specified in the ordering sheet for a specific project.

Protection relay integration to SCS (also to station bus) and SMS are provided:

- according to IEC 60870-5-103:1997 or Modbus-RTU, Modbus-ASCII using two serial ports (RS-485 or fiber-optic communication line) via **XT4** and **XT5** connectors;
- according to IEC 61850-8-1 (MMS, GOOSE), IEC 60870-5-104:2006 via Ethernet ports (100 Base-T or 100 Base-F) from **XT1** and **XT2** connectors. Data structure complies with IEC 61850-7.[3]

Protection IEDs should be connected to "digital" CTs and VTs over a process bus based on IEC 61850-9-2 standard protocol. For this purpose two Ethernet ports are available (100 Base-T or 100 Base-F) via **XT4** and **XT5** connectors, ensuring this way reception of data flow from digital CTs and VTs according to IEC 61850-9-2 (Sampled Values - SV). IEC 61850-9-2 LE Specification is supported, as well as IEC 61850-8-1 (GOOSE). The device can process up to six IEC 61850-9-2 LE streams when operating under digital stream receiving conditions.[4]

On the rear panel some specific communication ports can be placed for special types of protections:

- two serial ports connected to **XT3** terminal block are intended for remote data communication via an optical communication channel according to IEEE C37.94 standard (for example, for line current differential protection);
- communication port for power line carrier (PLC) (also high-frequency carrier) transceivers (**XT3**) of various types applied to different teleprotection schemes (for instance, in directional permissive and blocking line protection schemes).

Assignments of communication ports are given in Table 1.29.

---

[2] To connect a terminal via the front port, the CP210x VCP driver version: 6.7.6 is required.

[3] Communication ports for operation with standard IEC 100 Base-F should be implemented at special request.

[4] Communication ports for operation with standard IEC 61850-9-2 should be implemented at special request.

Table 1.29: Back panel connectors designation

| Connector designation | Type of interface |
|---|---|
| XT1 | Ethernet 100 Base-T/ Ethernet 100 Base-F |
| XT2 | Ethernet 100 Base-T/ Ethernet 100 Base-F |
| XT3 | HF carrier ports/ fiber optic (two line differential protection ports) |
| XT4 | RS-485/ FO (SCADA)/ Ethernet 100 Base-T/ Ethernet 100 Base-F |
| XT5 | RS-485/ FO (SCADA)/ Ethernet 100 Base-T/ Ethernet 100 Base-F |
| XT6, XT11 | Ethernet 100 Base-T* |
| XT20 | Ethernet 100 Base-T* |
| XT7, XT8, XT9, XT10 | Ethernet 100 Base-T/ Ethernet 100 Base-F* |
| * Availability is determined by the order sheet and the type used. | |

Baud rate of port interface:

- 100Base-TX and 100Base-FX Ethernet – up to 100 Mbit/s;
- RS-485 (fiber-optic communication line) – up to 0.2 Mbit/s;
- Fiber-optic communication line for line differential protection – up to 2.048 Mbit/s.

Communication port connectors designation is presented in Appendix E.

Access to TOR 300 file system is provided by means of FTP protocol via Ethernet port. Both, active and passive operating modes are supported. Anonymous access is ensured, i.e. read-only access to disturbance files only. Simultaneously only one FTP connection is maintained. When the current connection is not active within three minutes, it is forcibly disconnected.

Assignment and technical data of communication ports

### 1.2.8.1.1 Port with Ethernet 100Base-TX interface

Ethernet 100Base-TX port is used for connection of IED to a local area network via communication line based on the twisted pair cable. Technical data of the port is given in the Table 1.20, connector pins assignment is shown in Table 1.30.

Table 1.30: Ethernet 100Base-TX port. Connector pins assignment
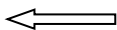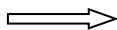
| Pin | Signal | Assignment |
|---|---|---|
| 1 | Transmission + (TX+) | Transmission of positive signal by IED |
| 2 | Transmission – (TX–) | Transmission of negative signal by IED |
| 3 | Reception + (RX+) | Reception of positive signal by IED |
| 6 | Reception – (RX–) | Reception of negative signal by IED |

To protect the unit against overvoltage the additional devices can be connected in each transmission segment. These devices are not a part of the IED delivery and are supplied optionally.

### 1.2.8.1.2 Port with Ethernet 100Base-FX interface

Ethernet 100Base-FX port connected to fiber optic cable is recommended for SCS communication under harsh electromagnetic environment. Such port implementation provides galvanic isolation and the highest interference immunity of communication channel. Port version includes two connectors for fiber optic cable connection, with connector assignment as shown in Table 1.31. Port technical data is presented in Table 1.21.

Table 1.31: Ethernet 100Base-FX connector assignment

| Connector symbol | Assignment |
|---|---|
| ⇐ | Rx – reception of signals by device |
| ⇒ | Tx – transmission of signals by device |

### 1.2.8.1.3 Port with RS-485 interface

RS-485 communication port provides a half-duplex communication via twisted pair cable with the devices on the two-wire link. This method of communication is recommended in a case of rather small amount of devices on simple objects, when use of fiber-optic cable is economically unjustified. Pin assignment of the RS-485 interface connector is given in Table 1.32 and corresponding technical data in Table 1.22.

Table 1.32: RS-485 port pin assignment

| Contact | Signal | Value |
|---------|--------|-------|
| 1, 6 | Common | Signal grounding |
| 2, 7 | DATA B (D+) | The positive data input/output |
| 3, 8 | DATA A (D−) | The negative data input/output |
| 4, 9 | R | Terminating resistor pin |

Port operation is ensured by a two-wire circuit connection of the homonymous contacts, however at longer link is recommended to use the cable shield as the third conductor for signal potential equalization. Besides, to reduce signal reflections in a long communication line and increase noise immunity, the termination resistors should be installed at the ends of the communication link. Nominal value of terminating resistor must be equal to the cable characteristic impedance. Typical value for the twisted pair cable is 120 Ohm.

### 1.2.8.1.4 Built-in fiber optical port (for SCADA and line differential protection)

Fiber optic technology is recommended for the purposes of SCS communication due to complex electromagnetic environment. Fiber optic communication is used also for the communication between line differential protection IEDs. Such version of port implementation provides galvanic insulation and maximum immunity of communication channel. Implementation contains two fiber optic connectors with the assignment given in Table 1.33 and technical data according to Table 1.23.

Table 1.33: Connector assignment for built-in fiber optical port

| Connector | Assignment |
|-----------|------------|
| Dark | RX – signal reception by IED |
| Light | TX – signal transmission by IED |
| Note - Color marking is applied only to the multimode version of the port. | |

### 1.2.8.1.5 Power Line Carrier (PLC) or High-frequency carrier port (HF-port)

PLC port is used for communication of the relay with PLC transceivers of different types (type is to be approved by Relematika).

Following signals are sent from TOR 300 PLC transmitter:

- to start the signal transmission;
- to inhibit auto-control of PLC link.

From the PLC receiver the relay is receiving the HF signal sent by the remote end transmitter.

Pin assignment of the PLC port connector is given in Table 1.34 and corresponding technical data in Table 1.24.

Table 1.34: Pin assignment of Power Line Carrier (PLC) port

| Contact | Signal | Value |
|---------|--------|-------|
| 1 | Autocontrol inhibit | High-speed output relay for inhibiting auto-control of HF carrier transmitter (polarity of connection doesn't matter) |
| 2 | | |
| 3, 7 | HF start (+) | High-speed output relay for triggering HF carrier transmitter |
| 4, 8 | HF start (−) | |
| 5, 9 | HF reception (+) | Binary input for signal reception from HF carrier receiver |
| 6, 10 | HF reception (-) | |
| **Additional parameters** | | |
| **Channel** | | |
| Autocontrol inhibit | Maximum allowed commutation current | 50 mA |
| HF start | Maximum allowed commutation current | 50 mA |
| HF reception | Capacity of current-limiting resistor | 0.25 W |
| | Resistance of current-limiting resistor | 3 kΩ |
| | Minimum input voltage required to generate a logic unit | 15 V |

PLC port operation is ensured by a two-wire circuit connection of the similar contacts, however at longer connecting cables, it is necessary to ensure the minimum value of logical one voltage at channel input "HF reception". For "Autocontrol inhibit" and for "HF start" channels – the required level of electrical quantity (current, voltage) of logical one at the HF carrier transmitter input.

## 1.3 TOR 300 functionality

TOR 300 IEDs perform all the required functionality for relay protection, automation, and control of the power system, as well as measurement, signalling, event recording, disturbance recording and communication functions in accordance with provided software and hardware. Basic software (SW) with the help of library functions ensures communication between application software and the device hardware platform. Application SW together with   the library modules of basic SW provides the execution of a complete protection scheme, which is designed with the help of a PCAP graphical programming tool. The complete scheme is usually divided into analog signal processing part, logical scheme part and configuration part, which enables to implement all basic and additional functions.

PCAP software allows creating initial logical scheme on the manufacturing plant and then to adjust it in accordance with the certain project requirements during engineering and commissioning works.

Instead of PCAP graphical programing tool a separate RelayTool software is provided for monitoring the IEDs, viewing and changing settings in setting groups, downloading disturbance records and event list, performing basic configuration of inputs, outputs, LEDs, communication protocols and etc.

Using BSCOPE software the disturbance records can be viewed and analyzed.

### 1.3.1 Processing of analog input values

Analog signal processing algorithm ensures communication with analog-to-digital (A/D) converter, calibration, filtering, calculation and delivery of various measured analog values. During calibration process, it is possible to adjust input CT and VT signal values by their amplitude and phase angle. In general, TOR 300 enables measurement and calculation of current, voltage, impedance, power, energy, network frequency values as well as corresponding amplitude and RMS values, phase angles, symmetrical and transient signal components with possibility to display and transfer them via communication channels. A PCAP graphical programming tool comprises a sufficient set of mathematical elements required for calculation of all the required parameters, while the hardware platform makes it possible to connect current, AC and DC voltage power sources, depending on a TOR 300 version and functionality.

Basic technical data and characteristics of measurement channels are shown in 1.1.2 and 1.1.3.

### 1.3.2 Protection functions

Various protection functions can be implemented in different versions of TOR 300 relays. Protection functions of the certain version of TOR 300 are described in the corresponding document (AIPB.656122.011-XXX OM2).

TOR 300 IEDs include a list of basic and additional functions of relay protection and automation, monitoring and control of different power system elements such as power transmission lines, transformers, autotransformers, reactors, generators, busbars, stubs, capacitor banks, circuit breakers, disconnectors and other power system elements within the voltage range from 6 kV to 750 kV on the basis of the following basic functions:
- phase differential protection;
- current differential protection of distributed objects with optical communication channel;
- directional comparison carrier current protection;
- distance protection including teleprotection schemes;
- current differential protection for transformers, generators, etc.;
- over/under current protections;
- protection and automation with voltage, frequency and power control;
- breaker control functionality;
- fire-extinguishing automation;
- disconnector blocking, control, etc.;
- local system integrity protection.

### 1.3.3 Binary inputs

Binary inputs are intended for receiving and processing of the external binary signals from operational current circuits. General technical data and characteristics of binary inputs are given in 1.1.4.

Binary inputs are assigned to the certain internal functions by the help of PC based RelayTool or PCAP software, i.e. certain internal variables can get their logical value according to the state of assigned binary inputs.

### 1.3.4 Binary outputs

Output relays are providing binary (control) signals to the external circuits. Basic technical data and characteristics of output relays are given in 1.1.6.

Internal binary signals are assigned with the help of RelayTool or PCAP software to specified output relays and transferred through their "dry" contacts to external auxiliary circuits. Output relay "Failure" is not configurable and is driven by the central processor.

### 1.3.5 LED indication

In order to display the current state of IED the following LEDs are available on local HMI panel (Appendix B):

- three LEDs with fixed functionality: **READY**, **TEST**, **ERROR**;

- general purpose configurable LEDs; their number depends on TOR 300 version (16, 24/32, 48 or 60);

- three LEDs on control buttons with fixed control function: **I**, **O**, **L/R**;

- LEDs on **K1**, **K2**…**K50** control buttons; their number depends on IED version (6, 13/16, 36 or 50).

LEDs operating modes are described in Table 1.35.

Table 1.35: Local HMI LEDs operating modes

| LED name | Light mode | Operating mode |
|---|---|---|
| **READY** | green | Power is On |
| **TEST** | yellow | Device is in a test mode, see par. 2.6 |
| **ERROR** | red | Permanent internal failure detected by self-supervision system |
| **O**[1] | red<br>green | Controlled switching device (e.g. circuit breaker) is turned off (colour opposite to LED **I** colour is selected by the settings) |
| **I**[1] | green<br>red | Controlled switching device (e.g. circuit breaker) is turned on (colour opposite to LED **I** colour is selected by the settings) |
| **L/R** [1] | green | Control mode of switching devices using buttons I, O: **LOCAL** - manual control, **REMOTE** - remote |
| **K1, K2…K50** | green<br>red | LED operating mode is specified by configuration |
| **General**[2] | red<br>green | LED operating mode is specified by configuration |
| [1] These LEDs can be configured by PCAP graphical programming tool only.<br>[2] These LEDs can be configured via RelayTool and PCAP software. | | |

By using PC based RelayTool and PCAP software it is possible to configure LEDs operating modes, representing the switch position of the corresponding controlled IEDs.

It is also possible to configure each of general LEDs in two indication modes. Each LED corresponds to one logical signal.

LED starts blinking periodically with changing colour in the following cases:

- at presence of a signal assigned to two indication modes of one LED at a time;

- at presence of two different signals assigned to different indication modes of one LED.

There is a possibility to invert LED signals and to latch LED state in a non-volatile memory. When IED is energized, latched LEDs revert to the state recorded before the power-off.

Recorded LED states can be reset by **RESET** button on a front panel, by issuing a signal to the corresponding binary input or by a command from a SCS via communication channels.

Functionality of programmable LEDs in an indication module is configurable. Signal combination, names, color and assignment can be changed for project specific requirements.

### 1.3.6 Device control via local HMI

A local HMI (Appendix B) provides the following items:

- three control buttons, which are used for control of switching devices displayed on local HMI single line diagram (only at presence of graphical TFT display);

- four menu navigation push-buttons;
- one "command acknowledge" and one "command cancel" buttons;
- two functional push-buttons;
- one button for resetting of local LEDs;
- four navigation buttons **MENU**, **SET**, **MEASUREMENT**, **MNEMO**;
- one button for switching on the switching device **I** (availability depends on the version);
- one button for switching off the switching device **O** (availability depends on the version);
- one button for selecting the control mode LOCAL / REMOTE (availability depends on the version);
- programmable control buttons (**K1**, **K2**…**K50**).

For detailed information on user interface buttons refer to 2.5.2.

### 1.3.7 Disturbance recording

TOR 300 IED includes disturbance recording functionality designed for recording of disturbances with a view of their further analysis. Recordings are stored in COMTRADE® format (IEC 60255-24:2013). PC based RelayTool software enables selection of disturbance recorder parameters as given in Table 1.36. Up to 29 starting conditions can be set by proper selection of starting signals. Four types of starting modes for each of the starting signals are provided, see Table 1.37.

Starting conditions for each separate disturbance recording can be viewed both via local HMI and RelayTool software.

Disturbance recorder capacity depends on the amount of recorded signals. Available duration and sampling rate of each disturbance recording is shown in Table 1.36. Disturbance recordings are automatically archived in IED. The number of stored disturbance recordings with a duration of at least 10 s is minimum 30. Maximum buffer capacity is 200 saved recordings. Recording are stored according to the FIFO principle; when the buffer is overflown, the oldest recording is overwritten with the new one. When starting conditions are fulfilled, all binary input and output signals, as well as start-up reasons are recorded. All measured and selected calculated values, as well as up to 256 additional logical signals are recorded; the recorded content is defined during the IED configuration procedure. Binary input signals are registered after the defined trip and reset time delays are expired in accordance with 1.1.4. Registered binary output signals are the command signals, initiating operation of the output relays.

Table 1.36: Disturbance recorder setting parameters

| Parameter (HMI notation) | Range | Description |
|---|---|---|
| Pre-fault recording time (**Prefault**) | (100 – 500) ms step 100 ms | Pre-fault recording time (before the first starting condition occurred) |
| Post-fault recording time (**Postfault**) | (500 – 5000) ms step 100 ms | Post-fault recording time (after starting condition disappeared) |
| Maximum allowed recording time (**Max.duration**) | (1000 – 10000) ms | Maximum disturbance recording time, Should be more, than a sum of parameters **Prefault and Postfault** |
| Sampling rate | 1000, 2000, 4000 Hz | Signal sampling rate |

Sampling rate must be 1000 Hz or 2000 Hz. Value of 4000 Hz is available in special cases.

Table 1.37: Disturbance recorder start-up modes

| Start signal type | Description |
|---|---|
| DR start at signal change | Disturbance record duration is set by recording parameter values **Prefault and Postfault** (Figure 1.4a) |
| DR start at signal appearance | |
| DR start at signal loss | |
| Continuous DR starting | Disturbance record duration is determined by the duration of starting signal with addition of **Prefault and Postfault** values. Maximum duration is limited by the value of parameter **Max.duration**. If starting conditions duration exceeds **Max.duration**, then disturbance recording terminates. After that, when starting conditions disappear, an additional disturbance recording is made, duration of which is determined by the value of recording parameters **Prefault and Postfault** (Figure 1.4b) |

Figure 1.4 below presents a disturbance recorder operational principle under various starting conditions.

When a start signal occurs upon its change, appearance or loss, a pre-fault information, duration of which is determined by the parameter **Prefault,** is stored in the memory. When triggering is finished the disturbance recording is prolonged for the time defined by the parameter **Postfault**. Recording duration of one disturbance recording is determined by the sum of recording parameters **Prefault** and **Postfault**.

When a start signal of continuous starting type appears, a disturbance recording can have a variable duration, equal to the sum of continuous start duration (e.g. protection trip signal) with **Prefault** and **Postfault** durations but not exceeding the value of **Max.duration**. When the starting signal lasts longer, than the value set by the parameter **Max.duration**, an additional disturbance recording is created at starting signal reset with duration equal to the sum of the parameters **Prefault** and **Postfault** (Figure 1.4b).
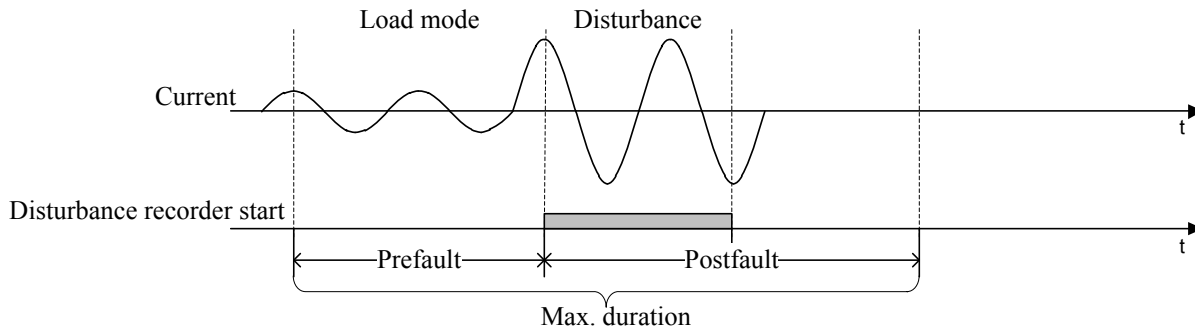
a) Recorder start upon signal change, rise, reset
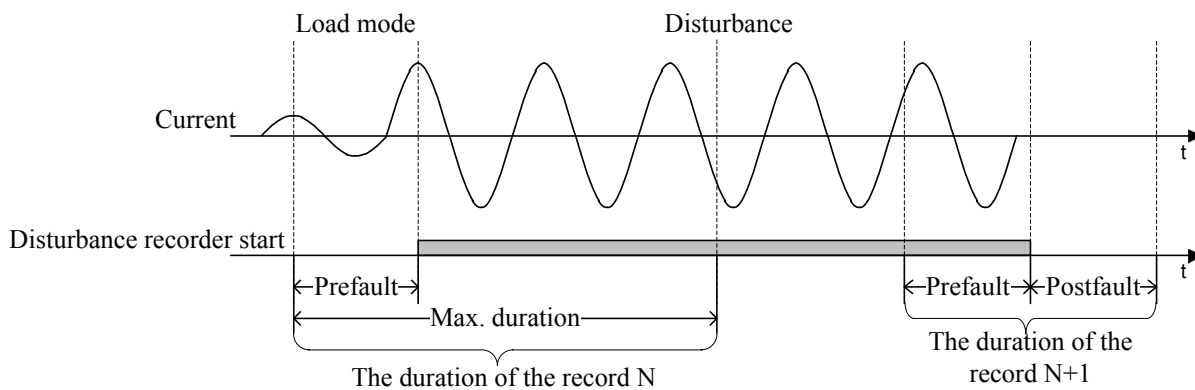
b) Continuous start of the disturbance recorder

Figure 1.4: Definitions of disturbance recorder operating times

An additional blocking is provided to prevent non-volatile internal memory from overflowing when a bounce occurs for any start-up reason. The blocking is performed if any reason for the start was in operated state for more than 20% of the time more than 1 hour in total. The blocking is returned with a subsequent decrease in the total duration to 10%.

The blocking of disturbance recorder start-up bounce is implemented from the software version 2.15 of the IED.

The recordings upload is performed via SMS or SCS or by the help of RelayTool software. Disturbance recordings can be also uploaded via FTP protocol. For preliminary and additional disturbance analysis fast report function can be used via the **Fast view** window in RelayTool software, which contains a summary of a start time, disturbance duration, reasons of start, available settings, etc.

### 1.3.8 TWFL disturbance recorder (DR)

A functional HF disturbance recording (DR) module is implemented in the device with the TWFL. DR is intended to record wave transients in ETL for the purpose of subsequent analysis. Recording and storage of HF disturbance recordings is carried out independently of the main disturbance recordings (1.3.7):

- HF DR has a separate trigger condition;
- Recording of HF-disturbance recordings can performed in parallel to the main oscillograms;
- HF-disturbance recordings are stored in non-volatile memory of TWFL unit;

- time on the HF-disturbance recording is synchronized with high precision global time from the source of global time integrated into TWFL (Figure 1.4a).

The capacity of the HF DR is 50 oscillograms. Each of the HF oscillograms has a duration of 400 ms and a sampling rate of 1 MHz. The duration of the pre-alarm and alarm modes is 200 ms each (Figure 1.4a). HF disturbance recording includes three currents and three voltages connected to the measurement inputs of TWFL unit. The recording of HF-oscillograms is organized in such a way that the oldest HF-oscillogram is erased and a new one is written in its place when there is an overflow.

Unloading of recorded oscillograms is carried out with the help of ACS or specialized software. The time of unloading one oscillogram of TWFL with the help of specialized software is about 15 minutes. It is also possible to read oscillograms using the FTP interface through the communication ports **XT1** or **XT2**. Oscillograms are located in the directory: /distrec/enis/ and sorted by date.

### 1.3.9 Event recording

TOR 300 IEDs include an event recorder, intended for time tagging of binary signals triggering from 0 to 1 and vice versa, which are used for further analysis of protection, measuring elements, logic, etc. during different system events. Time tagging accuracy is 1 ms.

Maximum event recorder capacity is 1500 events, which are stored in ROM. Event storage is performed according to the FIFO principle. Up to 256 different logical signals can be recorded; the event list is defined by RelayTool or PCAP software.

All events with their time-tags can be viewed via local HMI, all events can be sent to SCS or SMS system. Specified software is used to upload of the Event log.

### 1.3.10 Communication with Substation Control System (SCS)

Integration with APCS is supported according to Table 1.38.

Table 1.38: Integration of PAC devices

| Standard | Port | Connector |
|---|---|---|
| GOST R IEC 60870-5-101-2006 | RS-485 or FOCL | **XT4, XT5** |
| GOST R IEC 60870-5-103-2005 | RS-485 or FOCL | **XT4, XT5** |
| ModBus-RTU, ModBus-ASCII | RS-485 or FOCL | **XT4, XT5** |
| SPA-Bus | RS-485 or FOCL | **XT4, XT5** |
| ModBus-TCP | Ethernet | **XT1, XT2** |
| GOST R IEC 60870-5-104-2004 | Ethernet | **XT1, XT2** |
| IEC 61850-8-1 MMS | Ethernet | **XT1, XT2/XT7, XT8** |
| IEC 61850-8-1 GOOSE | Ethernet | **XT1, XT2/XT7, XT8** or **XT4, XT5/XT9, XT10** |
| IEC 61850-9-2 | Ethernet | **XT4, XT5/XT9, XT10** |

If communication between clients via any of the protocols remains inactive for more than 2 minutes an automatic disconnection by timeout is generated.

Supported communication interfaces for TOR 300 are specified in 1.2.6. Configuring of TOR 300 IED functionality for communication with SCS is done via RelayTool software.

Remote control commands are configured with the help of RelayTool or PCAP software. Maximum number of control commands is 32.

Information about the current state of all the programmable keys, the current state of the control mode, device malfunction, and the device blocking based on the results of self-diagnosis can be transmitted to the process control system.

List of parameters and events for data transmission to SCS depends on a specific project scheme (functional logical diagram) and installed functional modules. Standard list of parameters for typical functional logic scheme is formed at manufacturer place in correspondence with the set of protection, automation and other functions used in a certain project. Parameters and settings to be sent to SCS should be selected according to SCS requirements at the stage of project design process and implemented during the commissioning stage.[5]

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[5] List of parameters sent to the process control system is provided on request.

## 1.3.11 Application in digital substations using IEC 61850 standard

Device integration in digital substations is ensured using the IEC 61850 series of standards.

Note – The ability to integrate the device in digital substations using the IEC 61850-8-1 GOOSE and IEC 61850-9-2 SV protocols has been implemented since IED software version 2.15.

### 1.3.11.1 Communication interfaces to support the IEC 61850 standard

The IED's support for the IEC 61850 standard, as well as the availability of process bus ports, is specified in the IED's order card. Description of characteristics of Ethernet ports is given in 1.2.8.1.1, 1.2.8.1.2.

The station bus ports are configured via Ethernet 1 menu item (XT1, XT2 connectors), and the process bus ports via Ethernet 2 menu item (XT4, XT5 connectors) (2.5.17.1.2).

The ports of additional communication unit (connectors XT7, XT8, XT9, XT10) are configured according to AIBP.656122.011 IS2.

Both bus ports support the IEC 62439-3 PRP redundancy protocol to ensure data reception and transmission reliability. The choice of PRP mode is carried out separately for each bus through the menu **Mode**.

In addition, for traffic control in the digital substation, the ports of both buses support virtual networking (VLAN) mode. You can set up to 16 VLAN numbers for each bus. Enabling and disabling VLANs, as well as configuring whether ports belong to VLANs is carried out for each of the buses in the corresponding **Ethernet** menu item.

### 1.3.11.2 Support IEC 61850-8-1 MMS protocol

The IEC 61850-8-1 MMS protocol is supported via the station bus ports. The IED supports up to 6 simultaneous connections to the IED via the IEC 61850-8-1 MMS protocol. Depending on the configuration of the IED data model, both the first edition of 61850 (Edition 1, 2003A) and the second edition (Edition 2, 2007B) are supported.

The IED provides support for the operation services according to the IEC 61850 standard using the following main functions:

- receiving the structure of the device and reading data;

- working with data sets;

- working with reports;

- working with settings and groups of settings;

- control;

- reading disturbance recordings.

The IED processes the quality attributes of each of the signals using internal diagnostics.

Detailed information about the device's ability to support the IEC 61850 standard is given in AIPB.656122.011 DO2 "TOR 300 series protection and automation intelligent electronic device". Additional information on the implementation of the IEC 61850 protocol for testing (PIXIT)".

#### 1.3.11.2.1 Get device structure and read data

Services are provided for obtaining the structure of logical devices and logical nodes implemented in the IED, data objects and attributes, types and classes of logical nodes and data, parameters of control blocks.

#### 1.3.11.2.2 Working with datasets

The device supports services for working with data sets. Within the framework of the standard, static and dynamic data sets created during operation process are implemented. The data set can include any elements of the device structure.

#### 1.3.11.2.3 Working with reports

The device supports reporting services. Buffered and unbuffered report types are implemented.

Report parameters can be configured via the service software or directly by the client application.

#### 1.3.11.2.4 Working with settings and setting groups

It is possible to support the work with setting groups via MMS (setting group activation).

If there is an additional configuration of the IED, it is also possible to edit individual settings of the IED (by default, this option is not used).

#### 1.3.11.2.5 Control functions

The device supports all control models provided by the standard:

- status-only (only status);

- direct-with-normal-security (direct control with normal security);

- sbo-with-normal-security (SBO control with normal security);

- direct-with-enhanced-security (direct control with increased reliability);

- sbo-with-enhanced-security (SBO management with enhanced security).

The control model can be changed using the service software in the IEC 61850 configuration of the IED. By default, all controls that can be managed are set to the "direct-with-normal-security" management model.

### 1.3.11.2.6 Reading disturbance recordings

The device supports the service of working with files, within which the operations of reading the disturbance recordings from the device via the MMS protocol are implemented. Operations for deleting and writing files are not provided by the device software.

Files of disturbance recordings, can be transferred either as separate files in COMTRADE format or as a zip archive, depending on the archiving settings.

### 1.3.11.3 IEC 61850-8-1 GOOSE protocol support

The IED provides the IEC 61850-8-1 GOOSE protocol support via the station bus and process bus ports.

The number of received and sent GOOSE messages and signals in them depends on the type of the IED and its configuration. The number of GOOSE signals sent is at least 100; the number of GOOSE signals received is at least 20.

With the help of GOOSE messages, the IED is able to receive and send logical signals (single and double states) in an arbitrary data structure (defined by the configuration).

Reception of signals using GOOSE messages is performed with quality control of the signals themselves and control of the test flag.

The time between receiving a signal and sending it in a GOOSE message is no more than 10 ms on the station bus and no more than 3 ms on the process bus.

Note – GOOSE messages contain a mandatory VLAN number, which is set in the service software. When you enable VLAN on the ports of the station or process bus, you must configure the supported VLAN numbers for the Ethernet ports, otherwise GOOSE messages with a VLAN number that is not in the port settings will not be transmitted or received.

### 1.3.11.4 IEC 61850-9-2 SV protocol support

The IED supports receiving of measurements digital streams (SV) according to the IEC 61850-9-2 LE specification.

The configuration of the received analog signals is carried out using the service software and depends on the specific application of the IED.

Note – SV streams contain a mandatory VLAN number, which is set in the service software. When you enable VLAN on process bus ports, you must configure supported VLAN numbers for Ethernet ports, otherwise SV streams with a VLAN number that is not in the port settings will not be accepted.

### 1.3.11.5 Device operating modes

The device supports the following modes according to IEC 61850:

- On – normal operation mode of the device. The quality of the data in the logical nodes corresponds to the normal value ("validity = good");

- Test – testing mode of functions and protections, in which its impact on digital communications and output relays is limited. The quality of all data in the 61850 is transmitted with the "test = TRUE" flag set;

- Off – IED is out of operation mode. In this mode, the quality of all signals in the 61850 is invalid ("validity = invalid"). This mode is used to exclude any influence of the device on the process.

## 1.3.12 Service software

### 1.3.12.1 RelayTool software for monitoring and configuration

RelayTool software is a PC based software tool, which has been designed to:

- monitor Intelligent Electronic Devices on the site;

- view and edit settings, fix their changes and compare different setting files;

- download and analyze disturbance recordings via BSCOPE software, manual trigger of disturbance recording, change disturbance recorder parameters;

- monitor signals (view their current values), diagnose communication channels with IEDs;

- download and view event logs;

- configure different signals towards binary inputs, outputs, LEDs, disturbance recorder, event recorder, SCS communication protocols and etc.;

- authorize users.

For details, refer to RelayTool User manual.

The service software is connected to the IED via the BDUbus protocol. When connecting via the RS-485 port, select the BDUbus protocol (2.5.17) in the corresponding menu. Up to six clients can be connected simultaneously via the Ethernet ports (XT1, XT2 connectors).

### 1.3.12.2 PCAP software for flexible logic programming

PCAP software is a PC based software tool, which is designed to:
- create functional logic diagrams using graphical elements;
- analyze, validate and convert schemes to IED files;
- create new measuring modules and functional blocks;
- program analog processing of measured values;
- configure of analog inputs, binary inputs and outputs, LED indication for disturbance and event recorders, signals for SCS communication and etc.;
- determine the appearance of user-defined HMI;
- edit parameter structure;
- upload/download diagrams to/from IED;
- authorize users.

For details, refer to PCAP User manual.

### 1.3.12.3 BSCOPE software for disturbance record analysis

BSCOPE software is a PC based software tool, which is designed to:
- read recordings stored in COMTRADE® format (IEC 60255-24:2013);
- display recorded waveforms of analog and binary signals;
- calculate and display analog signals phases and modules;
- calculate and display power frequency, symmetrical components;
- calculate and display user defined signals;
- plot phasor diagrams and hodographs;
- print recordings.

For description refer to BSCOPE User manual.

## 1.4 Labelling and sealing

TOR 300 has labelling in accordance with design documentation and IEC 60255-27:2005, which is done in a way providing its clarity and preservation during its life time.

Each IED has a label on the rear panel, which shows:
- manufacturer trademark;
- name and notation of the device;
- rated auxiliary supply voltage;
- binary inputs rated voltage;
- manufacturing date (month, year);
- serial number of the device;
- "Made in Russia" mark;
- sign of product conformity.

Shipping container is labelled with handling signs "Fragile", "Keep dry", "Top".

Labelling of transportation box, when the IED is shipped separately (not within the relay cubicle), contains also:
- recipient name;
- shipping address;
- device notation;
- device serial number;
- additional information specified by the ordering documentation.

Device design does not provide sealing.

## 1.5 Packaging

TOR 300 packaging is done in accordance with Relematika design documentation for storage and transportation conditions. Allowed storage time is given in Sec. 4.

## 2 OPERATIONAL GUIDELINES

### 2.1 Operating limitations

Device operation and maintenance should be performed according to these instructions. Operating conditions concerning the influence of climatic and mechanical factors shall comply with the requirements as to 1.1.9.

IED possibility to operate under the conditions, which differ from the specified ones should be coordinated with Relematika company.

### 2.2 Getting started and commissioning

#### 2.2.1 Safety information

When getting started and commissioning, one should be guided by all applicable instructions and directives, as well as present operation manual instructions.

Only specially trained personnel should be admitted for installation, maintenance and operation of devices.

Removing/inserting of modules from/to the IED and working on its connectors should be performed only on a de-energized device.

Before power-on and during operation, the IED should be reliably earthed by the ground screw, placed on the IEDs rear panel, to the earthing loop (bay, cubicle, case) with the shortest earthing path by a copper wire of at least 4 mm$^2$ section area.

#### 2.2.2 Visual inspection

A packed device should be put on a horizontal surface according to the manipulation sign "This side up". Remove the transport package and assure that its content corresponds to the packaging list.

Examine the delivered IED to ensure that it has no mechanical, package damages, occurred during transportation. Check that marking is available and not damaged.

In a case of any deviations or damages of the device, Relematika or its official representative should be informed immediately.

#### 2.2.3 Installation and connection

Overall and installation dimensions are specified in Appendix B. Install the IED accordingly to its location.

Connect an earthing wire as to 2.2.1.

Connect the device according to approved project and present operating instructions. Connection should be carried out with the wires as it is described in 1.2.

#### 2.2.4 Commissioning

At delivery, each TOR 300 IED has default factory settings. During its commissioning all the settings should be checked and, if required, changed according to 2.4.

In order to put the unit into commissioning, all the required operations, specified in Table 2.3 for testing at initial power-on should be performed.

When shipping the IED as a part of a relay protection cubicle, all the required tests for the cubicle at initial power-on should be performed in accordance with the attached operating documentation.

### 2.3 Information security

This function is implemented in IED software version 2.15 and higher.

Authorized access to IED functions is implemented via user groups with different access rights, as presented in Table 2.1.

Table 2.1: User groups

| Group name | Group description | Group user by default | Default password |
|---|---|---|---|
| **Relematika** | Group intended for manufacturer's specialists during service works and etc. Contains only one user | Relematika | * |

| Group name | Group description | Group user by default | Default password |
|---|---|---|---|
| **Admin** | Group used for adding and deleting users in groups **Relay specialists**, **Operating personnel**, **Guests** | Admin | admin |
| **Relay specialists** | Group, allowing functions for relay protection operating and commissioning staff | Engineer | 1 |
| **Operating personnel** | Group, allowing functions for operating staff. Contains at least one user | Operator | 1 |
| **Guests** | Group, allowing basic (reading) functions. Contains only one user | Guest | – |
| * Accessible only to Relematika specialists. | | | |

Basic access rights to IED functionality via local HMI are presented in Table 2.2.

Table 2.2: Access rights to IED functionality

| HMI function | RM | A | R | O | G |
|---|---|---|---|---|---|
| LED indication reset via **RESET** button (2.5.2) | + | + | + | + | + |
| **I, O,** L/R and **K1, K2, …., K50** buttons usage (2.5.2) | + | – | + | +/–[1] | – |
| Event list clearing (2.5.8) | + | – | – | – | – |
| Disturbance records clearing (2.5.9) | + | – | – | – | – |
| Disturbance recorder manual start (2.5.9) | + | – | + | + | – |
| Settings group editing/activation/creation/deleting (2.5.13) | + | – | + | – | – |
| Disable configuration via Ethernet port [2] | + | + | – | – | – |
| Test output signal selection (2.5.15) | + | – | + | – | – |
| **Test/Operation** mode selection, test mode parameters changing (2.5.15) | + | – | + | – | – |
| LED test (2.5.16) | + | – | + | – | – |
| Hardware test (2.5.16) | + | – | + | – | – |
| Communication port adjustment (1.2.8)[3] | | | | | |
| Communication port adjustment (2.5.17.1) | + | – | + | – | – |
| **Date/Time** adjustment (2.5.17.2) | + | + | + | + | + |
| Synchronization methods adjustment (2.5.17.3, 2.5.13.7) | + | – | + | – | – |
| Entering, editing, deleting accounts [3] | + | + | – | – | – |
| User and password editing [4] | + | + | – | – | – |
| Entering, editing, deleting MAC and IP addresses [3] | + | + | – | – | – |
| Enabling/disabling the service mode [4] | + | + | – | – | – |
| Access to reading audit log data [3] | + | + | – | – | – |
| Enable/disable physical identification [4] | + | + | – | – | – |
| Setting up a smart card reader [4] | + | – | + | – | – |
| Associating smart card with user account [3] | + | + | – | – | – |

[1] It is possible to disable authorized access using the menu Delete.

[2] The function can only be controlled via the HMI display menu.

[3] The function can be controlled only with the help of RelayTool service software.

[4] The function can be controlled using the on-screen HMI menu and RelayTool service software.

In Table 2.2 the following abbreviations of groups are used: RM – "Relematika", A – "Admin", R – "Relay specialists", O – "Operative personnel", G – "Guests".

When IED is started the user **Guest** is activated. User group selection can be done via menu **Settings/Access** (2.5.17.4) or via dialog box which appears in a case of function operation without proper right access. Adding and deleting of the users in groups and their passwords changing can be done only via RelayTool software (1.3.12). Current user session is terminated, if the user is changed via local HMI, after inactivity timeout expiration or at restart and power loss.

Disabling configuration via Ethernet allows you to enable or disable remote updating of settings. The function can only be controlled using the HMI screen.

The setting change mode via the network is controlled through the **Settings/Security** menu items by setting the parameter "Eth conf disable" ("On" – enable, "Off" – disable). After exiting the menu, the screen will ask you to confirm the change of settings, allowing you to save the changes.

## 2.4 Parameter setting

IED is freely configurable and has adjustable parameters. Table 2.3 shows IED settings, which can be entered via HMI user interface.

Table 2.3: IED parameters configurable via HMI

| Setting | Editable parameters |
|---|---|
| Bay connection parameters (2.5.18) | Rated values of currents, voltages, other measurable values; measuring transformer parameters |
| Communication parameters (2.5.17.1) | Selection of a communication protocol and its parameters |
| Time and date parameters, synchronization method (2.5.17.3, 2.5.13.7) | Date, time and UTC |
| Test (2.5.15) | Disturbance recorder enabling, check signal definition |

RelayTool software should be used for configuration of the parameters given in Table 2.4.

Table 2.4: Configurable parameters

| Object | Editable parameters |
|---|---|
| Protection function settings | Activation/deactivation and operating mode (setting position selection), entering setting values |
| Analog inputs | Selection of CT and VT ratings |
| Binary inputs | Configuration of corresponding hardware input and connection to logical signal |
| Binary outputs | Configuration of corresponding hardware output and connection to logical signal |
| LEDs | Configuration of corresponding LED and connection to logical signal |
| Disturbance recording | Disturbance recorder parameters, definition of starting and operating conditions, setting of analog and binary signals |
| Event recording | Logical signals configuration |
| Test | Disturbance recorder parameters, check signal definition |
| Comm. parameters of TWFL | Ethernet communication port settings |

## 2.5 User interface (local HMI) structure

### 2.5.1 Local HMI structure

Local human-machine interface is divided into two functional parts: user interface module and LED module.

A user interface module provides double-direction communication. This means that:

- an event can occur and is displayed in HMI menu, in order to inform operator and to induce him for some action;

- operator can display certain information himself if necessary.

User interface module consists of display and push buttons. The display represents current controlled object and IED status. The IED interface is based on a tree-coded menu with navigation possibility by means of push buttons. The push buttons can perform various functions, depending on position in a menu structure.

LED indication module has up to 114 LEDs. Each LED has a name on the front panel according to the appointed function. LED indication modes are specified in 1.3.5.

### 2.5.2 Assignment of control buttons

The functionality of the buttons presented below is described for single pressing of each particular button.

The **C** button (Cancel) has two main functions:

- **cancel** any operation presented in a dialog window;

- **exit** the present level or move one step higher in the menu tree.

The **E** button (Enter) executes the following functions:

- **enter** down to the lower-level menu marked with cursor;

- **execute** - confirm a displayed action;

- **confirm** presented numeric values and selection of an item from the list;

- **move** to the parameter fast editing menu.

The **Left** (◄) and **Right** (►) arrow buttons have the following functions:

- fast cursor move (over four items or up to the page beginning/end) between menu items on the same level;

- move the cursor in a horizontal direction in parameter editing mode in order to change the active character location;

- switching between FLOC reports for supervised lines on the idle screen.

The **Up** (▲) and **Down** (▼) arrow buttons have four functions:

- move up and down between the current menu items on the same level;

- move between the confirmation alternatives in a command window;

- change parameter value in edit mode;

- switch between information windows in standby mode.

The **F1** button is designed to view different reference information:

- settings description in **Settings** menu;

- reference phasor for analog signals in **Measurements** menu;

- switching to SD selection mode.

Note – Analog signal is taken as a reference signal, the angle of which is used as the basis for comparison with the similar analog signals.

The **F2** button is used to fast move from standby screen to corresponding menu item and enhanced editing mode.

The **LOCAL/REMOTE** button is used for selection of the control mode "LOCAL" or "REMOTE" for switching equipment (breaker, disconnector, short circuit switch, etc.) selected on the IED HMI screen using the buttons **I**, **O**. The signal from the button is summed according to the scheme OR with a similar input signal for selecting the control mode from a discrete input. Button LEDs provide control of the current control mode.

Button **I** is for switching On the switching device, Button **O** is for switching Off the switching device.

**MENU**, **SET, MEASURMENT, MNEMO** buttons are intended for ease of navigation and provide transition to the corresponding section of the HMI.

The **RESET** button is used to reset the IED alarm signalling.

Note – The functions of the buttons are given for pressing them once.

### 2.5.3 Assignment of function keys

Buttons **K1**,**K2**…**K50** are intended for software functions control (enabling/disabling like physical switches) and to performing single commands (like physical buttons). Control access is password protected. At single pressing on such button, the acknowledgment request menu appears. These buttons can be used as operational buttons and as switches on control panels and cubicles. In the first case, a logical signal is sent to IED logic-diagram as long as the button is pressed. When using the button as a switch (with two fixed positions), every pressing changes the state of the program key and the value of the state is sent to the IED logic. The state of the program key is stored in non-volatile memory.

For some functions of the IED (input/output of protections, modes of operation of automation), it is possible to control the operation using function keys or an input signal from discrete input, as well as using remote control from an automated process control system via the IEC 61850-8-1 MMS protocol. Local and remote control modes are performed independently. When local control is selected, the resulting signal actuating the IED logic is controlled by pressing the function button or by an input signal from the discrete input, while actuating control commands from the APCS is blocked. Switching the control key to the remote control mode does not change the value of the resulting signal until a new control command appears from APCS system. In remote mode, the action of the function key is blocked. Switching the key from remote to local control mode also does not change the value of the resulting signal until the first press of the function button or the appearance of an input signal.

The resulting signals are transmitted to APCS system, and the corresponding LED next to the function button turns on.

When the value "Blocking action from buttons" is set, the action of the buttons is blocked, while the control of the button signal is carried out by the signals "Set button state" and "Reset button state".

The interface of the RelayTool software also provides the possibility of inverting the button LEDs and latching-up the button LEDs states; in this case, the LEDs are reset by pressing the **RESET** button.

### 2.5.4 Working with the graphic display

Pressing **MNEMO** button will open a list of available mnemonic schemes. Navigate through the menu using the buttons **Up** (▲) and **Down** (▼), and select with the help of **E** button.

Pressing **MEAS** button will open the vector diagram. Use **Left** (◄) and **Right** (►)buttons to select the list of displayed signals, use **Up** (▲) and **Down** (▼)buttons to move along the list.

HMI control of switching devices is only allowed in LOCAL control mode.

Switching to the switching device selection mode is carried out using **F1** button. The selected switching device is marked with a rectangular frame. The switching device is selected using the **Left** (◄) and **Right** (►)buttons.

Pressing **F1** button again will display a list of all available switching devices of the active mnemonic diagram.

The lower part of the display shows the name of the selected switching device, its current state (Enabled/Disabled/Intermediate (can be optionally set by the developer), as well as the permission to control (Enabled/Disabled/Blocked/Faulty).

Switching On and Off of the switching device is carried out using **I** and **O** buttons, respectively. When you try to change the state of the switching device, the IED will require you to confirm the decision by pressing **E** button, or cancel the action by pressing **C** button.

### 2.5.5 Standby mode

As soon as the IED is turned on, the local HMI enters the standby mode/ In this mode the IED screens switch sequentially, displaying the following information:

- data on disturbance recordings: number, date and time of the latest recording, cause of triggering;
- information on the latest events: signal abbreviation, status (0 or 1), date and time of the event;
- information on failures detected by built-in self supervision: WARNING!!! ERROR!, description of the failure;
- information on the current measured values;
- information about the last unviewed FLOC reports in the case of internal fault (for every monitored line a separate report is displayed): date and time of the fault, the distance from the fault place to the IED place of installation, faulty phases, negative and zero sequence alarm values, FLOC calculation method, two-ended FLOC status.

Screens are displayed only when records, events, failures or selected values are available. The screen displaying a failure has the highest priority: when a failure is detected, only this screen is displayed.

Every screen displays date, time and active setting group number "Active group" at the top.

Display turns off when inactive for 2.5 minutes. Press any button to activate the display screen.

The HMI display switches to standby mode screen after 60 minutes if no button is activated.

### 2.5.6 User interface menu

User interface menu is the main tool for controlling IED operation and receiving information about its state.

Pressing the **E** button will switch the device from standby mode to the main menu.

The main menu (depending on IED version) includes the following items:

- Measurements (2.5.7);
- Events (2.5.8);
- Disturbance recorder (2.5.9);
- Circuit Breaker diagnostics (2.5.10);
- Line parameters (2.5.11);
- Fault locator reports (2.5.12);
- TWFL (2.5.13);
- Settings (2.5.14);
- Testing (2.5.15);
- Diagnostics (2.5.16);
- Parameters (2.5.17);
- Information (2.5.18);
- IEC 61850 (2.5.19).

The lower-level menu content depends on the device current state and therefore some of the items could be not available. An active state is indicated at the top screen line (for example, Settings).

There are several screen types in a menu:

- **selection list** (most of the menu): current selection is underlined with a cursor in the left part of the screen; jumping to the sub-menu is possible;
- **list without selection** (indication of read-only parameters): there is no cursor on the screen;
- **dialog window** (request for an action execution): no cursor, functions of the buttons are shown on the screen.

If the number of menu items exceeds the number of the screen rows, symbols ↑, ↕ or ↓ are shown on the left top of the scrollbar.

### 2.5.7 Measurements

The menu **Measurements** represents the current values of analog and logical signals. **This is a configurable menu.** The factory setting of menu content depends on the IED version and generally can include the following items.

Input signals

The **Input signals** menu shows the states of binary input signals, grouped on HW modules basis. Each signal is defined by its number, name and value (logical 1 or 0).

Output signals

The **Output signals** menu shows binary output signals, grouped on HW modules basis. Each signal is defined by its number, name and value (logical 1 or 0).

> Input and output signal numbers correspond to addressing designation of each signal in the functional logical diagram.

Analog signals

The menu **Analog signals** represents measured analog values:

- primary and secondary measured values of phase currents and voltages (fundamental harmonic), their symmetrical components;
- DC currents and voltages (if used);
- primary values of active and reactive power (phase and total), in the line (transformer); power factor;
- primary and secondary values of phase-to-ground and phase-to-phase impedances, as well as symmetrical component impedances;
- frequency.

Displayed information about analog values is determined by the firmware and is not common for all IEDs. This menu can also include calculated analog values.

AC current and voltage values are displayed in a polar form (RMS value and voltage phase-angle value for phase A). DC currents and voltages are displayed in RMS values. Impedances are shown in polar form (absolute value in Ohm, argument value in degrees).

Reference signal data is displayed by pressing **F1** in **Analog signals** menu.

## 2.5.8 Events

The **Events** menu is used to display information about the events, recorded by the IED. All recorded events are stored in the internal non-volatile memory.

The Event menu contains the following items:

- **List** – event info representation;
- **Clear all** – removal of all events from the memory.

View events

The menu **List** allows user to choose the event for viewing. Consecutive pressing of **E** button opens the screens on which the date, time (in HH.MM.SS.XXX format, where XXX are milliseconds) and event list are displayed. For selected event the data, time and setting group number are represented.

Clear all events

The menu **Clear all** (with acknowledgement) allows the user to erase event recorder internal memory, for example, after commissioning or configuring the device, when the previous information is not actual.

**Clear all** function should be used with caution since it leads to permanent loss of event data.

This menu can be used only by Relematika specialists.

## 2.5.9 Disturbance recorder

The **Disturbance recorder** menu is used to display information recorded by the device during the latest disturbance situation. All disturbance recordings are stored in an internal non-volatile memory. They can be accessed via a process control system or RelayTool software.

The menu Disturbance recorder contains the following items:

- **Records list** – contains information about saved disturbance recordings and their quantity;
- **Clear all** – clears all disturbance recordings from the memory;
- **Manual trigger** – manual start of a disturbance recorder (requires confirmation);
- **Parameters** – viewing of disturbance recorder parameters.

View

The User is offered to select a disturbance recording to be viewed. In the **Records list** menu the current, previous and next disturbance recording are displayed with the time stamp (in the format DD.MM.SS.XXX, where XXX are milliseconds), disturbance duration, short name of a signal, which has initiated triggering of the current disturbance recording. Scrolling through the list of recordings is made by means of **Left** and **Right** control buttons.

After selecting of a desired disturbance recording with **E** button, the user jumps to the next menu level, containing the following information about the recording:

**Triggering** – List of signals, which initiated the disturbance recording;

**Events** – List of events recorded by the IED;

**Clear** – Erasing the current recording from the internal memory (requires confirmation).

Clearing the disturbance recorder memory

The **Clear all** menu (with confirmation) makes possible to clear the internal memory, for example, during device commissioning or configuration, when the previous information is not actual.

The **Clear all** function should be used with care as it leads to permanent loss of data about all the previous disturbance conditions recorded by the IED.

This menu can be used only by Relematika specialists.

Manual triggering

The **Manual trigger** menu is used for manual triggering of disturbance recorder. Use this function to get a snapshot of the controlled object status.

Parameters

The **Parameters** menu contains information about the parameters of disturbance recorder function:

- **Max.duration** – Maximum disturbance recording length, in ms;
- **Postfault** – postfault disturbance recording length (after triggering conditions disappear), in ms;
- **Prefault** – prefault disturbance recording length (before triggering conditions appear), in ms;
- **Sample rate** – sampling frequency;
- **Archiving** – permission for automatic compression of the records in separate *.zip archive;
- **Signal names** – choosing a signal name to be displayed with the recording: Eng – internal tag, Ru1251 – user short name.

Disturbance recorder parameters can be edited by means of the RelayTool or PCAP software.

## 2.5.10 Circuit Breaker diagnostic

**Breaker diagnostics** menu is used to display information about the controlled circuit breaker (CB).

Menu **Trip time** contains information about the date and time of the last circuit breaker operation and corresponding tripping time (in ms) for each phase separately.

**Trip currents** menu contains information on the last circuit breaker currents at breaking for each phase (kA) separately.

**Breaker state** contains the following information:

- **Mech. life, %** – the remaining mechanical resource of the CB (percentage);
- **Mech. life** – the remaining number of mechanical durability cycles;
- **N breaks** – the number of breaks;
- **Com. life A** – the remaining breaker phase A switching life time (percentage);
- **Com. life B** – the remaining breaker phase B switching life time (percentage);
- **Com. life C** – the remaining breaker phase C switching life time (percentage);
- **Reset conditions** – sets the state of the CB to the initial (default) values: recovers values to the maximum residual resource;
- **Reset counter** resets trip counter after maintenance.

The user can correct the remaining switching resource for each phase separately, as well as set the residual mechanical resource. Selecting a value with **E** button takes the user to set the value of the function parameter. Further, the user will be offered to enter a new value of this parameter. Entry confirmation is made by pressing **E** button.

Menu **Closing time** contains information about the date and time of the last circuit breaker closing.

## 2.5.11 Line parameters

The **Line parameters** menu is represented in IEDs with fault location function. Depending on the number of controlled lines, one or several lines could be displayed in the menu.

The menu for each line includes the number of the correspondent fault locator, line name, length and a list of line sections as well as communication parameters of remote terminal with FLOC function. If FLOC module is out of operation, than message "Module disabled" is displayed after the line name. Each section is displayed in the following format: serial number, type and name. Each line section should have one of the following designations: **L** means a simple line section, **T** stands for a tapped line, **E** denotes load (end line section), **M** indicates inductive coupling for the section between controlled and parallel line. Figure 2.1 below shows an example of a line sections list.



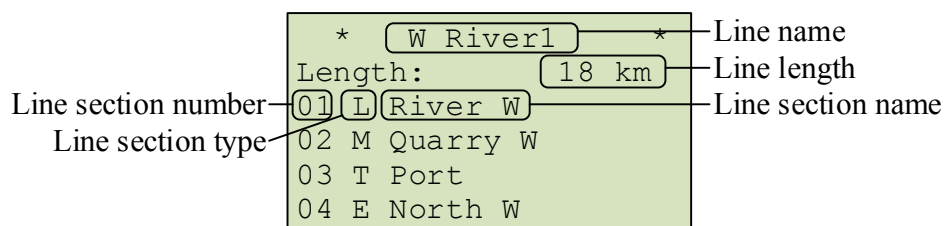Figure 2.1: List of line sections, example

In order to change a line name press **F2** button in any of the line sections and select the item **Change line name**.

To add a new section press **F2** button in one of the line sections, select the item **Insert section** and confirm addition of a section. The new section will be added before the current one as a simple line section with the same parameters.

To delete a section press **F2** button in the selected section, choose the item **Delete section** and confirm deletion. The first line section should be of "simple line" type, the end section – of "load" type. To avoid mistakes in setting the line configuration, removing of the first and the last sections is prohibited.

In order to change line section parameters and section type, select the desired line section and press **E** button. Figure 2.2 shows an example of section parameters.

```
 *  01 L River W     *
Name        River W
Type           1-Line
Length,   km =   2.00
R10,  Ohm/km = 0.198
X10,  Ohm/km = 0.479
```

```
R00,   Ohm/km = 0.346
X00,   Ohm/km = 1.256
B10,   uS/km  = 0.000
B00,   uS/km  = 0.000
R1s,   Ohm    = 0.010
```

```
X1s,   Ohm    = 6.040
R0s,   Ohm    = 0.010
X0s,   Ohm    = 2.850
```

Figure 2.2: Line section parameters, example

The Communication settings menu item allows you to set the IP address of the remote IED and the number of the corresponding FLOC block of the remote IED to perform two-way FLOC.

To test the connection, select the **Communication Test** item and confirm its execution. The **Communication Settings** menu displays the current communication status with the remote IED and the date/time of the last successful communication session. An example of configuring communication with a remote FLOC IED is given in Figure 2.3.

```
*   Comm. Parameters  *
IP  : 192.168.050.002      IP address of
                           remote IED
NblkRem:  1                FLOC block number
                           of remote IED
Communication test
Communication:      yes    Current communication
Last session:              status
```

Date/time of last
successful session        `01.03.22 20:12:22`

Figure 2.3: An example of configuring the communication with a remote FLOC IED

## 2.5.12 FLOC (Fault locator) reports

The menu **FLOC reports** is displayed in IEDs with the fault location function. The menu includes the following items:

- **List** – fault locator reports are presented as a list;
- **By dates** – Fault locator reports are grouped by months and dates;
- **Clear all** – a command to clear all fault locator reports.

In the event when FLOC module for the line is out of service, instead of the above items, the line "Module out of service" is displayed.

The latest operations are displayed at the beginning of the lists. To view the whole information press **E** button in the selected report. In certain cases a list of possible fault locations can be displayed with the distance from the IED place of installation to the place of fault locations being indicated. Detailed information is available at each of the possible points.

In the first line of a fault locator report the date and time of the fault are presented. The second line contains a serial the name of the line. The third line displays the number of a faulted line section, its type and name. The fault locator also displays:

- **Distance** – distance to fault from the IED installation point;
- **Method** – fault location calculation method;
- **Status** – two-ended fault location status;

- **Phases** – faulted phases;
- **Duration –** fault duration;
- **Resistance** – fault resistance at fault location;
- **Imp.** – faulted loop impedance.

The report also comprises the **Analog signals** item, where pre-fault and fault values for the given operation are presented. The fault locator report includes a number of the setting group, which was active during the fault location calculation (**Setting group**).

At the end of the report, there are items **Automatic FLOC** and **Manual FLOC**, which show the results, respectively, of the automatic calculation generated at the time of the short circuit and the calculation performed at the user's command. In both cases, the results of the double-way FLOC, the single-way FLOC of self and remote IEDs can be listed here. All indications are brought to their end.

Item **Calculation** indicates the reason of calculation: automatic calculation (**autom.**) or manual calculation (**manual**). Automatic calculation is performed at the moment of fault occurrence. Manual calculation is done by the user command, for example, after line parameters adjustment. Manual calculation has a higher priority. Its result replaces the result of automatic calculation.

Figure 2.4 presents an example of a fault locator report for the internal fault. A report example for the fault in forward direction is given in Figure 2.5.

```
↕03.02 11:01:22.239 *
Line River
02 W Port
Distance:       8.1 km
Method:  double-sided
Status:         final
```

```
Phases:        B-C-N
Duration:       78 ms
Resistance:   2.7 Ohm
Imp.:   2.8+j 2.8 Ohm
Calculation:   autom.
```

```
Settings group:     1
Analog signals
Automatic locator
Manual locator
```

Figure 2.4: An example of fault locator report at internal fault

```
↕04.02 11:00:21.289 *
Line River
Forward fault
Method:  single-sided
Status:         final
Phases:           B-0
```

```
Duration:       78 ms
Imp.:  18.8+j23.8 Ohm
Calculation:   autom.
Settings group:     1
Analog signals
Automatic locator
```

```
Manual locator
```

Figure 2.5: An example of a fault locator report at fault in forward direction

It is possible to recalculate the distance to the fault. For this, press **F2** button on a selected fault locator report, select the item **Recalculate report** and confirm recalculation. Fault location will be recalculated with an active fault locator setting group of parameters. A new fault locator report with the same date as the initial report will be created. A recalculated report will be accessible in the menu item **Automatic FLOC**.

## 2.5.13 TWFL

**TWFL** menu is displayed on the IEDs with TWFL function. The menu contains a list of the following items:

- **Reports TWFL** – list of FLOC reports;
- **GPS information** - data from the GPS-receiver of TWFL module;
- **Status** – status of TWFL module, information about the current state of communication via a serial communication channel;
- **List of records** - information about HF-oscillograms and their number;
- **Manual start** - manual start of the HF-oscilloscope (requires confirmation);
- **Communication via HF-channel** – information about the current state of communication via a serial communication channel (active only when a serial communication channel is entered between TWFL semi- sets);
- **Synchronization of TWFL** – setting the synchronization of the main clock of the IED from the GPS-receiver of TWFL module;
- **SW versions** – information about software versions of TWFL module**.**

2.5.13.1 TWFL reports

The **TWFL Reports** menu displays TWFL reports. The menu contains the following items:

- **List of lines** - displaying information about TWFL reports**;**
- **Clear all** – deletion of all reports from the memory.

For each of the lines, reports can be displayed in the following form:

- **List** – TWFL reports are presented in the form of a list;
- **By date** – TWFL reports are grouped by the dates.

The earliest operations are displayed at the beginning of the lists. To view full information, press **E** button on the selected report. In certain cases, a list of possible short circuit locations can be displayed indicating the distance from the IED installation site to the fault location. Full details are also available for each of the possible locations.

The first line indicates the serial number of TWFL report. Each report provides the following information:

- name of the damaged line (**Line**);
- distance to the fault location from the IED installation location (**Xf**);
- time of registration of an electromagnetic wave in a local IED (**Time**);
- time of registration of an electromagnetic wave in a remote IED (**Time**).

2.5.13.2 TWFL GPS information

The **GPS Information** menu displays information about geolocation: the number of available GPS satellites, the coordinates of location of the GPS antenna (longitude, latitude and altitude), and the current time of TWFL module. The **GPS Information** menu is for reference use only. The actual state of synchronization of the TWFL module with the global time is displayed in the **Status** menu.

2.5.13.3 Status of TWFL module

The **Status** menu displays the following information:

- list of lines controlled by the device containing TWFL function, and the status of communication with each of the remote semi-sets (Remote communication);
- current state of the IED hardware (**Communication**, **In order** and **Error code**). In the normal state, the signals in the **Communication** and **In order** menu are active (**Yes**), and **Error code** is zero. In the event of a fault, the signals change to the **No** state and the error code number is displayed;
- status of TWFL module time synchronization with global time (**Synchronization**). Time synchronization availability after switching on the IED or after changing the settings and configuration in the IED does not exceed 15 minutes;
- availability of TWFL module for start-up (Ready). The signal is active (**Yes**) if there is synchronization with global time and there are no IED malfunctions. In the state **No**, the TWFL function is not ready to start.

If any malfunction of the IED is detected, it is necessary to perform actions in accordance with 3.4.4.

2.5.13.4 List of HF-disturbance recordings

The **Record List** menu represents HF-disturbance recordings of TWFL. The screen displays the numbers of the previous, current and next disturbance recordings in the list, as well as the date and time (in the format HH.MM.SS.XXXXXX, where

XXXXXX are microseconds) when HF DR was triggered. Navigating through the list is done with the **Left** and **Right** control buttons.

2.5.13.5 Manual start of HF DR

The **Manual Start** (with confirmation) menu is used to perform forced recording, initiates an instantaneous generation of HF disturbance recording. This function is used to take a snapshot of the state of the controlled object.

2.5.13.6 Serial communication channel status

In the **HF Communication** menu, the **Manual start** command is available to start a communication test via a serial communication channel. The time of the last successful serial communication session is displayed in the **Session** line. The manual communication test is only available from the host side. The menu is active only when a serial communication channel is entered between TWFL semi-sets.

2.5.13.7 Synchronization of TWFL

The main clock of the IED can be synchronized from the GPS-receiver of TWFL module with an error from 0 to minus 1.01 s. To do this, in the **TWFL Synchronization** menu, set the **TWFL Synchronization** parameter to **Yes**. The synchronization period is set using the **Period, min** parameter, a value of 240 min is recommended.

It is not recommended to use this synchronization method in conjunction with other methods.

2.5.13.8 SW versions

The **Software Version** menu contains information about the software versions of TWFL module.

## 2.5.14 Settings

Use the **Settings** menu to view and edit different parameters for protection functions included in the IED and to set their operating modes. The IED can have up to sixteen setting groups, one of which is set as active. An active group number is displayed in a standby mode and in the main menu. Reference information is displayed by pressing **F1** in the setting menu row.

2.5.14.1 View

Use the **View** menu to view the current setting values, timers' characteristics, state (positions) of programming switches.

2.5.14.2 Edit

In order to edit parameters enter the **Edit** menu, select an active group, enter a password and select a setting. By pressing **E** button the user will be get the possibility to change the parameter. Confirm entry by **E** button. In order to enter the extended settings editing mode press **F2**.

When the setting is changed, exit the menu, then you will be offered to save the changes.

Parameters can be also edited with the RelayTool software.

2.5.14.3 Activate

Enter the **Activate** menu in order to select (change) an active setting group from the list. The user will be offered to enter a required password so that the changes would come into effect.

> A setting group can also be activated via a binary input.

2.5.14.4 Create

Use the **Create** menu to create a setting group with default values.

2.5.14.5 Delete

Use the menu **Delete** to delete selected setting group(s).

## 2.5.15 Testing

There are functions, which are impossible to test without participation of qualified maintenance personnel. In order to test functionality of measuring elements, the device is set into the test mode. For detailed description of the test mode refer to 2.6.

Use the **Testing** menu to verify the IED operation capability**:**

- **Test output** – setting the operating test output relay. A submenu includes the **Reset** function which, if selected, de-energizes the relay, which then cannot be controlled until the next signal assignment;
- **Test mode** – test mode enabling/disabling;
- **Enable recording** – enable/disabling of disturbance and event recording during the active test mode;
- **Number of trig**. – number of disturbance recorder triggering in a test mode (resets on test mode exit).

- **SCADA test** – displayed in a test mode, used for automatic testing of communication protocols (IEC 103, IEC 104, IEC 61850, Modbus).

## 2.5.16 Diagnostics

TOR 300 has built-in internal failure detection functions, which enable detecting and alarming (output signal, LED indication) the internal faults in operating mode. Use the **Diagnostics** menu to check the IED status according to self-supervision tests:

- **Status** – shows general and current status of the hardware (central and signal processor, peripheral units). When a failure is detected, it contains error codes, see 3.4.3;
- **LEDs** – contains three LED tests on the front panel of the IED. The first test is used to check the red light of the bicolor general purpose LEDs, function keys and the yellow light of the Test LED. The second test is for checking the green light mode of the bicolor general purpose LEDs, function keys, the "Operation" LED, the switchgear status LEDs, the switchgear control mode. In the third test, all bicolor general purpose LEDs cycle change cyclically red and green colors, while single-color LEDs flash. When selecting the "LEDs" function, the user controls their status visually;
- **Hardware** – switching to an expanded testing mode. In this mode all external circuits are to be disconnected, protections are taken out of operation. The detailed description of a testing mode is presented in 2.6.2;
- **Information** – contains information about the number of the device starts, the last start (date, time in the format HH:MM:SS.XXX, where XXX stands for milliseconds), reset function (resets information about all the starts), software version.

## 2.5.17 Parameters

Use the **Parameters** menu to edit the displayed data and time, to set communication parameters for connection with a process control system, entering and editing the access rights to IED functions.

> The internal clock accuracy is important for joint (simultaneous) analysis of disturbances from several IEDs.

### 2.5.17.1 Communication ports

**Comm. ports** menu contains the following elements: **RS-485/FOCL** (connectors XT4, XT5), **Ethernet 1** (connectors XT1, XT2), **Ethernet 2** (connectors XT4, XT5) with editable settings for joint work of several IEDs within the same network and for remote access to the device.

### 2.5.17.1.1 Menu RS485/FOCL

**RS-485/FOCL** menu (Port 1 (XT4 connector), Port 2 (XT5 connector) is used to view and setting up (select and configure) communication port parameters and contains the following:

- **Protocol** - selection of the communication protocol IEC 103, ModBus, NMEA0183, SPA-Bus, RFID, IEC101, BDUBus (specialized internal protocol for communication with the graphic programming environment and service software);
- **Communication parameters** - setting parameters:

- Speed – selection of the baud rate for each port. The communication speed is a discrete value from the list: 2400, 9600, 19200, 38400, 57600, 115200, 230400. The unit of measurement is bit/s;
- Data bits - selection of the number of data bits;
- Parity – a parity bit, usually set to zero or one so that the total number of ones in a byte is always either even or odd. Used to control the correctness of data transmission;
- Stop bits - bits that indicate the end of the transmitted byte;

- **Param. protocol** – specific parameters of the protocol used on this communication port (not defined for NMEA0183, SPA-Bus, RFID).

For IEC 103, IEC101:

- **Address** – address of the device in the network according to GOST R IEC 60870-5-103-2005, GOST R IEC 60870-5-101-2006, respectively;
- **Timeout** - the maximum allowable time for generating a response, ms;
- **Delay** - delay in the communication channel, µs;
- **Oscillograms** – defines the procedure for working with disturbance recordings according to GOST R IEC 60870-5-103-2005, GOST R IEC 60870-5-101-2006 and contains:

- a) List - determines the number of disturbance recordings transmitted by the device (last eight (standard), last 16, 24 or all);
- b) Erase - whether to erase disturbance recordings after uploading;
- c) Notify - whether to generate a spontaneous message with a list of new disturbance recordings.

For ModBus:

- **Address** – address of the device in ModBus network;
- **Timeout** - the maximum allowable time to generate a response, ms;
- **Mode** - select ASCII or RTU mode.

For BDUBus:

- **Address** – address of the device in BDUBus network.

### 2.5.17.1.2 Menu Ethernet 1 and Ethernet 2

**Ethernet 1** (connectors XT1, XT2) and **Ethernet 2** (connectors XT4, XT5) menu is used to view and set communication port parameters and contains the following:

- **MAC** – unique MAC-address of a device. This number is used to identify a sender and receiver of a frame;
- **IP** – unique network address in computer network, created according to IP protocol;
- **Mask** – IP network mask;
- **Gate** – IP gateway address;
- Protocols - used when connecting according to the standard GOST R IEC 60870-5-104-2004, the menu sets the depth of IED output information from the event log (in days);
- **Mode –** selection of communication ports operation mode**:**

- PRP – the specified port operates in PRP mode (On/Off). If network does not support PRP, the mode should be switched off, otherwise communication problem could occur.
- Switch is used when there is no PRP at the facility or if the IED is connected to the station/process bus using the Redbox communication processing unit (via ports XT7, XT8)/XT9, XT10);
- Hot standby is used when there is no PRP at the facility and it is necessary to provide redundancy. The mode provides simultaneous connection of the IED to the facility network via two ports, while one port is always used for receiving and transmitting data, the other is in reserve. If communication is lost on the active port, it switches to the backup port;

- **VLAN** – in PRP mode, VLAN parameter of incoming GOOSE messages can take values from 0 to 16. **With other VLAN values, the IED will not receive and send GOOSE messages**;
- **PRP settings** - parameter setting:

- SVF period – packet sending period, s;
- MAC - send address.

> The settings Gate and PRP in Ethernet 1 menu and in all Ethernet 2 menu items should be applied only after IED restart.

### 2.5.17.2 Menu Date/Time

**Date/Time** menu provides is used for editing of date, time and UTC (Universal Time Coordinate) parameters. Non-volatile clock indication format is: DD.MM.YY, hh:mm, UTC indication.

### 2.5.17.3 Menu **Time sync.** methods

The **Time sync. methods** menu contains:

- **Methods** – synchronization method selection: **HMI** (possibility of time correction via HMI), **BDUBus** (technological interface of BDUBus), **RTC** (real-time clock), **1PPS** (synchronization input), **IEC103**, **NTP/SNTP**, **IEC104**, **MODBUS**, **NMEA0183**, **SPA-BUS**, **PTP**;
- Parameters – threshold (minimum difference between the IED and server time, above which the time from the server will be applied), ms.

Notes

1 PPS mode settings are applied only after terminal reboot.

2 You can select one accurate (Int. RTC, PPS) and one inaccurate method at the same time.

3 When selecting PTP method other methods are disabled.

4 When using any of the given synchronization methods, the method of synchronizing the main clock of the terminal from the GPS receiver of the TWFL module (2.5.13.7) should be disabled.

### 2.5.17.4 Menu **Access**

The **Access** menu is intended for user selection and password entry.

2.5.17.5 Menu Permissions

The **Permissions** menu is designed to select the operation with or without a password with the function keys **K1**, **K2**...**K50** (Control FK) and the buttons for controlling switching devices on the mnemonic diagram **LOCAL/REMOTE**, **I**, **O** (Control KA).

2.5.17.6 Security menu

The **Security** menu is intended for entering parameters for accessing IED functions and contains:

- **Min.Length** - the minimum number of password characters required to set it (Error! Link source not found.). It is recommended to use user passwords of the maximum length (eight characters), consisting of uppercase and lowercase letters and numbers. The set value will be valid only for created accounts and when changing the passwords of existing accounts**;**
- **Pass life time** - password expiration date;
- **Pass complexity** – selection of the minimum allowable character set. If the requirement is enabled - the simultaneous presence of uppercase and lowercase letters of English alphabet and numbers, when the requirement is turned off - any letters of English alphabet or numbers;
- **Blocking attempts count** – the number of invalid input attempts in each user session, upon reaching of which the account is blocked;
- **Blocking time** – account lockout time;
- **Service mode** – enable/disable service mode;
- **Inhibit Eth conf.** – selection of the mode of changing  settings and configuration;
- **Use RFID** – identification with the help of smart cards.

Changing settings in the **Security** menu is available only to users of the "Administrator" role.

## 2.5.18 Information

The **Information** menu displays information about the controlled power system object and IED parameters:

- **ID** – IED identifier in SCADA (the parameter is used for disturbance recording header);
- **Bay** – protected bay name;
- **S/S** – substation/station name (the parameter is used for disturbance recording header);
- **Ser.N** – IED serial number.

## 2.5.19 IEC 61850

The **IEC 61850** menu is used to display the status and to check the operability of the IEC 61850 server, located within the device:

- substation bus, where MMS and GOOSE protocols are used (**Station bus** menu item);
- process bus, where GOOSE and SV protocols are used (**Process bus** menu item).

In the lines of **Station bus** and **Process bus** menu items, the following status is displayed:

- **OK** – all IEC 61850 protocols used in the selected bus are properly configured and operate correctly;
- **Err** – wrong configuration has been found for at least one of the protocols used on the bus.

Menu **Station bus** contains items:

- **Inc. GOOSE** – statuses of incoming GOOSE-messages;
- **Outg. GOOSE** – statuses of outgoing GOOSE messages;
- **MMS server** – status of MMS server operability.

Menu **Process bus** contains items:

- **Inc. GOOSE** – status of incoming GOOSE-messages;
- **Outg. GOOSE** – status of outgoing GOOSE messages;
- **Inc. SV** – status of incoming sampled values.

The lines of each specified menu items indicate:

- **Off** – given protocol is turned off or is not used;
- **OK** – given protocol operates properly;
- **Err** – given protocol configuration is wrong.

Incoming GOOSE-messages adjusted in the device are displayed as a list in **Inc. GOOSE** menu. Each message representation has the following parameters:

- **MAC** – MAC-address of incoming GOOSE-message, to which the device is subscribed;
- **ID** – GOOSE-message identifier;

- **ConfRev** – GOOSE-message configuration revision number;
- **StNum** – number of state change of signals in GOOSE-message;
- **SqNum** – number of message retransmissions.

Outgoing GOOSE-messages configured in the IED are displayed as a list in **Outg. GOOSE** menu. Each message is represented by the following parameters, which can be used for verification:

- **MAC** – MAC-address of outgoing GOOSE-message;
- **StNum** – number of state change of signals in GOOSE-message;
- **SqNum** – number of message retransmissions.
- Error – diagnostic error code (Table 2.1).

Table 2.1: Diagnostic error codes when a malfunction is detected when receiving GOOSE messages

| Error code | Description |
|---|---|
| 0x0000 | No errors |
| 0x0001 | Error comparing AppID (app identifier) |
| 0x0002 | Simulation bit compare error |
| 0x0004 | Control block reference comparison error |
| 0x0008 | Dataset reference comparison error |
| 0x0010 | Message id comparison error |
| 0x0020 | Field "Test" comparison error |
| 0x0040 | Error in config revision |
| 0x0080 | Error comparing the number of elements in the dataset |
| 0x0100 | Error in counting the number of elements in a dataset |
| 0x0200 | Datatype comparison error in dataset |
| 0x1000 | Error in variable size comparison |
| 0x8000 | GOOSE message waiting error |

Outgoing GOOSE messages configured in the terminal are displayed in the Outgoing menu item. GOOSE as a list. For each of the messages, the following parameters are displayed to check the correctness of the configuration:

- MAC – MAC address of the outgoing GOOSE message;
- StNum – number of signal state change in GOOSE message;
- SqNum – message re-transmission number.

The menu **MMS server** contains the following information:

- **Analog** – number of configured analog signals;
- **Binary** – number of configured binary signals;
- **Control** – number of configured control signals;
- **Settings**  – number of configured settings;
- **Clients** – number of clients connected to server.

Incoming SV streams, adjusted in the IED according to IEC 61850-9-2LE are displayed as a list in **Inc. SV** menu. Each SV stream representation has the following parameters, which can be used for verification:

- **MAC** – MAC-address of incoming sampled values stream;
- **ID** – SV stream identifier;
- **ConfRev** – SV stream configuration revision number;
- **SampleNum** – number of samples in SV stream.

## 2.6 Test mode

In the IEDs units two test modes are implement for built-in protection functions and hardware.

## 2.6.1 Test mode for protection functions

Application and operation

The **Test mode** for protection functions is intended for testing of measuring elements and generation of logical signals. Test mode allows the user to perform protection tests in disabled state for a specific functionality as well as under the operation.

Signal transmission to the control system in a test mode is subject to communication protocols specified in 1.2.6.

Disturbance and event recording are automatically switched off when the **Test mode** is activated. At the same time, protection functions, various background tasks, configuration functions, operation with settings and system event recording are still active.

Test mode is initiated by issuing a **Test IED** signal to the binary input or via menu **Testing** (**Test mode** submenu). It is as well possible to enter the test mode using RelayTool software. During the test mode the output relays are blocked and **Test** LED (green) is lit.

When the test mode is enabled, the quality of data sent via IEC 61850 protocols (MMS, GOOSE) is marked as "test". This should be taken into account when interacting with external equipment using the IEC 61850 standard.

Test mode setup

The item **Test output** in the **Testing** menu assigns logic signals to the output relay **Test output**. The submenu contains a complete list of logical signals in the form of a numerical notation corresponding to one on the functional logical diagram and a short signal name. The menu title displays designation of a logical block containing functional element under the test.

RelayTool software is used to select output relays to be blocked in a test mode in order to avoid unnecessary operation of output relays.

Disturbance and event recording can be enabled from the **Testing** menu**:**

- from menu item **Enable recording;** in this case disturbance and event recording are enabled. Disturbance recording is performed according to standard triggering conditions; triggering on test output should be configured separately;
- from menu item **Number of trig**.; in this case disturbance recorder is triggered by test output, all other triggering conditions are disabled.

> The menu items **Enable recording / Number of trig.** are active only in the test mode.

After **Test IED** signal is reset, the IED exits the test mode and returns to normal operation.

## 2.6.2 Hardware test mode

Function and operation

The **Hardware test** mode is used for checking the operation of the hardware nodes during periodic tests or before commissioning in order to determine failures in the hardware components.

Protection functions, disturbance and event recording as well as self-diagnostic functionality stop automatically when entering the **Hardware test** mode.

When the test detects an error (mismatch), it should be reported in a failure protocol, so the possibility of fixing the test result is provided, whether the test result is successful or not.

Preparation for testing

Before testing it is necessary to disconnect from the TOR 300 IED the following circuits:

- binary input signals,
- analog input signals,
- binary output signals,
- input HF carrier signals,
- output HF carrier signals.

When entering the test mode via **Diagnostics** menu the following requirement must be confirmed (Figure 2.6).

```
   Is IED disconnected
    from input/output
        circuits?



   <C>-No     <E>-Yes
```
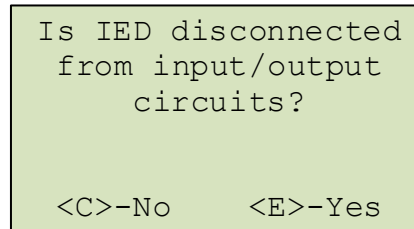
Figure 2.6: Confirmation of circuit disconnection

If disconnection of all input and output circuits is confirmed by **Yes**, the option the test mode is activated and the output relay operation is allowed.

When "No" option is chosen the outputs relays are automatically blocked and corresponding message is displayed (Figure 2.7) on the display. In the test mode binary outputs are not checked (items **Test IO modules** and **Test HF module**).

```
      Output relays
      operation is
        DISABLED!


          <E>-Next
```
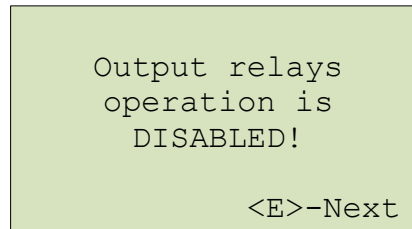
Figure 2.7: Confirmation of binary outputs disabling

Running the tests

Test mode started and a list of tests is displayed in the **Diagnostics** menu:

- Display test;
- Test keyboard;
- LED test;
- Test CP module;
- Test IO modules;
- "Failure" test;
- HF-board test;
- Test special relays.

Each particular test runs after the appropriate menu choice in HMI has been confirmed. All tests, except the keyboard test, can be cancelled by pressing **C** button.

After finishing of each test it is necessary to confirm its result (message: **Is test passed? <C>–No <E> –Yes** appears on the display and the appropriate button should be pressed).

Test result is displayed on the screen in front of the corresponding menu item as **ok** or **er**.

Testing the display (by selecting the **Display test** item)

The test checks the functionality of display.

During the test:

- all segments of the display are lit simultaneously, then the screen is cleared;
- all segments are lit and dimed sequentially.

Keyboard test (by selecting Buttons item)

By this test functionality of control buttons on local HMI is checked.

The test is carried out by short-time pressing of each separate button and checking, that the corresponding symbol of pressed button is activated in "B**uttons**" line. By this test, the operation of all device's buttons can be checked (Figure 2.8).

```
Button:
MENU  SET  MEA  MNEM  Res
F1      <    ^     >
F2      C    v     E
L/R      SwOn   SwOff
    <C>+<E> - Exit
```

Figure 2.8: Control buttons test

The exit is done by briefly pressing of both, **E** and **C** buttons or by receiving the corresponding command via diagnostic port.

Functional keys

Checking is carried out by briefly pressing the button, while on the screen in the line **Gr.X** (where X is the group number) the button number should be displayed in reverse order.

LED test (by selecting the **LED Test** item)

All signalling LEDs, except **ERROR**, are checked after activating the LED test.

During testing the verification of the following states is provided:

- all LEDs are turned off;
- LEDs are turned on in the "red" and "yellow" color mode;
- LEDs are turned on in the "green" color mode;
- turning on and off of each double-color LED twice (in "red" light mode, and then in "green" light mode), and each single-color LED once.

Microprocessor module test (by selecting MB test item)

For verifying the correct operation of the real-time clock chip, installed in the CP module, device displays a message about date and time data (Figure 2.9). It is necessary to acknowledge the displayed information.

```
*         MB test        *
Date     01.01.2022
Time     22:01:22


Displayed correctly?
 <C>-No        <E>-Yes
```

Figure 2.9: Check of real-time clock

For checking the validity of file system, the information about all devices and system parts is displayed (Figure 2.10):

- device name (ram, oscil, boot, log);
- total/free memory in kB;
- validation status of file operations.

If all operations are correctly executed a message "passed" is displayed. To continue the tests of the logic module press **E**.

```
*         MB test        *
       Device:     oscil
Memory:  9793/ 2588kB
File ops.:   passed


<C>-Exit      <E>-Next
```

Figure 2.10: Check of file system correctness

On error of file operations the line **File ops** indicates one of the following messages (Figure 2.11):

- error creating file – **er crt f**;
- error writing to file – **er wr f**;
- error closing the file – **er cls f**;
- error opening the file – **er opn f**;
- error reading the file – **er rd f**;
- error deleting the file – **er del f**.

```
*       MB test        *
Device:       oscil
Memory:       0/   0kb
File ops:     er del f


<C>-Exit      <E>-Next
```

Figure 2.11: Example of error during File ops test

It is necessary to make sure that all data is correctly displayed and then press **E** to continue CP module test.

Messages with the names of the missing files are displayed, when checking for the presence of the obligatory protection files.

When detecting the absence of obligatory protection files the test is considered to be passed **unsuccessfully** and it is required to copy the information displayed on the screen and report it to Relematika.

"Failure" relay test (by selecting **"Failure"** test item)

The test is intended for checking the operability of "**Failure**" relay and **ERROR** LED. The command for changing the relay state is entered by pressing **E** button. Relay closes or opens when triggering its state with the help of **Up** and **Down** buttons. Together with closing/opening of the relay the **ERROR** LED must be accordingly turned on/off.

When the test procedure is over, the "**Failure**" relay opens and **ERROR** LED, respectively, turns off.

Test of power supply and/or binary input/output modules (by selecting the **IO-board test** item)

This test checks modules containing binary inputs and outputs. Depending on the configuration of TOR 300, this menu contains the appropriate number of items, equal to the number of modules.

When entering the **IO-board test** submenu, the screen displays the following information line by line, depending on TOR 300 version (Figure 2.12):

- type of tested module;
- number of binary inputs and outputs on the module;
- information about status of binary input channels;
- information about status of binary output channels;
- number of checked outputs during the outputs test.

Symbol "–" in lines **Inputs** and **Outputs** of Figure 2.12 means the absence of input signal or opened contacts of output signal, **digit** – means the existence of input signal or closed contacts of the relay. Digit corresponds to the least significant digit of binary input/output number (exp., for input 4.9, digit "9" is displayed, for output 4.10 – digit "0" is displayed).

```
 *Test Slot01-P3021 *
 8in/5out
 Inputs:  |12------
>Outputs: |--3--

 Output No.:   03
```

Figure 2.12: Check of binary inputs/outputs

Check of binary inputs is carried out by applying auxiliary voltage to the IED binary inputs.

Check of binary outputs (relay outputs) of tested module is carried out by changing of their status by means of **E** button. Button **C** is used to exit the output relays status changing mode. Output relay state is changed by pressing **Up** or **Down** buttons correspondingly.

Out of the relay state changing mode it is possible to choose the next or the previous module from the list by means of **Right** or **Left** buttons respectively.

When another module is selected for testing or testing of the module is terminated, the status of the output relays is reset.

Test of HF binary inputs and outputs (By selecting **HF-board test** mode)

This test checks the operation of binary inputs and outputs of HF communication module (Figure 2.13). In the first line after the title information about the status of module binary inputs is displayed, in the second line – the information about module binary outputs status is displayed.

The states of inputs/outputs are assigned in the following way: «–» – logical «0», «*» – logical «1».

```
*     HF-board test     *
 Inputs:    -
>Outputs:  -*
           ‾
```

Figure 2.13: Check of HF binary inputs/ outputs

Entering the mode of binary output state changing is carried out with the help of **E** button.

When the test is finished, the status of binary outputs is reset.

Test of fast operating relays (Relay test)

This test checks the operation of fast speed relays of B3028 module (if installed) (Figure 2.13).

The states of relay outputs are assigned in the following way: «–» – logical «0», «*» – logical «1».

```
   *  Test relay *

> Outputs: ----*
               ‾
```

Figure 2.14: Check of fast speed (special) relays

Entering the mode of binary output state changing is performed with the help of **E** button.

When the test is finished, the status of binary outputs is reset.

## 3 MAINTENANCE

### 3.1 General

#### 3.1.1 Maintenance cycle

The tests are carried out within the appropriate time limits and to the extent as agreed with the customer. The test scope can be reduced during the operation and test procedures can be changed according to the Customer's internal maintenance rules for microprocessor based (protection) equipment. ***In any case, first of all, it is necessary to observe the necessary internal rules of the owner of the company.***

Relematika recommendation for IEDs maintenance cycle is eight years.

Maintenance and repair of IEDs should be carried out by specially trained, certified personnel, Relematika representatives.

### 3.2 Safety precautions

The IEDs are designed as fire-proof in accordance with GOST 12.1.004-91 and provide safety in accordance with IEC 61439-1:2011, GOST 12.2.007.0-75.

At operation and maintenance of the IED one should be guided by the appropriate standards and rules applied for microprocessor relay protection devices.

Requirements towards personnel and operator's instructions required for operation and maintenance of the device are specified in 2.2.1 of this Operation manual.

The IED causes no environmental hazard when operated and stored according to the requirements.

### 3.3 Maintenance order and operability checks

**Only specially trained personnel should be admitted to maintenance of the above mentioned equipment.**

**Relematika should be immediately informed in case of any defects being detected within tested TOR 300 IED or PC communication device.**

Table 3.1 presents required activities during corresponding maintenance works.

Table 3.1: Types of activities during IED maintenance

| Checking activities |
|---|
| a) visual inspection: check for marks of shocks, leakage including dried-up spots, oxidized spots on metal surfaces, dust content, visual inspection of input and output signal terminals, contact surface condition of communication interface terminals |
| b) internal inspection: dust removal; visual inspection of circuit components for overheating marks, loosening of soldered connections due to cracks, check for oxidation; supervision of connector joint and mechanical component fastening, screw connection tightening |
| c) insulation resistance test of independent circuits (except for communication interface circuits) towards the rack and between each other |
| d) dielectric strength test of independent circuits (except for communication interface circuits) towards the rack and between each other |
| e) operability check of binary inputs, output relays and LEDs |
| f) setting (or check) of required IED configuration according to accepted design solutions and technical characteristics (functions) |
| g) setting (or check) of relay settings according to the defined configuration |
| h) checking the validity of displayed quantities and phase angles of currents (voltages) from an external source |

| Checking activities |
| --- |
| i) testing of operating parameters (settings) and reset ratios of each measuring element when applying current (voltage) from an external source; monitoring of LED status during operation |
| j) testing of protection operating time for compliance with set time delays |
| k) test for absence of maloperation during connection and disconnection of auxiliary supply voltage with repeated energizing after 0.5 s at the minimum value of the setting range with current (voltage) set for 0.8 of the operating current (voltage) |
| l) test of IED operation with the set values and measurement of the operating value change at auxiliary supply voltage equal to 0.8 and 1.1 $U_{rated}$ |
| m) test of measuring elements and logic circuit interaction with supervision of all the output relay contacts status and visual inspection of LEDs and signalling lamps status. The test is performed with auxiliary supply voltage equal to 0.8 $U_{rated}$ and provided that corresponding operation of each measuring element and presence of required signals to binary protection inputs is ensured |
| n) test of protection and control functions with output relay contact action towards the circuit breaker or other switching devices control circuits |
| o) test of event recording, disturbance recording, protection parameter displaying functions |
| p) test of bay breaker or other switching devices control (close/open) |
| q) test of common control and signalling operation with other devices, with required actions to the breaker or other switching devices |
| r) test under load conditions |

## 3.3.1 Insulation resistance and strength test

Insulation test is performed in a cold state according to IEC 60255-27:2005 requirements.

3.3.1.1 Before the tests

Before starting the test the following actions should be obligatory taken:

- de-energize the relay and disconnect all external AC (be sure to short-circuit the incoming current circuits before their disconnection) and DC circuits;
- connect circuits inside the independent groups by temporary jumpers. Depending on a version of TOR 300 (cubicle) the following independent groups of circuits can be differentiated:
  - AC current;
  - AC voltage;
  - TWFL AC current;
  - TWFL AC voltage;
  - capacitive voltage divider current;
  - binary inputs;
  - power supply;
  - alarm (signalling) circuits;
  - trip coil 1 and close coil auxiliary circuits;
  - trip coil 2 auxiliary circuits;
  - output relays.

3.3.1.2 Insulation resistance measurement

Insulation resistance measurement between the circuits connected to each other and the housing, also between each circuit and the rest of circuits connected to each other is performed by mega-ohmmeter with 1000 V for the circuits with rated voltage of more than 60 V according to the rules of technical maintenance. Measured insulation resistance should be at least 100 MOhm for all specified cases.

3.3.1.3 Insulation strength test

Insulation strength between the mentioned circuits towards the housing and between themselves should be tested with the test voltage of 1000 V and frequency of 50 Hz for 1 min. After the test, the IED insulation resistance should be measured once again. Insulation resistance test is considered to be successful if the insulation resistance value remains within at least 100 MOhm.

### 3.3.2 Checking the applied setting parameters and configuration

Checking of the applied setting parameters and configuration is performed according to the detailed project design documentation. A local HMI is used for an active setting group selection and setting adjustment (2.5.13).

TOR 300 is shipped with default factory configuration. Using the PCAP or RelayTool software a customer can change the default configuration.

For a list of parameters to be configured see 2.4.

### 3.3.3 Testing the validity of displayed analog values

External output circuits should be disconnected from the IED's output terminals.

The test is carried out by applying current and voltage from an external source to corresponding TOR 300 connectors. Current and voltage values and phase angles are monitored on local HMI display and/or by RelayTool software. Additionally, current and voltage values can be viewed via web-interface.

Here and further, a specialized protection testing device is used as an external source.

### 3.3.4 Protection parameters (settings, protection functions, measuring elements) check

External output circuits should be disconnected from the IED's output terminals. Test procedure for the protection functions is performed according to their description and applicable standards.

During the tests as per paragraphs 0 and 0 the corresponding LEDs are also supervised.

Testing of protection functions measuring elements

Testing of measuring elements is carried out by supplying from an external source currents and/or voltages, corresponding to the setting values of the tested functions (simulation of fault conditions). Measuring element operation is supervised by the operation of the corresponding check output relay with operation and reset parameters being recorded.

Testing of complete protection functions

Testing of complete protection functions (measuring elements and related logic circuits interaction) is carried out by simultaneous activating of the logical signals and currents and/or voltages, corresponding to the tripping state. Supervision is performed by detecting the operation of check output relay or others.

### 3.3.5 Test of IEDs functionality when applying and removing auxiliary supply voltage

External output circuits should be disconnected from the IED's output terminals. When operating currents of 90 % of operating values are applied to the IED, auxiliary supply voltage is de-energized and energized once again. During the test no protection operation should occur.

### 3.3.6 Test of operation towards the central signalling system and interaction with external devices

Test of IED operation towards the central signalling system and interaction with external devices is carried out by commissioning personnel according to the established procedures.

### 3.3.7 Test of IED interaction with other low voltage equipment

Possibility of operation on primary equipment control circuits should be eliminated. Test of interoperation with another low-voltage electrical equipment available on the site is carried out by simulating corresponding conditions and supervision of output signalling.

### 3.3.8 Testing the IEDs under load (current and voltage) conditions

Depending on IED version, operating current and voltage test includes the following:
-    test of current circuits by measuring secondary load currents in phases;
-    test of serviceability and connection correctness of voltage circuits;
-    current circuit connection check for each current transformer group using vector diagram and checking it against the actual power direction in a primary circuits;
-    test for correct connection of fuse failure blocking and power swing blocking;
-    test for correct connection of directional overcurrent (also power and impedance) relays;
-    test for correct assembly of differential protection current circuits by measuring the differential and bias currents;
-    test for correct connection of carrier aided (HF power-line carrier) protections.

## 3.4 Failure list and troubleshooting

### 3.4.1 Introduction

Failures can occur due to improper transportation, storage and maintenance, component wear. Self-supervision (diagnosis) system tests for failures at power-on and during operation of the IED.

### 3.4.2 Self-diagnostic

Self-diagnostic is divided to the following two stages: initial (at power on/restart of IED) and continuous (during IED operation).

Self-diagnostic comprises supervision of the following important IED components: CP module, power supply module, binary input/output modules and HMI module. Binary input/output units include current-based supervision of output relays coils. Self-diagnostic information is collected from all controllers within the device and is analyzed in central and signal processors.

> IED self-diagnostic does not supervise output relay contacts (for example, "stuck" state), binary input operability and winding integrity of input current and voltage transformers.

When a persistent failure is detected within any of the supervised elements, and **ERROR** LED is lit on IED front panel and control of output relays is blocked.

When a failure is detected during the operation, two error code sets are generated, current and general. Current error code represents the self-diagnostic state at the present moment, general code displays all detected failures, including fleeting and then disappeared faults.

Information about detected failures is available under the **Diagnostics/Status** menu item.
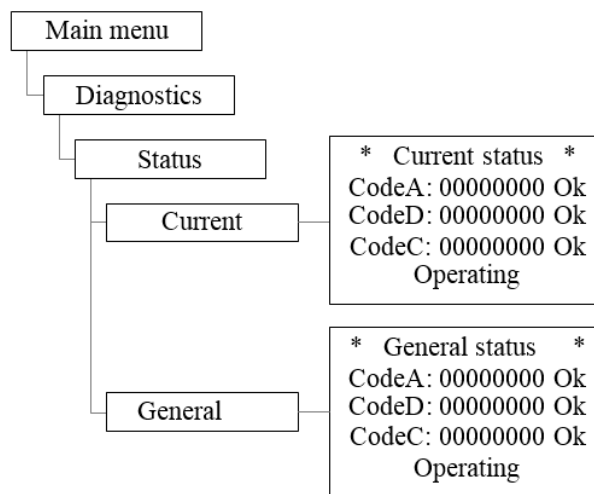


Figure 3.1: Example of Diagnostic / Status menu

The following three code types are displayed in menu items **Current** and **General**:

- **Code A** means the failures detected by central processor (CP);
- **Code D** displays the failures detected by signal processor (DSP);
- **Code C** (auxiliary) means total amount of failures detected in peripheral units (power supply, binary input/output). Entering the menu item and pressing **E** button initiate failure codes per each module, second right digit indicates the number of the module starting from the power supply unit.

The displayed codes make possible identification of every detected failure. The list of codes is given in Table 3.2 and Table 3.3.Text descriptions of failures are available by entering the menu item (except for C codes).

### 3.4.3 Error codes

Failures, which are detected during continuous self-diagnostic are presented in a hexadecimal notation according to the rules stated below.

**Error code** consists of eight digits and comprises information about the type of failure. Every digit is a hexadecimal number of four binary-code bits ( Table 3.4: ). Every bit corresponds to a certain event (failure), the list of which is given in Table 3.2

and Table 3.3. Zero self-diagnostic codes mean no faults detected. A failure code provides information about one or several faults detected simultaneously. For example, code A is 00000001 means: "CP module fail 1" (serial bit number is 1, digit is 1); 00000200 denotes "CP module fail 6" (serial bit number is 2, digit is 3); 00000800 stands for "Scheme error 1" (serial bit number is 4, digit is 3), 00000A01=00000800+00000200+00000001 indicates "CP module fail 1", "CP module fail 6", "Scheme error 1". Other codes are generated in the same way.

Table 3.2: Error code A

| HMI message | | Description |
|---|---|---|
| Error code | Text | |
| 0x00000001 | CP module fail 1 | Central processor board failure |
| 0x00000002 | CP module fail 2 | Central processor board failure |
| 0x00000004 | SW failure 1 | Software failure |
| 0x00000008 | HMI failure 1 | HMI board failure |
| 0x00000010 | CP module fail 3 | Central processor board failure |
| 0x00000020 | Parameters fail | Central processor board failure |
| 0x00000040 | CP module fail 4 | Central processor board failure |
| 0x00000080 | Dist. rec. fail | Central processor board failure |
| 0x00000100 | CP module fail 5 | Central processor board failure |
| 0x00000200 | CP module fail 6 | Central processor board failure |
| 0x00000400 | Clock reset | Central processor board failure |
| 0x00000800 | Scheme error1 | Central processor board failure |
| 0x00001000 | SV error | Receiving or transmitting of SV-signals failure |
| 0x00002000 | ASW error | Failure raised by functional diagram logic |
| 0x00004000 | ASW block error | Failure raised by functional diagram logic with device disabling |
| 0x00008000 | ADC failure | Central processor board failure |
| 0x00010000 | HMI failure 2 | HMI board failure |
| 0x00020000 | HMI failure 3 | HMI board failure |
| 0x00040000 | HMI failure 4 | HMI board failure |
| 0x00080000 | HMI failure 5 | HMI board failure |
| 0x01000000 | No setting gr | Setting group not entered |
| 0x02000000 | No calibration | No calibration |
| 0x08000000* | HMI exchange failure | HMI exchange failure |
| * It can occur when using the IED version with a remote panel, if the remote panel is disabled and the "Remote" mode is not selected using RelayTool software and hardware complex. | | |

Table 3.3: Error code D

| HMI message | | Description |
|---|---|---|
| Error code | Text | |
| 0x00000001 | CP module fail 7 | Central processor board failure |
| 0x00000002 | CP module fail 8 | Central processor board failure |
| 0x00000004 | CP module fail 9 | Central processor board failure |
| 0x00000008 | SW failure 2 | Software failure |
| 0x00000010 | SW failure 3 | Software failure |
| 0x00000020 | CP module fail A | Central processor board failure |

| HMI message | | Description |
|---|---|---|
| **Error code** | **Text** | |
| 0x00000040 | CP module fail B | Central processor board failure |
| 0x00000080 | CP module fail C | Central processor board failure |
| 0x00000100 | CP module fail D | Central processor board failure |
| 0x00000200 | SW failure 4 | Software failure |
| 0x00000400 | CP module fail E | Central processor board failure |
| 0x00000800 | AI config fail | Analog input configuration failure |
| 0x00001000 | BIO config fail | Binary in./out. config. failure |
| 0x00002000 | BIO module fail | Input/output board failure |
| 0x00004000 | CP module fail F | Central processor board failure |
| 0x00008000 | SW failure 5 | Software failure |
| 0x00010000 | Scheme error2 | Some functional block is missing in device |
| 0x00020000 | Scheme error3 | Invalid setting |
| 0x00040000 | Scheme error4 | Invalid sampling rate |
| 0x00080000 | CP module fail G | Central processor board failure |
| 0x00100000 | CP module fail H | Central processor board failure |
| 0x00200000 | DPL block error | DPL block error |
| 0x10000000 | Reserved | |
| 0x20000000 | Scheme error5 | Diagram initialization failure |
| 0x40000000 | SW failure 6 | Software failure |
| 0x80000000 | CP module fail I | Central processor board failure |

Table 3.4: Hexadecimal number of four binary-code bits

| Error code digit value (hexadecimal code) | Active bit numbers (binary code) |
|---|---|
| 0 | 0000 |
| 1 | 0001 |
| 2 | 0010 |
| 3 | 0011 |
| 4 | 0100 |
| 5 | 0101 |
| 6 | 0110 |
| 7 | 0111 |
| 8 | 1000 |
| 9 | 1001 |
| A | 1010 |
| B | 1011 |
| C | 1100 |
| D | 1101 |
| E | 1110 |
| F | 1111 |

### 3.4.4 Troubleshooting

In case a **persistent** failure is detected, which can cause a possible maloperation or failure to operate, the output circuits of the IED are set out of operation; in this case **ERROR** LED is lit. Signalling is provided by a normally-closed contact. Possible failures and troubleshooting are given in Table 3.1.

**If failure is detected, report registered error codes, text description of a failure, information about latest device restart and configuration to Relematika or its representative.**
**Only specially trained personnel with dedicated equipment and tools is admitted to perform troubleshooting service.**
**After the failure is repaired and before the IED is put again into operation, the corresponding parameters (settings, disturbance recorder parameters, etc.) should be checked. Assure that IED operates properly**.

Upon detection of the failure, it is necessary **first** to write down the error codes, which are displayed on the HMI and described in 3.4.3, and in Table 3.1, than report it to Relematika or its representative. In some cases (for short-term failures) it can be sufficient to interrupt power supply to remove the failure.

Table 3.1: Troubleshooting

| Symptoms | Possible cause | Error code | Troubleshooting |
|---|---|---|---|
| The device does not start at power on, **READY** LED is off | Failure in power supply module | _ | Power supply module repair/replacement |
| The device does not start at power on, but **READY** LED is on. Text "**Relematika**" is displayed on HMI | Failure in central processor module | _ | Central processor module repair/replacement |
| The message about that the analog channels of the terminal are not calibrated | Analog channels of the IED are not calibrated | A:0x02000000 | Calibrate the IED |
| No logic signal appears after applying power supply to one of the binary inputs | Failure in the input assembly of one of binary input/output modules | D:0x00002000* | Binary input/output module repair/replacement |
| Persisted closed/open state of output relay, which does not correspond to the applied action | Failure in the output assembly of one of binary input/output modules | D:0x00002000* | Binary input/output module repair/replacement |
| Hardware module error message at device start-up or during operation | Failure of some of the binary input/output modules, power supply module | D:0x00002000 | Detect a faulty module, using error codes. Restart the device by short-time (for 3 s.) power reset. If the failure remains after device restart, repair/replace the module |
| SW error message | Single SW failure. Possible central processor module failure. | A:0x00000002 A:0x00000004 D:0x00000002 D:0x00000004 D:0x00000008 D:0x00000010 D:0x00000020 D:0x00000040 D:0x00000080 D:0x00000100 | At repeated error appearance, update a protection circuit with service SW and restart the device by short-time (for 3 s) power reset. If the problem remains, repair/replace central processor module |

| Symptoms | Possible cause | Error code | Troubleshooting |
|---|---|---|---|
| | | D:0x00000200 | |
| Parameters reset message | Single failure of non-volatile memory of recorders and settings | A:0x00000020 | Configuration parameters should checked and set. If the problem remains, repair/replace central processor module |
| Disturbance recording memory error message. Previous disturbance recordings could be lost. | Single failure of disturbance recorder non-volatile memory | A:0x00000080 | Function restores automatically. If the problem remains, repair/ replace central processor module. Emergent device disabling is not required |
| Clock error message | Single time reset | A:0x00000400 | Check and set device time parameters, if necessary. If the problem remains, repair/ replace central processor module. Emergent device disabling is not required |
| Messages about error caused by configuration or protection scheme | Device operates with false or improper protection scheme | A:0x00000800 D:0x00000800 D:0x00001000 D:0x00010000 D:0x00020000 D:0x00040000 D:0x20000000 | Check the compliance between the diagram and protection scheme, update the diagram with service SW |
| Settings file missing message | Missing settings file | A:0x01000000 | Download and activate setting group |
| Other errors | | | Perform troubleshooting and repair/ replace faulty module |
| * Does not detect output relay contact failure (for example, contact sealing), also binary input operability, input CT and VT winding integrity. | | | |

## 3.5 Disposal

On expiry of specified service life IED should be dismantled and disposed. No special safety measures should be taken while dismantling and disposing of a device nor special tools and accessories are required.

## 4 TRANSPORTATION AND STORAGE

Transportation and storage conditions correspond to 1.1.9. Permissible shelf life period before commissioning is two years.

Loading, fixing and transportation of the device should be carried out according to valid regulations for carriage of goods by corresponding means of transportation.

## 5 MANUFACTURER WARRANTY

Relematika ensures compliance of IEDs with the standard specifications subject to operating, transportation and storage conditions by the customer.

The warranty period is 5 years from the date of putting the device into operation, but not more than 5.5 years from the date of shipment. Extended warranty is provided in agreement with the Manufacturer.

Manufacturer warranty does not cover IEDs with mechanical damages and are not valid in the case of breach of operating conditions (influence of increased values of voltage, current, disturbance level, ingress of moisture and foreign current-conductive materials or objects inside the rack, etc.).

If device is supposed to be returned to Relematika, it should be packed in a package ensuring safety during storage and transportation.

The Manufacturer should guarantee repair or replacement of the device during its lifetime. Shipment term of spare parts from Relematika warehouse should not exceed three months from the moment of signing the contract for purchasing of these spare parts.

## APPENDIX A
## (obligatory)
## Ordering structure

TOR 300  XXXX XXXMC, XXX,IX, =220, RS485, Eth-X, Y, H-X,H-X  UHL3.1

Terminal type

Functional version (code from 1 to 4 signs)

Program version

Version with extended maintenance cycle

Version of measuring tools

Hardware version

Execution indicator :
– 0 (without display)
– 1 (alphanumeric)
– 2 (grafical)

Auxiliary voltage :
– constant (=) or alternating (~),
– Voltage value, V

Port version (XT4/XT5) :
– 0 (without port)
– RS485 or FOCL
– Eth-T (twisted pare) or Eth-F (FO cable)

Port version (XT1/XT2) :
– Eth-T – with twisted pair
– Eth-F – with fiber-optic cable

Port version (XT3) :
– 0 (without port)
– MM – 2 multimode
– SS – 2 single mode
– MS – 1 multimode or 1 single mode
– HF – HF-port
– FR – fast relays

Version of special block :
– 0 (no special block)
– TWFL-01 (3I + 3U)
– SS – 2 single mode
– H-T, H-T – comm.ports RedBox XT7/XT8
and XT9/XT10 with twisted pair
– 0, H-T – XT8/XT9 – without port, XT9/
XT10 with twisted pair
– H-F, H-F – comm.ports RedBox XT7/XT8
and XT9/XT10 fiber-optic cable
– HF – HF-port
– FTR – fast thyristor relays

Climatic version according to GOST 15150

Category of placement according to GOST 15150

The hardware version is defined by Relematika according to application version, quantity and type of analog inputs and binary inputs and outputs specified in order form.

Figure A.1: 1/4 x 19" housing layout

**APPENDIX B**
**(obligatory)**
**Layout, overall and mounting dimensions**
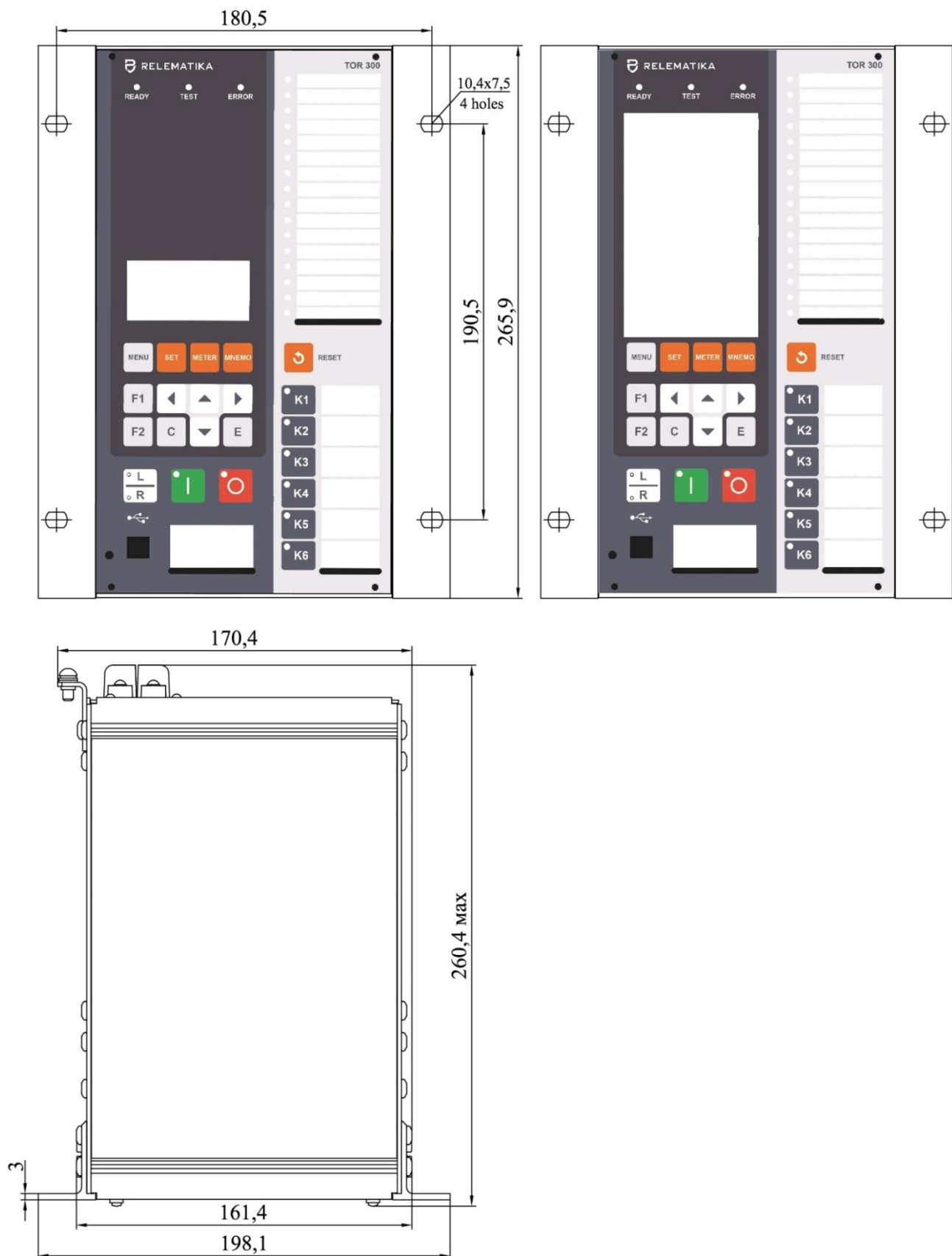


TOR 300 weight for 1/4 x 19" casing is max. 7 kg

Figure B.2: 1/4 x 19" housing layout
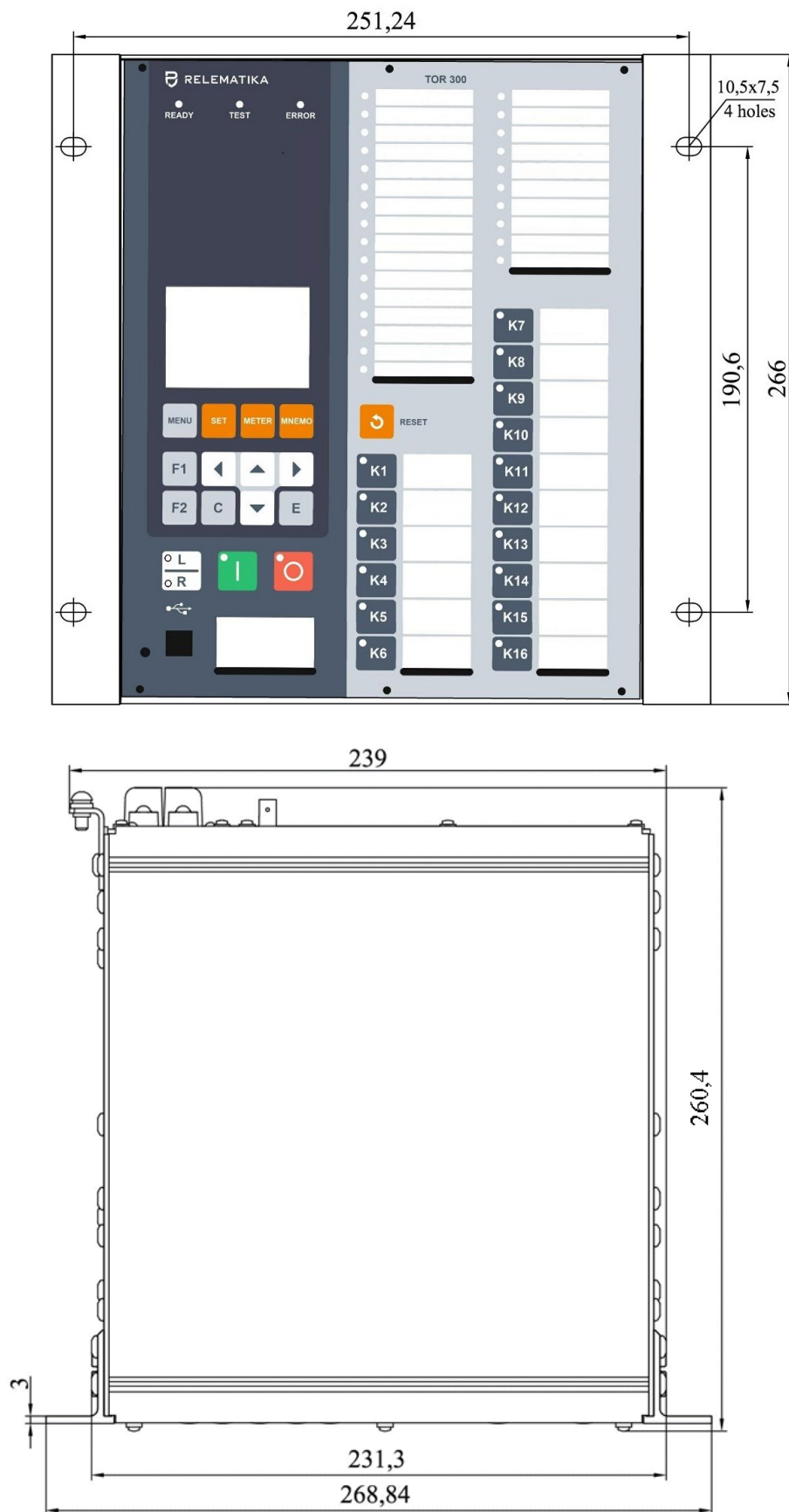
TOR 300 weight for 1/2 x 19" casing is max. 10 kg

Figure B.3: 1/2 x 19" housing layout (example with alphanumeric display, 16 buttons) (POLYRACK casing)
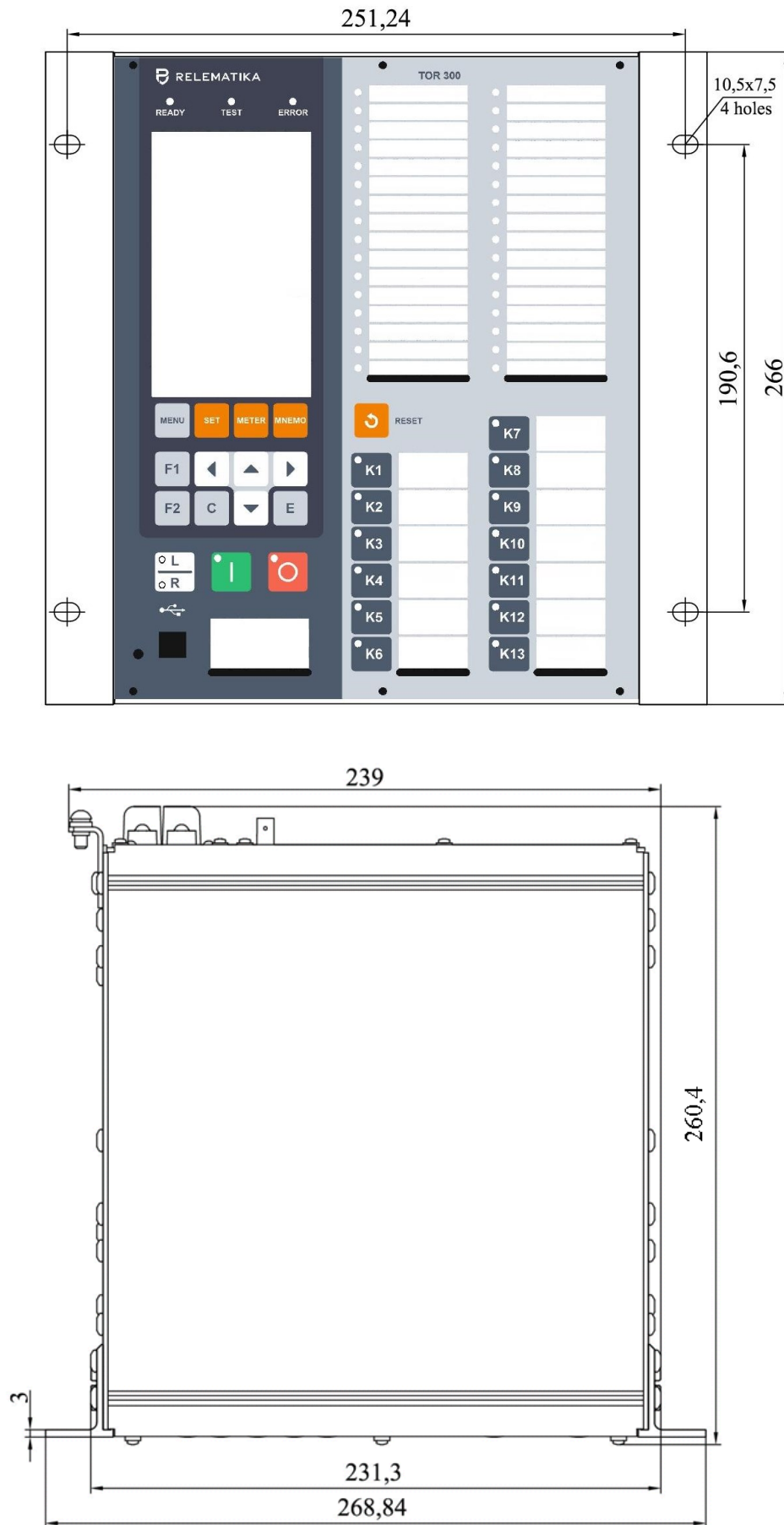
Figure B.4: 1/2 x 19" housing layout (example with graphic display, 16 buttons) (POLYRACK casing))

TOR 300 weight for 3/4 x 19" casing is max. 13 kg
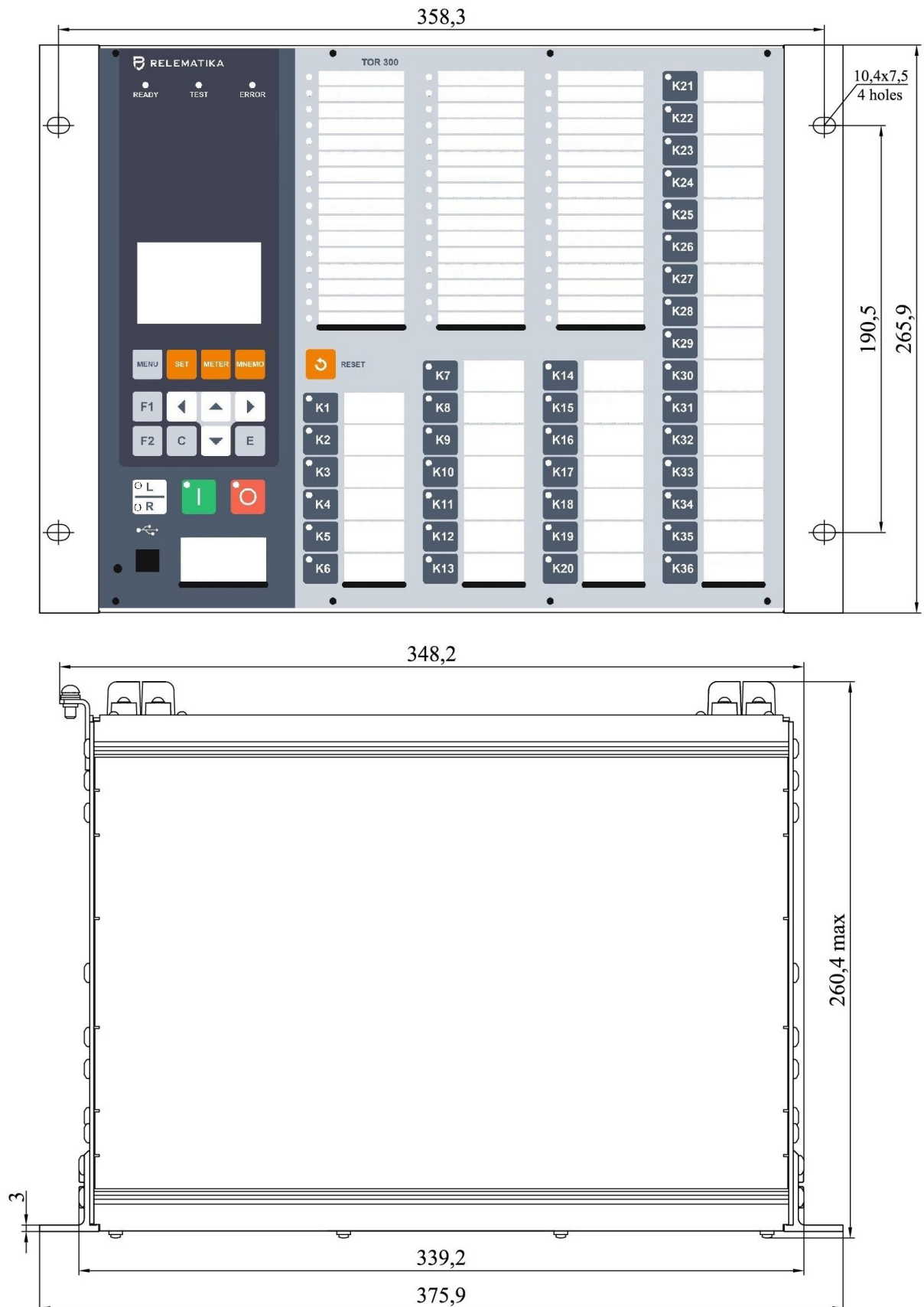
Figure B.5: 3/4 x 19" housing layout (example with alphanumeric display)
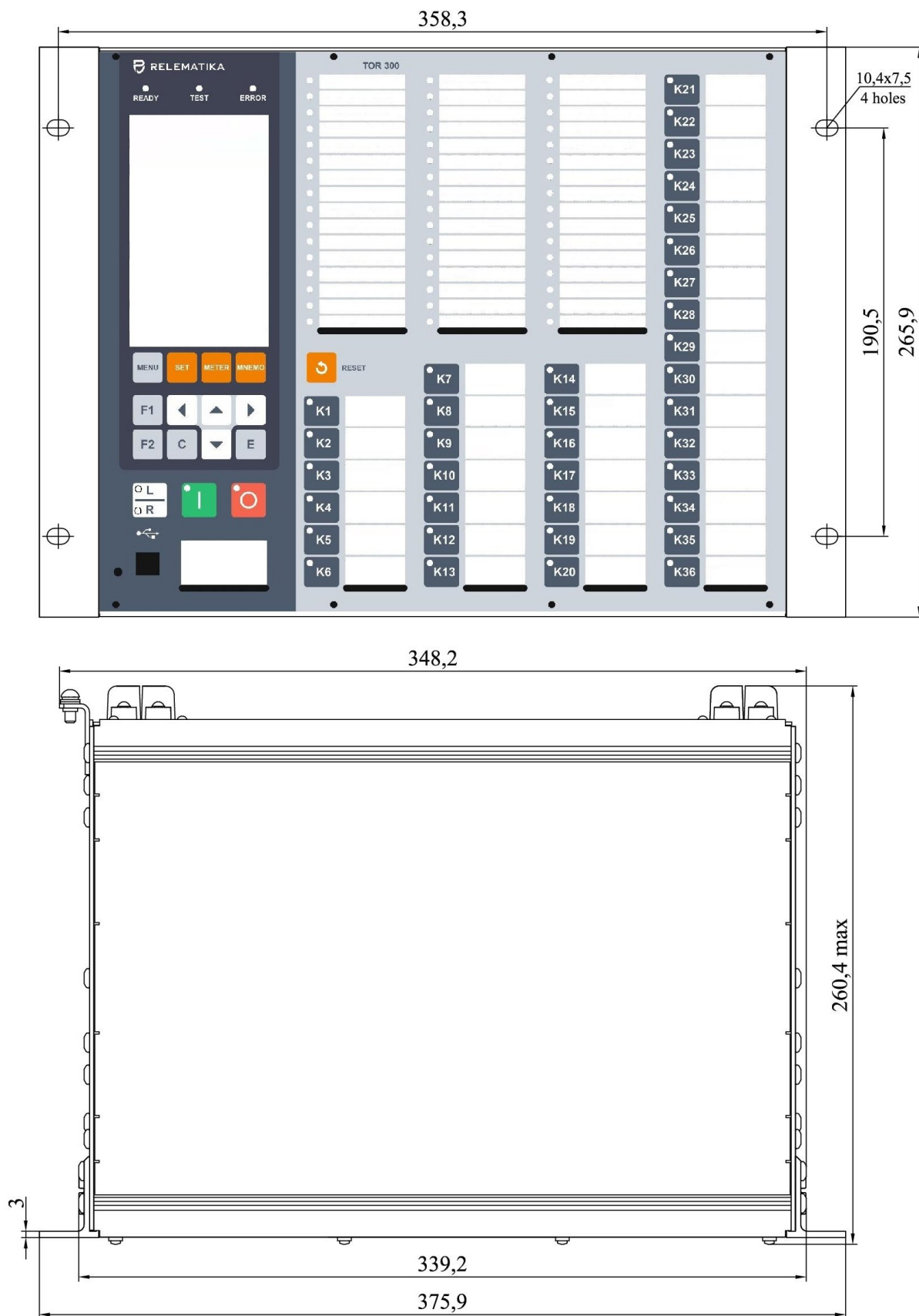
TOR 300 weight for 3/4 x 19" casing is max. 13 kg

Figure B.6: 3/4 x 19" housing layout (example with alphanumeric display)
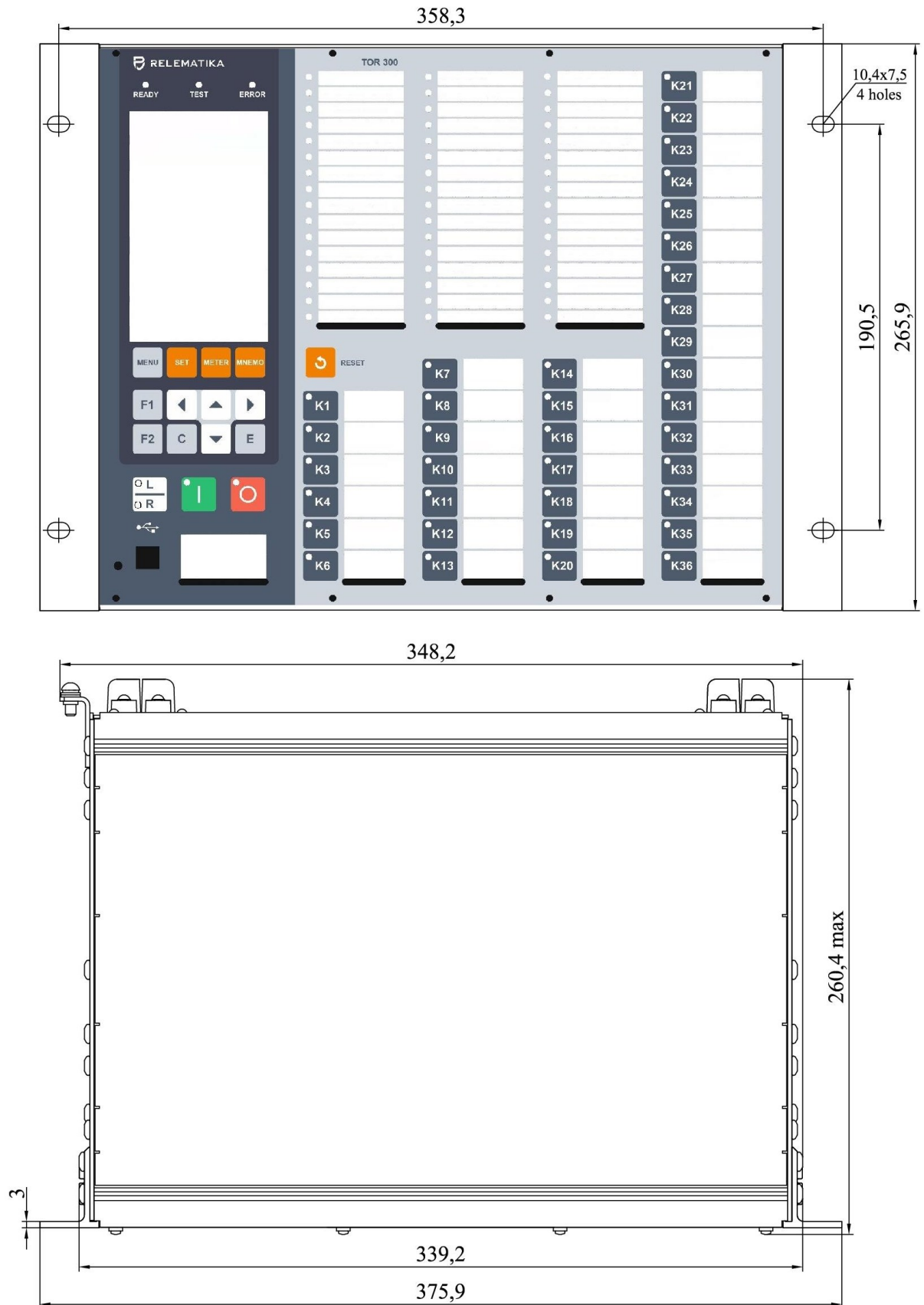
Figure B.7: 3/4 x 19" housing layout (example with graphic display)
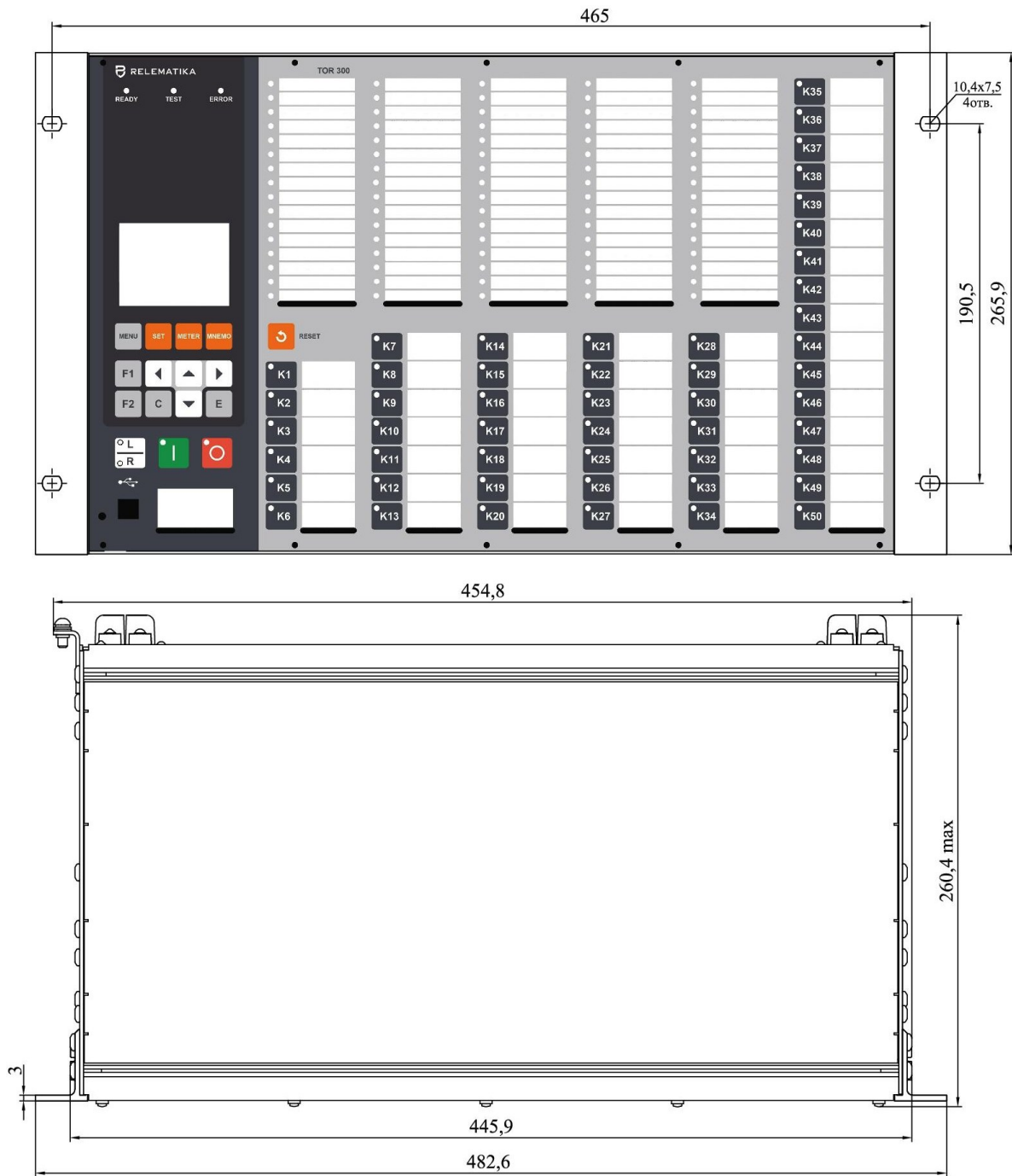
TOR 300 weight for 1/1 casing is max. 15,5 kg

Figure B.8: 1/1 x 19" housing layout (example with alphanumeric display)
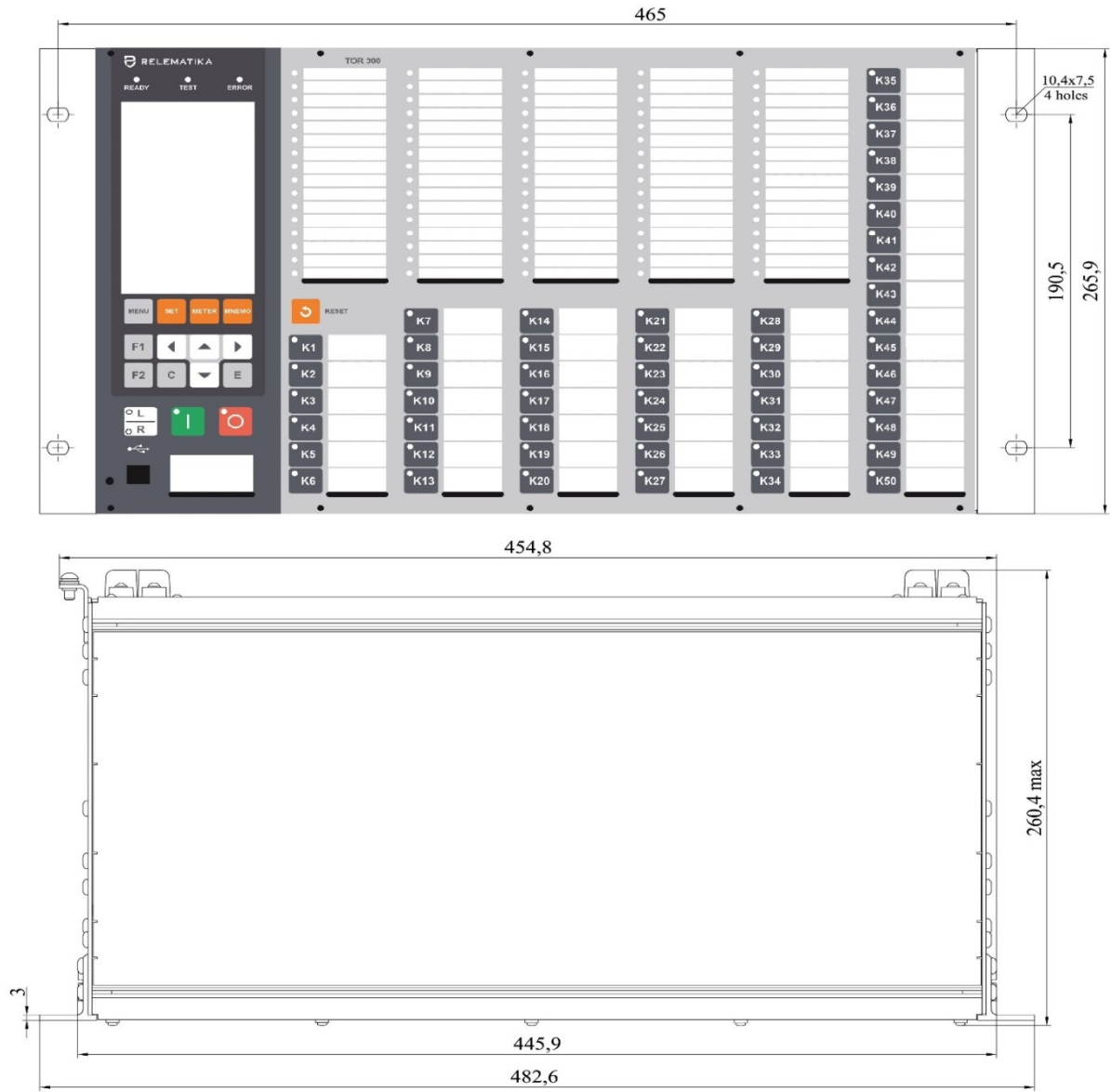
Figure B.9: 1/1 x 19" housing layout (example with alphanumeric display)

VPT-2 outline
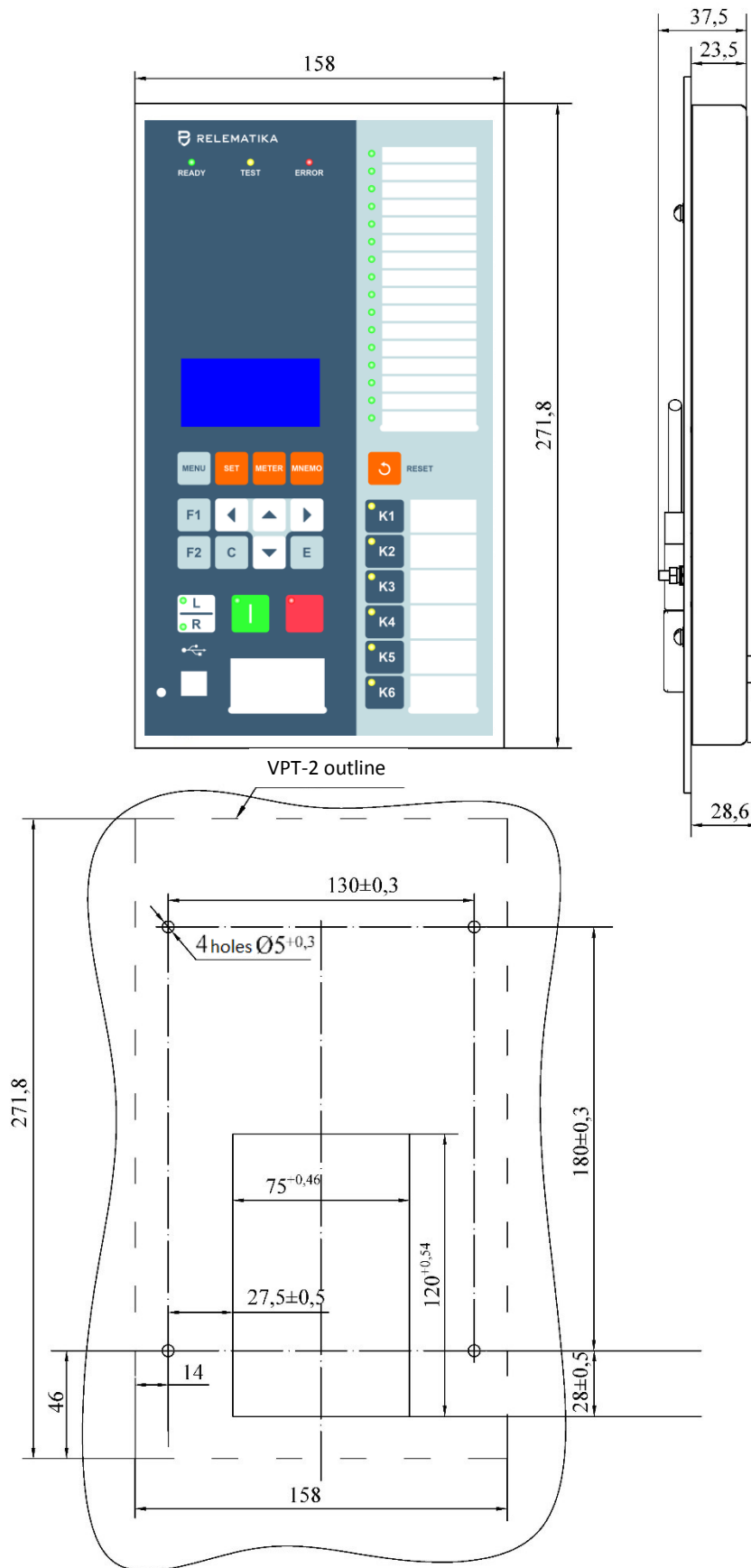
The remote control weight is max. 0,65 kg

Figure B.10: Layout, overall and mounting dimensions for the remote control VPT-02
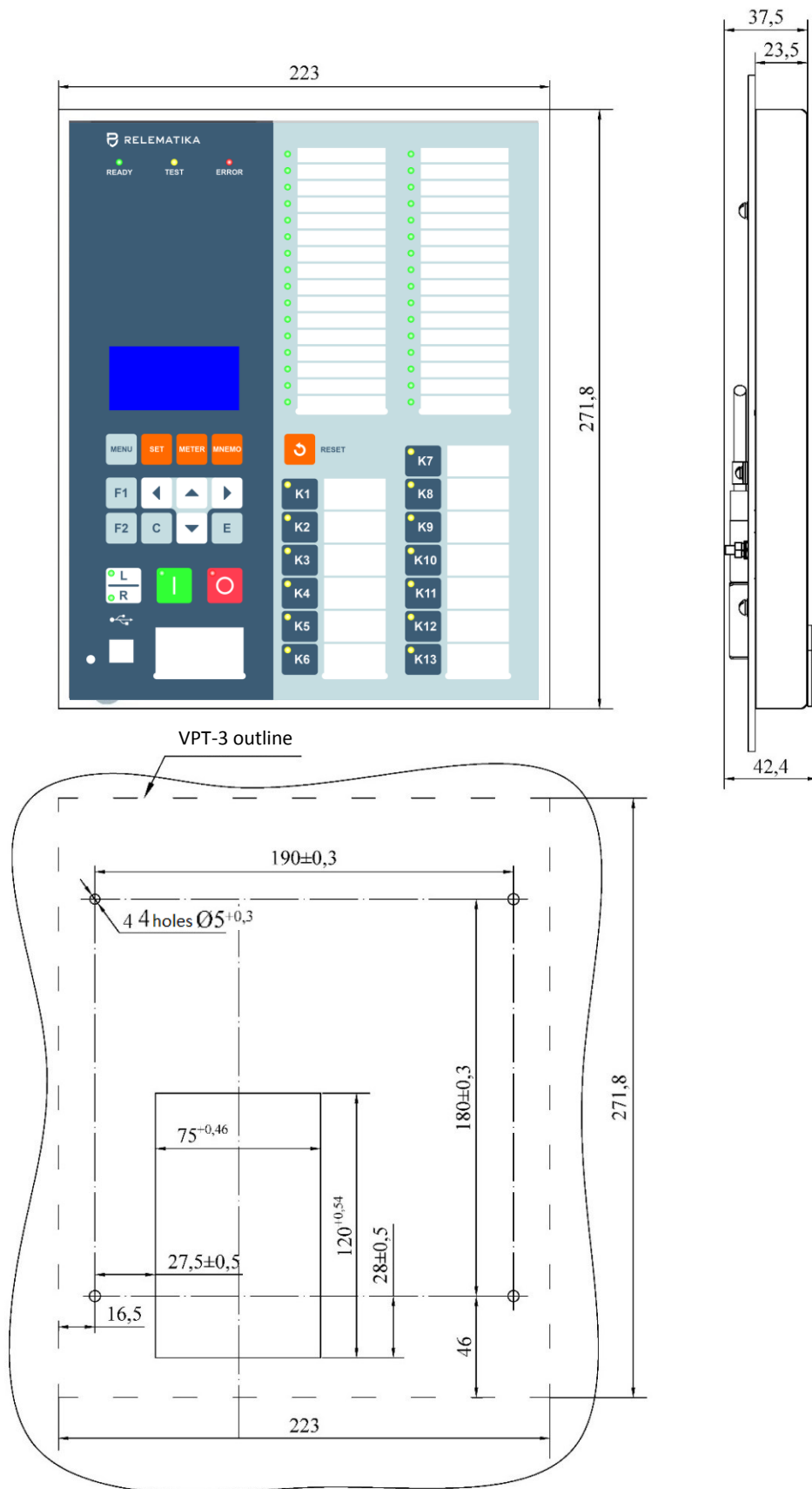
The remote control weight is max. 0,85 kg

Figure B.11: Layout, overall and mounting dimensions for the remote control VPT-03
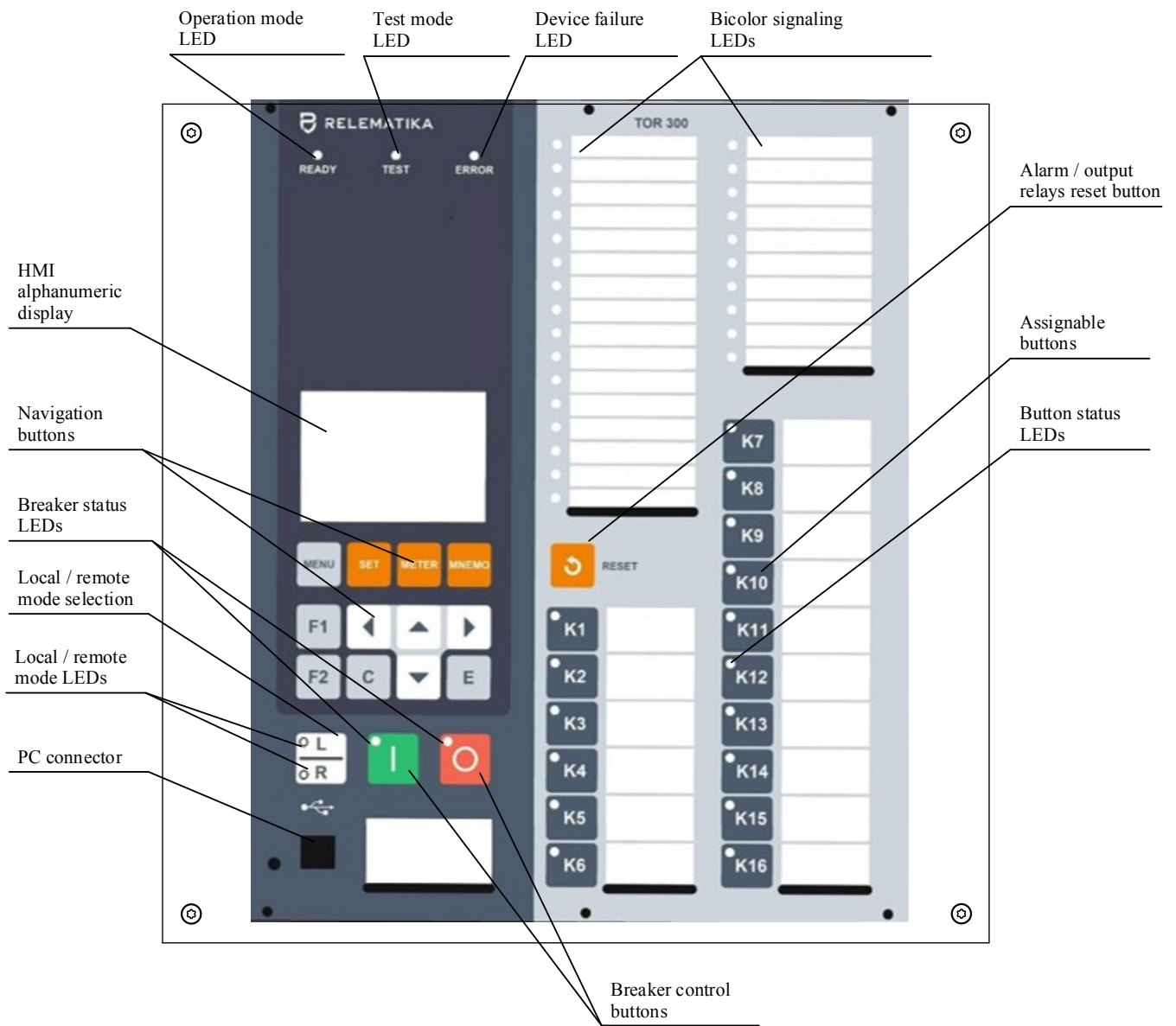
Figure B.12: The location of control and display elements for TOR 200, example with alphanumeric display

# APPENDIX C
## (obligatory)
## Binary inputs and outputs

**a)**

| 1 | Relay1.1 |
| 2 | Relay1.1 |
| 3 | Relay1.2 |
| 4 | Relay1.2 |
| 5 | Relay1.3 |
| 6 | |
| 7 | Relay1.3 |
| 8 | Relay1.4 |
| 9 | |
| 10 | Relay1.4 |
| 11 | Relay1.5 |
| 12 | |
| 13 | Failure |
| 14 | Relay1.5 |
| 15 | |
| 16 | Failure |
| 17 | |
| 18 | |

| 1 | Power supply |
| 2 | |
| 3 | Input1.1 |
| 4 | Input1.1 |
| 5 | Input1.2 |
| 6 | Input1.2 |
| 7 | Input1.3 |
| 8 | Input1.3 |
| 9 | Input1.4 |
| 10 | Input1.4 |
| 11 | Input1.5 |
| 12 | Input1.5 |
| 13 | Input1.6 |
| 14 | Input1.6 |
| 15 | Input1.7 |
| 16 | Input1.7 |
| 17 | Input1.8 |
| 18 | Input1.8 |

**b)**

| 1 | RelayN.1 |
| 2 | |
| 3 | RelayN.2 |
| 4 | |
| 5 | RelayN.3 |
| 6 | RelayN.4 |
| 7 | |
| 8 | RelayN.5 |
| 9 | RelayN.5 |
| 10 | |
| 11 | RelayN.6 |
| 12 | RelayN.6 |
| 13 | |
| 14 | RelayN.7 |
| 15 | |
| 16 | RelayN.8 |
| 17 | RelayN.9 |
| 18 | |

| 1 | RelayN.10 |
| 2 | RelayN.11 |
| 3 | RelayN.12 |
| 4 | |
| 5 | InputN.1 |
| 6 | InputN.2 |
| 7 | Common |
| 8 | InputN.3 |
| 9 | InputN.4 |
| 10 | Common |
| 11 | InputN.5 |
| 12 | InputN.6 |
| 13 | Common |
| 14 | InputN.7 |
| 15 | InputN.8 |
| 16 | Common |
| 17 | InputN.9 |
| 18 | Common |

**c)**

| 1 | RelayN.1 |
| 2 | |
| 3 | RelayN.2 |
| 4 | |
| 5 | RelayN.3 |
| 6 | RelayN.4 |
| 7 | |
| 8 | RelayN.5 |
| 9 | RelayN.5 |
| 10 | |
| 11 | RelayN.6 |
| 12 | RelayN.6 |
| 13 | |
| 14 | RelayN.7 |
| 15 | |
| 16 | RelayN.8 |
| 17 | RelayN.9 |
| 18 | |

| 1 | RelayN.10 |
| 2 | RelayN.11 |
| 3 | RelayN.12 |
| 4 | |
| 5 | InputN.1 |
| 6 | InputN.2 |
| 7 | InputN.3 |
| 8 | InputN.4 |
| 9 | InputN.5 |
| 10 | InputN.6 |
| 11 | Common |
| 12 | InputN.7 |
| 13 | InputN.8 |
| 14 | InputN.9 |
| 15 | InputN.10 |
| 16 | InputN.11 |
| 17 | InputN.12 |
| 18 | Common |

**d)**

| 1 | |
| 2 | |
| 3 | InputN.1 |
| 4 | InputN.1 |
| 5 | InputN.2 |
| 6 | InputN.2 |
| 7 | InputN.3 |
| 8 | InputN.3 |
| 9 | InputN.4 |
| 10 | InputN.4 |
| 11 | InputN.5 |
| 12 | InputN.5 |
| 13 | InputN.6 |
| 14 | InputN.6 |
| 15 | InputN.7 |
| 16 | InputN.7 |
| 17 | InputN.8 |
| 18 | InputN.8 |

| 1 | Common |
| 2 | InputN.9 |
| 3 | InputN.10 |
| 4 | InputN.11 |
| 5 | InputN.12 |
| 6 | InputN.13 |
| 7 | InputN.14 |
| 8 | InputN.15 |
| 9 | InputN.16 |
| 10 | InputN.17 |
| 11 | InputN.18 |
| 12 | InputN.19 |
| 13 | InputN.20 |
| 14 | InputN.21 |
| 15 | InputN.22 |
| 16 | InputN.23 |
| 17 | InputN.24 |
| 18 | Common |

**e)**

| 1 | RelayN.1 |
| 2 | |
| 3 | |
| 4 | |
| 5 | RelayN.2 |
| 6 | |
| 7 | |
| 8 | |
| 9 | RelayN.3 |
| 10 | |
| 11 | |
| 12 | |
| 13 | RelayN.4 |
| 14 | |
| 15 | |
| 16 | |
| 17 | RelayN.5 |
| 18 | |

| 1 | RelayN.6 |
| 2 | |
| 3 | |
| 4 | |
| 5 | InputN.1 |
| 6 | InputN.2 |
| 7 | InputN.3 |
| 8 | InputN.4 |
| 9 | InputN.5 |
| 10 | InputN.6 |
| 11 | Common |
| 12 | InputN.7 |
| 13 | InputN.8 |
| 14 | InputN.9 |
| 15 | InputN.10 |
| 16 | InputN.11 |
| 17 | InputN.12 |
| 18 | Common |

N is the serial number of a module (1 – power supply module),

a) power supply module type S3021;

b) binary IO module type B3023; c) binary IO module type B3021;

d) binary IO module type B3601; e) binary IO module type B3029

Figure C.1: Basic D30xx transformer modules layout

# APPENDIX D
# (obligatory)
# Layout of transformer modules



TV – input voltage transformers (VT type), TCVD – current input 0.15 A (TCVD type),

TA – input current transformers (CT1 type – 1 A or 5 A, CT2 type – 0.2 A, CT3 type – 0.02 A)

Figure D.1: Basic D30xx transformer modules layout

D3112       D3113       D3114

D3121       D3123       D3125       D3132
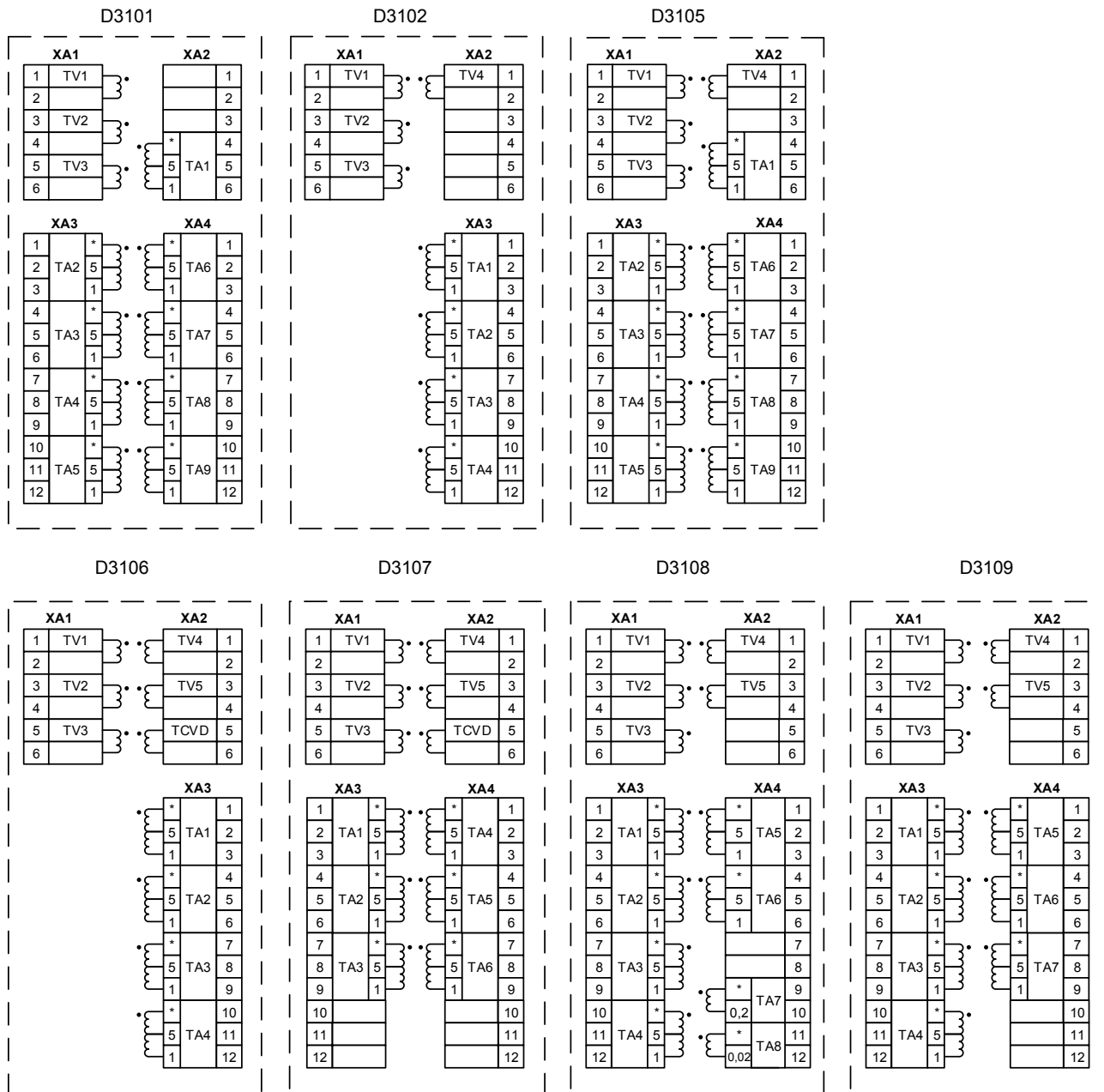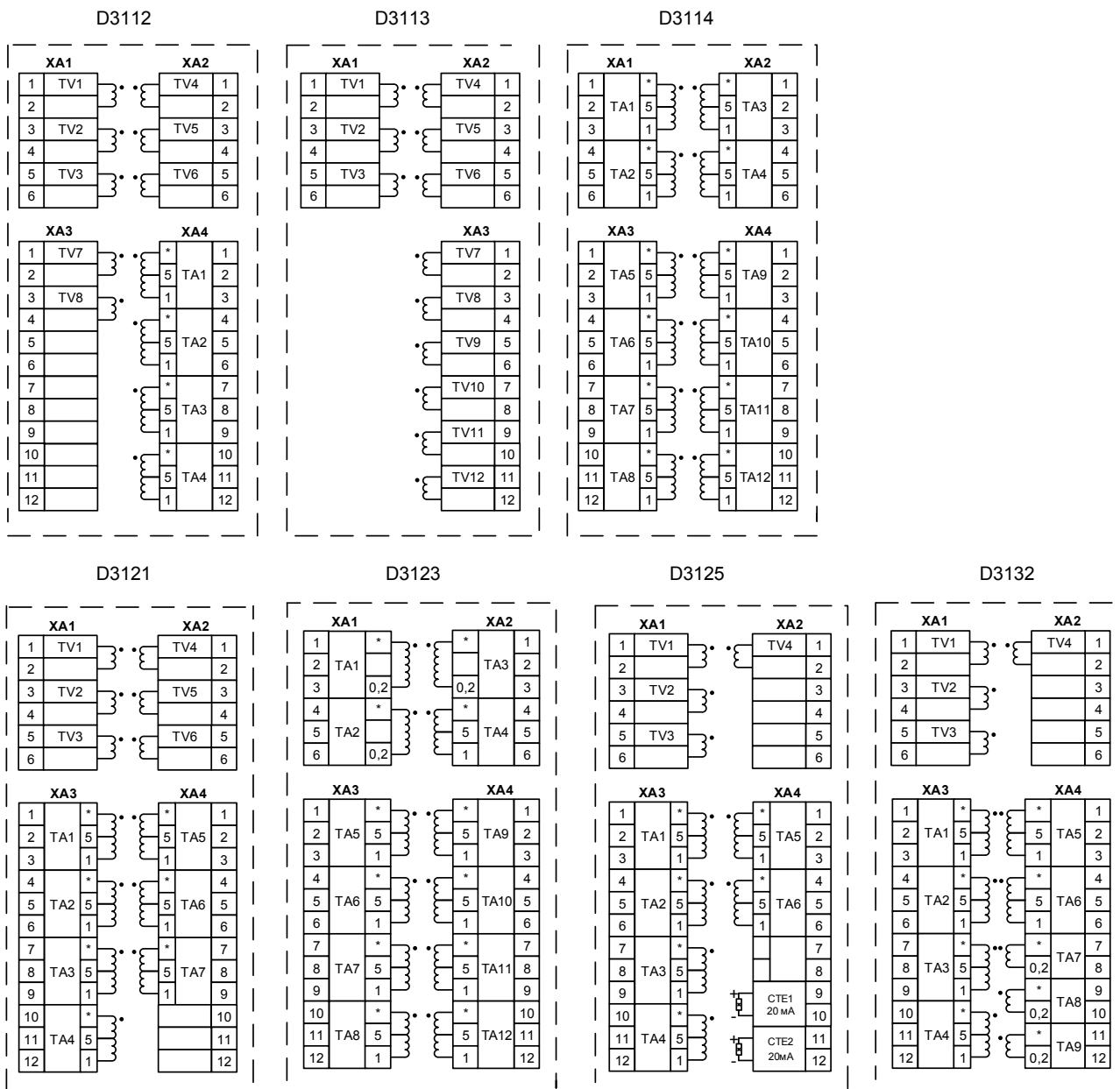
TV – input voltage transformers (VT type), CTE – ±20 mA DC/AC current inputs (CTE1 type),

TA – input current transformers (CT1 type – 1 A or 5 A, CT2 type – 0.2 A, CT3 type – 0.02 A)

Figure D.2: Basic D30xx transformer modules layout
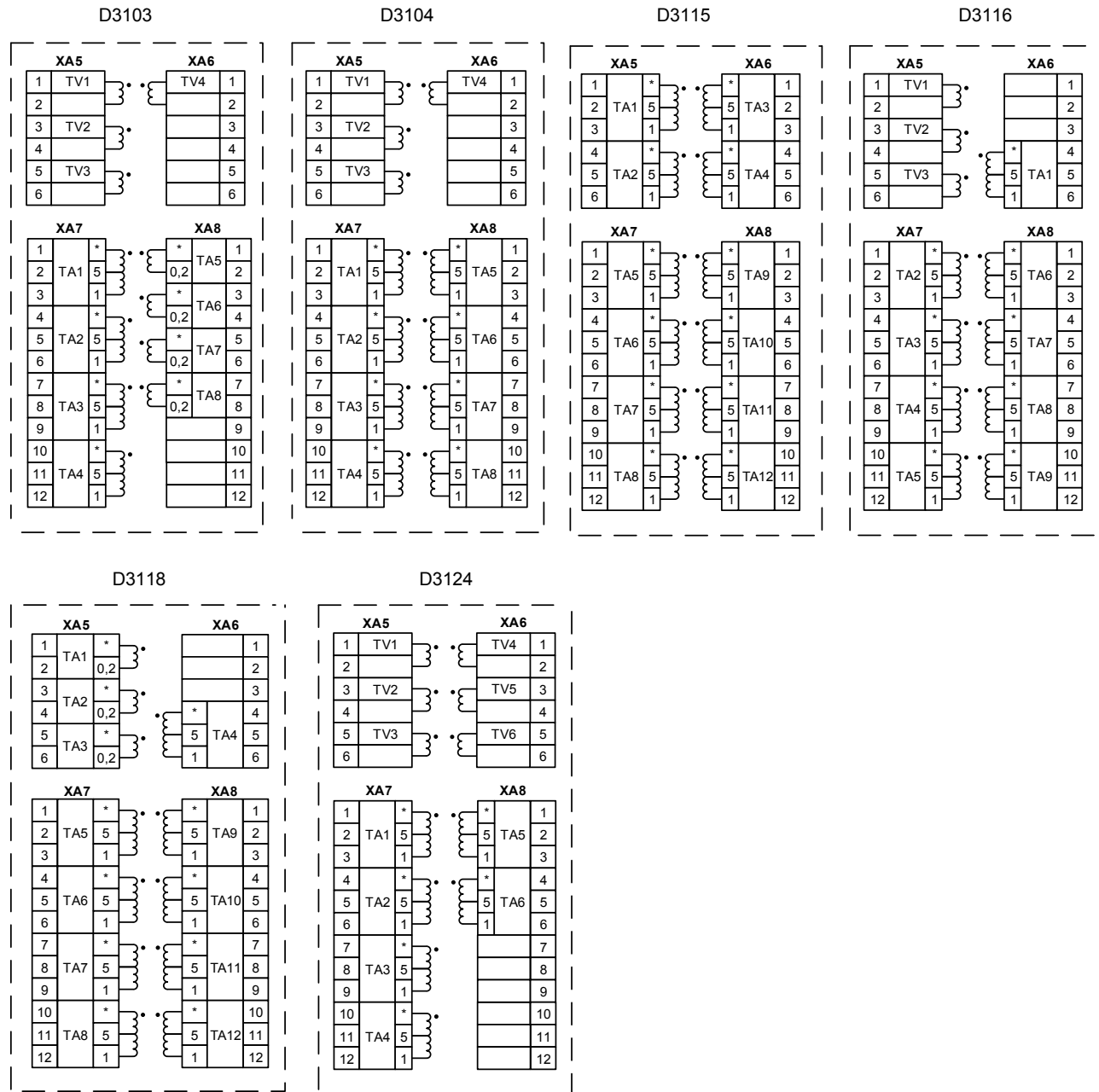
TV – input voltage transformers (VT type),

TA – input current transformers (CT1 type – 1 A or 5 A, CT2 type – 0.2 A, CT3 type – 0.02 A)

Figure D.3: Additional D30xx transformer modules layout

## APPENDIX E
## (obligatory)
## Communication port contacts designation

**a)**

| Circuit | | ≺ | «XT1» («XT4») |
|---|---|---|---|
| 100 Base-T Ethernet | Tx+ | 1 | |
| | Tx- | 2 | |
| | Rx+ | 3 | |
| | Rx- | 6 | |

| Circuit | | ≺ | «XT2» («XT5») |
|---|---|---|---|
| 100 Base-T Ethernet | Tx+ | 1 | |
| | Tx- | 2 | |
| | Rx+ | 3 | |
| | Rx- | 6 | |

**b)**

| Circuit | | ≺ | «XT1» («XT4») |
|---|---|---|---|
| 100 Base-F Ethernet | Rx | ← | |
| | Tx | → | |

| Circuit | | ≺ | «XT2» («XT5») |
|---|---|---|---|
| 100 Base-F Ethernet | Rx | ← | |
| | Tx | → | |

**c)**

| Circuit | | ≺ | «XT20» |
|---|---|---|---|
| 100 Base-T Ethernet | Tx+ | 1 | |
| | Tx- | 2 | |
| | Rx+ | 3 | |
| | Rx- | 6 | |

Figure E.1: Ethernet communication ports

**a)**

| Circuit | | ⇉ | «XT4» |
|---|---|---|---|
| RS-485 | Common | 1 | |
| | D+ | 2 | |
| | D− | 3 | * |
| | R | 4 | |

| Circuit | | ⇉ | «XT5» |
|---|---|---|---|
| RS-485 | Common | 5 | |
| | D+ | 6 | |
| | D− | 7 | * |
| | R | 8 | |

**b)**

| Circuit | | ≺ | «XT4» |
|---|---|---|---|
| FO (SCADA) | Rx | Dark | |
| | Tx | Light | |

| Circuit | | ≺ | «XT5» |
|---|---|---|---|
| FO (SCADA) | Rx | Dark | |
| | Tx | Light | |

The jumpers are used if device is installed at the end of communication line. Resistor quantity should not exceed two.

Figure E.2: Communication ports of RS-485 and fiber optic for SCADA

| Circuit | | ⊰ | «XT6» |
|---|---|---|---|
| 100 Base-T Ethernet | Tx+ | 1 | |
| | Tx- | 2 | |
| | Rx+ | 3 | |
| | Rx- | 6 | |

| Circuit | | ⊰ | «XT7» |
|---|---|---|---|
| 100 Base-T Ethernet | Tx+ | 1 | |
| | Tx- | 2 | |
| | Rx+ | 3 | |
| | Rx- | 6 | |

| Circuit | | ⊰ | «XT8» |
|---|---|---|---|
| 100 Base-T Ethernet | Tx+ | 1 | |
| | Tx- | 2 | |
| | Rx+ | 3 | |
| | Rx- | 6 | |

a)

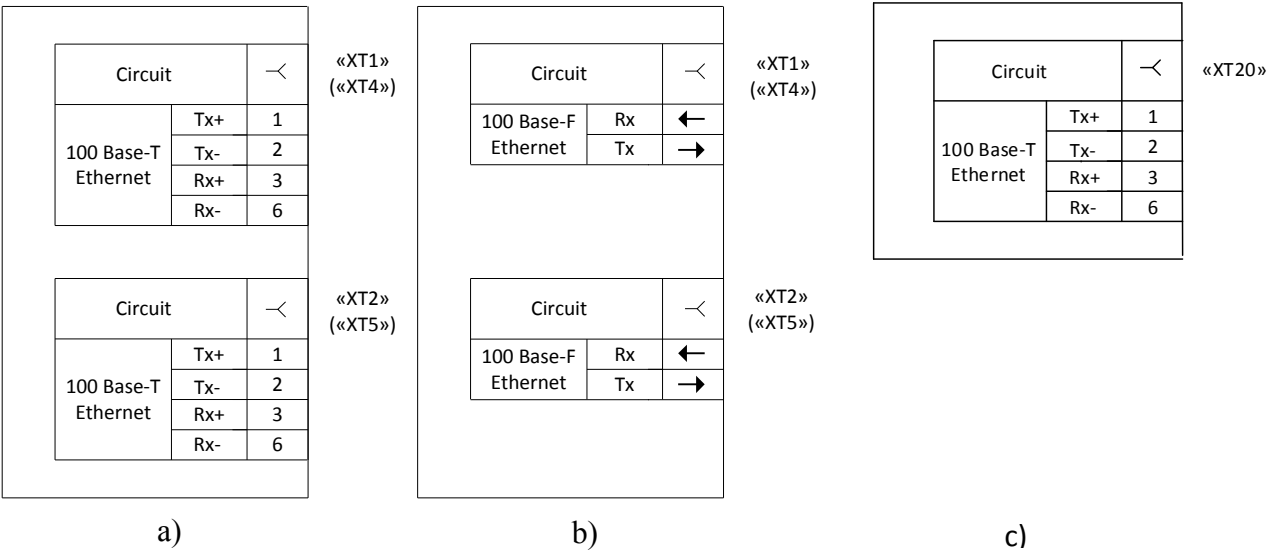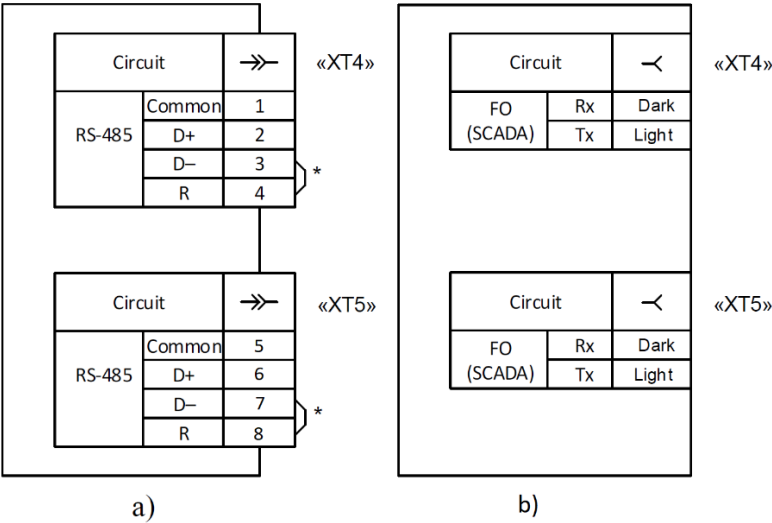| Circuit | | ⊰ | «XT6» |
|---|---|---|---|
| 100 Base-T Ethernet | Tx+ | 1 | |
| | Tx- | 2 | |
| | Rx+ | 3 | |
| | Rx- | 6 | |

| Circuit | | ⊰ | «XT7» |
|---|---|---|---|
| 100 Base-F Ethernet | Rx | ← | |
| | Tx | → | |

| Circuit | | ⊰ | «XT8» |
|---|---|---|---|
| 100 Base-F Ethernet | Rx | ← | |
| | Tx | → | |

b)

| Circuit | | ⊰ | «XT9» |
|---|---|---|---|
| 100 Base-T Ethernet | Tx+ | 1 | |
| | Tx- | 2 | |
| | Rx+ | 3 | |
| | Rx- | 6 | |

| Circuit | | ⊰ | «XT10» |
|---|---|---|---|
| 100 Base-T Ethernet | Tx+ | 1 | |
| | Tx- | 2 | |
| | Rx+ | 3 | |
| | Rx- | 6 | |

| Circuit | | ⊰ | «XT11» |
|---|---|---|---|
| 100 Base-T Ethernet | Tx+ | 1 | |
| | Tx- | 2 | |
| | Rx+ | 3 | |
| | Rx- | 6 | |

c)

| Circuit | | ⊰ | «XT9» |
|---|---|---|---|
| 100 Base-F Ethernet | Rx | ← | |
| | Tx | → | |

| Circuit | | ⊰ | «XT10» |
|---|---|---|---|
| 100 Base-F Ethernet | Rx | ← | |
| | Tx | → | |

| Circuit | | ⊰ | «XT11» |
|---|---|---|---|
| 100 Base-T Ethernet | Tx+ | 1 | |
| | Tx- | 2 | |
| | Rx+ | 3 | |
| | Rx- | 6 | |

d)

Figure E.3: Communication modules

| Circuit | | ⊸< | «XT3» |
|---|---|---|---|
| FO (DPL) | Rx | Dark | «Rx1» |
| | Tx | Light | «Tx1» |
| FO (DPL) | Rx | Dark | «Rx2» |
| | Tx | Light | «Tx2» |

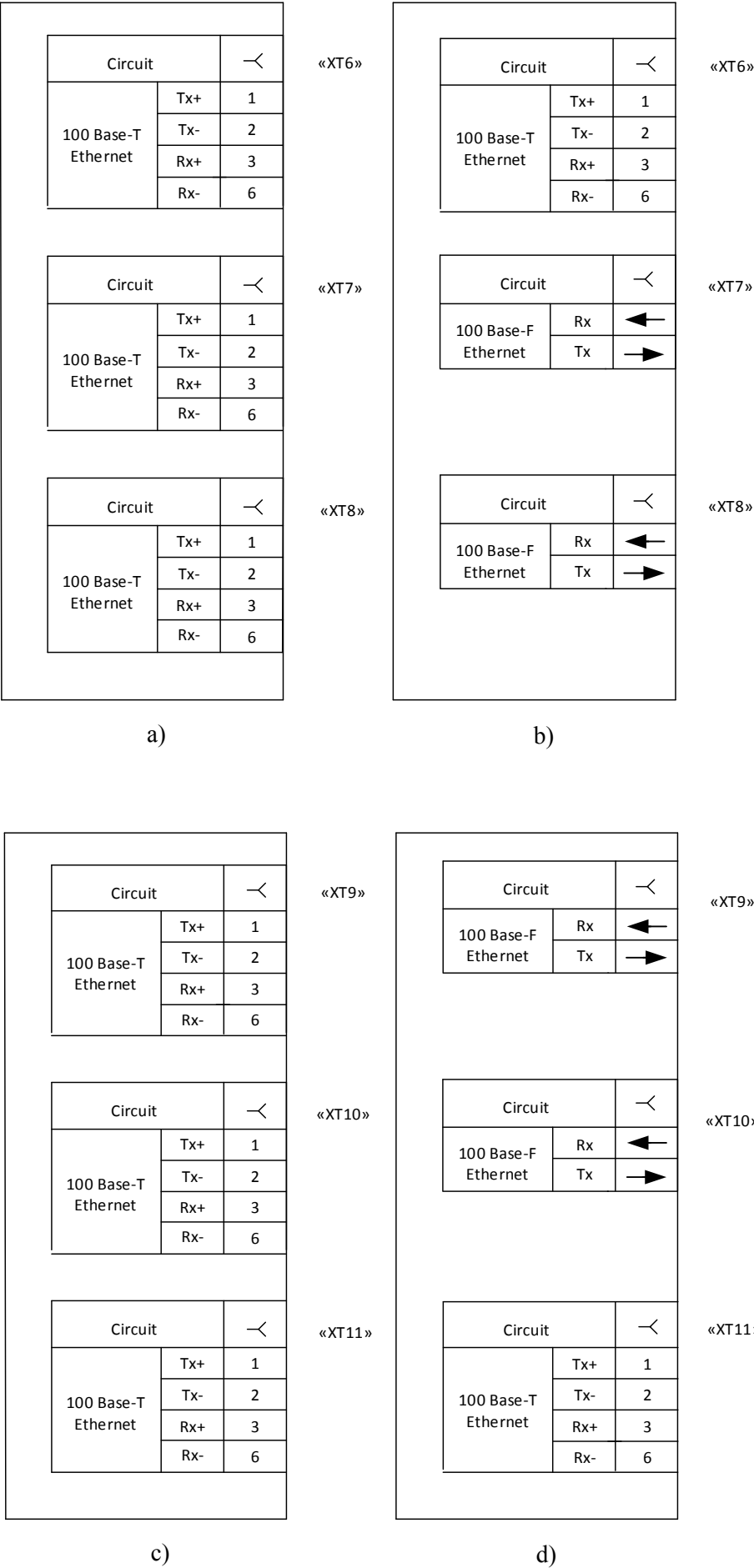| Circuit | ⟶≫⟶ | «XT3» |
|---|---|---|
| Output relay contacts | 1 | |
| | 2 | |
| +OUT | 3 | |
| -OUT | 4 | |
| +IN | 5 | |
| -IN | 6 | |
| +OUT | 7 | |
| -OUT | 8 | |
| +IN | 9 | |
| -IN | 10 | |

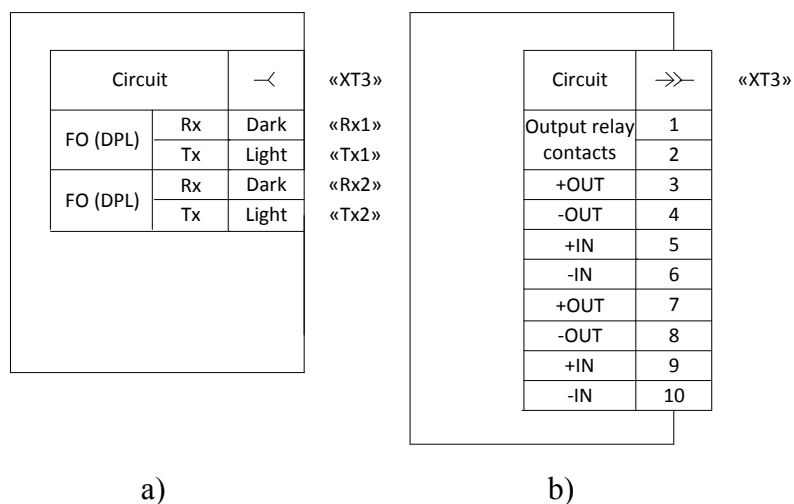a)                                                  b)

Figure E.4: Communication ports of fiber optic line differential protection and HF carrier ports (for carrier type protections)

Communication ports are described in Table E.1.

Table E.1: Communication port description

| Connector designation on a backplane | Figure | Communication port |
|---|---|---|
| «XT1» («XT4») | C.1 a) | Ethernet 100 Base-T |
| | C.1 b) | Ethernet 100 Base-F |
| «XT2» («XT5») | C.1 a) | Ethernet 100 Base-T |
| | C.1 b) | Ethernet 100 Base-F |
| «XT4», «XT5» | C.2 a) | RS-485 |
| | C.2 b) | Fiber-optic communication line (SCADA) |
| «XT3» | C.3 a) | Fiber-optic communication line (line current differential protection) |
| | C.3 b) | HF communication ports (carrier types of protection) |
| «XT6», «XT11» | C.3 | Ethernet 100 Base-F |
| «XT7», «XT8», «XT9», «XT10» | C.3 a), c) | Ethernet 100 Base-F |
| | C.3 b), d) | Ethernet 100 Base-F |
| Note – If there are four Ethernet ports, XT4, XT5 connectors are used. | | |

If four Ethernet ports are available, XT4 and XT5 connectors are used.

# APPENDIX F
## (obligatory)
## List of equipment and measuring instruments

Table F.1 – List of equipment and measuring instruments

| Name of equipment | Range of measured (controlled) values | Accuracy class or measurement error | Recommended equipment or normative document |
|---|---|---|---|
| Voltmeter universal digital | (0 – 1000) V | ±0,1 % | GDM-8246 GDM-8245 |
| Multimeter digital | (0 – 750) V, (0 – 10) A | ±0,1 % | APPA-107N, APPA-109N |
| AC ammeter | (0,5 – 1) A, (5 – 10) A | 0,5 | E537, E539 |
| DC power supply | (0 – 6) A, (0 – 30) V | ±0,5 % | GPS-2303, GPS-3303, GPS-4303 |
| DC power supply | (8 – 300) V, (1 – 30) A | $\pm(0,005 U_{set}+0,2V)$ $\pm(0,005 I_{set}+0,02A)$ | GPR |
| Milliohmmeter | from 10 µOhm to 1 kOhm | ±(0,1 %+0,5 µOhm) | MIKO-7 |
| Megaohmmeter | (0 – 1000) MOhm 500 V | ± 15 % | ES0202/1-G |
| Electronic oscilloscope | (0 – 300) V, (5 – 400) HZ | ±10 %. ±1 % | TDS2012, GDS-820S |
| Electronic stopwatch-meter of time parameters | from 1 to 999999 ms | at DC ±(0,0001 T +0,1 ms), at AC ±(0,0001 T +1 ms +0.5 period), where T is the measured value of the time interval | IVPR-203M TC 4282-001-33865949-2009 |
| Calipers | (0 – 400) mm | ±0,05 mm | SchC-II-400-0,05 GOST 166-89 |
| Meter of resistance, humidity and degree of aging of electrical insulation | (50 – 2500) V, 50 Hz | ±10 % | MIC-2500 |
| Installation for testing electrical safety | (100 – 5000) V | ±(0,03U+30 V) | GPT-815 |

Note - When carrying out tests and checks, it is allowed to use other equipment that ensures the measurement of controlled parameters with an accuracy not lower than required.

**ABBREVIATIONS**

| | |
|---|---|
| AC | Automatic Control |
| ACPS | Automatic Control Process System |
| ADC | Analog Digital Convertor |
| BDUBus | Proprietary technological protocol |
| BI/BO | Binary Input/Output |
| CP | Central Processing |
| CVT | Capacitive Voltage Devider (Transformer) |
| DPL | Differential Protection of the Line |
| DR | Disturbance Recorder |
| DSP | Digital Signal Processing |
| ETL | Electric Transmission Line |
| FLOC | Fault LOCator |
| FO | Fiber Optic |
| IED | Intelligent Electronic Devices |
| IP-address | IP address of the IED in LAN |
| GPS | Global Positioning System |
| GLONASS | Global Navigation Satellite System |
| HF | High-Frequency |
| HMI | Human Machine Interface |
| ME | Measuring Element |
| MVT | Measuring Voltage Transformer |
| NTP/SNTP | Network Time Protocol/Simple Network Time Protocol |
| OM | Operation Manual |
| PAC | Protection Automation & Control |
| PC | Performance Criteria |
| PDP | Phase Differential Protection |
| PLC | Power Line Carrier |
| PPS | Peripheral Power Supply |
| RAM | Random-Access Memory |
| ROM | Non-Volatile Memory |
| SBO | Select – Before - Operate |
| SCS | Substation Control System |
| SL | Severity Level |
| SMS | Substation Monitoring System |
| SW | Software |
| TWFL | Travelling Wave Fault Locator |