# TRACTION NETWORK MONITORING AND PROTECTION SYSTEM SMTN-3

**CITY ELECTRIC TRANSPORT** ■
**RAILWAYS** ■ **METRO** ■ **INDUSTRY**

# TRACTION NETWORK MONITORING AND PROTECTION SYSTEM

With increased traffic stream and reduction of rolling stock movement interval arises an ever-greater need for intelligent relay protection devices provided for contact networks protection against overloads and short circuit currents. For these purposes, PLUTON experts developed **innovative traction network monitoring and protection system SMTN-3**, the third generation of protection devices based on leading-edge technologies.

Traction network monitoring and protection system, series SMTN-3 is provided for:

- traction network protection against short circuit current and harmful overloads;
- traction network parameters monitoring in real-time;
- data acquisition for the following analysis of emergency processes;
- providing operating personnel with data in the shortest time possible for the following analysis.

## COMPLIANCE WITH INTERNATIONAL STANDARDS

Traction network monitoring and protection system SMTN-3 produced by PLUTON was successfully type-tested for compliance with the standards of International Electrotechnical Commission (IEC) in Aucoteam GMBH Test Center (Berlin, Germany).

Traction network monitoring and protection system corresponds to international standards:

- IEC60068-2 ("Environmental tests"),
- IEC60255-21 ("Electrical relays - Part 21: Vibration, shock, seismic resistance"),
- IEC 60255-26 ("Measuring relays and protection systems - part 26: Requirements to electro-magnetic compatibility").

## APPLICATION AREA

SMTN-3 is applied in traction substations switchgears:

- in city electric transport,
- metro,
- railways,
- industrial enterprises,
- mining industry.

## SYSTEM CAPABILITIES

Traction networks protection is provided by monitoring of traction network voltage and current dynamics change. In case of protective functions preset parameters exceed the system issues a command to open high speed circuit breaker.

SMTN-3 provides the following operation capabilities:

- **measurement** of traction network voltage and current value and shape in different modes, including short-circuit in line;
- **protection** of traction network against short-circuit currents, including remote short circuits low currents and overloads;
- **oscillography and long-term memory record** of voltage and current value and shape under short circuits (one of emergency process protections detection in traction network);
- **waveforms storage and display**, as well as data for further analysis transfer to upper level system (or PC);
- **software-based internal configuration setting** (protections input, protective characteristics selection, number of protection stages, etc.);
- local and remote **input, storage and display of protection settings**;
- **storage of two setting sets** and switching of setting sets by external signal;
- **information** on the number and time of protections operation storage and **output**;
- **analysis** of current distribution between incoming panels.

## BENEFITS

- traction network protection against short circuit current and harmful overloads;
- remote data access using Ethernet and Web interface;
- high reliability and computing power;
- high speed and high value measuring accuracy;
- international standards compliance.



▲ SMTN-3 system modules

## SYSTEM MODULS

SMTN-3 is designed as a set of separate modules, fixed on DIN-rail and connected with each other:

- **measuring module** with voltage divider is located in high voltage area (busbar compartment);
- **processing module** is located in low voltage area (control compartment).

Measuring and processing modules are interconnected with optic cable that provides transmission of information between modules, as well as galvanic isolation between high voltage measuring circuits and secondary circuits.
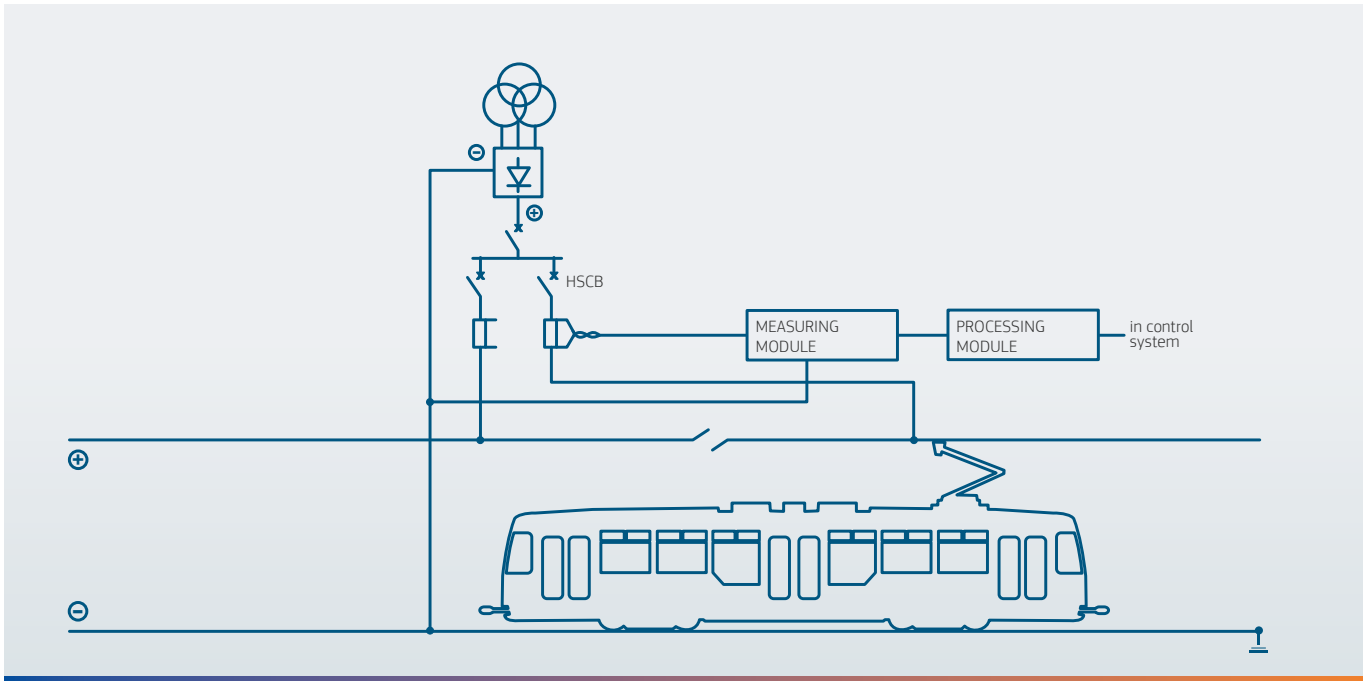
▲ Functional diagram



▲ Measuring module

▲ SMTN-3 system modules in assembly with DC switchgear

▲ Processing module

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# SYSTEM COMPONENTS FUNCTIONS



▲ Processing module

## Processing module

Processing module processes all the data received from measuring module and other additional modules, as well as digital inputs. Processing module consists of several computer systems, interconnected with data busbars.

### Main functions:

- primary processing and storage of current data from measuring module;
- current and voltage values normalization;
- validity diagnostics and control of data received from measuring module;
- protection functions (analysis of data from measuring module according to protection algorithms);
- generation of switching devices emergency tripping signals in accordance with protection functions;
- registration and storage of traction network emergency processes data;
- system events logging;
- system settings storage;
- system self-test;
- communication with traction substation automated control system upper-level system;
- access to changing and configuration of system parameters using "Human Machine" interface (HMI).

## Measuring module

Measuring module is directly connected to voltage and current measurement primary sensors. Current sensor is a resistive element of power circuit (shunt). Voltage sensor is a resistive voltage divider located inside measuring module. It is provided for the measured voltage reduction to the level suitable for further processing in the electronic modules.

### Main functions:

- matching with the primary sensors (shunts, voltage dividers);
- galvanic isolation of low voltage circuits from traction network high potential using static power supply unit;
- processing of analog input electrical quantities to match them with processing module interfaces;
- pre-filtering of input signal based on analog and digital filters;
- transfer of input electrical values analog processed data in processing module using optic cable.



▲ Measuring module

## PROTECTION FUNCTIONS

SMTN-3 provides smooth and reliable operation of the system, as well as filtering against false tripping.

It performs the following **protection functions:**

- instantaneous overcurrent;
- overcurrent protection;
- current rate of rise protection;
- current increment directional protection;
- overvoltage protection;
- undervoltage protection;
- thermal protection;
- breaker failure.

## ADDITIONAL FUNCTIONS

Optionally, the system is equipped with the following systems (modules) that extend functional range of the system as a whole:

- line tester (short circuits tester);
- cable insulation control system.

**Cable insulation control system** continuously monitors cable insulation resistance and in case of insulation degradation gives a warning signal to open high-speed circuit breaker.

Cable insulation control system is provided for internal and external cable insulation resistance values measurement in traction networks up to 1000 V DC.

Data transfer between cable insulation control system and SMTN-3 central unit is going via optical fiber. Moreover, optical fiber provides electrical isolation between systems modules and ensures safe usage of device.
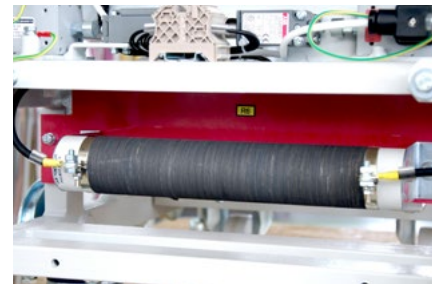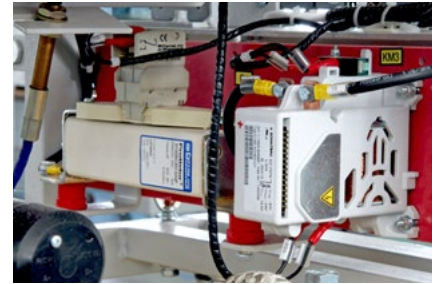


▲ Line tester (short circuits tester)

**Line tester (short circuits tester)** allows to determine line impedance before high-speed circuit breaker closing. In case if line impedance is lower then the setting parameter, the system issues a prohibition to close high-speed circuit breaker.



▲ Cable insulation control system

# EVENTS AND PARAMETERS LOGGING

SMTN-3 generates and stores the following records:
- events log;
- failures log;
- emergency oscillograph records.

The records are stored on nonvolatile solid data storage medium, that guarantees high reliability and data storage in case of devices power supply interruption.

SMTN-3 system provides generation and storage of emergency oscillograph records. Emergency oscillograph record generation is performed when one of protective functions operates.

Two records of emergency oscillograph are generated and saved when one of the protection functions operates:
- "Fast track";
- "Slow track".

Emergency oscillograph records include:
- current and voltage oscillogram generated directly from the measured values (sampling period 50 μs for "Fast track" and 100 ms for "Slow track"); state diagram of digital inputs and outputs for the entire duration of voltage and current oscillogram recording;
- track generation astronomical time;
- kind of tripped protection;
- tripping protections settings.

The length of "Fast track" and "Slow track" oscillograms is fixed and contains 2048 current and voltage values.

Time of each record is:
- "Fast track" - 100 ms;
- "Slow track" - 100 s.

"Fast track" and "Slow track" oscillograms contain successive current and voltage values up to one of protection functions tripping (hereinafter "Prehistory") and after one of protection functions tripping (hereinafter "Post-history").

Number of current and voltage values in "Prehistory" for each track is an individually set parameter and can be changed with the help of settings.

SMTN-3 stores up to 200 records of emergency processes. When the limit is exceeded, a new record will be saved instead of the oldest one.

SMTN-3 system also logs maximum values of current and voltage. When newly measured current or voltage values exceed the previously logged ones, new values are recorded instead of old ones. Comparison is made independently for current and voltage channels.

Recorded maximum values can be reset, provided that new maximum values logging cycle begins anew.
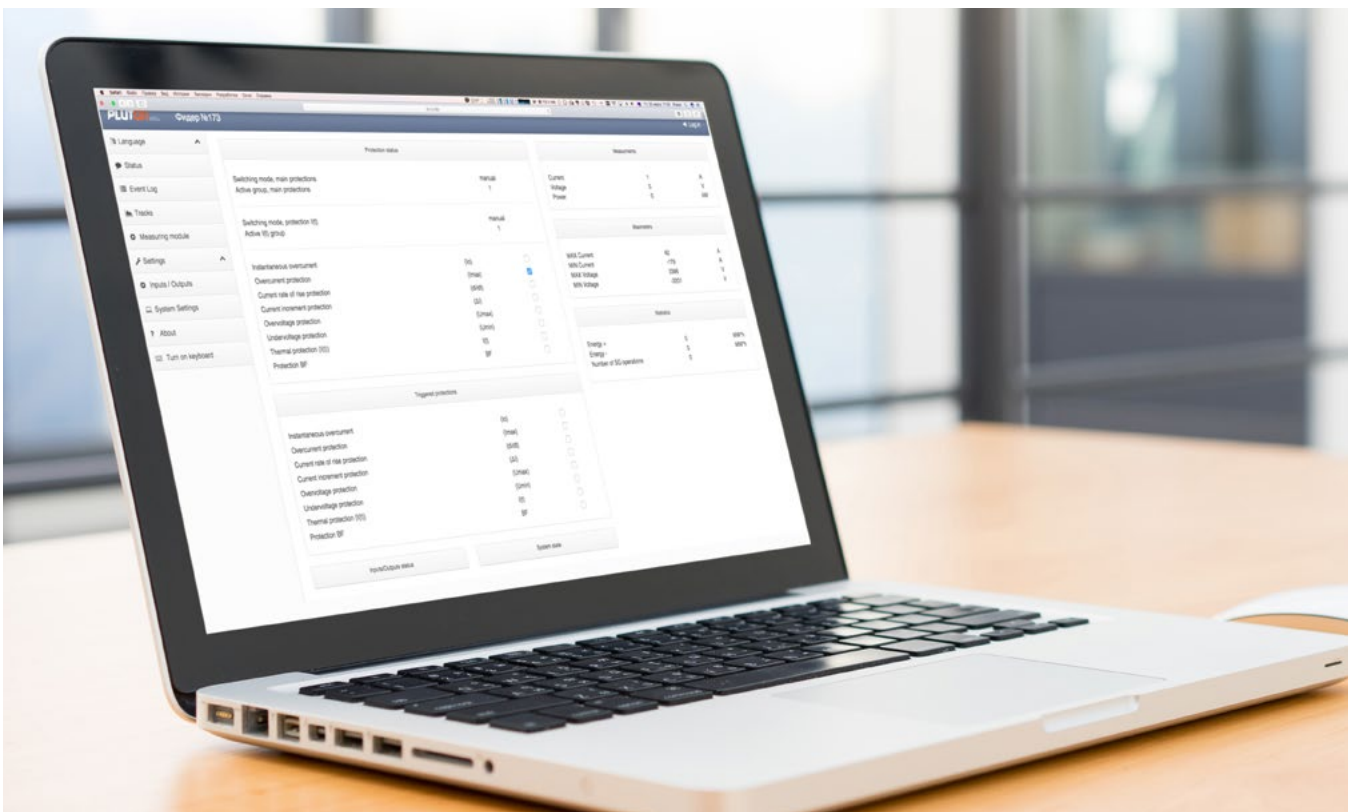


▲ HMI interface on panel PC screen

Emergency records can be viewed using Web interface, read by upper level system via Ethernet or saved on external USB-disk for later analysis using a PC.



**Integration with SCADA systems**

**Remote access to data using Ethernet (ModBus TCP/IP) interface**

**Saving Data to USB**

▲ Access to system data



▲ Parameters setting in Web interface

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# PARAMETERS SETTING

SMTN-3 system provides the following methods of parameters setting, both of the system itself and protection functions parameters:

- local "Human Machine" interface based on LCD touch screen;
- remote "Human Machine" interface based on Web technologies;
- remote access to device using ModbusTCP/IP protocol, for upper level systems and power management systems, etc.

Remote "Human Machine" interface based on Web technology is an integrated Web server in each SMTN-3 processing module.

It does not require any additional software installation on computer. This interface is used to configure, display and analysis of data acquired by SMTN-3 system.

Communication with SMTN-3 Web server can be fulfilled via Ethernet cable or by wireless connection via PC, tablet or smartphone. Only Web browser installed on the device is needed to work with SMTN-3 Web server.
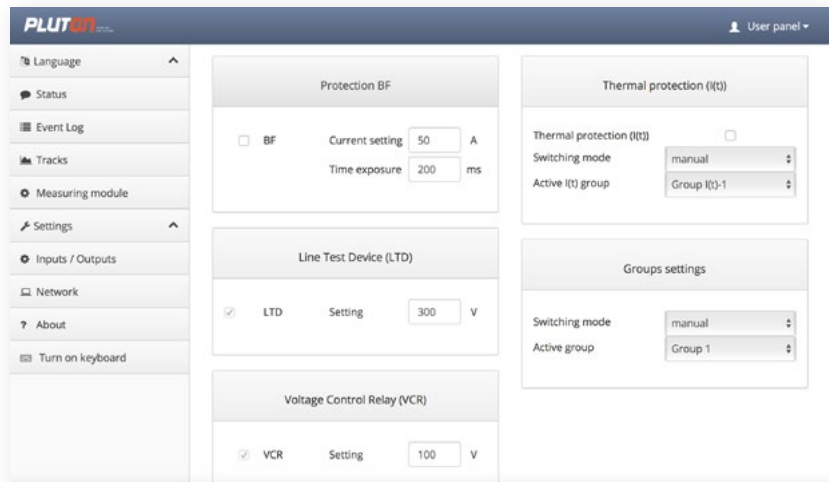
"Human Machine" interface is in English and Russian languages. The interface can also be implemented in other languages.
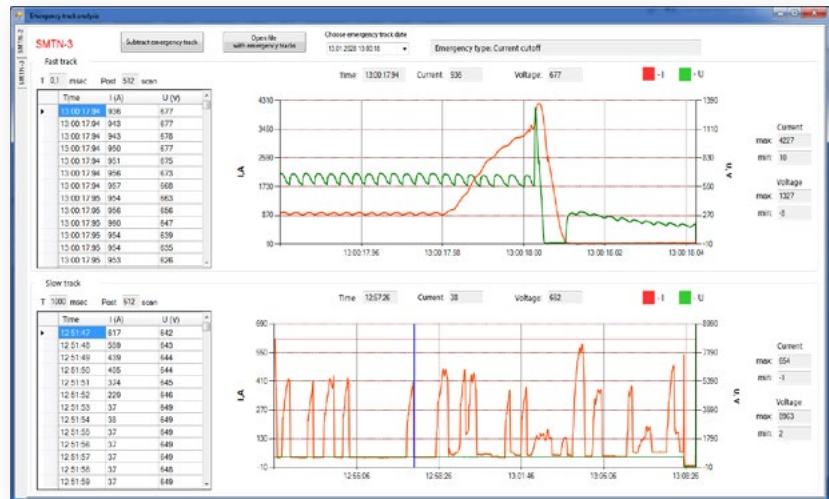


▲ Remote viewing of emergency records



▲ Fast track curve in Web interface



▲ Parameters setting screen in Web interface

# MAIN TECHNICAL DETAILS OF TRACTION NETWORK MONITORING AND PROTECTION SYSTEM SMTN-3

| Name of parameter | | Value |
|---|---|---|
| **Main parameters** | | |
| Number of current measuring channels | pc. | 1 |
| Number of voltage measuring channels | pc. | 1 |
| Type of current sensor | - | Shunt |
| Power circuit voltage measuring range | V | -2000...+2000*<br>-8000...+8000* |
| Input voltage range for power circuit current measuring channel (DC generated voltage on shunt) | V | -0.5...+0.5 |
| Current measuring range<br>where:<br>Ish – shunt rated current;<br>Ush – voltage drop on shunt under rated current. | A | $I_{max} = \pm \dfrac{0.4 \cdot I_{sh}}{U_{sh}}$ |
| Measured values sampling period | μs | 50 |
| Current measuring accuracy, max, of Ish | % | 0.5 |
| Voltage measuring accuracy, max, of measuring range | % | 0.5 |
| Insulation strength between measuring module  power circuit and power supply circuit, minimum | kV | 10<br>(30)* |
| **Measured values** | | |
| | - | • Current (current channel)<br>• Voltage (voltage channel)<br>• Power (calculated)<br>• Energy (calculated)<br>• Test current (Line tester channel) |
| **External signals** | | |
| Number of high speed digital outputs | pc. | 5 |
| Digital outputs designation | - | Signals issuing is set individually for each output under one or several protection functions tripping |
| Number of digital inputs | pc. | 5 |
| Digital inputs designation | - | Set individually for each input:<br>• HSCB condition control,<br>• external opening signal,<br>• timesync. |
| **Power supply** | | |
| Rated operating voltage | V | ⚌ 5; 12; 24 ; 48, 110; 220<br>≈110; 220 |
| SMTN-3 system max consumed power, max | W | 15 |
| Permissible voltage long-term tolerances | % | -15...+10 |
| **Communication interfaces** | | |
| Data transfer interface | - | Ethernet |
| Data transfer protocols | - | Web technologies<br>Modbus TCP/IP |
| **Reliability** | | |
| Mean Time Between Failures (MIL-HDBK-217F) | hours | 100 000 |
| Total average lifetime<br>(under condition of the required technical maintenance activities provision) | years | 25 |

| Name of parameter | | Value |
|---|---|---|
| **Design** | | |
| Protection degree of modules in acc. with DIN VDE 0470 and EN 60529 or IEC 529 | | IP3X |
| Cooling | | natural, air |
| Type of modules mounting | | DIN-rail (TH 35, EN 50022) |
| **Protection functions** | | |
| Code ANSI | 50<br>76<br><br><br>59<br>27<br>49<br>BF | • Instantaneous overcurrent<br>• Overcurrent protection<br>• Current rate of rise protection<br>• Current increment directional protection<br>• Overvoltage protection<br>• Undervoltage protection<br>• Thermal protection<br>• Breaker failure |
| Period of data processing by protective functions algorithms | µs | 50 |
| Number of settings groups | | 2 |
| **Measuring and logging functions** | | |
| Measured values | | • Current<br>• Voltage<br>• Power<br>• Energy<br>• HSCB tripping counter<br>• Test Current (Line tester Channel) |
| Number of recorded oscillograms under emergency event** occurrence | pc. | 2<br>• "Fast track"<br>• "Slow track" |
| Emergency oscilligraph records coverage width | | • Current curve;<br>• Voltage curve;<br>• Digital inputs and outputs state diagram;<br>• Astronomical time;<br>• Type of tripped protection. |
| Emergency oscilligraph records coverage depth | points | 2048 (for each measured value) |
| Signals sampling frequency in "Fast track" record | kHz | 20 |
| Signals sampling period in "Slow track" record | Hz | 10 |
| "Fast track" record time coverage depth | ms | 100 |
| "Slow track" record time coverage depth | s | 100 |
| Prehistory *** record time coverage depth in "Fast track" record | points | Set<br>0 - 2048 |
| Prehistory *** record time coverage depth in "Slow track" record | points | Set<br>0 - 2048 |
| Number of emergency oscillograph stored records | | 200 |
| **Local human interaction interfaces** | | |
| | | LCD touch-screen or<br>LED indication and control element |
| **Operating conditions** | | |
| Ambient temperature range | °C | +1…+60 |
| Relative air humidity, under temperature (Upper value) | % | 60, 20 °C<br>(80, 25 °C) |

\* - depending on measuring module design, for application in city electric transport with traction network voltage up to 1000 V or for application in railway transport with traction network voltage up to 4000 V
\*\*- one of protections tripping is considered to be emergency event
\*\*\* - prehistory is a diagram of measured values up to emergency event occurrence

# TRACTION NETWORK MONITORING AND PROTECTION SYSTEM TYPE TESTS

| Name of parameter | Normative | Note |
|---|---|---|
| **Electric tests** | IEC 255-5 | - |
| **EMC compliance tests** | | |
| Radio interference voltage on power supply terminals | IEC 60255-26 CIS PR 22, class A | Frequency range: (0.15 – 30) MHz |
| Radio interference field intensity | IEC 60255-26 CIS PR 22, class A | Frequency range: (30 – 6000) MHz Measuring distance: 3 m |
| Radiated electromagnetic field immunity | IEC 60255-26 IEC 61000-4-3 | Frequency range: (80 – 1000) MHz, Field intencity: 10 V/m |
| Conducted interference immunity, inducted by radio-frequency electromagnetic field | IEC 60255-26 IEC 61000-4-6 | Frequency range: (0.15 – 80) MHz Interference voltage: 10 V |
| Nanosecond pulses immunity | IEC 60255-26 | Test pulses amplitude: - signal and feed lines – ± 4 kV - communication lines – ± 2 kV Pulse repetition frequency – 5 kHz Test pulse: 5/50 ns |
| Electrostatic discharge tolerance (EDS) | IEC 60255-26 IEC 61000-4-2 | Air discharge - ± 8 kV Contact discharge - ± 6 kV |
| Microsecond pulse interference immunity | IEC 60255-26 IEC 61000-4-5 | Test pulse: 1,2/50 µs Test pulses amplitude: - signal and feed lines: "two-wire" – ± 2 kV "earth-return" – ± 4 kV - communication lines: "earth-return" – ± 4 kV |
| Power frequency magnetic field immunity | IEC 60255-26 IEC 61000-4-18 | Magnetic field intensity: 100 A/m |
| Power failures and interruption resistance | IEC 60255-26 IEC 61000-4-11 | Power failure: U int. min - 30 % - 500 ms U int. min - 60 % - 200 ms Power interruption: - 20 ms |
| Decaying oscillatory waves resistance | IEC 60255-26 IEC 61000-4-18 | Frequency: 1 MHz Signal and feed lines: - "two-wire" - 1 kV - "earth-return" - 2.5 kV Communication lines: - "earth-return" - 1 kV |

| Name of parameter | Normative | Note |
|---|---|---|
| **Mechanic tests** | | |
| Sinusoidal vibration influence immunity | IEC 60068-2-6<br>IEC 60255-21-1 | Frequency: 2-200 Hz;<br>Acceleration amplitude 20 m/s$^2$ (2 g)<br>Scanning rate: 1 octave/min<br>Duration: 20/axe<br>In 3 orthogonal axes |
| Single-impacts immunity | IEC 60068-2-27<br>class 2 | Acceleration amplitude - 100 m/s$^2$ (10g);<br>Pulse duration –11 ms,<br>3 impacts per each of 6 directions |
| Long-term impacts immunity | IEC 60068-2-27<br>class1 | Acceleration amplitude - 100 m/s$^2$ (10g);<br>Pulse duration – 16 ms,<br>1000 impacts per each of 6 directions |
| Transportation and storage | IEC 60255-21-2<br>IEC 60068-2-27 | Vertically:<br>- 750 m/s$^2$, 6 ms, 200 picks<br>- 150 m/s$^2$, 11 ms, 2000 picks<br>- 100 m/s$^2$, 11 ms, 8800 picks<br>Horizontally:<br>- 120 m/s$^2$, 11 ms, 400 picks |
| Free fall resistance | IEC 60068-2-31 | Height 1 m<br>From 6 sides |
| **Climatic tests** | | |
| Ad test:  Cold, in operation | IEC 60068-2-1 | -10 °C<br>Holding: 72 h. |
| Ab test:  Cold, off-load | IEC 60068-2-1 | -40 °C<br>Holding: 72 h. |
| Bd test: Sensible heat, in operation | IEC 60068-2-2 | +60 °C<br>Holding: 72 h. |
| Bb test:  Sensible heat, off-load | IEC 60068-2-2 | +60 °C<br>Holding: 72 h. |
| Nb test: Temperature drift | IEC 60068-2-14 | Minimum temperature  -10 °C<br>Maximum temperature  +55 °C<br>Holding: 3 h.<br>2 cycles |
| Cab test:  Damp heat. Constant mode | IEC 60068-2-78 | Temperature  +55 °C<br>Humidity  93 %<br>Holding: 96 h. |
| Db test:  Damp heat. Cyclic mode | IEC 60068-2-30 | +25 °C/ 95 % ->  +55 °C/ 93 %<br>Holding: 12 h.<br>2 cycles<br>+55 °C/ 93 % -> +25 °C/ 95 %<br>Holding: 12 h.<br>2 cycles |

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