Treetech®


# Product Manual

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# 1 Preface

## 1.1 Legal Information

**The information contained in this document is subject to change without notice.**

This document belongs to Treetech Tecnologia and may not be copied, transferred to third parties, or used without express authorization, in accordance with Law 9.610/98.

### 1.1.1 Disclaimer

Treetech Tecnologia reserves the right to make changes without prior notice to all products, circuits, and functionalities described herein in order to improve their reliability, function, or design. Treetech Tecnologia assumes no responsibility resulting from the application or use of any product or circuit described herein, nor does it transfer any licenses or patents under its rights, nor the rights of third parties.

Treetech Tecnologia may hold patents or other types of intellectual property registrations and rights described in the content of this document. Possession of this document by any person or entity does not grant them any rights to these patents or registrations.

## 1.2 Presentation

This manual presents all the recommendations and instructions for the installation, operation, and maintenance of the Bushing Monitor - BM.

## 1.3 Typographical conventions

Throughout this text, the following typographical conventions have been adopted:

**Bold:** Symbols, terms, and words in bold have greater contextual importance. Therefore, pay attention to these terms.

*Italics:* Foreign language terms, alternative terms, or terms used outside of formal contexts are italicized.

<u>Underlined</u>: References to external documents.

## 1.4 General and safety information

This section will present relevant aspects regarding the safety, installation, and maintenance of the BM.

### 1.4.1 Safety symbols

This manual uses three types of risk classification, as shown below:

**Warning:**
This symbol is used to highlight certain observations, alerting the user to a potentially dangerous operational or maintenance procedure that requires greater care in its execution. Minor to moderate injuries may occur, as well as damage to equipment.

**Caution:**
This symbol is used to alert the user to a potentially dangerous operational or maintenance procedure where extreme caution must be exercised. Serious injury or death may occur. Possible damage to equipment will be irreparable.

**Risk of electric shock:**
This symbol is used to alert the user to an operational or maintenance procedure that, if not strictly followed, could result in electric shock. Mild, moderate, or severe injury or death may occur.

### 1.4.2 General symbols

This manual uses the following general-purpose symbols:

**Important**
This symbol is used to highlight information.

**Tips**
This symbol represents instructions that facilitate the use of or access to functions in BM.

### 1.4.3 Minimum recommended profile for the BM operator and maintainer

The installation, maintenance, and operation of equipment in electrical substations require special care; therefore, all recommendations in this manual, applicable standards, safety procedures, safe work practices, and good judgment must be used during all stages of handling the Bushing Monitor - BM.

Only authorized and trained personnel, operators and maintenance staff, should handle this equipment.

To handle the BM, the professional must:

1. Be trained and authorized to operate, ground, start, and shut down the BM, following maintenance procedures in accordance with established safety practices, which are the sole responsibility of the BM operator and maintainer;
2. Being trained in the use of PPE (Personal Protective Equipment), CPE (Collective Protective Equipment), and first aid;
3. Being trained in the operating principles of the BM, as well as its configuration;
4. Follow the regulatory recommendations regarding interventions on any type of equipment within an electrical power system.

### 1.4.4 Environmental and voltage conditions required for installation and operation

The following table lists important information regarding environmental and voltage requirements.

Table 1 - Environmental conditions

| Condition | Range/description |
|---|---|
| Supply voltage | 85~250 Vac/Vdc |
| Application | Equipment for indoor use in substations, industrial environments and similar settings. |
| Indoor/outdoor use | Indoor use |
| Degree of protection (IEC 60529) | IP20 |
| Altitude* (IEC EN 61010-1) | Up to 2000 m |
| **Temperature (IEC EN 61010-1)** | |
| Operation | -40...+85 °C |
| Storage | -50...+95 °C |
| **Relative humidity (IEC EN 61010-1)** | |
| Operation | 5...90% - Non-condensing |
| Storage | 5...90% - Non-condensing |
| Overvoltage (IEC EN 61010-1) | Category II |
| Pollution level (IEC EN 61010-1) | Degree 2 |
| Atmospheric pressure** (IEC EN 61010-1) | 80...110 kPa |

* Altitudes above 2000 m already have successful applications.
** Pressures below 80 kPa already have successful applications.

### 1.4.5 Instructions for testing and installation

This manual should be available to those responsible for the installation, maintenance, and users of the Bushing Monitor - BM.

To ensure user safety, equipment protection, and proper operation, the following minimum precautions must be followed during the installation and maintenance of the BM.

1. Read this manual carefully before installing, operating, and maintaining the BM. Errors in the installation, maintenance, or adjustments of the BM may cause false alarms, failure to issue relevant alarms, and thus lead to a misunderstanding of the true health and operational status of the transformer or application, since the BM is designed to withstand electrical substation environments, also encompassing industrial and commercial environments.

2. The installation, adjustments, and operation of the BM must be performed by personnel trained and familiar with power transformers, control devices, and substation equipment control circuits, or who are familiar with and trained to implement the IED in its application.

3. Special attention should be given to the installation of the BM, including the type and gauge of the cables, the installation location and commissioning, including the correct parameterization of the equipment.

The BM must be installed in a sheltered environment (an open panel in a control room or an enclosed panel for outdoor installations) that does not exceed the temperature and humidity specified for the equipment.

Do not install the BM near heat sources such as heating resistors, incandescent lamps, and high-power devices or devices with heat sinks. Installation near ventilation openings or where it may be exposed to forced airflow, such as the inlet or outlet of cooling fans or forced ventilation ducts, is also not recommended.

If the panel where the BM is installed has a window, use a G20 or higher quality film to prevent direct sunlight (ultraviolet rays) from hitting the equipment. If the window glass is dark, this procedure is not necessary.

### 1.4.6 Instructions for cleaning and decontamination

Be careful when cleaning the BM. Use **only** a damp cloth with soap or detergent diluted in water to clean the housing, faceplate, or any other part of the equipment. Do not use abrasive materials, polishes, or harsh chemical solvents (such as alcohol or acetone) on any of its surfaces.

Turn off and unplug the equipment before cleaning any of its parts.

### 1.4.7 Instructions for inspection and maintenance

For inspection and maintenance of the BM, the following observations should be followed:

Do not open your equipment. There are no user-serviceable parts inside. This must be done by Treetech technical support or technicians accredited by them. This equipment is completely maintenance-free, and visual and operational inspections, periodic or not, can be performed by the user. These inspections are not mandatory.

All parts of this equipment must be supplied by Treetech, or one of its authorized suppliers, according to its specifications. If the user wishes to acquire them in another way, they must strictly follow Treetech's specifications for this. This will ensure that the performance and safety of both the user and the equipment are not compromised. Failure to follow these specifications may expose the user and the equipment to unforeseen risks.

Opening the BM at any time will void the product warranty. In cases of improper opening, Treetech will also be unable to guarantee its correct functioning, regardless of whether the warranty period has expired or not.

## 1.5 Customer Service

Are you already familiar with our online customer service platform?

CS

On the CS page, you'll find a quick and direct communication channel with our support team. Get your questions answered, resolve problems, and keep your Treetech product application up-to-date.

The Treetech knowledge base is also available, including catalogs, manuals, application notes, frequently asked questions, and more.

In some cases, it will be necessary to send the equipment to Treetech's Technical Assistance. Our Customer Service department will explain the entire procedure and provide the necessary contact information.

This manual accompanies firmware version 1.14r1

## 1.6 Warranty Terms

The Bushing Monitor - BM will be guaranteed by Treetech for a period of 2 (two) years, starting from the date of purchase, exclusively against any manufacturing defects or quality flaws that render it unsuitable for regular use.

The warranty will not cover damage to the product resulting from accidents, misuse, incorrect handling, incorrect installation and application, inadequate testing, or if the warranty seal is broken.

Any need for technical assistance should be communicated to Treetech or its authorized representative, presenting the equipment along with the corresponding proof of purchase.

Treetech provides no express or implied warranty other than those stated above. Treetech does not guarantee the suitability of BM for a particular application.

The seller shall not be liable for any property damage or for any losses or damages arising from, connected with, or resulting from the purchase of the equipment, its performance, or any service possibly provided in conjunction with the BM.

Under no circumstances shall the seller be liable for any losses incurred, including but not limited to: loss of profits or income, inability to use the BM or any associated equipment, capital costs, costs of purchased energy, costs of substitute equipment, installations or services, downtime costs, claims from the buyer's customers or employees, regardless of whether such damages, claims or losses are based on contract, warranty, negligence, tort or otherwise. Under no circumstances shall the seller be liable for any personal injury of any kind.

# 2 Introduction

## 2.1 Intended use

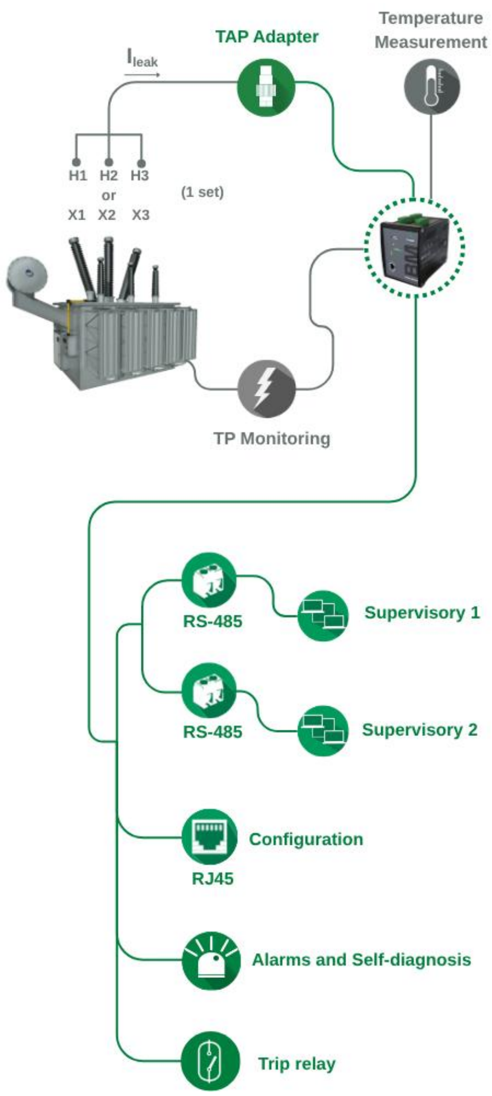



Figure 1 - System topology

Bushings are fundamental components in high-voltage equipment, being widely used in power transformers and shunt reactors. Their main function is to enable the passage of electric current between the external environment and the interior of the equipment, while simultaneously ensuring the necessary electrical insulation from the casing.

Due to this essential function, bushings are subject to high dielectric stresses, making any insulation failure a critical factor for the integrity of the equipment. A problem in this structure can result in severe damage and, in extreme situations, cause the total destruction of the equipment. In the case of power transformers, for example, the financial losses resulting from a dielectric failure can be hundreds of times greater than the cost of the bushing itself that caused the problem.

To mitigate these risks, the BM (Bushing Monitor) was developed, an advanced monitoring system capable of detecting variations in leakage current, tangent delta, and capacitance. This continuous monitoring allows for the identification of potential insulation failures at an early stage, contributing to the reliability and longevity of high-voltage equipment. It is performed in an integrated manner, analyzing all three bushings in the three-phase system. By comparing the measurements between them, the BM can detect even subtle changes, making the maintenance process safer, more efficient, and more reliable.

## 2.2 Scope of application

Among the various types of bushings available, those most notable for application in high and extra-high voltage equipment are condenser bushings, in which the insulating body consists of several concentric cylindrical insulating layers, interspersed with cylindrical conductive layers whose function is to uniformize the electric field as much as possible.

The innermost conductive layer can be electrically connected to the main conductor, thus increasing the radius and decreasing the electric field in this region (also reducing the intense electric fields that can be caused by roughness in the main conductor).

The outermost conductive layer is connected to the bushing flange, which in turn is grounded. The intermediate conductive layers remain insulated, with fluctuating potential. For outdoor applications, this entire assembly will be contained in a waterproof enclosure, often made of porcelain or another ceramic material.

The connection of the last (or one of the last) conductive layer to ground is usually made through a removable connection near the base of the bushing, called a test connection.

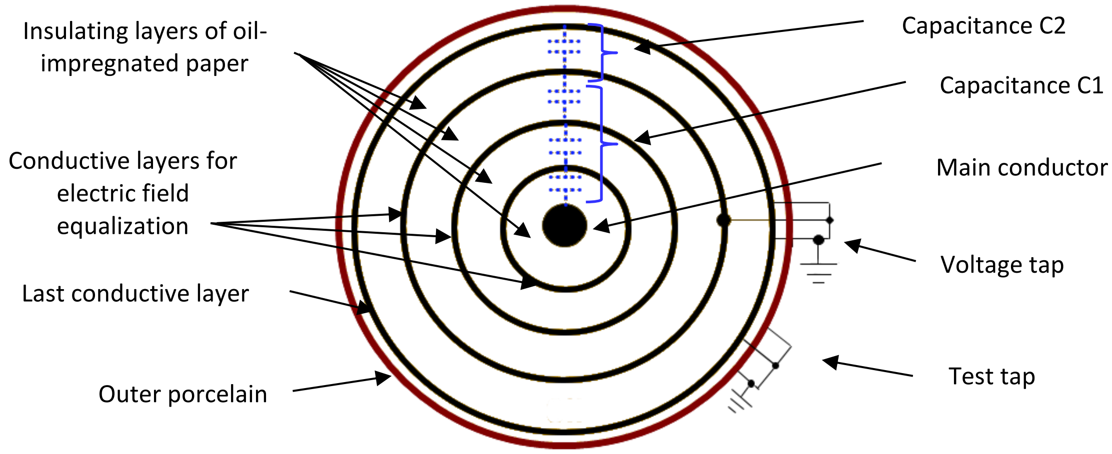



Figure 2 - Top view of a condenser bushing

## Potential and test taps

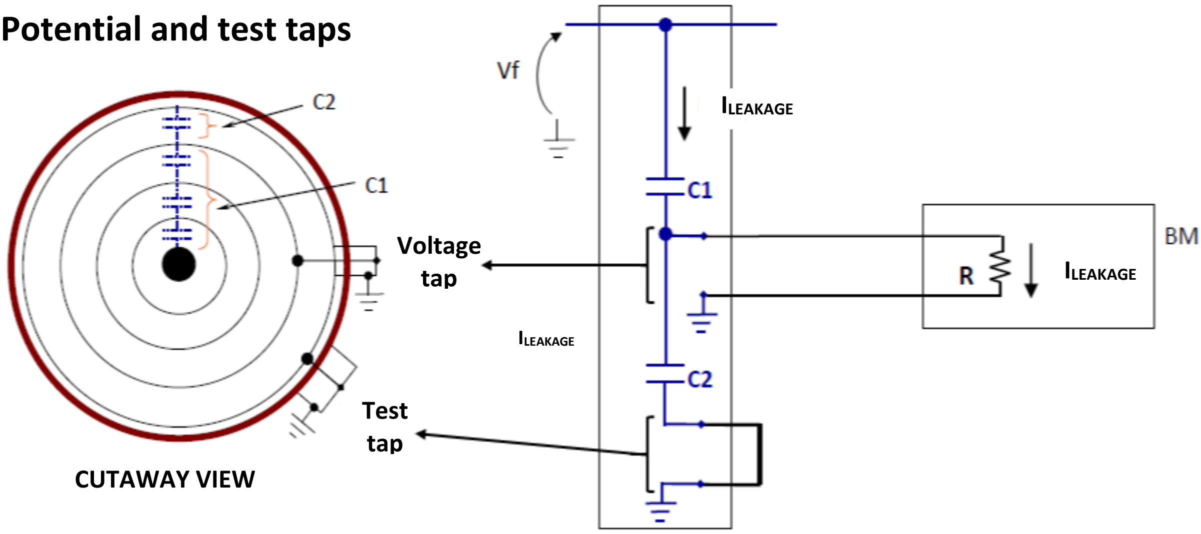



Figure 3 - Construction form of a condenser bushing

The assembly described above acts electrically as several capacitors connected in series, forming a capacitive voltage divider. In this way, the total potential difference of the main conductor relative to ground is divided equally among the various capacitors.

When operating voltage is applied to a condenser bushing, a current, called leakage current, begins to circulate through its insulation, mainly due to its capacitance and, to a much lesser extent, due to its dielectric losses (expressed by the dissipation factor or tangent delta). This current is measured through the voltage tap. Figure 4 illustrates this situation, in which we can observe the electrical equivalent obtained with the construction shown in Figure 3, with the bushing already energized.

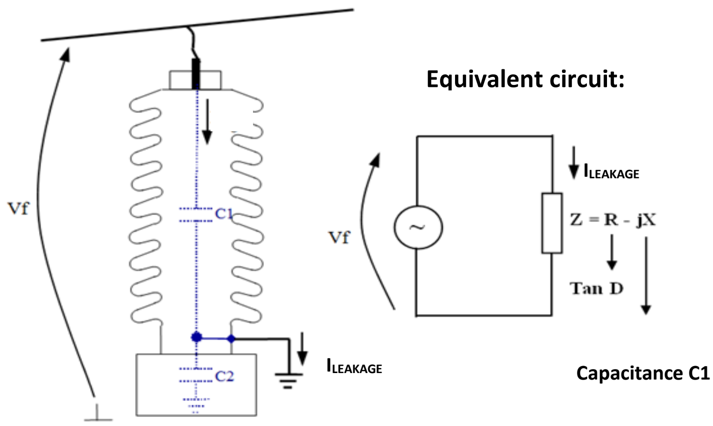



Figure 4 - Equivalent circuit of an energized condenser bushing

The objective of online monitoring of condenser bushings is to detect changes in the bushing's insulation in its early stages, indicating the development of conditions that could lead to dielectric failure of the equipment, providing information for analysis and decision support. This requires detecting, with the bushing energized, changes in capacitance and in the tangent delta of the insulation, that is, changes in the impedance "Z" of the bushing's insulation.

## 2.3 Basic operating philosophy

In each of the bushings, the leakage current $I_{leakage}$ flows through capacitance C1 to ground,as shown in Figure 3 passing through the test tap or voltage tap, this current being a function of the phase-to-ground voltage and the insulation impedance. Therefore, any change in insulation impedance (capacitance or dissipation factor) will be reflected in a corresponding change in leakage current, which, in theory, could be used to detect the change in impedance.

However, one of the obstacles to detection as described above is the magnitude of the changes one wishes to monitor. Changes as small as an algebraic increase of 0.3% in the dissipation factor of a bushing can represent the difference between a new bushing in good condition and a bushing at the limit of acceptable performance. It is evident that such a small change in the dissipation factor will cause a practically insignificant change in the bushing's leakage current, making its detection by monitoring only the leakage current of each bushing unfeasible.

One technique that allows overcoming the demonstrated practical limitation is the use of the vector sum of the leakage currents of the three bushings in a three-phase system. In such an arrangement, the three leakage currents are approximately 120° out of phase with each other, and normally have the same order of magnitude, since the three bushings have capacitances that are in principle similar and the voltages of the three phases are close to equilibrium. Therefore, the sum of the three leakage currents tends to be considerably smaller than each of the leakage currents taken individually, as illustrated in Figure 5(a), for a given initial condition of capacitances and dissipation factors.

Now, assuming that there is a change in the capacitance and dissipation factor of the phase A bushing, as shown in Figure 5(b), the Change Vector, which expresses the displacement of the current *Ia* from its initial value to its final value, is also reflected in the summation current, which is altered relative to its initial value according to the same Change Vector. This Change Vector has practically insignificant weight when compared to the magnitude of the leakage current of phase A. However, the same does not occur when this vector is compared to the summation current, which allows its detection and, consequently, the detection of the change that occurred in the impedance of the bushing in question. Each change detected in the summation current is attributed to only one bushing within the three-phase set., selected based on the angle of the change vector relative to the leakage currents of the bushings. This selection takes into account the fact that the probability of simultaneous occurrences in two or three bushings of the three-phase set is quite low.

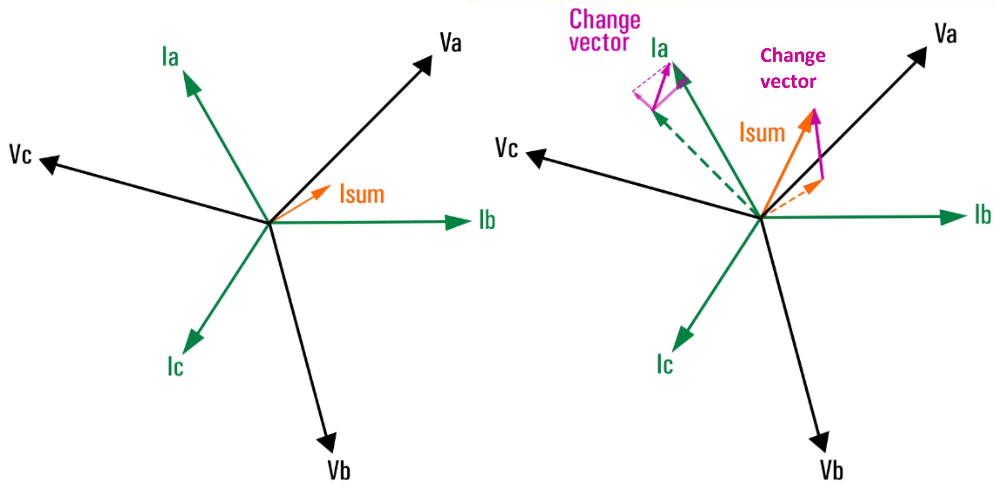



Figure 5 - Leakage currents and summation of three bushings in a three-phase system: (a) For a given initial condition; (b) With a change in the capacitance and dissipation factor of the bushing of phase A

Based on the above, some intrinsic characteristics of the method used can be observed:

- It is necessary to determine an initial current reference for the system, and then compare it to the new online measurements, in order to determine the changes that occurred in the capacitance and dissipation factor of the bushings;
- The absolute capacitance and tangent delta values of the bushings are not measured; instead, the variations in these parameters are measured. However, once the initial capacitance and tangent delta values of each bushing are known (values present when the initial current reference is determined), measuring the variations allows us to know the current capacitance and tangent delta values;
- In the case of new bushings, the nameplate values determined by the bushing manufacturer can be used as initial capacitance and tangent delta values. However, for bushings already in operation, it is recommended that, during the installation of the online monitoring system, these parameters be measured using offline methods, with the bushings de-energized. This ensures that the monitoring system is using correct initial values;
- In the event of alarms due to high capacitance or tangent delta in one of the bushings, not just one, but all bushings in the three-phase set should be checked, for example, through offline capacitance and tangent delta measurements.

Another issue not addressed so far is that leakage currents and summation current are influenced not only by changes in capacitance and tangent delta of the bushings, but also by changes in phase-to-ground voltages at each bushing. This influence is eliminated through mathematical and statistical treatments performed on the measurements, which is why the process of determining the initial current reference is carried out within a default period of 7 days after the start of operation of the monitoring system.

As explained above in the introduction, the physical construction of the bushing creates a capacitive voltage divider. The lower portion of this divider is normally short-circuited, grounding the bushing tap, so that its voltage to ground is zero volts. To allow for the measurement of the bushing's leakage current, this direct grounding is removed and replaced by the leakage current measurement circuit. Due to the low impedance of this circuit, the tap voltage to ground remains close to zero. It should be noted that, in case of accidental interruption of this measurement circuit, the capacitive voltage divider will generate a voltage at the bushing tap that is normally higher than the dielectric strength of the tap to ground, risking damage to the bushing.

To prevent this from happening, the adapters connecting to the bushing taps are equipped with voltage limiting devices that conduct in case of an opening in the measuring circuit, creating a low-impedance path for leakage currents, so that the tap voltage relative to ground remains at a few volts. This limiting device is not susceptible to electrical or mechanical wear, allowing it to conduct leakage current indefinitely. For complete safety, each adapter is equipped with two protections connected in parallel, in a redundant configuration.

## 2.4 Features

- ✓ **Robust hardware**
  The BM design meets EMC (Electromagnetic Compatibility) standards to withstand harsh electromagnetic conditions in substations and operating temperatures from -40 to 85°.

- ✓ **Compact and versatile**
  The BM has compact dimensions, providing space savings and reduced installation costs.

## 2.5 Functions

- ✓ **Monitoring sets**
  Monitoring of 3 bushings (one set).

- ✓ **Alarms:**

  - Issuance of alarms in case of abnormalities, indicated by relays;
  - Adjustable timing, allowing identification of rapidly or very rapidly evolving defects.

- ✓ **Self-diagnosis**
  Detection of internal faults with indication from a relay.

- ✓ **PT Monitoring**
  In addition to measuring current, the BM also measures voltage.

- ✓ **Temperature measurement**
  The BM features a PT100 input, enabling temperature measurement for various applications.

- ✓ **Trip relay**
  Trip relay activation via current alarms.

## 2.6 Inputs, outputs and communication

### 2.6.1 Inputs

- ✓ 1 current input set for a three-phase bushing set (primary or secondary);
- ✓ 1 set of three-phase voltage input;
- ✓ 1 PT100 sensor input.

### 2.6.2 Outputs

- ✓ 3 normally open (NO) output contacts for absolute value alarms;
- ✓ 1 fixed output contact (NC) for self-diagnosis.

### 2.6.3 Communication

BM has:

- ✓ 2 RS-485 ports for communication using Modbus/DNP3 RTU protocols;
- ✓ 1 Ethernet RJ45 port for **parameterization**.

# 3 Design and installation

## 3.1 Installation and removal of terminals

The terminals have screws to ensure a better fit, so care must be taken during installation and removal.

- ✓ Use a 2.5 mm flathead screwdriver;
- ✓ Before removing the terminals, check that the screws are completely loose;
- ✓ Forcing removal with the screws tightened may damage the BM.

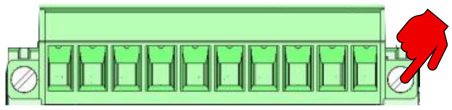


Figure 6 - Equipment terminal

## 3.2 Mechanical installation

### 3.2.1 Standard DIN rail installation

This equipment is compatible with standard DIN rail mounting and can be located on mounting plates inside panels. It is important to ensure that the BM is securely attached to the rail; if there are no other IEDs nearby, the use of a rail lock is also recommended. After mounting, proceed with the electrical installation.

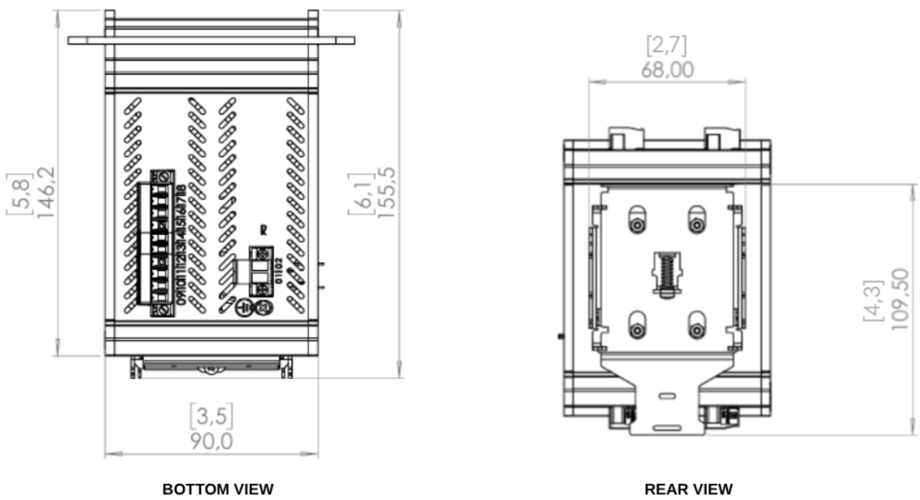



Figure 7 - Bottom and rear view

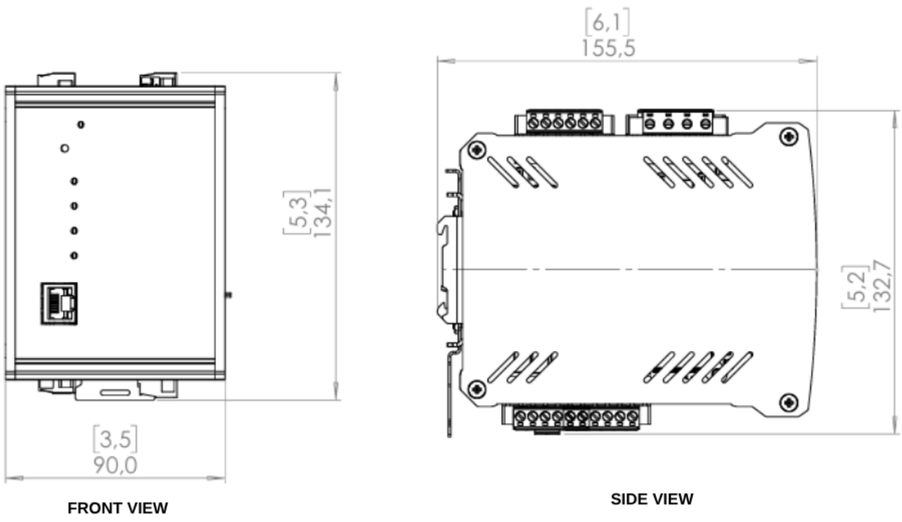
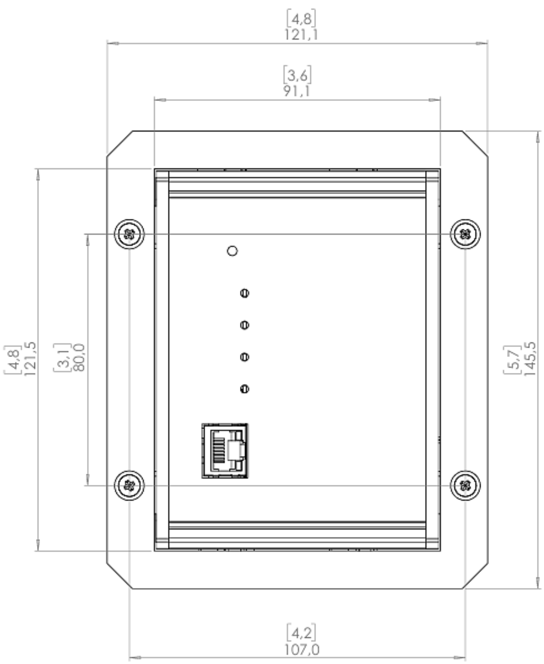



Figure 8 - Front and side view

### 3.2.2 Panel-mounted installation

The equipment can be installed recessed into panels, such as doors or front panels. It is important to observe the thickness of the panel's paint, as very thick layers can hinder insertion. It is also essential to ensure a firm fixation before carrying out the electrical installation. The dimensions of the equipment and the cutout required for mounting are presented below.




The panel cutout for IED mounting should be 91.1 x 121.5 mm

Figure 9 - Frame for panel mounting

## 3.3 Electrical installation

Some special precautions must be taken for the design and installation of the BM, as described below:

The connection terminals are installed on the top of the BM, in three removable connectors, to facilitate coupling. For information on cable gauges, see Table 2 - .

Study and understand the application in which you intend to use the BM, learn about its functional, electrical, and configuration characteristics. This way you will be able to take full advantage of the equipment and minimize risks to your safety.

The following circuit breaker specification is recommended when used exclusively for BM:

• AC/DC Power Supply, Phase-Neutral: Single-pole circuit breaker, 1 A ≤ In ≤ 2 A, curve B or C, standards NBR/IEC 60947-2, NBR/IEC 60898 or IEEE 3004.5;
• AC/DC Power Supply, Phase-to-Phase: Bipolar circuit breaker, 1 A ≤ In ≤ 2 A, curve B or C, standards NBR/IEC 60947-2, NBR/IEC 60898 or IEEE 3004.5.

A circuit breaker should be used immediately before the power input (Universal power supply - 85 ~ 250 Vdc/Vac, <12 W, 50/60 Hz).

The circuit breaker must have the number of poles corresponding to the number of phases used in the power supply, and the poles must only interrupt the phases, never the neutral or ground. It must provide thermal and electrical protection to the conductors supplying the equipment and must be located near the equipment and easily maneuverable by the operator.

Additionally, it must have indelible markings indicating that it is the electrical disconnect device for the BM.

The minimum isolation for circuits connected to the BM is 300 $V_{rms}$ for auxiliary equipment and transducers, such as Pt100 Ω at 0 °C, and up to 50 $V_{rms}$ for self-powered equipment.

The minimum insulation is 1.7 $kV_{rms}$ or equipment powered up to 300 $V_{rms}$, according to IEC 61010-1.

These values relate to the intrinsic isolation of devices connected to the BM. Cases where this value does not apply to equipment or devices connected to the BM will be explicitly stated in this manual.

### 3.3.1 Cable specification

Table 2 - Cable specification

| Cable specification | | |
|---|---|---|
| ***Function*** | ***Specification*** | ***Observation*** |
| Power supply GND | 1.5mm² to 2.5mm² | - |
| TAP adapter | **Exposed to the weather:** Shielded cable (BTC), 2 x 18 AWG, EPR 90°C insulation, 0.6/1 kV.<br><br>**Protected from the weather:** Shielded cable (BTC), 2 x 18 AWG, PVC insulation. | Mandatory, referring to NBR7286 |
| Three-phase voltage signal | 1.5mm² | - |
| PT100 | **Exposed to the weather:** 3x16 AWG cable with EPR insulation.<br>**Protected from the weather:** 3x18AWG cable with PVC insulation. | This specification is mandatory and covers distances up to 265m. For greater distances, cables sized according to the installation requirements must be used. If you have any questions, contact the Treetech team; see **Customer Service**. |
| Relays | **1.5 mm²:** Minimum gauge for signaling (self-diagnostics, alarms...).<br><br>**2.5 mm²:** Minimum gauge for power circuits (TRIP relay). | Recommended according to the specification in NBR5410. |
| RS485 | Cabo 2x18AWG PVC | It is recommended to consult the **Communication** topic for installation. |

### 3.3.2 Wiring diagram

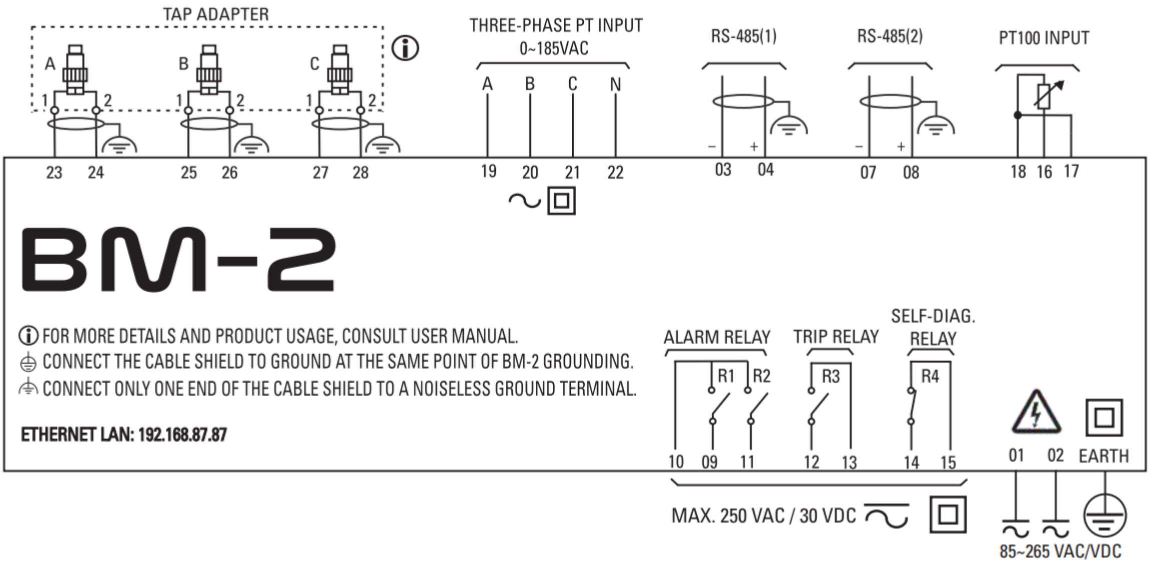



Figure 10 - Wiring diagram

### 3.3.3 Input terminals

Table 3 - Inputs

| Inputs | |
|---|---|
| **Power supply**<br>Universal power input – 85 ~250 Vac/Vdc, 50/60Hz, 12 W. | 01 – Vac/Vdc<br>02 – Vac/Vdc<br>Ground |
| **Three-phase voltage input**<br>This is a three-phase voltage input, where each of the three inputs corresponds to phases A, B, and C of a set of three-phase bushings. This input allows the measurement of amplitudes and phase shift angles between the phases. | 19 – Phase A<br>20 – Phase B<br>21 – Phase C<br>22 – Neutral |
| **Bushing set**<br>See . | 23 – Signal input (Adapter A)<br>24 – Common input (Adapter A)<br>25 – Signal input (Adapter B)<br>26 – Common input (Adapter B)<br>27 – Signal input (Adapter C)<br>28 – Common input (Adapter C) |
| **Input for PT100**<br>Input for direct connection of a PT100 Ω sensor at 0 °C, in a three-wire measurement configuration. | 17 – Common<br>16 – VM<br>18 – VR |

### 3.3.4 Output terminals

Table 4 - Outputs

| Outputs | |
|---|---|
| **Signaling relays**<br>Relay (NO) with fixed function, relay 1 being for capacitance and relay 2 being for tangent delta. | 09 – Relay 1 (NO)<br>10 – Common<br>11 – Relay 2 (NO) |
| **Trip relay**<br>This relay (NO) has the function of switching off the transformer and is activated when an alarm is triggered by high or very high leakage current. | 12 – Relay 3 (NO)<br>13 – Common |
| **Self-diagnosis relay**<br>Relay (NC), signals internal faults, power supply issues, or problems with the connection cables. | 14 – Relay 4 (NC)<br>15 – Common |

The combined total current of all relays must not exceed 5 A.

The relays in the signaling group share the same common terminal. It is strictly forbidden to connect different phases or distinct power sources in the same group. All loads driven by this relay group must use the same phase and voltage reference.

### 3.3.5 Communication

Table 5 - Communication

| Communication | |
|---|---|
| **RS-485 (2)**<br>Connection to data acquisition system, Modbus RTU or DNP3 protocols, via shielded twisted-pair cable. | 03 – (-)<br>04 – (+)<br>07 – (-)<br>08 – (+) |
| **RJ45 (Configuration)**<br>Configuration via HTTP, primarily used for equipment parameterization. This interface also allows for viewing measurements, as well as collecting and transmitting operational data. | 1 Ethernet |

#### Communication with the data acquisition system

Up to 31 devices can be interconnected on the same communication network. The communication protocols available for this connection are Modbus® and DNP3.

The connection between the BM and the data acquisition system must be made using a shielded twisted-pair cable, maintaining an uninterrupted shield throughout the entire length. If intermediate terminals are needed for serial communication, the cable shield should also pass through the terminal to avoid interrupting the connection.

In conjunction with the termination resistors, pull-up and pull-down resistors should be used at only one point in the network, as shown in Figure 7.

The 5V DC power supply for the pull-up and pull-down resistors can be internal to the data acquisition system. Note that some communication equipment may already have these resistors installed internally, eliminating the need for external resistors. The maximum distance of 1200 m between the ends of the communication network must be observed.

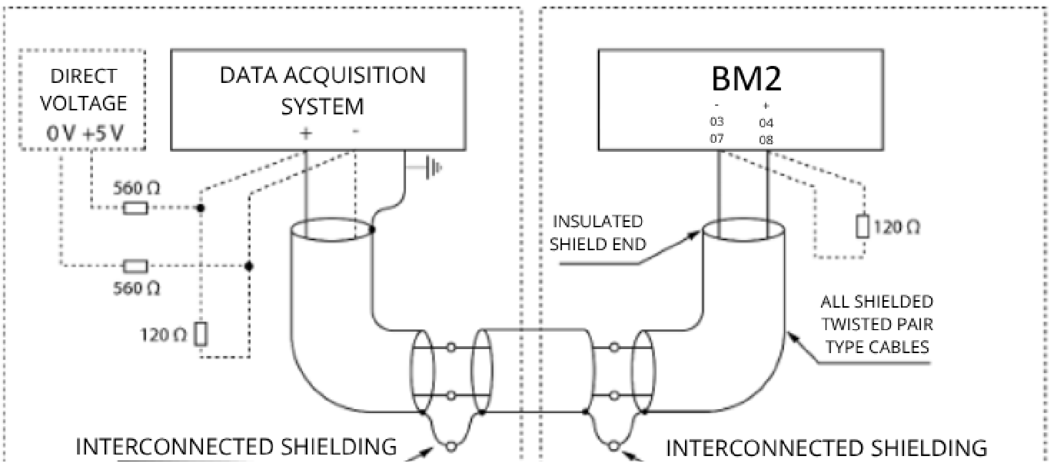


Figure 11 - Connection and grounding of the RS-485 serial communication shield

### 3.3.6 Temperature sensor

The BM has an input for a Pt100 Ω RTD temperature sensor at 0 °C. The sensor must be connected to the BM with shielded cables, maintaining a continuous shield and grounding only at the end connected to the equipment. If intermediate terminals are used, the shielding must pass through them without interruption, and the unshielded sections should be as short as possible.

The maximum permissible resistance per path is 3 Ω (6 Ω for the total path between the PT100 and the BM). For a 1.5 $mm^2$ copper cable, this allows the sensor to be installed up to 265 m from the equipment. Different distances can be achieved with proper cable sizing. If you have any questions, please contact Treetech's CS Department, see **Customer Service.**

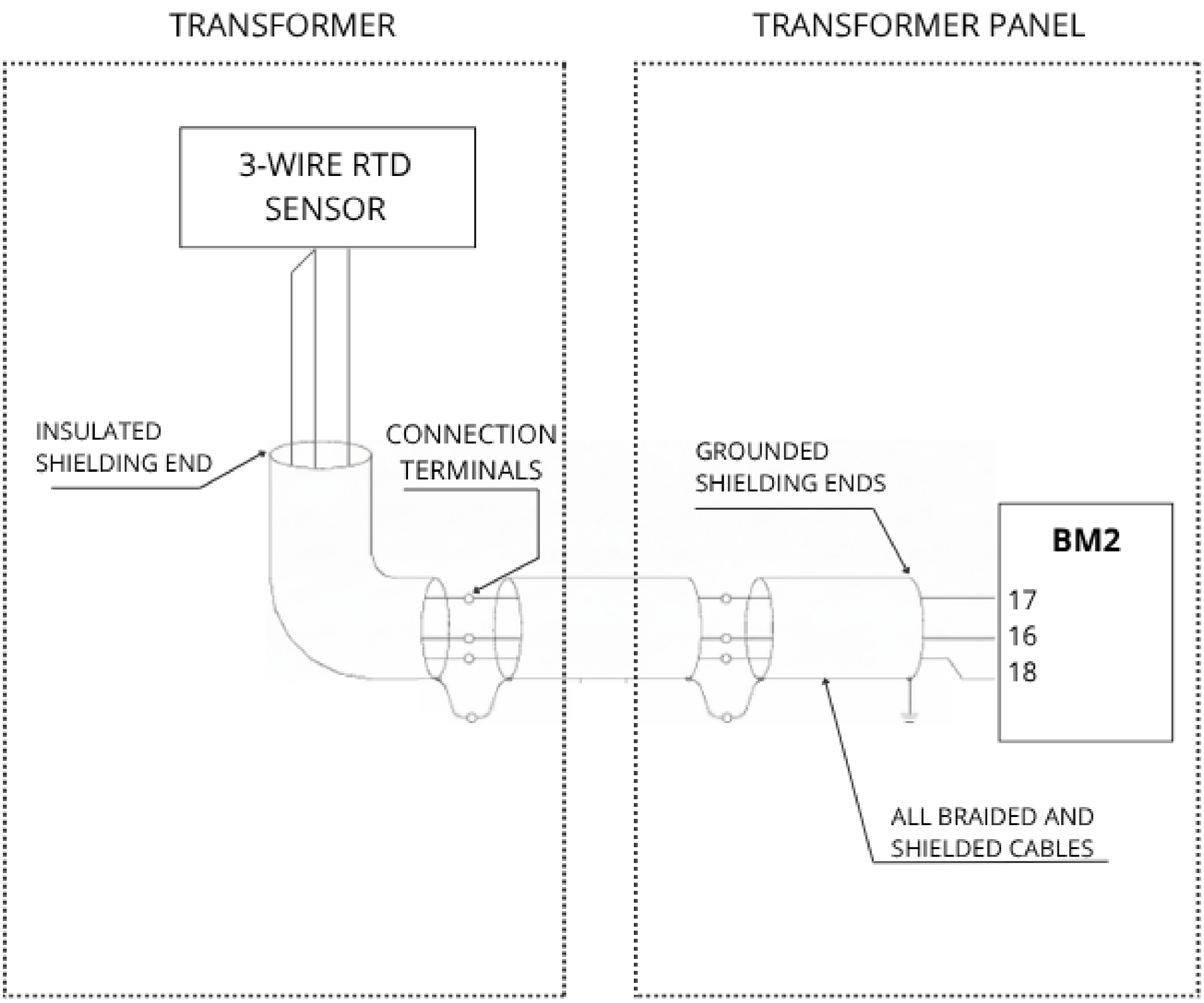



Figure 12 - Cable and grounding connection details and shielding

## 3.4 TAP adapter

Figure 13 - TAP Adapter Model 141

The TAP adapter is an essential accessory for the operation of the BM; it is responsible for establishing the electrical connection with the bushing's TAP and also ensures mechanical rigidity and sealing against weathering. This equipment has internal protection against overvoltages and overcurrents resulting from transient phenomena, and also has a safety system against accidental opening of the measuring circuit, the TAP opening protection. This protection directs the leakage current through a low-impedance path, allowing the system to continue operating indefinitely, although it is advisable to take immediate action.

### 3.4.1 Mechanical installation

Mechanical installation of the TAP adapter requires the transformer to be de-energized. Carefully remove the capacitive TAP cover and connect the adapter manually, without using tools, to avoid damage to the terminal. It is essential to secure it firmly, but without applying excessive force, and anchor the cables or conduits to nearby structures to reduce stress on the adapter.

### 3.4.2 Electrical installation

The electrical installation involves connecting the shielded cable between the TAP adapter and the equipment, ensuring effective grounding of the shielding at a single point. A continuity test must be performed on the contact pin to ensure the integrity of the ground connection, verifying the drainage of leakage currents through the common terminal. The entire process must follow electrical safety recommendations and Treetech installation specifications. To learn how to perform the continuity test, see the TAP adapter installation procedure.

To ensure the cable's mechanical strength, the use of very small gauges is not recommended, in order to reduce the possibility of accidental opening of the bushing's TAP. Gauges of 18 AWG or 0.75 mm² are indicated. The shielding of the connecting cables between the TAP adapters and the BM should also pass through terminals, preventing their interruption.

The unshielded cable section, due to the splice, should be as short as possible, and the shielding should be grounded at only one end, preferably at the tap adapter.

**CAUTION:** Under no circumstances should the bushing tap remain open while the bushing is energized. Therefore, it is highly recommended that the cables from the tap adapters not be connected directly to the current inputs of the transformer, but that short-circuitable intermediate terminals (such as those used for current transformer circuits) be used. See Figure 10. This makes it possible to short-circuit the intermediate terminals and divert leakage currents, allowing the transformer to be taken out of operation even with the bushings energized.

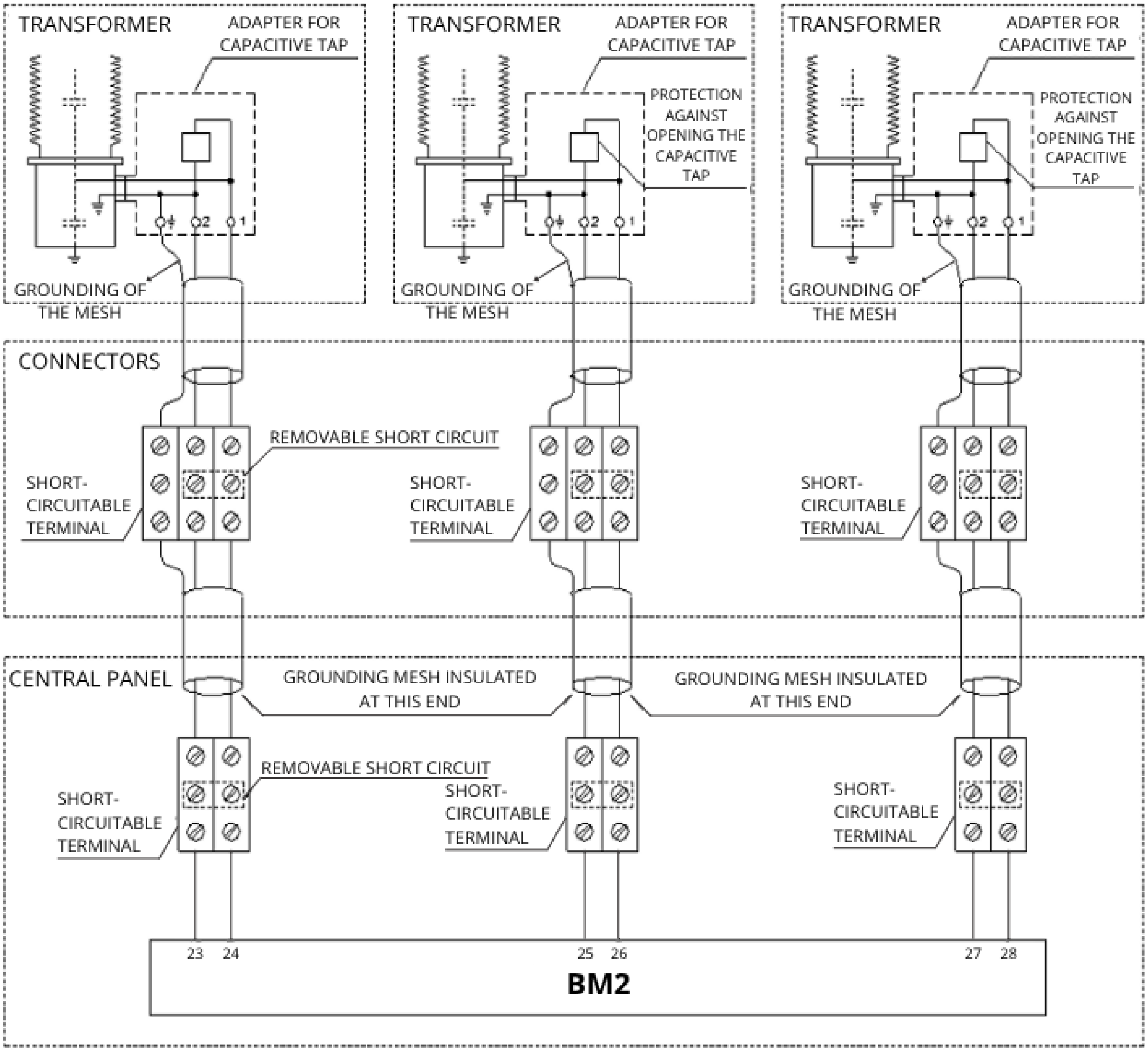
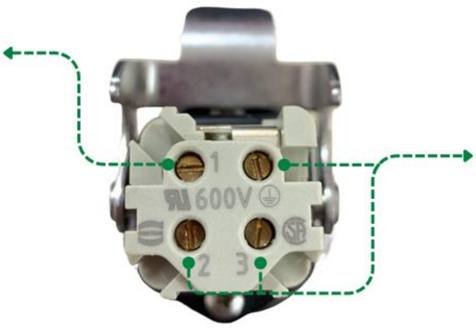



Figure 14 - Connection and grounding details

### 3.4.3 Layout of the TAP adapter socket terminals

**Terminal 1:** Signal terminal, connected to the signal input of the BM, see **Input terminals**.




**Terminals 2, 3 and ground:** Connected to each other and to the common terminal of the BM, see **Input terminals**.

Figure 15 - TAP adapter socket terminal

# 4 Operation

The equipment does not have a display or physical keys on its front panel for navigation; the only operation that can be performed directly on the front panel is changing the serial communication parameters using the “Default Address” button. Status, alarm, and internal fault signaling is provided by indicator lights (LEDs). The BM also features a user-friendly and intuitive web interface, through which it is possible to configure the equipment, download logs, and download databases.

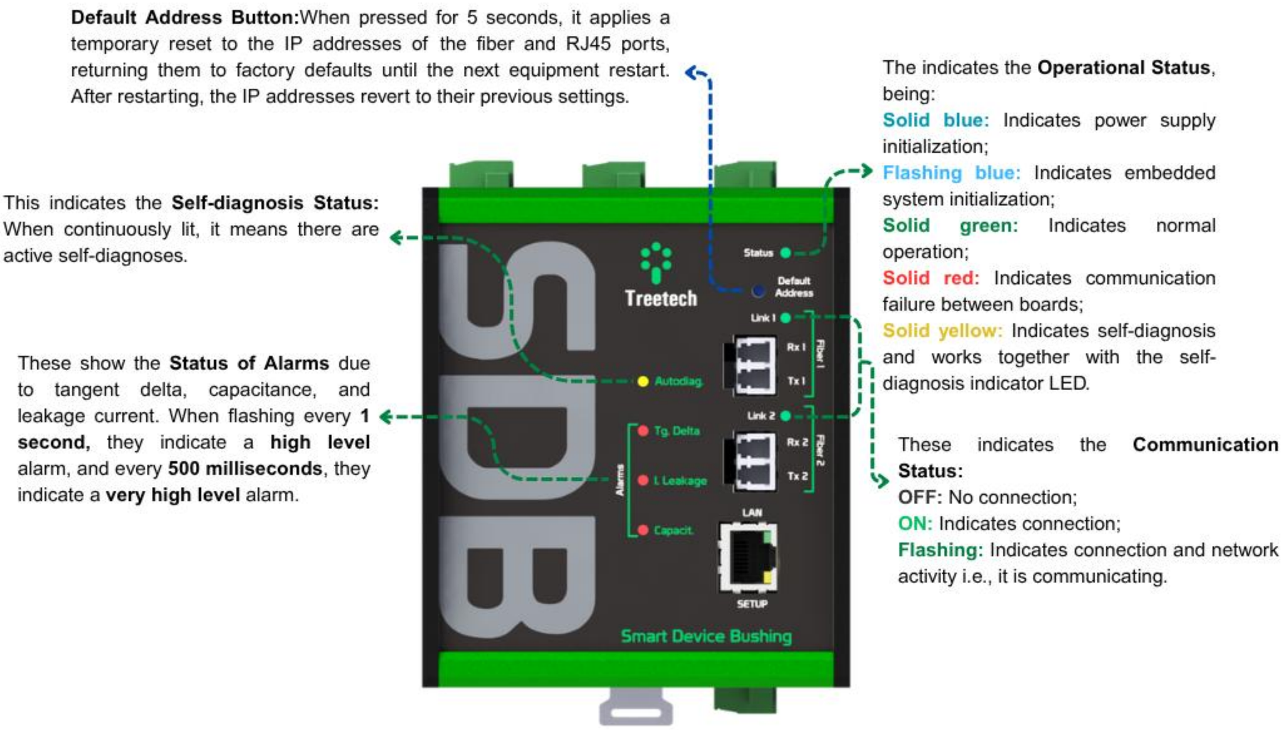



Figure 16 - Operation via BM front panel

## 4.1 General information about the Web Interface

The web interface of the Bushing Monitor - BM allows access to all the equipment's functionalities. Through it, you can access the tabs: Online, File Transfer, Parameterization (only after logging in) and About, where information about measurements, product versioning information, log download, among others, is available.

### 4.1.1 Login

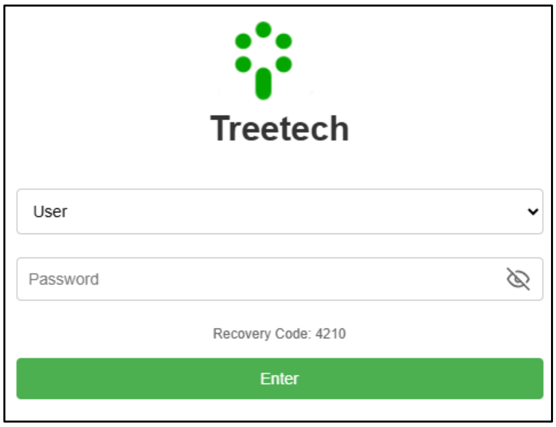



Figure 17 - Login screen

In order to promote greater security, to access the BM parameterization tab, it is necessary to log in with your username and password.
For first access:

**Profile:** User
**Password:** 0

Afterwards, it can be changed by the user; a password will be displayed above the "Enter" field.

### 4.1.2 File transfer

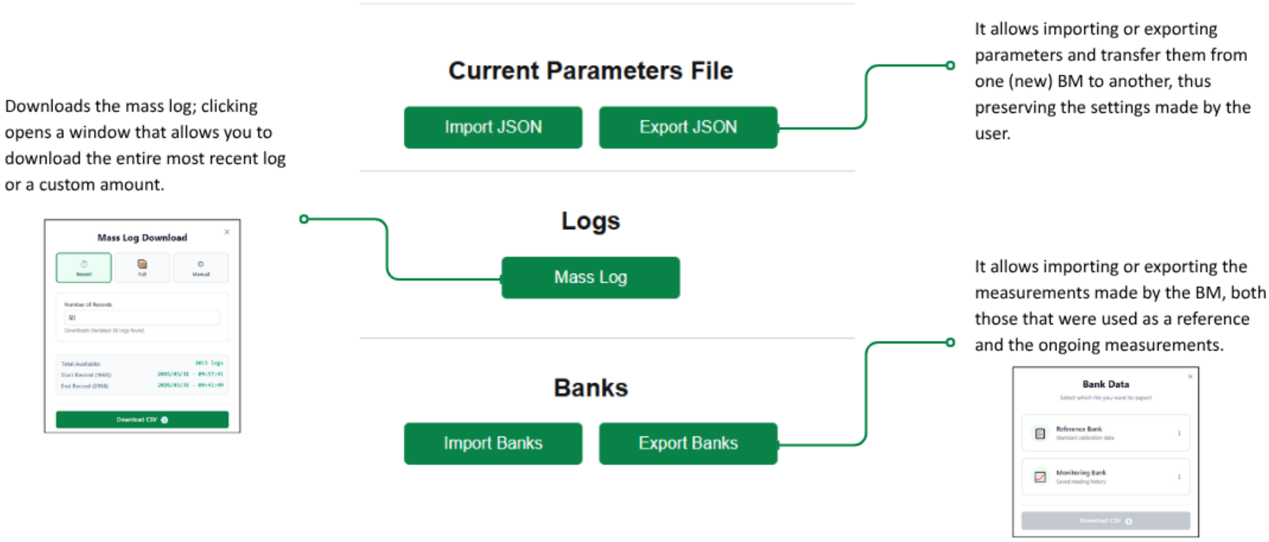
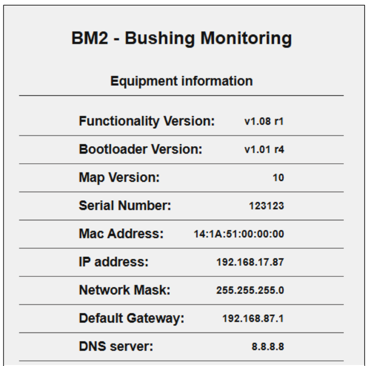



Figure 18 - File transfer screen

### 4.1.3 About



**BM2 - Bushing Monitoring**

Equipment information

| | |
|---|---|
| Functionality Version: | v1.08 r1 |
| Bootloader Version: | v1.01 r4 |
| Map Version: | 10 |
| Serial Number: | 123123 |
| Mac Address: | 14:1A:51:00:00:00 |
| IP address: | 192.168.17.87 |
| Network Mask: | 255.255.255.0 |
| Default Gateway: | 192.168.87.1 |
| DNS server: | 8.8.8.8 |

Figure 19 - About screen

The "about" page contains useful information for the efficient use of the product, such as:

- ✓ IP address;
- ✓ Firmware versions;
- ✓ Protocol map version.

# 5 Parameterization

To ensure the correct operation of the system, the Bushing Monitor (BM) requires parameter adjustments, which provide the necessary information for its proper functioning and continuous monitoring. All adjustments and configurations are performed exclusively through its web interface; to access it, follow these steps:

- ✓ Connect the BM to the network via the parameterization port;
- ✓ Log in (the parameterization screen will only appear after logging in);
- ✓ When typing the device's IP address into any browser, it's important to verify that the device used for access is connected to the same network as the BM.

For the first access to the web interface, use the default IP address: **192.168.87.87.**


Figure 20 - Parameterization section

## 5.1 Inputting and validating parameters

### Inputting parameters

For a parameter change to take effect in BM, you must click the "Apply" button after making the modifications. Changes made in the parameterization screens are stored temporarily and only become effective after clicking the "Apply" button.


Figure 21 - "Apply" button

## 5.2 Acquisition and analysis

### 5.2.1 Sampling settings

#### Sample interval between banks

Defines the interval for inserting samples into the banks.
**Adjustment range:** 5 to 2700 s
**Default:** 233 s

#### Number of samples considered for capacitance

Parameter that allows the definition of the number of samples for capacitance calculation.
**Adjustment range:** 10 to 5000
**Default:** 2600

#### Number of samples considered for tangent delta

Parameter that allows the definition of the number of samples for calculating the tangent delta.
**Adjustment range:** 10 to 5000
**Default:** 2600

#### Parameter to stop recording samples

Interrupts the insertion of samples into the banks.
**Adjustment range:** YES or NO
**Default:** NO

### 5.2.2 Initial phase parameters

#### Parameter for initial capacitance of phase ‘x’

Initial capacitance value.
**Adjustment range:** 50 to 3200 pF
**Default:** 500 pF

#### Parameter for initial tangent delta of phase ‘x’

Initial tangent delta value.
**Adjustment range:** 0.01 to 32.000 %F
**Default:** 0.3%

### 5.2.3 Adjustment parameters of the relevance curve

Relevance curve XA adjustment
**Adjustment range:** 0.000 to 5.000 %
**Default:** 0.450 %

Relevance curve XB adjustment
**Adjustment range:** 0.000 to 5.000 %
**Default:** 0.750%

Relevance curve YA adjustment
**Adjustment range:** 0.000 to 5.000 %
**Default:** 0.150% pF

Maximum percentage difference between redundant calculations
**Adjustment range:** 0 to 100 %
**Default:** 10%

Compensation activation
**Adjustment range:** ON or OFF
**Default:** OFF

## 5.2.4 Self-diagnosis

### 5.2.4.1 Validation and quality

**Parameter for maximum percentage of corrupted samples in the banks**
Indicates the maximum percentage of samples with errors that can be accepted, calculated based on the total number of samples stored in the banks.
**Adjustment range**: 0 to 100 %
**Default:** 5 %

**Parameter for maximum persistent offset in the sample to be saved in the banks**
This parameter defines the maximum allowed limit for the DC component present in the monitored signals; it should have tighter thresholds than the maximum DC value parameter for currents. See Frequency and signals.
**Adjustment range:** 0 to 65000 μA
**Default:** 50 μA

**Parameter for maximum angular distortion compared to the phase sequence of the first sample**
This parameter defines the maximum acceptable angular displacement between phases, taking as a reference the phase sequence recorded in the first sample of the reference bank.
**Adjustment range:** 0 to 360°
**Default:** 5°

### 5.2.4.2 Frequency and signals

**Parameter for maximum deviation from nominal frequency**
This parameter defines the maximum permissible deviation from the nominal frequency of the electrical system.
**Adjustment range:** 0.000 to 1.000 Hz
**Default:** 0.300 Hz

**Parameter for maximum difference between frequencies in the same group of signals**
This parameter defines the maximum allowed difference between the frequencies of the monitored signals in the same sample.
**Adjustment range:** 0.000 to 1.000 Hz
**Default:** 0.100 Hz

**Parameter for minimum current amplitude in the fundamental**
This parameter defines the minimum amplitude in the fundamental component of the current for the self-diagnosis to be triggered.
**Adjustment range:** 100 to 65000 μA
**Default:** 100 μA

**Parameter for minimum voltage amplitude in the fundamental**
This parameter defines the minimum amplitude in the fundamental voltage component for the self-diagnosis to be triggered.
**Adjustment range:** 1 to 65000 V

**Default:** 1 V

### Parameter for maximum DC value in currents

This parameter defines the maximum allowed limit for the DC component present in the monitored current signals.
**Adjustment range:** 0 to 65000 µA
**Default:** 100 µA

### Parameter for maximum DC value in voltages

This parameter defines the maximum allowed limit for the DC component present in the monitored voltage signals.
**Adjustment range:** 0 to 65000 V
**Default:** 1 V

### Parameter for maximum harmonic distortion relative to the True RMS value

This parameter defines the maximum allowed limit for total harmonic distortion (THD) relative to the True RMS value of the signal.
**Adjustment range:** 0.0 to 100.0 %
**Default:** 20.0 %

## 5.2.4.3 Summation ratio

### Parameter for current of dead zone of inconsistent summation self-diagnosis

This parameter defines the dead zone, which is the minimum RMS amplitude value required to enable self-diagnosis.
**Adjustment range:** 0 to 2000 µA
**Default:** 10 µA

### Parameter for maximum ratio for consistency of summations

This parameter defines the value that, when reached, triggers the self-diagnosis. This value is the difference between the sums.
**Adjustment range:** 0 to 200 %
**Default:** 50 %
**Note:** The self-diagnosis of inconsistent summation will only be triggered when the range of any summation (measured or calculated) exceeds the dead zone and the difference between them exceeds the configured percentage.

## 5.2.4.4 Voltage monitoring

### Parameter to enable voltage signal monitoring

**Adjustment range:** Enable or Disable
**Default:** Enable

## 5.2.5 PT100 sensor configuration

### Parameter to enable PT100 sensor

**Adjustment range:** Enable or Disable
**Default:** Disable

**Parameter to enable PT100 sensor simulation**
**Adjustment range:** Enable or Disable
**Default:** Disable

## 5.3 Communication

### 5.3.1 Serial communication ports (RS485 - 'X')

**Baudrate – User serial number 'x'**
Selects the baud rate for the RS-485 serial communication port.
**Adjustment range**: 4800 / 9600 / 19200 / 38400 / 57600 / 115200 bps
**Default:** 9600 bps

**Active protocol – User serial number 'x'**
Selects the standard protocol to be used for communication with data acquisition systems..
**Adjustment range:** Modbus or DNP3
**Default:** Modbus

**RS485 Network address – Serial**
Defines the BM address on the RS-485 communication port, for communication with data acquisition systems.
**Adjustment range:** 1 to 65519
**Default:** 247

**Delay in reception – User serial number 'x'**
This parameter defines the data reception wait time; in other words, it's the wait time for receiving a data packet.
**Adjustment range:** 5 to 500 ms
**Default:** 5 ms

**Transmission delay – User serial number 'x'**
This parameter defines the data transmission wait time; in other words, it's the wait time between one transmission and another.
**Adjustment range:** 5 to 500 ms
**Default:** 25 ms

### 5.3.2 Confirmation key

**Parameter for confirmation key to apply serial parameterization**
To apply the serial parameter settings, it is necessary to confirm the operation using the confirmation key. This key is only required for protocol changes, ensuring greater security.
**Adjustment range:** 0 to 65535
**Default:** 0
**Unlock value:** 43605

**Parameter for confirmation key to apply IP address parameterization**

To apply the IP address parameter settings, you must confirm the operation using the confirmation key. This key is only required for protocol changes, ensuring greater security.

**Adjustment range:** 0 to 65535
**Default:** 0
**Fixed value:** 43605

## 5.3.3 Network

### 5.3.3.1 Parameter for IP address

It defines the device's IP address on the network, allowing it to be identified and communicate with other devices.

**Parameter for IP address – byte 0**
**Adjustment range:** 0 to 255
**Default:** 192

**Parameter for IP address – byte 1**
**Adjustment range:** 0 to 255
**Default:** 168

**Parameter for IP address – byte 2**
**Adjustment range:** 0 to 255
**Default:** 87

**Parameter for IP address – byte 3**
**Adjustment range:** 0 to 255
**Default:** 87

### 5.3.3.2 Parameter for network mask

Configures the subnet mask, determining the range of IP addresses available for communication.

**Parameter for network mask – byte 0**
**Adjustment range:** 0 to 255
**Default:** 255

**Parameter for network mask – byte 1**
**Adjustment range:** 0 to 255
**Default:** 255

**Parameter for network mask – byte 2**
**Adjustment range:** 0 to 255
**Default:** 255

**Parameter for network mask – byte 3**
**Adjustment range:** 0 to 255
**Default:** 0

#### 5.3.3.3 Parameter for gateway address

Specifies the address of the default gateway, responsible for forwarding packets to external networks.

**Parameter for default gateway address – byte 0**
**Adjustment range:** 0 to 255
**Default:** 192

**Parameter for default gateway address – byte 1**
**Adjustment range:** 0 to 255
**Default:** 168

**Parameter for default gateway address – byte 2**
**Adjustment range:** 0 to 255
**Default:** 87

**Parameter for default gateway address – byte 3**
**Adjustment range:** 0 to 255
**Default:** 1

#### 5.3.3.4 Parameter for DNS server address

Defines the DNS server address, used to translate domain names into IP addresses.

**Parameter for DNS server address – byte 0**
**Adjustment range:** 0 to 255
**Default:** 8

**Parameter for DNS server address – byte 1**
**Adjustment range:** 0 to 255
**Default:** 8

**Parameter for DNS server address – byte 2**
**Adjustment range:** 0 to 255
**Default:** 8

**Parameter for DNS server address – byte 3**
**Adjustment range:** 0 to 255
**Default:** 8

## 5.4 System and control

Allows date and time settings in UTC format.

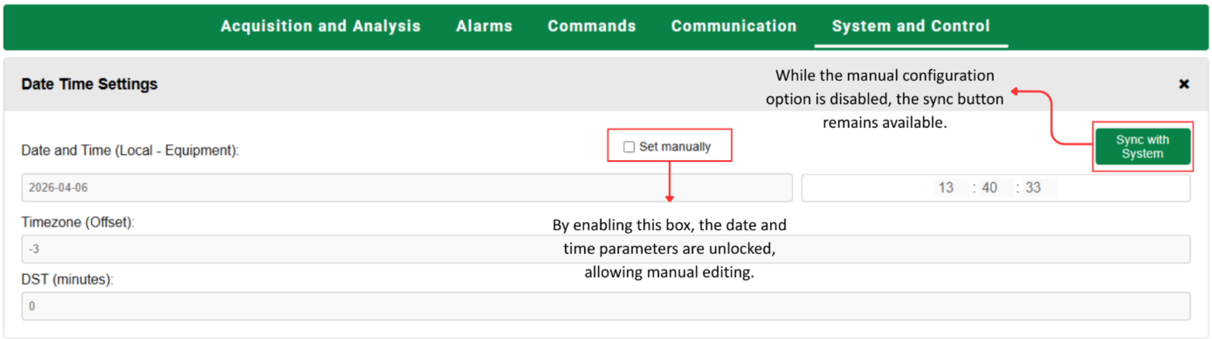



Figure 22 - Date and time settings

### 5.4.1 Manually setting the date and time

**UTC Time – Year**

Adjusts the year.
**Adjustment range:** 1970 to 65535
**Default:** 2025

**UTC Time – Month**

Adjusts the month.
**Adjustment range:** 1 to 12
**Default:** 1

**UTC Time – Day**

Adjusts the day.
**Adjustment range:** 1 to 31
**Default:** 1

**UTC Time – Hour**

Adjusts the hour.
**Adjustment range:** 0 to 23 h
**Default:** 0 h

**UTC Time – Minutes**

Adjusts the minutes.
**Adjustment range:** 0 to 59 m
**Default:** 0 m

**UTC Time – Seconds**
Adjusts the seconds.
**Adjustment range:** 0 to 59 s
**Default:** 0 s

### 5.4.2 Time zone

Sets the time zone offset relative to UTC.
**Time zone – Hours**
Adjusts the time zone in hours.
**Adjustment range:** -24 to 24
**Default:** -3

**Time zone – Minutes**
Adjusts the time zone in minutes.
**Adjustment range:** 0 to 59
**Default:** 0

### 5.4.3 Mass log interval

**Parameter for time interval for saving the mass log**
Defines the interval for periodic saving of the mass log.
**Adjustment range:** 1 to 9999 min
**Default:** 60 min

## 5.5 Alarms

### 5.5.1 Automatic mode activation

**Parameter to enable automatic mode for the alarms due to leakage current**
Enables automatic alarms for leakage current.
**Adjustment range:** YES or NO
**Default:** YES

**Parameter to enable automatic mode for the alarms due to capacitance**
Enables automatic alarms for capacitance.
**Adjustment range:** YES or NO
**Default:** YES

**Parameter to enable automatic mode for the alarms due to tangent delta**
Enables automatic alarms for tangent delta.
**Adjustment range:** YES or NO
**Default:** YES

### 5.5.2 General settings

**Alarm hysteresis**
**Adjustment range:** 0 to 100%
**Default:** 5%

**Parameter to enable current TRIP**
**Adjustment range:** YES or NO
**Default:** YES

### 5.5.3 Percentages for automatic alarms

The **automatic alarm due to leakage current** is based on the average value obtained during the reference process. The configured percentage is applied to this average value.

**Parameter of percentage for automatic alarm due to high leakage current**
**Adjustment range**: 0 to 100 %
**Default:** 10%
**Note:** For this parameter to be displayed, the automatic mode for alarms due to leakage current must be enabled.

**Parameter of percentage for automatic alarm due to very high leakage current**
**Adjustment range:** 0 to 100 %
**Default:** 20%
**Note:** For this parameter to be displayed, the automatic mode for alarms due to leakage current must be enabled.

The automatic alarms related to **capacitance and tangent delta** are adjusted as percentage increases relative to their initial values. Initial values must be programmed before using automatic mode.

**Parameter of percentage for automatic alarm due to high capacitance**
**Adjustment range:** 0 to 100 %
**Default:** 10%
**Note:** For this parameter to be displayed, the automatic mode for alarms due to capacitance must be enabled.

**Parameter of percentage for automatic alarm due to very high capacitance**
**Adjustment range:** 0 to 100 %
**Default:** 20%
**Note:** For this parameter to be displayed, the automatic mode for alarms due to capacitance must be enabled.

**Parameter of percentage for automatic alarm due to high tangent delta**
**Adjustment range:** 0 to 100 %
**Default:** 10%
**Note:** For this parameter to be displayed, the automatic mode for alarms due to tangent delta must be enabled.
**Parameter of percentage for automatic alarm due to very high tangent delta**
**Adjustment range:** 0 to 100 %
**Default:** 20%
**Note:** For this parameter to be displayed, the automatic mode for alarms due to tangent delta must be enabled.

### 5.5.4 Alarm timing

**Parameter of timing for alarm due to high leakage current**
Sets the delay time for the alarm to be triggered.
**Adjustment range:** 0 to 3600 s
**Default:** 60 s

**Parameter of timing for alarm due to very high leakage current**
Sets the delay time for the alarm to be triggered.
**Adjustment range:** 0 to 3600 s
**Default:** 30 s

The following settings will only be displayed if the "**Parameter to enable current TRIP**" is enabled.

**Parameter of timing for tripping due to high leakage current**
Sets the delay time for the TRIP relay to activate upon the alarm due to high leakage current.
**Adjustment range:** 0 to 3600 s
**Default:** 75 s

**Parameter of timing for tripping due to very high leakage current**
Sets the delay time for the TRIP relay to activate upon the alarm due to very high leakage current.
**Adjustment range:** 0 to 3600 s
**Default:** 45 s

### 5.5.5 Manual thresholds

These parameters will only be displayed if the respective alarms are not configured in automatic mode.

#### 5.5.5.1 Leakage current – High

**Manual threshold parameter for high leakage current – phase 'x'**
Selection of desired values for the emission of the alarm due to high leakage current.
**Adjustment range:** 0.20 to 650.00mA
**Default:** 80 mA

#### 5.5.5.2 Leakage current – Very high

**Manual threshold parameter for very high leakage current – phase 'x'**
Selection of desired values for the emission of the alarm due to very high leakage current.
**Adjustment range:** 0.20 to 650.00 mA
**Default:** 90 mA

#### 5.5.5.3 Capacitance – High

**Manual threshold parameter for high capacitance – phase 'x'**
Selection of desired values for the emission of the alarm due to high capacitance.
**Adjustment range:** 50.0 to 6500.0 pF
**Default:** 515 pF

#### 5.5.5.4 Capacitance – Very high

**Manual threshold parameter for very high capacitance – phase 'x'**
Selection of desired values for the emission of the alarm due to very high capacitance.
**Adjustment range:** 50.0 to 6500.0 pF
**Default:** 525 pF

#### 5.5.5.5 Tangent delta – High

**Manual threshold parameter for high tangent delta – phase 'x'**
Selection of desired values for the emission of the alarm due to high tangent delta.
**Adjustment range:** 0.010 to 65.000 %
**Default:** 0.7 %

#### 5.5.5.6 Tangent delta – Very high

**Manual threshold parameter for very high tangent delta – phase 'x'**
Selection of desired values for the emission of the alarm due to very high tangent delta.
**Adjustment range:** 0.010 to 65.000 %
**Default:** 1.05 %

### 5.5.6 Trend-based alarms

**Estimated minimum time for alarm due to high capacitance - phase A/B/C (days):**
Defines a minimum time for triggering trend alarms due to high capacitance in phases A, B, or C.
**Adjustment range:** 1 to 365 days
**Default:** 30 days

**Estimated minimum time for alarm due to very high capacitance - phase A/B/C (days):**
Defines a minimum time for triggering trend alarms due to very high capacitance in phases A, B, or C.
**Adjustment range:** 1 to 365 days
**Default:** 30 days

**Estimated minimum time for alarm due to high tangent delta - phase A/B/C (days):**
Defines a minimum time for triggering trend alarms due to high tangent delta in phases A, B, or C.
**Adjustment range:** 1 to 365 days
**Default:** 30 days

**Estimated minimum time for alarm due to very high tangent delta - phase A/B/C (days):**
Defines a minimum time for triggering trend alarms due to very high tangent delta in phases A, B, or C.
**Adjustment range:** 1 to 365 days
**Default:** 30 days

# 5.6 Commands

## 5.6.1 Control and monitoring of banks

### Command to reset reference bank

**Adjustment range:** YES or NO
**Default:** NO

### Command to restart monitoring bank

**Adjustment range:** YES or NO
**Default:** NO

## 5.6.2 Maintenance and cleaning

### Command to clear alarm memory

**Adjustment range:** YES or NO
**Default:** NO

### Command to clear self-diagnosis memory

**Adjustment range:** YES or NO
**Default:** NO

### Command to reset maximum temperature

**Adjustment range:** YES or NO
**Default:** NO

### Command to clear temperature jump

**Adjustment range:** YES or NO
**Default:** NO

## 5.6.3 Resetting trend calculations

### Command to reset capacitance trend calculations in phase A/B/C

**Adjustment range:** YES or NO
**Default:** NO

### Command to reset tangent delta trend calculations in phase A/B/C

**Adjustment range:** YES or NO
**Default:** NO

## 5.6.4 Resetting communication settings

### Command to reset network parameters to default values

**Adjustment range:** YES or NO
**Default:** NO

### Command to reset serial parameters to default values

**Adjustment range:** YES or NO
**Default:** NO

## 5.6.5 Advanced

### Command to reset user parameters to default values

**Adjustment range:** YES or NO
**Default:** NO

### Command to reset the mass log

**Adjustment range:** YES or NO
**Default:** NO

# 6 Commissioning for entry into service

Once the equipment has been installed in accordance with this manual, commissioning should follow the basic steps below.

- ✓ Verify the electrical installation according to the recommendations in this manual. Check the correctness of the electrical connections (for example, through continuity tests);
- ✓ Ensure that no contact operations will interact with other systems during this phase. If necessary, isolate all control, alarm, and shutdown contacts;
- ✓ Perform all BM parameterization according to the instructions in this manual;
- ✓ Reconnect any contacts that may have been isolated;
- ✓ After installation, it is important to check the operation of the LEDs, especially the equipment status via its respective LED (see **Operation**).

# 7 Troubleshooting

## 7.1 Self-diagnosis

The following table contains recommended solutions for self-diagnoses. If the warning persists or reappears after some time, contact Treetech technical support (see **Customer Service**).

Table 6 - Self-diagnosis

| Self-diagnosis | Recommendation |
|---|---|
| Self-diagnosis of phase sequence | Check the installation; this self-diagnosis indicates that there may be a phase reversal, meaning the cables may be reversed. |
| Self-diagnosis of channel current with high frequency difference | Check the installation; it may also indicate an internal fault. |
| Self-diagnosis of channel current with low leakage current | Check the installation; this self-diagnosis indicates that there may be an error in the installation or loose cables. |
| Self-diagnosis of channel voltage with low voltage | Check the installation; this self-diagnosis indicates that there may be an error in the installation or loose cables. |
| Self-diagnosis of persistent offset in the sample bank | Check the TAP adapter; the display of this self-diagnosis may indicate a fault in the TAP adapter. |
| Self-diagnosis of channel current with offset outside limits | Check the TAP adapter; the display of this self-diagnosis may indicate a fault in the TAP adapter. |
| Self-diagnosis of calculated current summation with high frequency difference | Check the installation; it may also indicate an internal fault. |
| Self-diagnosis of calculated current summation with offset outside limits | Check the TAP adapter; the display of this self-diagnosis may indicate a fault in the TAP adapter. |
| Self-diagnosis of measured current summation with high frequency difference | Check the installation; it may also indicate an internal fault. |
| Self-diagnosis of measured current summation with offset outside limits | Check the TAP adapter; the display of this self-diagnosis may indicate a fault in the TAP adapter. |

| | |
|---|---|
| Self-diagnosis of frequency discrepancy | Check the installation; it may also indicate an internal fault. |
| Self-diagnosis of total harmonic distortion | Check the installation; it may also indicate an internal fault. |
| Self-diagnosis of PT100 calibration<br>Self-diagnosis of PT100 reading<br>Self-diagnosis of PT100 cable reading<br>Self-diagnosis of temperature jump<br>Self-diagnosis of overflow in PT100 readings | a) Check for poor connections or disconnections throughout the entire cable path connected to terminals 1 and 2 of the temperature sensor, including the connection to the BM, the feed-through terminals, and the connection to the sensor.<br><br>b) Check if shielded cable is being used to connect the temperature sensor to the BM.<br><br>c) Verify that the shielding of the temperature sensor cable is grounded only on one side of the connection and the other end is insulated.<br><br>d) Replace the faulty temperature sensor. |

## 7.2 Self-diagnosis of internal fault

If any of the self-diagnosis issues listed below occur, it is necessary to reset the BM. This can be done by removing and reconnecting the power supply. If the self-diagnosis issue persists or recurs after some time, it is recommended to contact Treetech technical support (see **Customer Service**) for analysis and appropriate guidance.

Table 7 - Self-diagnosis of internal fault

| Internal fault |
|---|
| Self-diagnosis of general inaccuracy in phase angles |
| Self-diagnosis of inconsistency in the summation |
| Self-diagnosis of measurement failure in the current assembly |
| Self-diagnosis of measurement failure in the voltage assembly |
| Self-diagnosis of channel current with indeterminate waveform |
| Self-diagnosis of channel current near ADC saturation |
| Self-diagnosis of channel current with angular inaccuracy |
| Self-diagnosis of calculated current summation with indeterminate waveform |
| Self-diagnosis of calculated current summation near ADC saturation |
| Self-diagnosis of calculated current summation with angular inaccuracy |
| Self-diagnosis of measured current summation with indeterminate waveform |
| Self-diagnosis of measured current summation near ADC saturation |

| |
|---|
| Self-diagnosis of measured current summation with angular inaccuracy |
| Self-diagnosis of error in the PT100 sensor calibration circuit |
| Self-diagnosis of error in internal flash memory |
| Self-diagnosis of error in external flash memory |
| Self-diagnosis of error in the internal temperature sensor on the board |
| Self-diagnosis of errors in the clock's RTC circuit |
| Self-diagnosis in the TRIP relay circuit (safe activation) |
| Self-diagnosis of channel tension with indeterminate waveform |
| Self-diagnosis of channel voltage near ADC saturation |
| Self-diagnosis of channel tension with angular inaccuracy |
| Self-diagnosis of low statistical performance |
| Self-diagnosis of many corrupted samples in the bank |

# 8 Technical data and type tests

## 8.1 Technical data

Table 8 - Technical data

| HARDWARE | |
|---|---|
| Supply voltage | 85...250 Vac/Vdc |
| Frequency | 50/60 Hz |
| Maximum consumption | <12 W |
| Operating temperature | -40...85 °C |
| Degree of protection | IP20 |
| Fixation | Panel<br>DIN rail |
| **INPUTS** | |
| Current inputs (1 set) | 0...100 mA |
| Three-phase voltage inputs (1 set) | 0...185 Vac |
| 1 RTD | PT100 Ω at 0ºC with 3 wires, range -55...200°C |
| **OUTPUTS** | |
| 1x Self-diagnosis relay | Normally Closed (NC) Contact<br>Dielectric strength: 4000Vrms<br>3 A at 125 VAC (NC)<br>3 A at 250 VAC (NC)<br>3 A at 30 VDC (NC) |
| 1x TRIP Relay | Normally Open (NO) Contact<br>Dielectric strength: 4000Vac<br>5 A at 125 VAC (NO)<br>5 A at 250 VAC (NO)<br>5 A at 30 VDC (NO) |
| 2x Signaling relays | Normally Open (NO) Contacts<br>Dielectric strength: 4000Vac<br>5 A at 125 VAC (NO)<br>5 A at 250 VAC (NO)<br>5 A at 30 VDC (NO)<br>The current carrying capacity of the common terminal is 5A. Therefore, if multiple relays are used simultaneously, the sum of their currents must respect this limit to avoid overload and overheating of the connection. |
| **COMMUNICATION INTERFACE** | |
| Communication protocols | DNP3<br>Modbus® RTU |

| | |
|---|---|
| Communication ports | 2 RS-485 |
| Configuration port | 1 RJ45 |
| **DIMENSIONS AND WEIGHT** | **DESCRIPTION** |
| Dimensions | 146.8 mm x 131.1 mm x 90 mm |
| Weight | Approx. 1000g |

## 8.2 Type tests

Table 9 - Type tests

| | |
|---|---|
| **IMMUNITY TO HIGH-ENERGY SURGES (IEC 60255-26:2023)** | |
| Differential mode | 2 kV (+/-) |
| Common mode | 4 kV (+/-) |
| **IMMUNITY TO ELECTRICAL TRANSIENTS (1 MHZ BURST, IEC 60255-26:2023)** | |
| Peak value 1st cycle | 2.5 kV (common mode), 1 kV (dif. mode) |
| Frequency | 1 MHz |
| Repetition rate | 200 bursts/s |
| **APPLIED VOLTAGE (IEC 60255-26:2023)** | |
| Dielectric strength | 2 kV at 60 Hz for 1 minute |
| Voltage impulse | 5 kV (+/-) |
| **IMMUNITY TO RADIATED ELECTROMAGNETIC FIELDS (IEC 60255-26:2023)** | |
| Frequency | 80...2500 Mhz |
| Modulation index | 80% and 1 kHz sinusoidal |
| Field intensity | 10 V/m |
| Power supply | 220 V / 60 Hz |
| **IMMUNITY TO CONDUCTED ELECTROMAGNETIC DISTURBANCES (IEC 60255-26:2023)** | |
| Field intensity | 10 Vrms |
| Frequency | 0.15 a 80 MHz |
| Modulation index | 80% and 1 kHz sinusoidal |
| Scan frequency | 150 kHz to 80 MHz |
| Fixed frequencies | 27 |
| Duration | 20 s |
| Power supply | 220 V / 60 Hz |
| **IMMUNITY TO INDUSTRIAL FREQUENCY MAGNETIC FIELDS (IEC 61000-4-8)** | |
| Magnetic field intensity and direction | 30 A/m<br>3 orthogonal axes |
| **ELECTROSTATIC DISCHARGES (IEC 60255-26:2023)** | |
| Air discharge | 15 kV |
| Contact discharge | 220 V / 60 Hz |
| **IMMUNITY TO FAST ELECTRICAL TRANSIENTS (IEC 60255-26:2023)** | |
| Power, inputs and outputs (Class A) | 4 kV (+/-) |
| Current output | 2 kV (+/-) |
| **CONDUCTED EMISSION (IEC 60255-26:2023)** | |
| Conducted emission limits (Class A) | 79 dB (uV) @ 150 kHz...500 kHz (QP)<br>73 dB (uV) @ 500 kHz...30 MHz (QP)<br>66 dB (uV) @ 150 kHz...500 kHz (AV)<br>60 dB (uV) @ 500 kHz...30 MHz (AV) |
| **RADIATED EMISSION (IEC 60255-25)** | |
| Radiated emission limits (Class B) | 50 dB (uV/m) @ 30 MHz...230 MHz (QP)<br>57 DB (uV/m) @ 230 MHz...1 GHz (QP) |
| **POWER FAILURE (IEC 61000-4-11)** | |
| Amplitude variation | 0...80% amplitude |

| | |
|---|---|
| Affected cycles | ½...300 cycles |
| Power supply | 85 V…265 V - 50/60 Hz |
| Short interruptions | 5 seconds<br>85 V and 265 V<br>50/60 Hz |
| **COLD TOLERANCE (IEC 60068-2-1)** | |
| Temperature | -40°C |
| Test time | 16 hours |
| **DRY HEAT TOLERANCE (IEC 60068-2-2)** | |
| Temperature | +85 ºC |
| Test time | 16 hours |
| **HUMID HEAT TOLERANCE (IEC 60068-2-78)** | |
| Temperature and relative humidity | +40 ºC...85% UR |
| Test time | 24 hours |
| **THERMAL CYCLE (IEC 60068-2-14)** | |
| Temperature range | -40…85 ºC |
| Total test time | 120 hours |
| **RESPONSE TO VIBRATION (IEC 60255-21-1)** | |
| Application mode | Sinusoidal |
| Amplitude and frequency range | 0.075 mm (10…59 Hz)<br>1 G (59…150 Hz) |
| Duration | 8 min/eixo |
| **VIBRATION DURABILITY (IEC 60255-21-1)** | |
| Application mode | Senoidal |
| Amplitude and frequency range | 2G (10…150 Hz) |
| Duration | 160 min/axis |

# 9 Specifications for ordering

In the product purchase order, it is necessary to specify:

- ✓ Product name;
- ✓ Quantity;
- ✓ Accessories.

Treetech

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