MANUAL DO PRODUTO

Treetech

BM

Bushing Monitor

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1 Foreword

1.1 Legal information

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1.1.1 Disclaimer

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1.2 Presentation

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

1.3 Typographical conventions

Throughout this text, the following typographical conventions were adopted:

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

Italics: Terms in foreign language, alternative or with their use outside the formal situation are written in italics.

Underlined: References to external documents.

1.4 General and safety information

This section presents relevant aspects of 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 alert 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 symbols:

Important
This symbol is used to highlight information.

Tip
This symbol represents instructions that facilitate the use or access to functions in the BM.

1.4.3 Minimum profile recommended for BM operator and maintainer

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

Only authorized and trained staff – operators and maintainers – should handle this equipment.

To handle the BM, the operator should:

1. Be trained and authorized to operate, ground, turn on and off the BM, following maintenance procedures in accordance with established safety practices, which are the sole responsibility of the BM operator and maintainer;
2. Be trained in the use of PPEs, CPEs and first-aid;
3. Be trained in the working principles of the BM, as well as its configuration;
4. Follow regulatory recommendations regarding interventions in any type of equipment included in an electric power system.

1.4.4 Environmental and voltage conditions required to installation and operation

The table below lists important information on the environmental and voltage requirements.

Table 1 - Operation conditions

Condition	Range/description
Application	Equipment for sheltered use in substations, industrial and similar environments
Indoor/outdoor use	Indoor use
Protection level (IEC 60529)	Front panel IP50, rear panel IP20
Altitude* (IEC EN 61010-1)	Up to 2000 m
Temperature (IEC EN 61010-1)	
Operation	-40...+85 °C
Storage	-40...+85 °C
Relative humidity (IEC EN 61010-1)	
Operation	5...95 % - Non-condensing
Storage	3...98 % - Non-condensing
Voltage fluctuation of the power supply (IEC EN 61010-1)	Up to ±10% of nominal voltage
Overvoltage (IEC EN 61010-1)	Category II
Degree of pollution (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 Test and installation instructions

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

To ensure user safety, equipment protection and correct 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 transformer's actual health and operational status.

2. The installation, adjustments, and operation of the BM must be performed by personnel trained and familiar with power transformers with mineral or vegetable oil insulation, control devices, and control circuits of substation equipment.

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.

4. When performing dielectric strength tests on the wiring (applied voltage), disconnect the ground cables connected to terminal 17 of the Interface Module and to terminal 1 of the Measurement Module, and disconnect the plug from the tap adapter, isolating its casing from any grounded part. Otherwise, the overvoltage protections inside the devices would be destroyed due to the application of high voltages for a long period (e.g., 2 kV for 1 minute).

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.

1.4.6 Cleaning and decontamination instructions

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.

1.4.7 Inspection and maintenance instructions

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 carried out by the user. These inspections are not mandatory.

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

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.

Do not attempt to access the equipment's factory menu (FABR). Attempting to access this menu with the wrong password will display the message VOID; after several attempts, it will completely block access to the equipment's menus and void the warranty.

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.

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.

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, mistreatment, improper 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 the 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

Bushings are accessories used in high-voltage equipment to allow the passage of electric current between the outside and inside of the equipment, also providing the necessary insulation from the equipment casing. Some of the most common applications include power transformers, shunt reactors, current transformers, and high-voltage dead-tank circuit breakers.

Although they are an accessory for the various pieces of equipment mentioned, and their individual cost is generally relatively small when compared to the overall cost of the device, bushings play an essential role in the operation of the equipment.

On the other hand, bushings are subject to considerable dielectric stresses, and a failure in their insulation can result in damage not only to the bushing but also to the equipment to which it is associated. In extreme cases, a dielectric failure in a bushing can lead to the total destruction of high-voltage equipment (in the case of a power transformer, for example, the losses in such an event can be several hundred times the cost of the bushing that caused the problem).

Treetech's Bushing Monitor allows for online monitoring, with the bushing energized, of the capacitance and dissipation factor (tangent delta) of the bushing insulation, which are important variables for the early detection of insulation deterioration. This helps prevent potentially catastrophic failures by detecting problems in their early stages.

Figure 1 - Parts of the Bushing Monitor

2.1 Features and functions

Bushing monitoring

BM utilizes engineering modules developed by Treetech to monitor the condition of the condenser bushings.

Robust hardware

The BM design exceeds EMC (Electromagnetic Compatibility) standards to withstand harsh electromagnetic conditions in substations and operating temperatures from -40 to 85°C.

Spare bushing operation

Programming for putting a spare bushing into service, in the case of single-phase transformer banks.

Protection against tap opening

Alarm indicating activation to protect against the opening of the bushing tap.

VFD type display (Vacuum Fluorescent Display)

High brightness, legible in any lighting and temperature condition.

Tap adapters

Connection via adapters to the Test or Tension taps of capacitance-graded bushings, in addition to the innovative monitoring capability via BPDs (Bushing Potential Devices).

Modular system

Configurable for monitoring 3, 6, or 9 bushings.

Alarm timing

Alarms due to high or very high bushing leakage current with adjustable timing, identifying rapidly or very rapidly evolving defects and reducing the risk of catastrophic failures.

Self-diagnosis

Verification of the consistency of alarms due to high and very high leakage current through measurement of the sum of currents, with blocking of false alarms and indication of self-diagnosis in case of inconsistency detection.

Data history

Internal clock and non-volatile memory for storing historical capacitance and tangent delta data and for alarm occurrences.

Automatic alarm adjustment

Automatic adjustment of alarm values for high or very high leakage currents during the learning period, with a user-programmed safety margin as a percentage.

Communication

Selectable serial communication port for RS-485 or RS-232 with Modbus and DNP3 protocols.

Compact and versatile

The BM has compact dimensions, providing space savings and reduced installation costs.

2.1.1 Inputs

- ✓ Inputs for 2 Pt100 temperature sensors, allowing recording and correlation of variations in insulation with fluctuations in ambient temperature, oil temperature, or other factors.

2.1.2 Outputs

- ✓ 7 configurable output contacts (NO or NC) for alarms based on absolute values, high evolution trends, or low, high, or very high leakage currents in the bushings;
- ✓ 1 fixed output contact (NC) for self-diagnosis;
- ✓ 2 configurable analog outputs for remote indication of capacitance and tangent delta. Configurable output range: 0...1, 0...5, 0...10, 0...20 or 4...20 mA.

2.1.3 Communication

- ✓ 1 RS-485 serial communication port;
- ✓ 1 RS-232 serial communication port;
- ✓ Modbus and DNP3 communication protocols.

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.

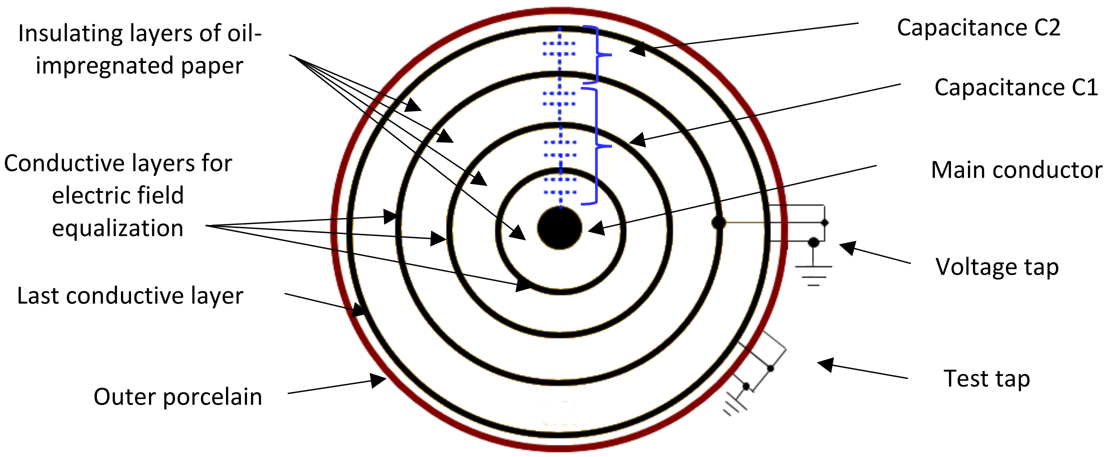


Figure 2 - Top view of a condenser bushing

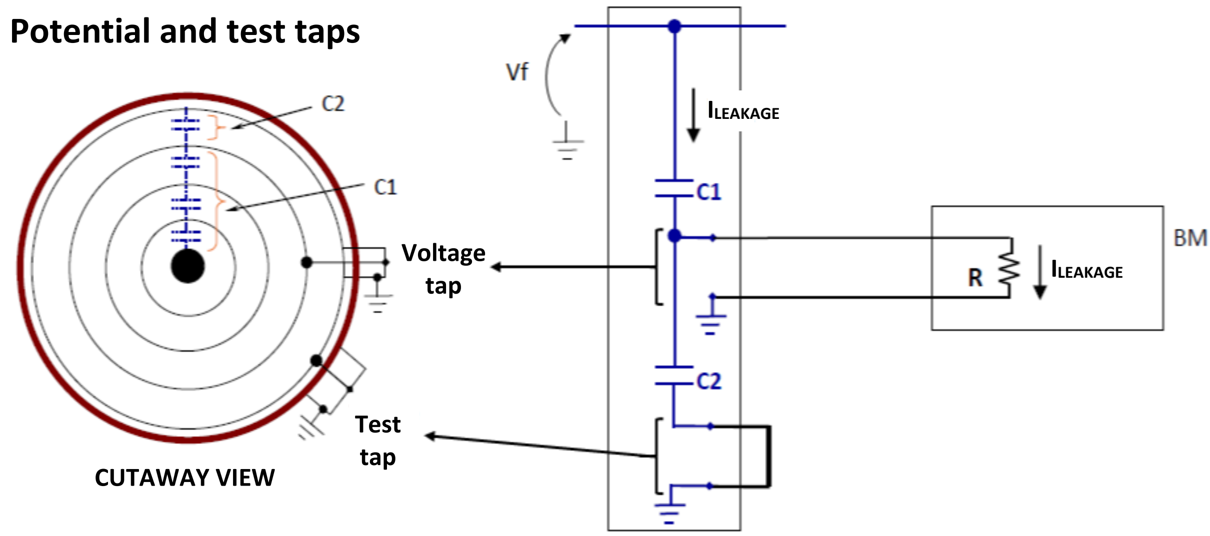


Figure 3 - Construction form of a condenser bushing

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.

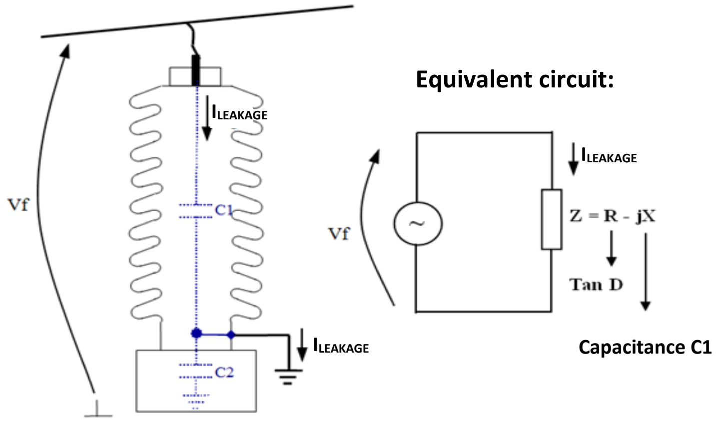


Figure 4 - Equivalent circuit of an energized condenser bushing

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, 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 120º 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. The changes detected in the summation current are always attributed to only one of the bushings in 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.

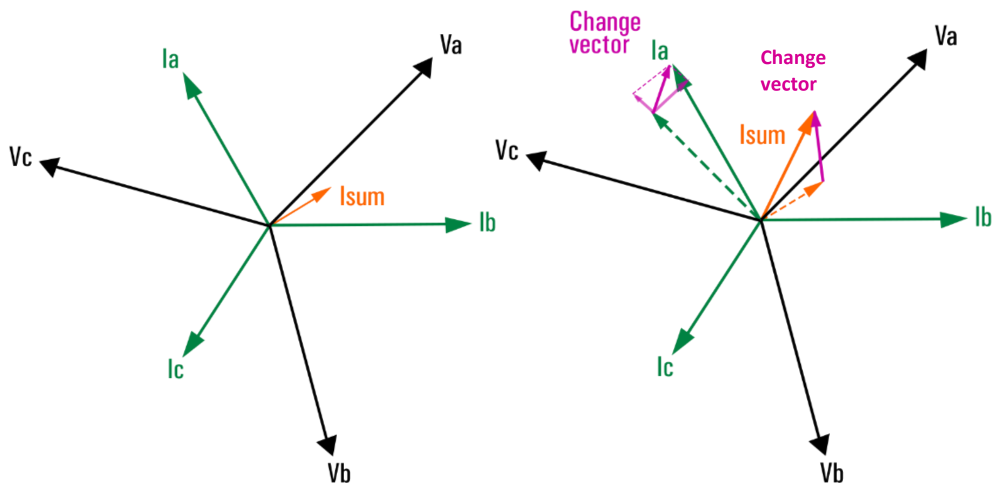


Figura 5 - Leakage currents and summation of three bushings in a three-phase system: (a) For a given initial condition; (b) With a change in the capacitance and dissipation factor of the bushing of phase A

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 period of 10 days after the start of operation of the monitoring system. The process of measuring the changes that occur, for the same reasons, has a response time to reach stabilization at the final value after a step change in capacitance or tangent delta of approximately 10 days.

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 Intended Use

Treetech's Bushing Monitor (BM) enables online monitoring, with the bushing energized, of variables such as capacitance, dissipation factor (tangent delta), and leakage current in transformer bushings. These critical variables are essential for the early detection of insulation deterioration. By detecting problems in their initial stages, the BM prevents catastrophic failures, contributing to the integrity and performance of electrical equipment.

2.5 Detection of defects with rapid evolution in bushings

Several experts in the electrical industry argue that the evolution of defects in bushings is slow and gradual, taking weeks or months. Given this premise, the response time of the monitoring system for variations in capacitance and tangent delta would not present any problem for detecting developing defects in the bushings, giving the user sufficient time to take action when a defect is detected. Experiences with periodic offline measurement of these variables, and with online monitoring, confirm this notion.

However, it should be taken into account that most of the data accumulated from bushing maintenance experience originates from periodic offline measurements, with intervals on the order of several years. Considering that, in the vast majority of cases, offline measurements will only be able to detect evolving defects and prevent bushing failures in cases where the defect has a slow evolution, it is therefore natural that the impression was conveyed that all failures have a slow evolution. In cases where the bushing failed in the interval between offline tests, it was impossible to know the actual speed of failure evolution, and many of them may have had rapid evolution.

With the popularization of online monitoring, which began very recently, the continuous tracking of changes in capacitance and tangent delta has allowed us to observe many cases where the evolution was indeed slow, but it has also highlighted some others where the evolution occurred rapidly or very rapidly. This fact brings to light the need for mechanisms in online monitoring systems to detect and alert the user when such defects occur. Simultaneously, the ability to detect defects with slow evolution of capacitance and tangent delta, already available with the vector summation technique of leakage currents, should not be lost.

To address this need, Treetech has developed a method, with patents pending worldwide, for detecting and alarming rapidly evolving defects where the bushing insulation is short-circuiting (increasing its capacitance) and heading towards imminent failure.

The immediate effect when the bushing insulation is short-circuited and heading towards complete failure is an increase in leakage current, due to the increase in equivalent capacitance when insulation layers are short-circuited.

This allows the Bushing Monitor to program limit values for triggering alarms due to high and very high leakage currents, providing two alarm levels with different severity levels. To prevent the triggering of false alarms caused by transient overvoltages, the alarms have user-adjustable timers.

In this case, the monitoring system would also act as a protection system, requiring a high degree of confidence that the measurement indicating an imminent failure is correct. The same need exists when the shutdown decision is manual and not automatic, as the operators' decision will be based on the information provided by the Bushing Monitor.

To ensure the reliability of the measurement and eliminate the possibility of false alarms due to hardware defects, for example, a strict consistency check is performed by the Bushing Monitor.

Any changes in the leakage currents of the bushings are also reflected in the vector sum of the currents. Therefore, the veracity of a high leakage current occurrence in one of the phases can be verified, before generating high or very high leakage current alarms, by comparing the measurements of the individual leakage currents with the measurement of the vector sum, which should always be consistent.

If a high leakage current measurement is not confirmed by the sum of the current measurements, the alarm is blocked. Instead of an alarm, the Bushing Monitor then issues a self-diagnostic warning alerting to the existence of inconsistencies in the measurements.

This procedure, for which patents are pending, ensures the reliability of high leakage current alarms, generating the necessary confidence in users to take actions based on this information, which in many cases could be drastic, such as the immediate shutdown of the transformer.

2.6 Recommendations for capacitance and tangent delta alarm thresholds

Below are some guidelines to support the parameterization of the Bushing Monitor - BM.

The main objective is not to suggest adjustments for the BM, but rather to provide guidance on how to proceed in case of alarms. However, the information is interesting because the suggested adjustments end up being shown implicitly and based on IEEE standards.

To clarify any doubts, the suggestions for adjustments implicit in the text are:

- High capacitance: 2 to 3% increase.

- Very high capacitance: 5% increase.
- High delta tangent: 100% increase.
- Very high tangent delta: 200% increase.
- Trend-based alarms: these alarms offer greater adjustment flexibility, so they are not mentioned in the manual, but a setting of 7 to 14 days is always suggested.

Based on IEEE standards C57.19.100-1995 and 2012 (IEEE Guide for Application of Power Apparatus Bushings), some procedures are recommended in case of alerts from online bushing monitoring.

Although the standard refers to off-line tangent delta and capacitance tests, as was the practice at the time it was written, the general guide has direct application to bushings monitored online, as will be shown below. Texts on “Regulatory Recommendations” were extracted from section 10.2.1 of IEEE C57.19.100-1995. Texts on “Application for online monitoring” are suggestions from Treetech.

Below is a general guide for the Online Condenser Bushing Monitor.

2.6.1 Capacitance

2.6.1.1 Regulatory recommendations

✓ **IEEE C57.19.100-1995:**

The bushing capacitance must be measured in each dissipation factor or power factor test, and the nameplate data and results from previous bushing condition tests must be carefully compared.
This is especially important with regard to multilayer condenser bushings, where an increase of 5% or more in the initially measured capacitance (or nameplate value) is reason enough to investigate whether the bushing is still suitable for continued service.

2.6.1.2 Application for online monitoring

- The bushing capacitance is monitored online and compared to alarm levels, which are based on the nameplate or previous test values plus a margin;
- If the capacitance increases by 5% from the initial value, the " Very High Capacitance " alarm will be displayed on the bushing monitor. (Unless the user has programmed it differently.);
- If the "Very High Capacitance" alarm sounds, the bushing must be removed from service;
- In addition to the capacitance alarm mentioned above, the Bushing Monitor has two other warning levels before the extreme "Very High Capacitance" level;
- The first level is the "Increasing Capacitance Trend" alarm, which is an advanced alert indicating that a "High Capacitance" alarm is likely to occur in the future. In this case,

observe the capacitance evolution to determine if it will reach the "High Capacitance" level;

- The second level is the "High Capacitance" alarm, typically set between 2% and 3% above the initial capacitance. In this case, we suggest a scheduled shutdown for offline testing. If high capacitance is confirmed, it is advisable to schedule the bushing's removal from service.

Practical recommendations

High alarm:

- **Standard:** 3 %
- **Recommended: 3 %**

Very high alarm:

- **Standard:** 5 %
- **Recommended: 5 %**

2.6.2 Tangent Delta

2.6.2.1 Regulatory recommendations

✓ **IEEE C57.19.100-1995:**

If a bushing shows an increase in dissipation or power factor over a period of time, more frequent tests should monitor this growth rate.
If, from the initial measurement, the value of the dissipation or power factor:

- Doubles, the frequency of tests should be increased or the service bushing should be removed.
- Triples, the service bushing should be removed.

✓ **IEC 60137:2008**

The maximum permissible value for Tangent Delta measured at the factory is 0.7% absolute, with the typical bushing being 0.35% absolute.

2.6.2.2 Application for online monitoring

Practical recommendations

High alarm:

- **Standard:** 100 %
- **Recommended:** double the initial value (100%) of variation or 0.700% in absolute value, whichever is greater.

Very high alarm:

- **Standard:** 200 %
- **Recommended:** three times the initial value (200%) of variation or 1.050% in absolute value, whichever is greater.

The minimum values are based on recommendations for a typical bushing with an initial tangent delta of 0.350%, according to IEC 60317:2008.
The recommended absolute minimum value for “alarm due to high delta tangent”, of 0.7%, is based on the IEC 60137:2008 standard and is justified by the fact that variations that occur naturally in the calculation of the delta tangent can trigger undue alarms if the alarm setting, based on a 100% increase over the initial value, results in a very low absolute value.
The recommended absolute minimum value for “alarm due to very high delta tangent”, of 1.05%, is suggested in order to maintain consistency and proportionality with the minimum recommended value for the “alarm due to high delta tangent” (0.7%).

3 Design and Installation

3.1 System topology

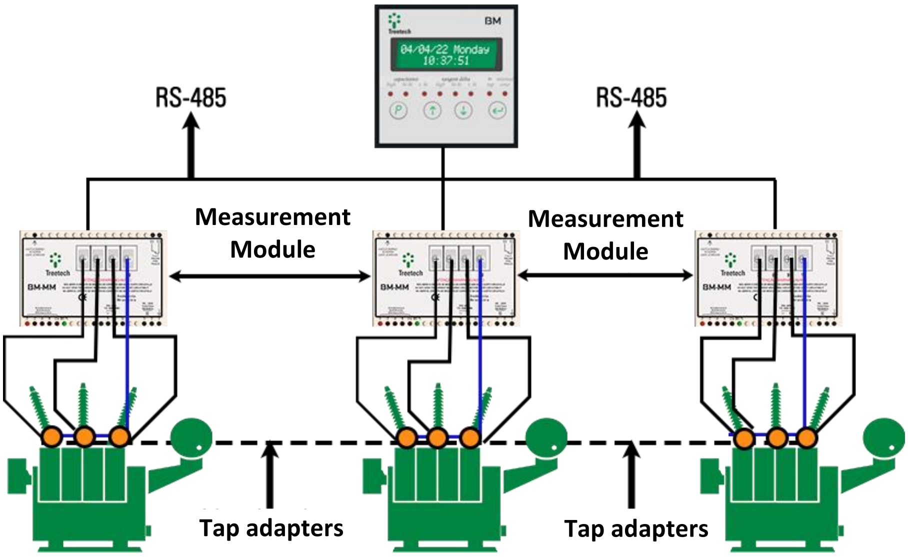


Figure 6 - Interconnection Block Diagram

The Bushing Monitor (BM) consists of 3 basic parts:

- **Adapter for test tap or voltage tap** - It provides the electrical connection to the bushing tap, also ensuring its mechanical rigidity and weatherproofing. It incorporates protection against overvoltages and overcurrents due to transient phenomena and protection against accidental opening of the measuring circuit, preventing the tap from remaining open. The mechanical construction of the adapter varies, following the different bushing taps available on the market;

- **Measurement Module - BM-MM** - It receives leakage currents from three bushings in a three-phase set, performs measurements of these currents and a first level of mathematical and statistical processing of the information, making it available to the Interface Module (BM-HMI) through an RS-485 serial communication port;

- **Interface Module** - BM-HMI - It receives information from one, two, or three measurement modules (BM-MM), displaying the current capacitance and tangent delta values of each bushing on the front displays. It also provides analog outputs (mA), alarm contacts, and RS-485 and RS-232 serial communication ports available to the user. Figure 6 illustrates the interconnections between these parts.

The following items are also required for the implementation of the BM bushing monitoring system:

- Shielded braided cable for interconnecting the serial communication ports of the BM-MM measurement modules and the BM-HMI Interface Module;

- Braided shielded cable for connection between bushing tap adapters and BM-MM measuring modules.

Figure 7 - Components of the Bushing Monitor - BM. (a) Adapter for test tap or voltage tap; (b) Measurement Module - BM-MM; (c) Interface Module - BM-HMI.

3.2 Mechanical installation

With the exception of the bushing tap adapter, the equipment of the Bushing Monitoring system must be installed protected from the elements, housed inside panels. An anti-condensation system must be in place.

3.2.1 Measuring tap adapter

At the start of Bushing Monitor (BM) operation, it will be necessary to configure the equipment with the current capacitance and tangent delta values of the bushings. For bushings already in operation, it will be necessary to measure these parameters conventionally, with the bushing de-energized. These measurements can be performed with the tap adapters already installed on the bushings, provided that the voltage at the tap does not exceed 9 V peak during the measurement process.

The bushing measuring tap adapter has variable dimensions due to differences in the mechanical construction of the bushing taps from different manufacturers or even between different models from the same manufacturer.

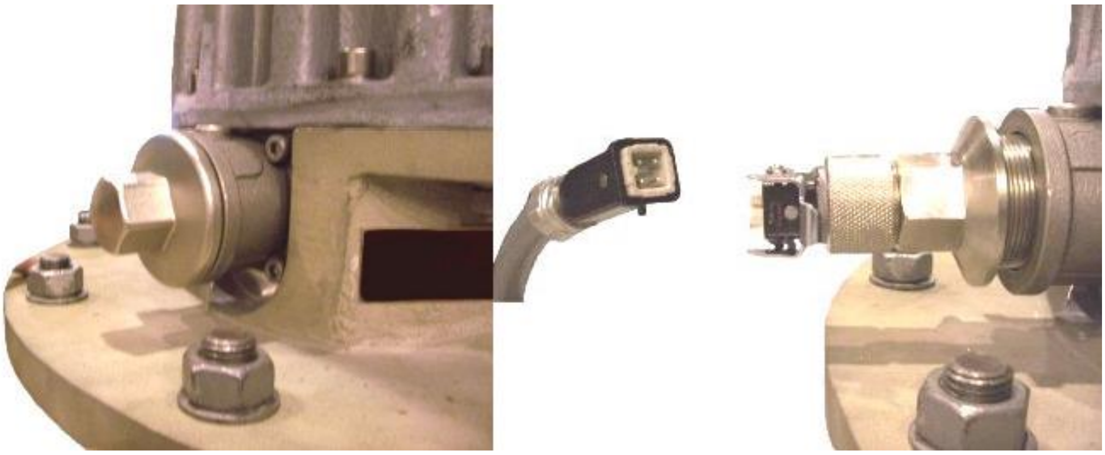


Figure 8 - Assembly of the adapter for capacitive tap

The adapter must be installed with the transformer de-energized. After running the cabling to the base of the bushing, connect the cables to the connection socket, paying attention to the pin numbering. After assembling the socket, remove the capacitive tap cover and connect the adapter, with the socket disconnected, as shown in Figure 8. Using force when connecting the adapter is not necessary and may damage the bushing tap. For more details, check our virtual wiki for the tap adapter installation procedure.

Tap adapters

After attaching the adapter, connect the plug to the adapter. Once installed, follow the commissioning procedure.

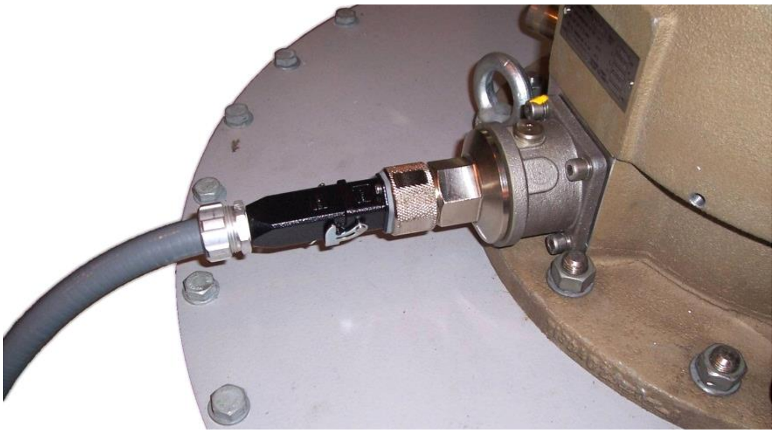


Figure 9 - Adapter installed

During the installation of the tap adapter, the following precautions must be taken:

- Threading by hand, without the aid of tools.
- Do not place, step on, or hang objects on the tap adapter. Always anchor the cable or conduit to a nearby structure to relieve mechanical stress on the outlet.

3.2.1.1 BSP x PG thread adapter

The BSP x PG thread adapter is used to connect the tap adapter and the tube that carries the electronic circuits to the bushing.

Material: Nickel-plated brass;

- **Male thread** PG11;
- **Female thread** BSP ½”.

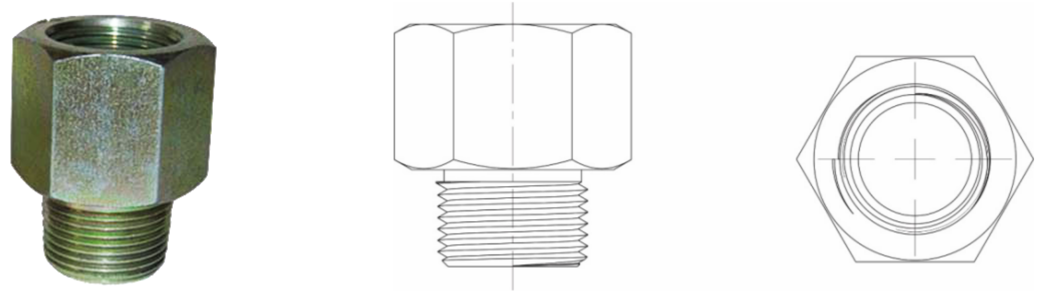


Figure 10 - BSP x PG thread adapter

3.2.2 Measurement module - BM-MM

The Measurement Module is suitable for mounting on a standard 35 mm DIN rail and can be located, for example, on mounting plates inside panels. Figure 11 shows the main dimensions of the equipment.

If the grounding recommendations for the cable shielding are observed, the Measurement Module can be installed up to 500 meters away from the bushings. Generally, it should be located as close as possible to the bushings to be monitored, with the ideal location for installing the BM-MM being inside the control panel on the transformer body or the centralizing panel of the transformer bank, in the case of single-phase transformer banks.

The connection terminals are installed on the front of the BM-MM. Cables from 0.5 to 2.5 mm^2, bare or with "pin" (or "needle") type terminals, can be used for the power supply and serial communication circuits. For the leakage current measurement cables from the bushing taps, "eyelet" type terminals of up to 2.5 mm^2 should be used.

For connecting the BM-MM and the tap adapter, it is recommended to use 0.75 mm^2 cables for applications up to 50 m; for distances exceeding this, application safety requirements should be evaluated. Larger cable gauges should be used for the interconnection between the transformer panel and the Measurement Module - MM panel.

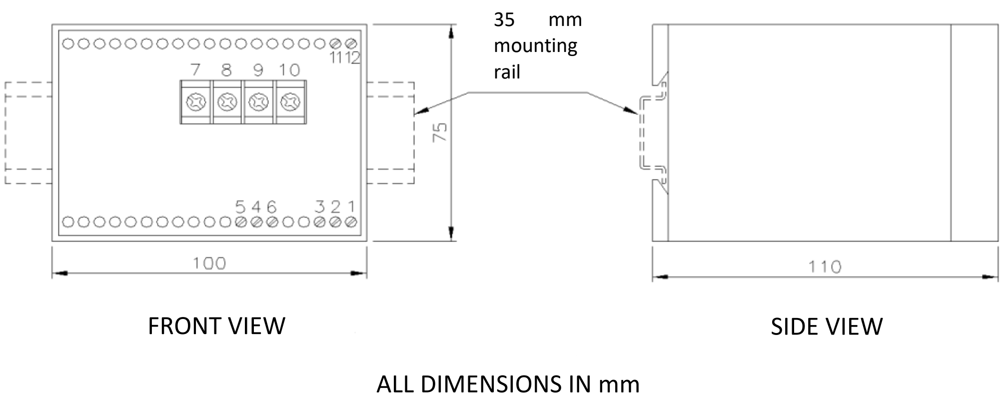


Figure 11 - Measurement module dimensions - BM-MM

3.2.3 Interface module - BM-HMI

The BM-HMI Interface Module is suitable for recessed mounting and can be fixed, for example, to doors or front panels. Mounting clips are supplied with the module. Figure 12 shows the main dimensions of the equipment, as well as the dimensions of the cutout in the panel for its insertion. Special attention should be paid to the thickness of the paint layers on the panel where the cutout is made, because in some cases, when high-thickness paint is used, the reduction in the cutout area may even prevent the insertion of the equipment.

The connection terminals are installed in 2 removable connectors on the back of the BM-HMI to facilitate connections. Cables from 0.5 to 2.5 mm², bare or with "pin" (or "needle") type terminals, can be used.

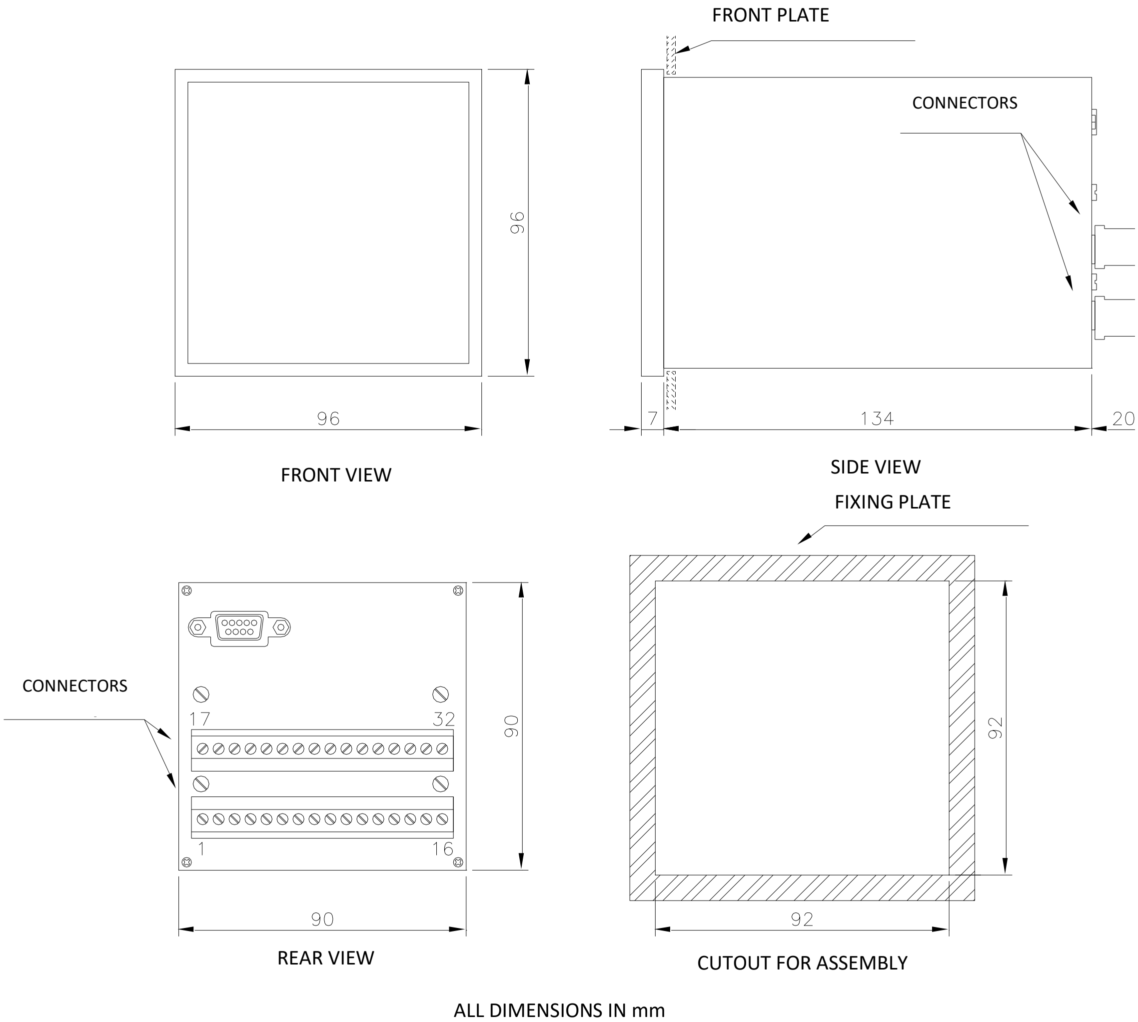


Figure 12 - Interface module dimensions - BM-HMI

3.3 Electrical Installation

3.3.1 Cable specification

Table 2 - Cable specification

Cable specifications		
Function	*Specification*	*Observation*
Power supply	1.5mm^2 to 2.5mm^2	-

TAP adapter	**Exposed to the weather:** Shielded cable (BTC), 2 x 18 AWG, EPR 90°C insulation, 0.6/1 kV. **Protected from the weather:** Shielded cable (BTC), 2 x 18 AWG, PVC insulation.	Mandatory, referring to NBR7286
Three-phase voltage signal	$1.5mm^2$	-
PT100	**Exposed to the weather:** 3x16 AWG cable with EPR insulation **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 Error! Reference source not found.
Relays	**$1.5\ mm^2$:** Minimum gauge for signaling (self-diagnoses, alarms...) **$2.5\ mm^2$:** Minimum gauge for power circuits (TRIP relay)	Recommended according to the specification in NBR5410
RS485/232	2x18AWG PVC Cable	-

3.3.2 Input and output terminals

3.3.2.1 Measurement module - BM-MM

Table 3 - BM-MM Inputs

Inputs	BM-MM Terminals
1) Auxiliary power supply and grounding: Universal power input - 38 ~ 265 Vac/Vdc, 50/60 Hz, 5 W	1 - ground 2 - dc/ac 3 - dc/ac
2) Measurement of leakage currents: It receives leakage currents from the bushings, originating from the tap adapters. There are three inputs in total, one for each phase of a three-phase bushing set. The return of leakage currents to ground occurs through a terminal common to all three phases.	7 - Phase A 8 - Phase B 9 - Phase C 10 - Common

Auxiliary power supply and grounding

The BM has a universal auxiliary power input (38 to 265 Vac/Vdc, 50/60 Hz) independent of the PT measurement input. However, it is possible to use the PT's own secondary voltage to power the equipment, through an external jumper connecting the measurement and power inputs in parallel. In this case, the equipment's consumption (8 W) and the PT's power should be taken into account.

Powering the BM through the substation's auxiliary services is advisable, especially when it is integrated into a serial communication network for data collection purposes for supervisory or monitoring systems.

Measurement of leakage currents

ATTENTION: 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 measuring modules, but that short-circuitable intermediate terminals (such as those used for current transformer circuits) be used. See Figure 13. This makes it possible to short-circuit the intermediate terminals and divert leakage currents, allowing the measuring module to be taken out of operation even with the bushings energized.

The connecting cable between the tap adapter and the Measurement Module must be of the shielded twisted-pair type. To ensure the mechanical strength of this cable, the use of very small gauges is not recommended, in order to reduce the possibility of accidental opening of the bushing tap. Gauges of 18 AWG or 0.75 mm^2 are indicated.

The shielding of the connecting cables between the tap adapters and the Metering Module must also pass through terminals, avoiding any 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. If the measurement module is installed in the control panel on the transformer tank itself, the shielding grounding can alternatively be done at the control panel itself.

Table 4 - BM-MM Outputs

Outputs	BM-MM Terminals
1) RS-485 Port - HMI: Connection to the RS-485 port of the Interface Module. Up to three Measurement Modules can be connected to the same Interface Module. **Terminal 6 - Mesh should not be connected at any point and should remain open.**	4 (+) 5 (-)
2) Self-Diagnosis Relay: Potential-free (NC) contact signals power failure, internal fault, or low leakage current (possible loss of connection to the bushing tap). When the Bushing Monitor is energized, this contact changes state, returning to the rest position in the event of a fault.	11 and 12

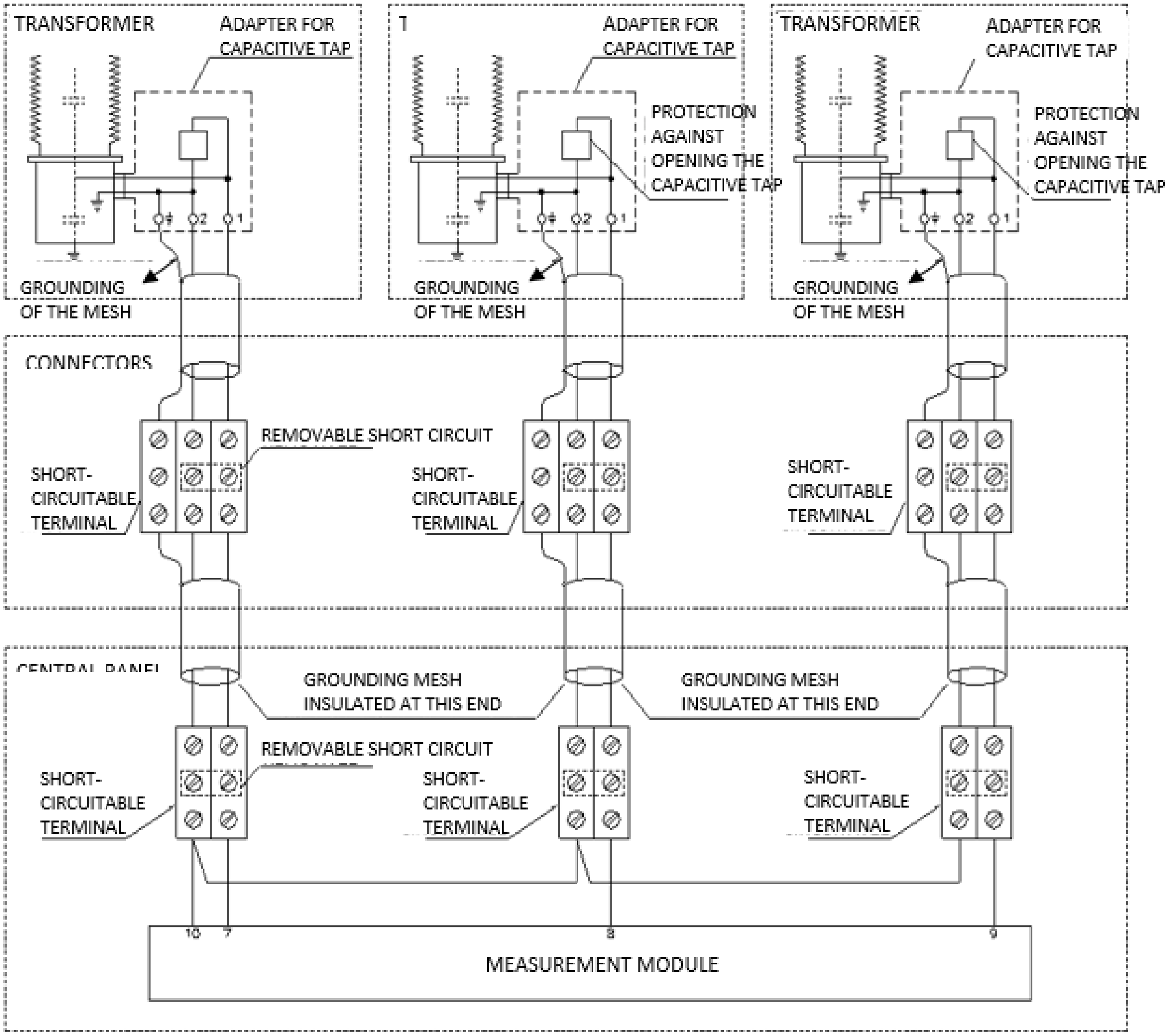


Figure 13 - Details of connection and grounding of the shielding of leakage current measuring cables, using short-circuit terminals.

RS-485 Port - HMI

The RS-485 serial communication ports of all measurement modules must be interconnected using a shielded twisted-pair cable, maintaining an uninterrupted connection up to its grounding point near the Interface Module - BM-HMI.

The unshielded cable section, due to the splice, should be as short as possible.

3.3.2.2 Interface Module - BM-HMI

The following inputs and outputs are available in this module:

Table 5 - BM-HMI Inputs

Inputs	BM-HMI Terminals

1) Auxiliary power supply and grounding: Universal power input 38 ~ 265 Vac/Vdc, 50/60 Hz, 8 W	17 - ground 18 - dc/ac 19 - dc/ac
2) RTD Inputs: This input allows the connection of up to additional temperatures, for example, ambient, tap changer, or others. The use of these inputs is optional. When using only RTD B, an external jumper must be used between terminals 26 and 27 of the BM-HMI, as shown in the wiring diagram.	RTD A 26, 27 and 28 RTD B 26, 27, 29 and 30 (see wiring diagram)
3) RS-485 Port - MM's: Connection to the RS-485 ports of the Measurement Module(s) via shielded twisted-pair cable. One, two, or three Measurement Modules can be connected to the same Interface Module.	20 (+) 21 (-)

If intermediate terminals are needed for interconnecting the RS-485 serial communication between the Measurement Modules and the Interface Module, and/or the RTD sensor, the cable shields must also pass through terminals to avoid interrupting them. The unshielded cable section – due to the splice – should be as short as possible. See Figures 13 and 14.

The maximum distance between the ends of the RS-485 serial communication network should be 1300 meters, using a termination resistor at each end with a value of 120 ohms.

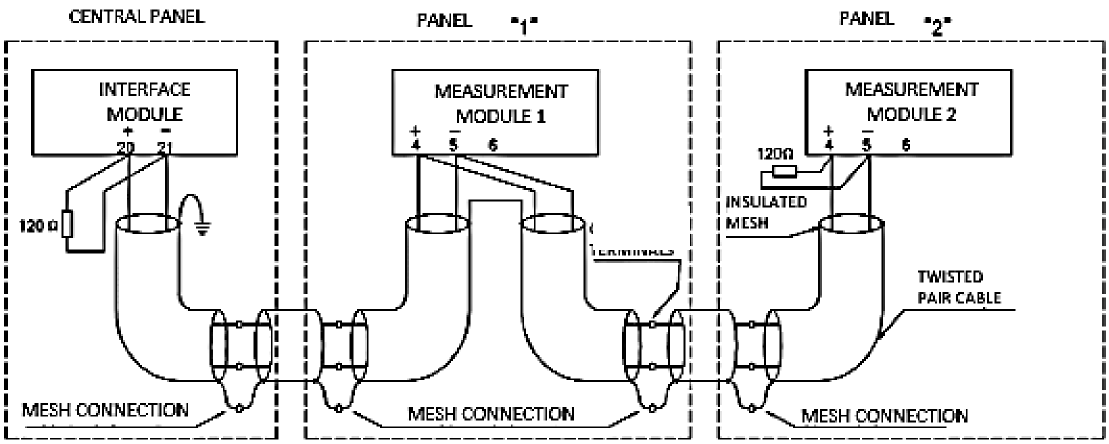


Figure 14 - Connection and grounding details for the shielding of the interconnecting cables between the Measurement Modules and the Interface Module.

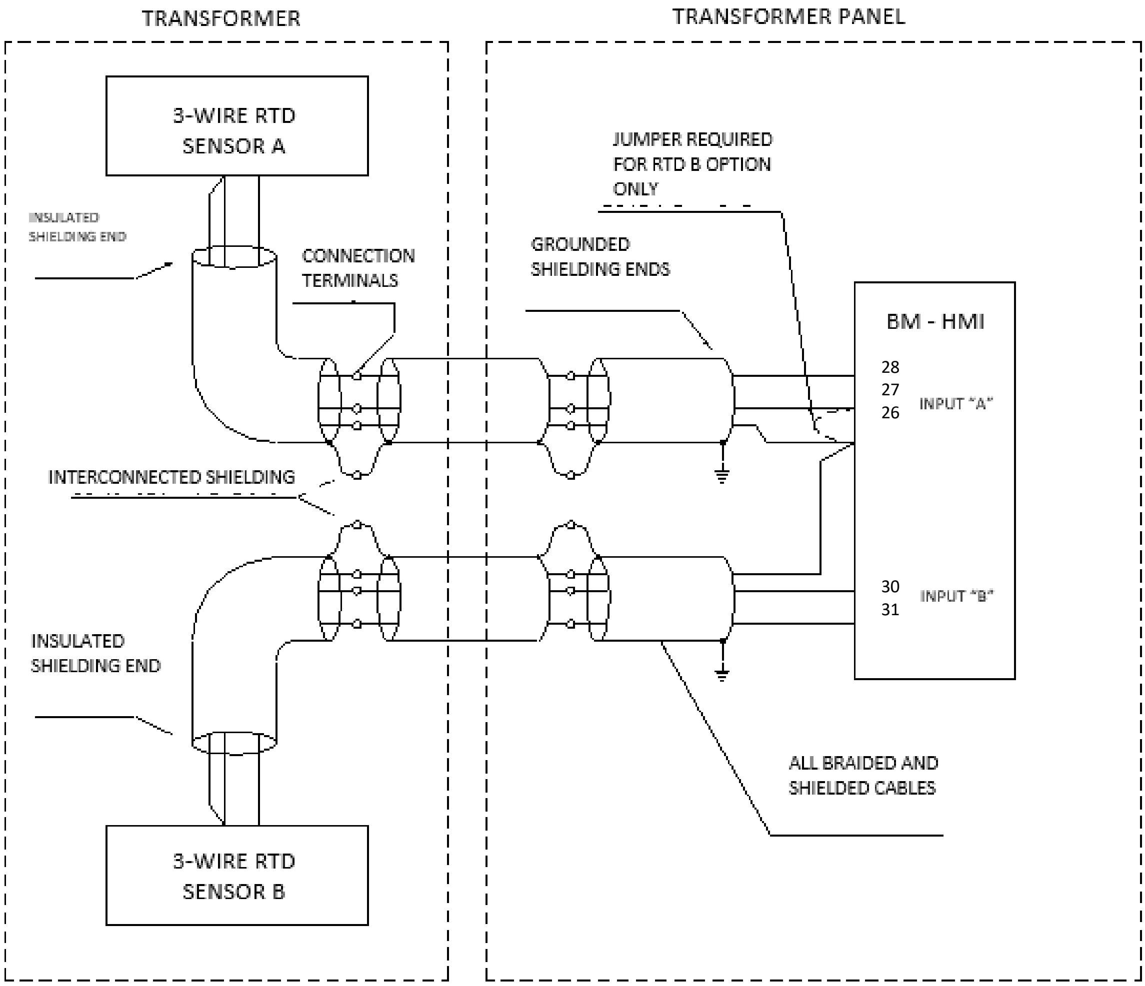


Figure 15 - Connection and grounding details for the cables and shielding between the Pt100 and BM-HMI.

Table 6 - BM-HMI Outputs

Outputs	BM-HMI Terminals
Current Loop Output: Programmable outputs for remote indication of current capacitance and tangent delta values of the bushings. Output pattern selected by software (0...1, 0...5, 0...10, 0...20 or 4...20 mA).	22 (+) common 23 (-) 24 (+) common 25 (-)
Self-Diagnosis Relay: Potential-free (NC) contact signals power failure, internal fault, or fault in the connecting cables. When the Bushing Monitor is powered on, this contact changes state, returning to the rest position in the event of a fault.	15 and 16
Programmable signaling relays (NO): Potential-free (NO) contacts with programmable function and operating mode (NO or NC). Alarms for high values, very high values, or even for high trends in capacitance and/or tangent delta, programmable through the menu.	1 and 2 - Relay 1 3 and 4 - Relay 2 9 and 10 - Relay 5 11 and 12 - Relay 6 13 and 14 - Relay 7

Programmable signaling relays (NC): Potential-free (NC) contact with programmable function and operating mode (NO or NC). Alarms for high values, very high values, or even for high trends in capacitance and/or tangent delta, programmable through the menu.	5 and 6 - Relay 3 7 and 8 - Relay 4
RS-485 / RS-232 Port - SCADA: Connection to data acquisition system, Modbus RTU or DNP3 protocols, via shielded twisted-pair cable (RS-485) or rear DB9 connector (RS-232).	31 (+) 32 (-) or DB9 connector (rear panel)

3.3.3 Application Diagrams

The BM bushing monitoring system has a modular design, where one Interface Module can receive information from up to three Measurement Modules. This design allows for various application combinations in three-phase and single-phase transformers, reactors, current transformers (CTs), or combinations of these devices. The following figures show some examples of possible connection diagrams for Tap Adapters, Measurement Modules, and the Interface Module.

Note that if there are spare transformers or reactors, their bushings will only be monitored when these units are put into service. To do this, disconnect the tap adapter from the unit being taken out of service from the measuring module and connect the cables from the tap adapter of the spare unit's bushing in its place.

ATTENTION: Special care must be taken to ensure that the tap of none of the bushings in operation is left open, as this could cause serious damage to the bushing and personal injury. It is recommended that even for bushings that are not in operation, the tap be kept grounded, only removing the ground connection when reconnecting to the measuring module.

Whenever any monitored bushing is replaced, the BM must update the initial capacitance and tangent delta values of the bushings entering operation and restart the initial reference learning process. To facilitate these operations, the “Bushing Replacement” menu can be used. This procedure should be performed in any of the situations exemplified below:

- Start-up of the reserve unit;
- Shutdown of the reserve unit and return to normal unit operation;
- Replacement of any bushing being monitored by a new bushing.

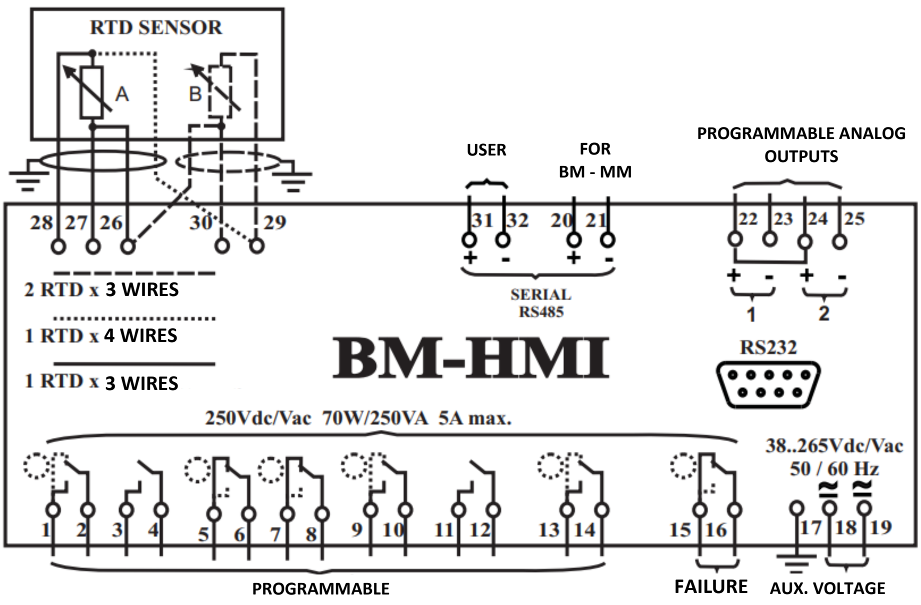


Figure 16 - Wiring diagram for the BM-HMI, the BM interface module

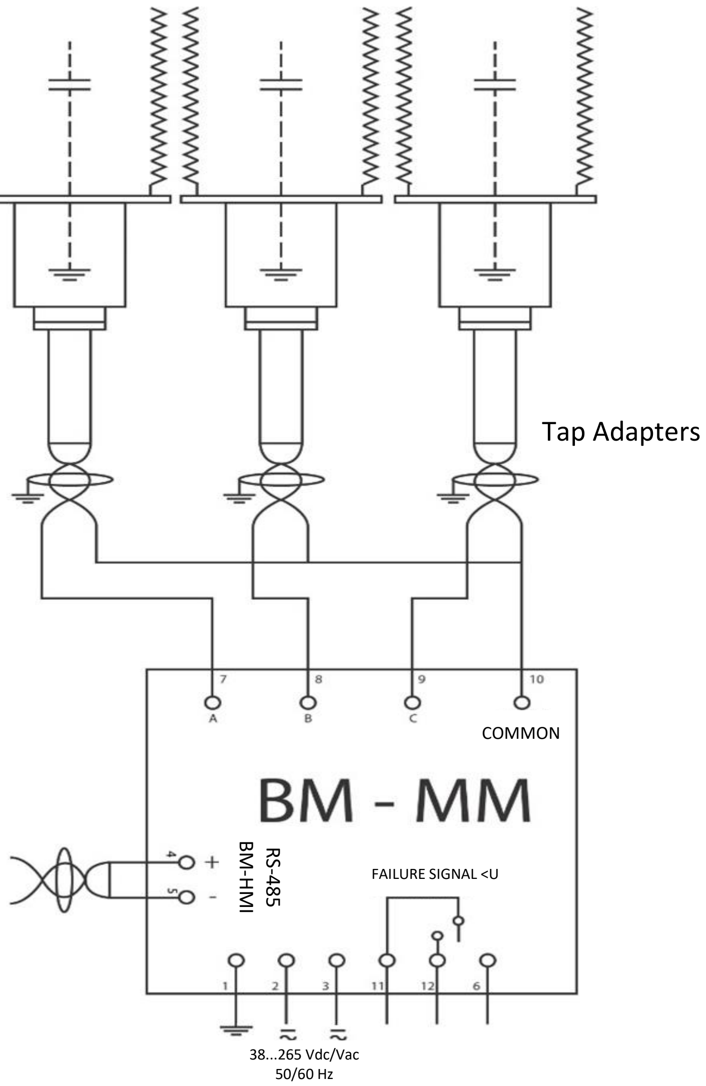


Figure 17 - Application diagram for the BM-MM, the BM measurement module

3.3.3.1 Suggestions for use

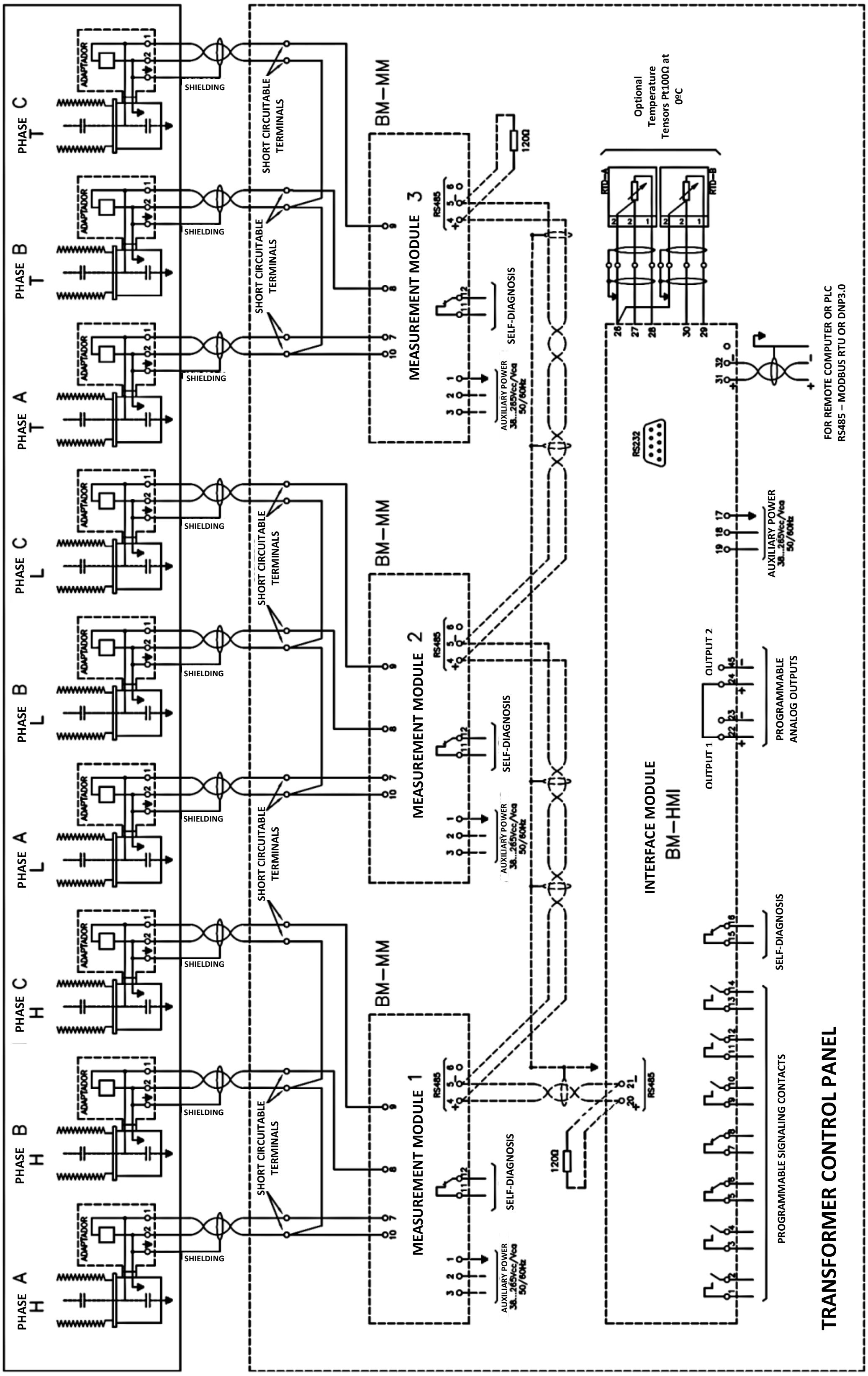


Figure 18 - Basic wiring diagram for application to a three-phase transformer monitoring 3 sets of bushings

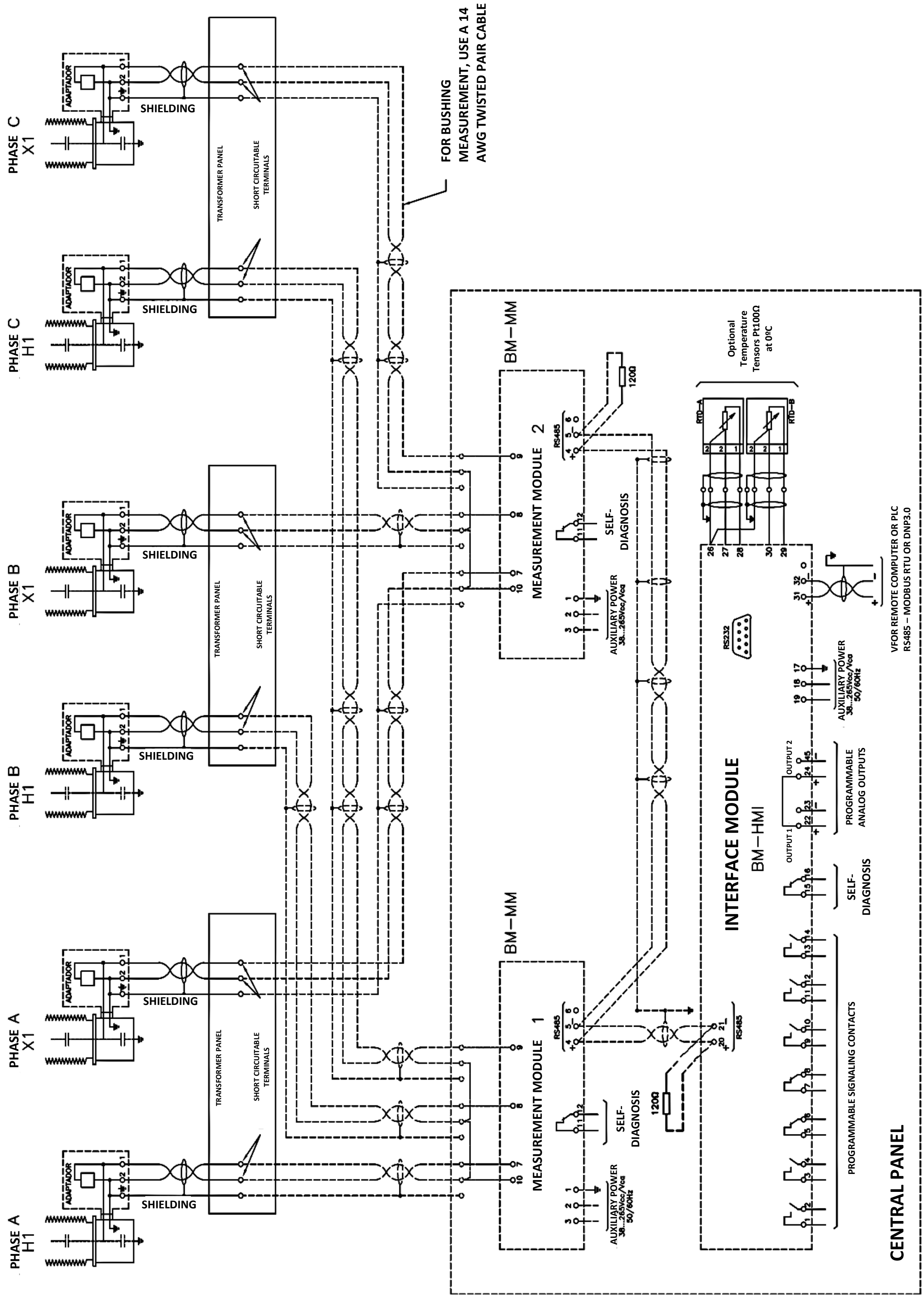


Figure 19 - Basic wiring diagram for application to a single-phase transformer bank monitoring 2 sets of bushings

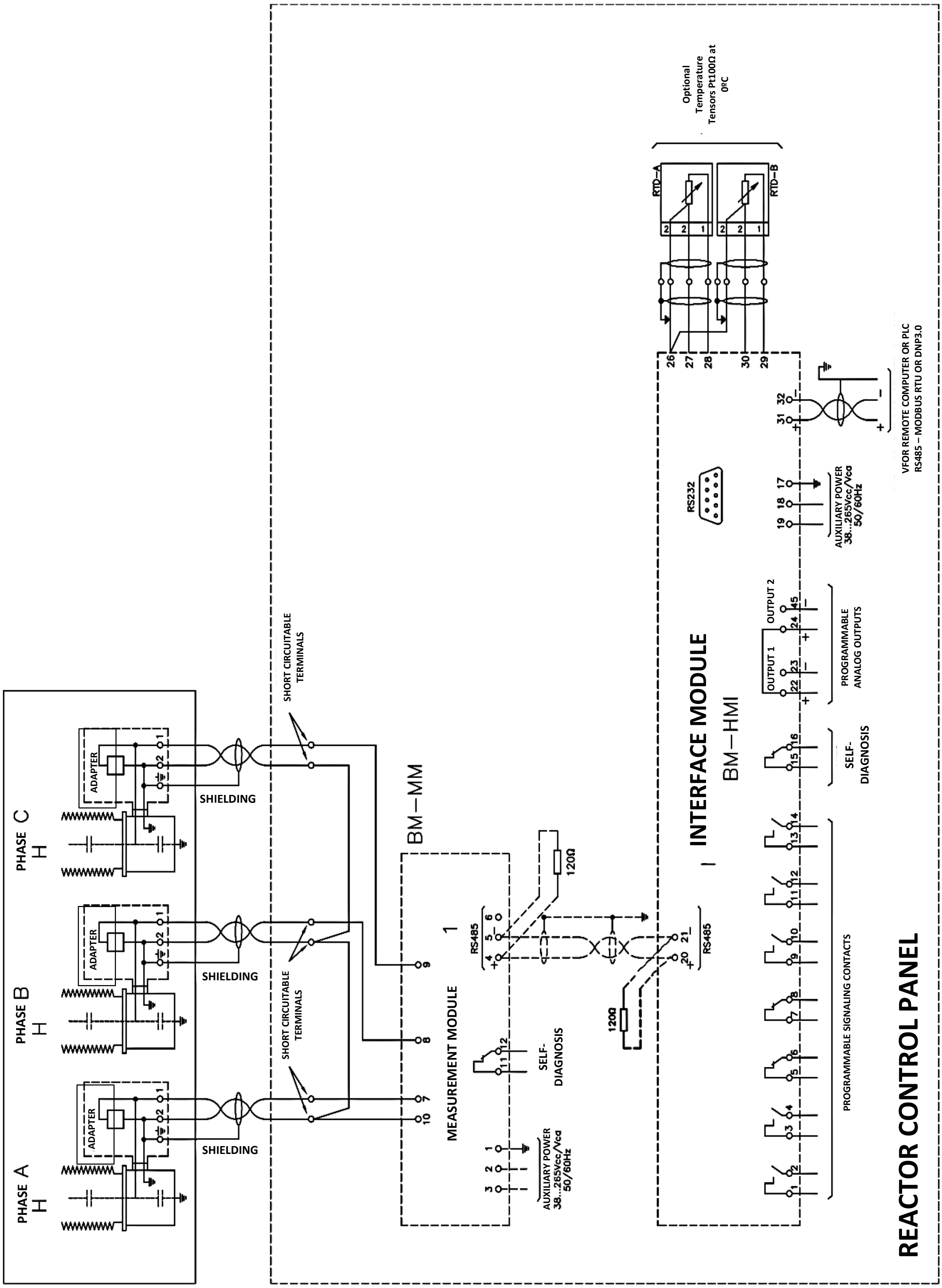


Figure 20 - Basic wiring diagram for application to a three-phase reactor, monitoring 1 set of bushings

3.4 Precautions

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

A circuit breaker must be used immediately before the power input (Universal power supply - 38 ~ 265 Vac/Vdc, <8 W, 50/60 Hz), corresponding to pins 14 and 15 of the BM. This 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, and provide thermal and electrical protection to the conductors supplying the equipment. The circuit breaker must be close to the equipment and easily operable by the operator. Additionally, it must have an indelible identification showing that it is the electrical disconnection device of the BM.

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 1015-2006;
- 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 1015-2006.

The minimum isolation for circuits connected to the BM is 300 Vrms for auxiliary equipment and transducers, such as Pt-100s, clip-on CTs powered by the BM, and up to 50 Vrms for equipment with its own power supply.

The minimum insulation is 1.7 kVrms for equipment powered up to 300 Vrms, according to IEC EN 61010-1.

These values relate to the intrinsic isolation of the 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.

4 Operation

4.1 Measurement Module Parameterization - BM-MM

Each Measurement Module connected to the same Interface Module must have a unique address, without repetitions. The addresses must be programmed according to the set of bushings connected to the module, as per the table below:

Table 7 - Programming addresses

Bushing set	Measurement Module Address
1	1
2	2
3	3

If there are only two measurement modules, only addresses 1 and 2 will be programmed; address 3 will not exist. Similarly, if there is only one measurement module, only address 1 will be programmed; addresses 2 and 3 will not exist.

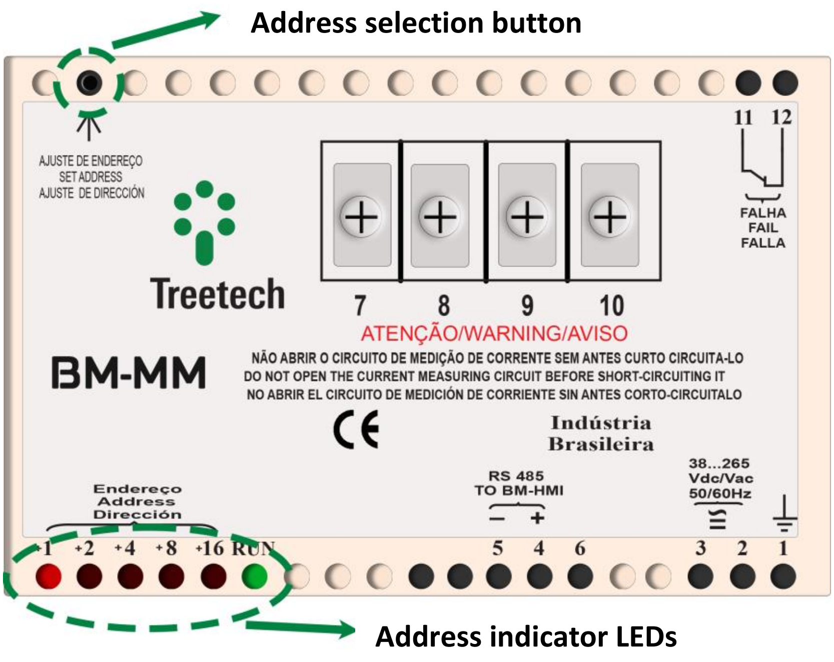


Figure 21 - Address programming in the Measurement Module

Programming the address on a Measurement Module is done by pressing the button located in the upper left part of the module with a pointed object (a pen, for example), as shown in the figure. To change the address, keep this button pressed. After 3 seconds, the address will begin to increment by one unit per second. Release the button when the desired address is reached. After reaching the maximum address (31), a new increment will return the address to the minimum (1).

The programmed address is displayed through the combination of LEDs located in the lower left part of the module (see Figure 21), as shown in the following table. Addresses 4 to 31 are reserved for future use.

Table 8 - Possible LED panel combinations

Measurement Module Address	Status of LEDs (1=on, 0=off)				
	+1	+2	+4	+8	+16
1	1	0	0	0	0
2	0	1	0	0	0
3	1	1	0	0	0
4	0	0	1	0	0
5	1	0	1	0	0
6	0	1	1	0	0
7	1	1	1	0	0
8	0	0	0	1	0
9	1	0	0	1	0
10	0	1	0	1	0
11	1	1	0	1	0
12	0	0	1	1	0
13	1	0	1	1	0
14	0	1	1	1	0
15	1	1	1	1	0
16	0	0	0	0	1
17	1	0	0	0	1
18	0	1	0	0	1
19	1	1	0	0	1
20	0	0	1	0	1
21	1	0	1	0	1
22	0	1	1	0	1
23	1	1	1	0	1
24	0	0	0	1	1
25	1	0	0	1	1
26	0	1	0	1	1
27	1	1	0	1	1
28	0	0	1	1	1
29	1	0	1	1	1
30	0	1	1	1	1
31	1	1	1	1	1

4.2 4.2 Local Operation of the Bushing Monitor - BM-HMI

All measurement queries and Bushing Monitor settings can be performed via the front panel of the Interface Module - BM-HMI, shown in Figure 21.

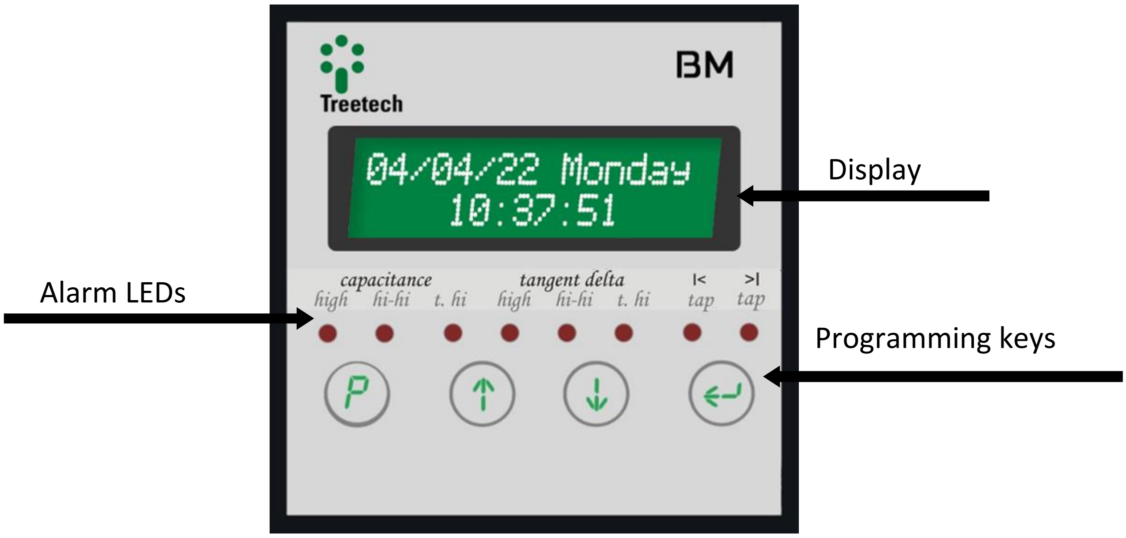


Figure 22 - Front Panel of the Interface Module - BM-HMI

4.3 Indicator LEDs

The indicator LEDs allow for easy visualization of any alarms and warnings, as shown in the figure below.

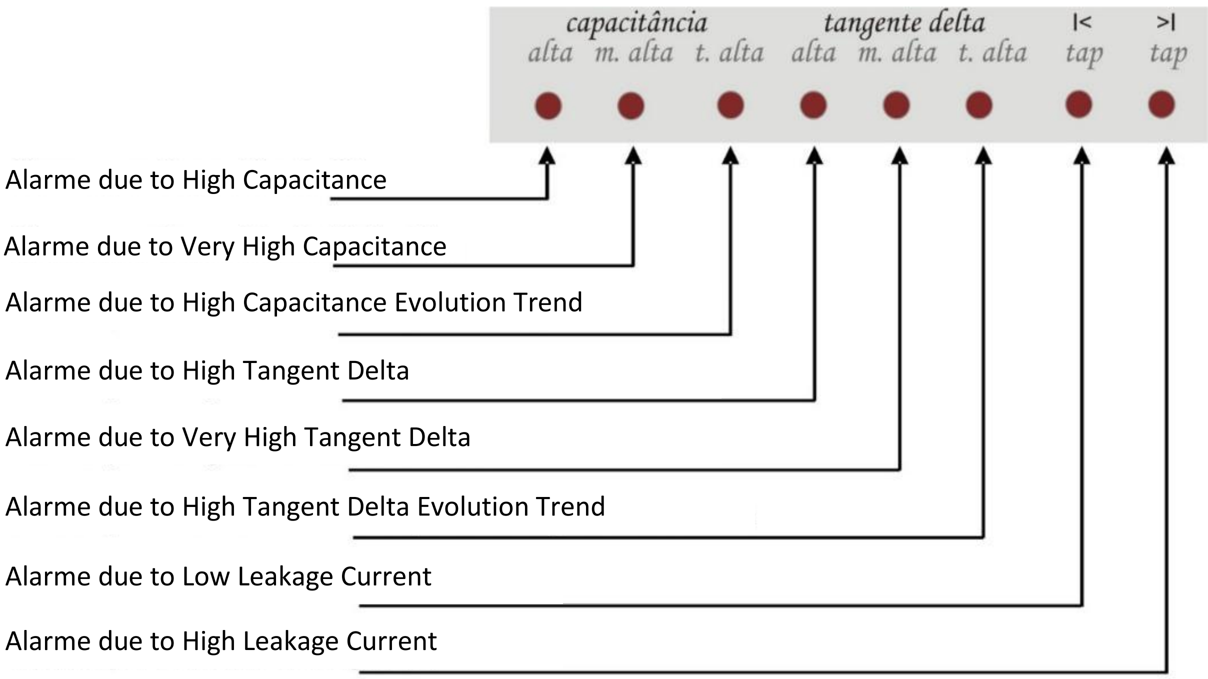


Figure 23 - Interface Module Indicator LEDs - BM-HMI

4.4 Operation and programming keys

The keys have the following functions:

Programming Key: On the measurement screens, it allows you to check the equipment's firmware version and access the password to enter the programming menu. In the programming menus, it exits the current menu, returning to the previous level menu. If activated while changing a parameter, it returns to the previous level menu without saving the change made.

Up Key: Navigation between measurement screens and between menus and programming parameters. During parameter editing, the programmed value increases.

Down Key: Navigation between measurement screens and between menus and programming parameters. During parameter editing, the programmed value decreases.

Enter Key: It switches between measurement screen groups, selects menus and parameters, and saves programmed values. It also allows adjustment of the display brightness.

4.5 Display

During normal operation, the BM-HMI Interface Module display will show the measured values or the date and time from the internal clock, according to the user's programming options:

- **Default screen**, where the user determines which screen should be indicated.;
- **Sequential format,** where the measurement screens are switched at intervals of approximately 10 seconds.

Regardless of the programmed mode, the measurement screens can be accessed manually using the keys and .

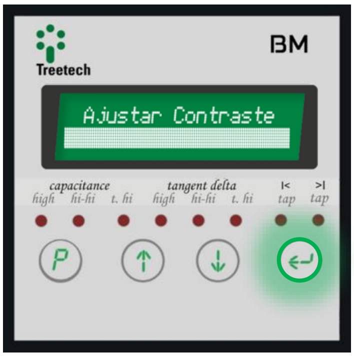
The BM display screens are divided into two groups: Main Displays and Auxiliary Displays. Switching between display groups can be done using the key .

The sequence of screens for the two groups of indications is shown in the subchapter **Error! Reference source not found.**.

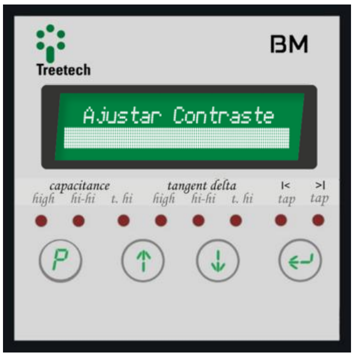
If any anomaly occurs, the corresponding error code will be displayed (see Troubleshooting).

4.6 Display contrast adjustment

The BM allows you to adjust the contrast of its display in seven brightness levels using the keypad on its front panel. Follow these steps to adjust the contrast:



On the initial measurement screens, pressing and holding the key will display the contrast adjustment screen.



Use the keys and to increase or decrease the brightness respectively.

Pressing the key and will save the new setting and the display will return to the indicator screens.

4.7 Indicator keys

During normal operation, the BM will display the measured quantities or the date and time from the internal clock, as programmed by the user. The display formats can be:

- Default screen, where the user determines which screen should be displayed;
- Sequential format, where the seven measurement screens are shown, with intervals of approximately 15 seconds;
- Static form, where a screen is displayed indefinitely.

When using the standard or static screen display options, the BM will intermittently invert (negative text) and normalize the display points' illumination to prevent premature display wear caused by displaying the same image for an extended period. Regardless of the programmed mode, the measurement screens can be accessed manually using the keys and .

The BM display screens are divided into two groups: main displays and auxiliary displays. Each group will contain information for the 3 measurement sets. Press to switch between them.

The main indicators show information on capacitance values, tangent delta per phase, and time for high and very high capacitance and tangent delta alarms.

The auxiliary indicators show information on daily increase in capacitance and tangent delta, phase and line voltages, current per phase, ABC leakage current, current summation, and angle.
On the query screens, pressing and holding one of the arrows is a shortcut to view the same information from the other set.

See below for the BM query screens:

Table 9 - Main indications

Main indications		
Date Day of the Week Time GMT	07/08/23 Segunda 09:44:57	
Capacitance per phase Measurement set 1	Conj1 pF A:000.0 B:000.0 C:000.0	
Tangent delta per phase Measurement set 1	Cj.1TD % A:000.0 B:000.0 C:000.0	
Time for alarm due to high capacitance Measurement set 1	Conj1 Cap.Alta Fase A > 90 dias	
Time for alarm due to very high capacitance Measurement set 1	Conj1 Cap.M.Alta Fase A > 90 dias	
Time for alarm due to high tangent delta Measurement set 1	Conj1 TandD Alta Fase A > 90 dias	
Time for alarm due to very high tangent delta Measurement set 1	Conj1 TD M.Alta Fase A > 90 dias	
Capacitance per phase Measurement set 2	Conj2 pF A:000.0 B:000.0 C:000.0	
Tangent delta per phase Measurement set 2	Cj.2TD % A:000.0 B:000.0 C:000.0	

Time for alarm due to high capacitance Measurement set 2	Conj2 Cap.Alta Fase A > 90dias	
Time for alarm due to very high capacitance Measurement set 2	Conj2 Cap.M.Alta Fase A > 90 dias	
Time for alarm due to high tangent delta Measurement set 2	Conj2 TandD Alta Fase A > 90 dias	
Time for alarm due to very high tangent delta Measurement set 2	Conj2 TD M.Alta Fase A > 90 dias	
Capacitance per phase Measurement set 3	Conj3 pF A:000.0 B:000.0 C:000.0	
Tangent delta per phase Measurement set 3	Cj.3TD % A:000.0 B:000.0 C:000.0	
Time for alarm due to high capacitance Measurement set 3	Conj3 Cap.Alta Fase A > 90 dias	
Time for alarm due to very high capacitance Measurement set 3	Conj3 Cap.M.Alta Fase A > 90 dias	
Time for alarm due to high tangent delta Measurement set 3	Conj3 TandD Alta Fase A > 90 dias	
Time for alarm due to very high tangent delta Measurement set 3	Conj3 TD M.Alta Fase A > 90 dias	

Table 10 - Auxiliary indications

Auxiliary indications		
Daily increase in capacitance Measurement set 1	Cj.1 pF/d A:0.00 B0.00 C:0.00	

Daily increase in tangent delta Measurement set 1	Cj.1 %/d A:0.000 B0.000 C:0.000	↑ ↓
Phase voltage Measurement set 1	Conj1 kV A:000.0 B000.0 C:000.0	↑ ↓
Line voltage Measurement set 1	Conj1 kV AB:00.0 BC:00.0 CA:00.0	↑ ↓
Current Measurement set 1	Conj1 mA A:00.00 B:00.00 C:00.00	↑ ↓
ABC leakage current Measurement set 1	Conj.1 Ifuga ABC 0° 000.0° 000.0°	↑ ↓
Sum of current and angle Measurement set 1	Conj1 As:000.0° Is: 00.000 mA	↑ ↓
Number of samples Measurement set 1	Conj.1 Referenc. Amostra: 0000	↑ ↓
Daily increase in capacitance Measurement set 2	Cj.2 pF/d A:0.00 B:0.00 C:0.00	↑ ↓
Daily increase in tangent delta Measurement set 2	Cj.2 %/d A:0.000 B:0.000 C:0.000	↑ ↓
Phase voltage Measurement set 2	Conj2 kV A:000.0 B:000.0 C:000.0	↑ ↓
Line voltage Measurement set 2	Conj2 kV AB:00.0 BC:00.0 CA:00.0	↑ ↓
Current Measurement set 2	Conj2 mA A:00.00 B:00.00 C:00.00	↑ ↓

ABC leakage current Measurement set 2	Conj.2 Ifuga ABC 0° 000.0° 000.0°	
Sum of current and angle Measurement set 2	Conj2 As:000.0° Is: 00.000 mA	
Number of samples Measurement set 2	Conj.2 Referenc. Amostra:0000	
Daily increase in capacitance Measurement set 3	Cj.3 pF/d A:0.00 B:0.00 C:0.00	
Daily increase in tangent delta Measurement set 3	Cj.3 %/d A:0.000 B:0.000 C:0.000	
Phase voltage Measurement set 3	Conj3 kV A:000.0 B:000.0 C:000.0	
Line voltage Measurement set 3	Conj3 kV AB:00.0 BC:00.0 CA:00.0	
Current Measurement set 3	Conj3 mA A:00.00 B:00.00 C:00.00	
ABC leakage current Measurement set 3	Conj.3 Ifuga ABC 0° 000.0° 000.0°	
Sum of current and angle Measurement set 3	Conj3 As:000.0° Is:00.000 mA	
Number of samples Measurement set 3	Conj.3 Referenc. Amostra:0000	

Note: The Bushing Monitor - BM does not measure voltage; therefore, phase and line voltages are calculated from capacitances and leakage current.

4.8 Alert screens

The BM can display alert texts on its screen to inform the user about the occurrence of certain events, such as alarms or parameterization errors. The alert screens and the procedures to follow will be shown in Chapter 7 - Troubleshooting, due to the function that originated them.

IHM Self-diagnosis

The self-diagnosis function implemented in the BM-HMI allows for the detection and diagnosis of any external defects or internal failures, enabling the user to quickly identify and correct problems in most cases.

MM Self-diagnosis

This indicates that an error occurred in one of the MM modules, as indicated by the module number and the corresponding error code.

5 Parameterization menus

To ensure the correct operation of the bushing monitoring system, several parameters must be adjusted on the BM-HMI to provide the equipment with the necessary information for its operation. Adjustments can be made via the front keypad, using the display, or through the RS-232 or RS-485 serial communication ports available to the user on the rear panel of the device.

The programmable parameters are organized into several submenus, all within a main menu with password-protected access. Within each submenu, the user will have access to a set of parameters that must be adjusted according to the needs of each application and the characteristics of the transformer/condenser bushings.

The parameterization menu map below will show all possible parameterization screens. To access the BM parameterization menu, simply follow the procedure below:

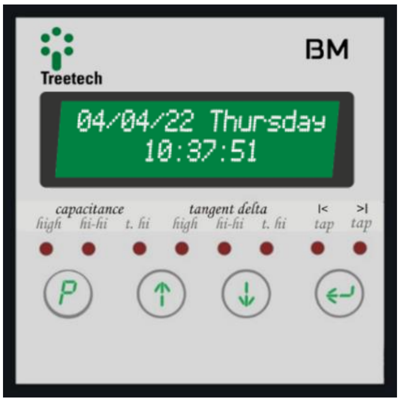


Figure 24 - Measurement screen

Figure 25 - Password screen

1) On any measurement display screen, press the key (P) for 5 seconds.

2) The access password screen will be displayed. Use the keys (↑) and (↓), adjust password.

Note: The initial number shown on this screen can be used to recover your password if you forget it. Please provide this number to our technical support department so they can decipher it, if necessary.

3) Using the keys (↑) and (↓), adjust the password to access the main menu (adjustment range = 0 to 999). The factory default password value is 0 (zero), and the password can be changed by the user (see settings menu).

Figure 26 - Password confirmation

Figure 27 - Language screen

4) After setting the password, press the key to confirm access to the programming menus.

5) The available submenus are shown, two at a time.

Use the keys and to navigate between them. The selected submenu is shown highlighted.

Press the key to access the desired submenu.

There are five menus for basic programming and one menu for advanced configuration. In most applications, basic programming alone will be sufficient for operating the Bushing Monitor:

- Language;
- Alarms;
- Leakage I Alarms;
- Relays Programming;
- Measurement Module;
- Adjust Clock;
- Advanced Configuration:
  - Settings;
  - Alarm;
  - Measurement Module;
  - Analog Output;
  - Factory Only.

The Factory Only submenu is used exclusively for technical support and is locked with a unique manufacturer password.

5.1.1 To access a menu:

- Use the key to select a menu or parameter;
- Within a menu, use the keys and/or to navigate between parameters and/or adjust them after they have been selected;
- To return to the previous parameter or exit the menu, use the key .

5.1.2 After accessing the desired menu:

- Use the keys and to navigate between menu parameters;
- Press to select the parameters you want to adjust;
- Use the keys and to adjust the desired value for the parameter;
- Press to save the change made to the parameter.

Press (P) to discard the parameter, returning to the main menu without saving any changes made to the parameters.

5.2 Parameter map

Below you can see the diagram of the menu structure:

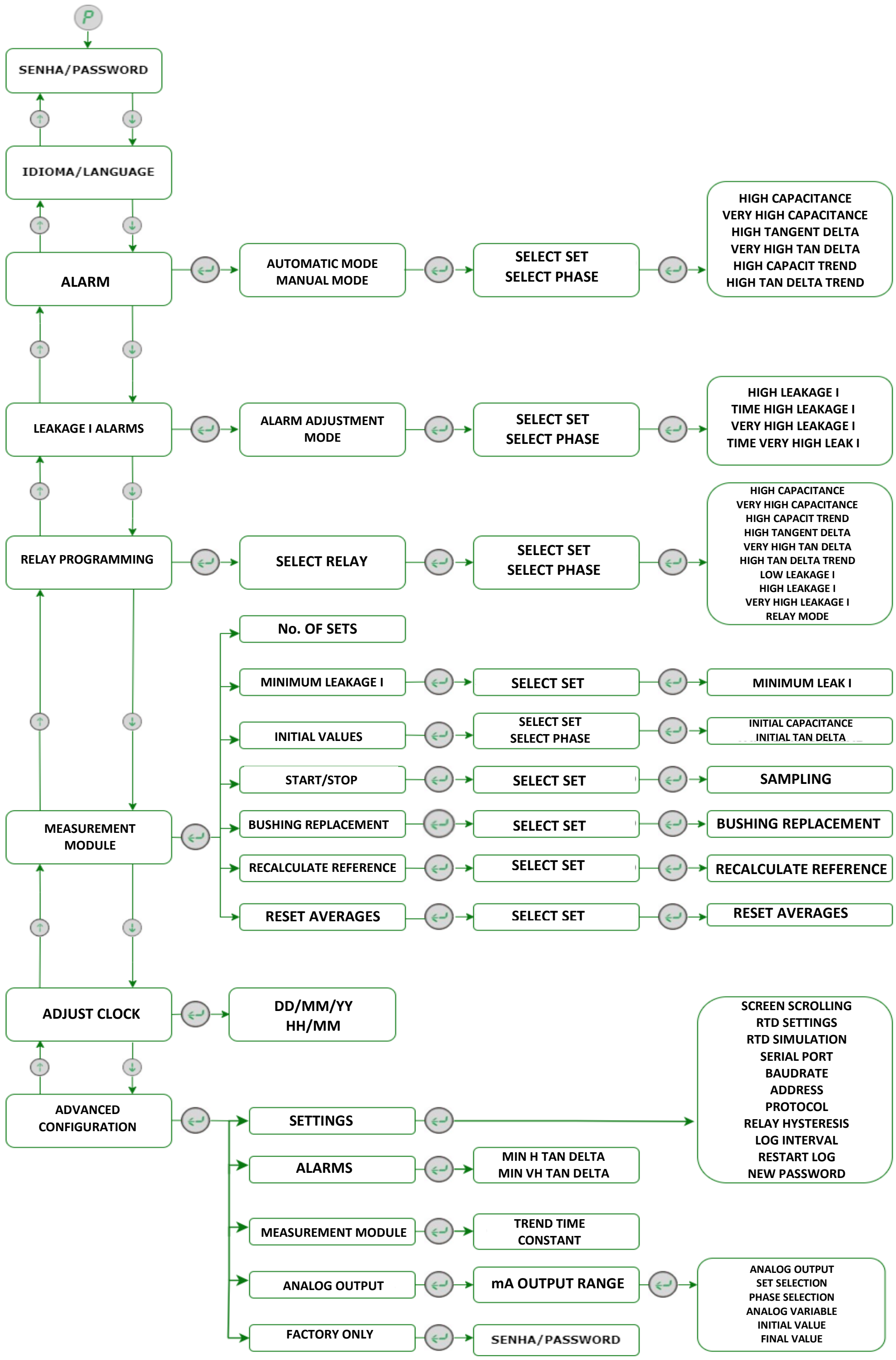


Figure 24 - Menu structure diagram

5.2.1 Language Menu

Selecting the interface language in which the device's subtitles will be displayed.

Adjustment range:

- Português;
- English;
- Español.

Default value: Português.

5.2.2 Alarm Menu

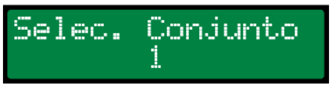
This allows access to the alarm submenu. The settings for alarm triggering (setpoints) are located within this submenu.

Automatic mode (recommended)

Alarms are set as percentage increases in capacitance and tangent delta relative to their initial values. Initial values must be programmed before using automatic mode.

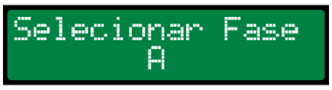
Programming mode in which alarm limit values are entered as absolute values of tangent delta (%).
The selection of each alarm to be adjusted is performed by first selecting the bushing to which the alarms refer, which is done by selecting the bushing set and then the bushing phase:

- **Set:** selection of the bushing sets for which you want to adjust the alarms.

  Adjustment range: set 1, 2, 3 or All.

- **Phase:** selection of the phase(s) of the selected set(s) belonging to the bushing(s) for which you want to adjust the alarms.

  Adjustment range: Phase A, B, C, R (Reserve) or All.

To make alarm adjustments faster, use the "Automatic" programming mode, selecting the "All" option in the set and phase choices. This way, with only 6 alarm adjustments, you can simultaneously program all 54 alarms for the bushings (9 bushings x 6 alarms = 54 alarms).

High capacitance

Selection of desired values for high capacitance alarm emission.

Adjustment range: 000.0 - 150.0% of initial capacitances;
Default value: 3.0%.

Very high capacitance

Selection of desired values for very high capacitance alarm emission.

Adjustment range: 000.0 - 150.0% of initial capacitances;
Default value: 5.0 %.

High tangente delta

Selection of desired values for high tangent delta alarm emission.

Adjustment range: 0 - 1500% of the initial tangent delta;
Default value: 100 %.

Recommended values: double the initial value (100%) of variation or 0.7% in absolute value, whichever is greater.

Very high tangente delta

Selection of desired values for very high tangent delta alarm emission.

Adjustment range: 0 - 1500% of the initial tangent delta;
Default value: 200 %.

Recommended values: three times the initial value (200%) of variation or 1% in absolute value, whichever is greater.

High capacitance evolution trend

Alarm setting for high capacitance trend, triggered if the number of days to reach high or very high capacitance values is less than the value set here.

Adjustment range: 1 to 365 days, in steps of 1.
Default value: 14 days.

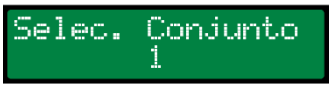
High tangente delta evolution trend

Alarm adjustment for high tangent delta trend, issued if the number of days to reach high or very high tangent delta values is less than the value set here.
Adjustment range: 1 to 365 days, in steps of 1.
Default value: 14 days.

Manual mode

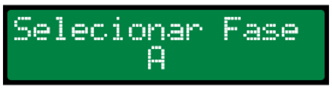
Programming mode in which alarm limit values are specified as absolute capacitance values (pF).
The selection of each alarm to be adjusted is performed by first selecting the bushing to which the alarms refer, which is done by selecting the bushing set and then the bushing phase:

- **Set:** selection of the bushing sets for which you want to adjust the alarms.

  Adjustment range: set 1, 2, 3 or All.

- **Phase:** selection of the phase(s) of the selected set(s) belonging to the bushing(s) for which you want to adjust the alarms.

  Adjustment range: Phase A, B, C, R (Reserve) or All.

High capacitance

Selection of desired values for high capacitance alarm emission.

Adjustment range: 0000.0 - 3200.0 pF;
Default value: 0515.0 pF.

Very high capacitance

Selection of desired values for very high capacitance alarm emission.

Adjustment range: 0000.0 - 3200.0 pF;
Default value: 0525.0 pF.

High tangente delta

Selection of desired values for high tangent delta alarm emission.

Adjustment range: 0.000 - 32.000;
Default value: 00.700.

Very high tangente delta

Selection of desired values for very high tangent delta alarm emission.

Adjustment range: 0.000 - 32.000;
Default value: 01.050.

High capacitance evolution trend

Alarm setting for high capacitance trend, triggered if the number of days to reach high or very high capacitance values is less than the value set here.

Adjustment range: 1 to 365 days, in steps of 1.
Default value: 30 days.

High tangent delta evolution trend

Alarm adjustment for high tangent delta trend, issued if the number of days to reach high or very high tangent delta values is less than the value set here.

Adjustment range: 1 to 365 days, in steps of 1.
Default value: 30 days.

5.2.3 Leakage Current Alarm Menu

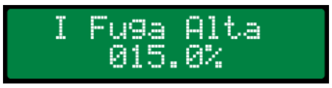
This provides access to the Leakage I Alarms submenu. This menu contains the programming for leakage current alarm values (nominal values). This process involves patented statistics and mathematical structures.

Adjustment mode

Automatic mode (recommended)

Alarms are defined as a percentage (%) of the typical leakage current increase, based on the highest value obtained during the BM learning process. If all sets and phases are configured with the same percentages, choose this parameter.

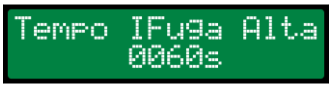
High leakage current



The setting is expressed as a percentage (%) if the adjustment mode parameter is enabled in automatic mode. If the adjustment mode parameter is set to manual mode, the setting is in mA.

Adjustment range: 000.1 to 200.0%, in 0.1 steps;
Default value: 015.0 %.

Time for high leakage current alarm



Adjustment of how long the leakage current must remain above the programmed value to trigger a high leakage current alarm.

Adjustment range: 30 to 1800 seconds, in steps of 1.
Default value: 0060s.

Very high leakage current

The setting is expressed as a percentage (%) if the adjustment mode parameter is enabled in automatic mode. If the adjustment mode parameter is set to manual mode, the setting is in mA.

Adjustment range: 000,1 a 200,0 %, em passos de 0,1;
Default value: 025.0 %.

Time for very high leakage current alarm

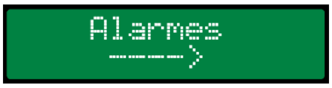
Adjustment of how long the leakage current must remain above the programmed value to trigger a very high leakage current alarm.

Adjustment range: 30 to 1800 seconds, in steps of 1.
Default value: 0060s.

Manual mode

Alarms are defined as direct values (mA) of leakage current.

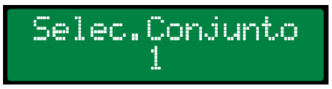
Alarms



In this submenu you can view the values calculated by the automatic mode, but you can only change them or set new values in manual mode.

The “Time High Leakage I” and “Time Very High Leakage I” are used in both modes.

Each alarm is adjusted by first selecting the bushings related to the alarms, which is done by selecting the bushing set and its phase:

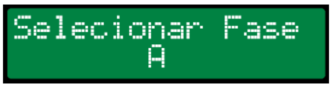


- **Set:** selection of the bushing sets for which you want to adjust the alarms.

  Adjustment range: Set 1, 2, 3 or All.

- **Phase:** selection of the phase(s) of the selected set(s) belonging to the bushing(s) for which you want to adjust the alarms.

Adjustment range: Phase A, B, C or All.

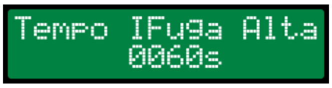


High leakage current

The setting is expressed as a percentage (%) if the adjustment mode parameter is enabled in automatic mode. If the adjustment mode parameter is set to manual mode, the setting is in mA.

Adjustment range: 000.01 to 150.00 mA;
Default value: 080.00 mA.

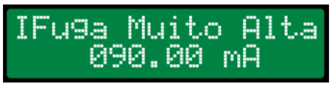
Time for high leakage current alarm



Adjustment of how long the leakage current must remain above the programmed value to trigger a high leakage current alarm.

Adjustment range: 30 to 1800 seconds, in steps of 1.
Default value: 0060s.

Very high leakage current



The setting is made in mA if the adjustment parameter is enabled in manual mode.

Adjustment range: 000.01 to 150.00 mA;
Default value: 090.00 mA.

Time for very high leakage current alarm

Adjustment of how long the leakage current must remain above the programmed value to trigger a very high leakage current alarm.

Adjustment range: 30 to 1800 seconds, in steps of 1.
Default value: 0060s.

To make alarm value adjustments quicker, use the "automatic" programming mode. If using "manual" mode, you can select the "All" option when choosing sets and phases.
In this way, by adjusting only four alarm values, the definitions for the 36 alarms for the bushings are made (9 bushings x 4 alarms per bushing = 36 total alarms).

5.2.4 Relay Programming Menu

Allows access to the relay programming submenu. This submenu contains the setup for the desired sets and phases, as well as the alarm and operating mode for each relay.

Relay selection

The desired relay must be selected for programming.

Adjustment range: 1 - 7.

Each relay can issue alarms for all three sets of measurements and the three monitored phases.

- **Set**: selection of bushing sets for alarm association with the relay.
- **Phase**: selection of phases for alarm association with relay.

Use the key ↵ to advance in the group and phase selections.

Use the keys ↑ and ↓ to select or deselect each set and phase.

The "→" sign indicates which sets and phases are selected.

Each relay can be triggered by one or more types of alarms, by selecting "YES" or "NO" for each of the following parameters:

- High Capacitance;
- Very High Capacitance;
- High Capacitance Evolution Trend;
- High Tangent Delta;
- Very High Tangent Delta;
- High Tangent Delta Evolution Trend;
- Low Leakage Current;
- High Leakage Current;
- Very high Leakage Current.

Adjustment range: YES, NO.

Relay operating mode

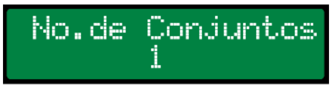
Selection of the operating logic of the relays, independent of the physical configuration of the relay.

Adjustment range: Normally Open / Normally Closed.

5.2.5 Measurement Module Menu

Allows access to the configuration submenu of the measurement modules.

Number of Sets

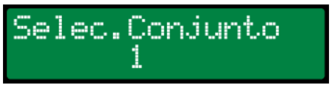


The number of three-phase bushing sets being monitored must be selected. This reflects the number of Measurement Modules connected to the Interface Module.

Adjustment range: 1 - 3.

Minimum leakage current

Minimum value of leakage currents, below which a low leakage current alarm will be triggered, which may indicate that a cable or current measurement circuit is open, and should be checked immediately. The BM does not issue this alarm if all three phases show low leakage current simultaneously, as it considers this to be a de-energization of the equipment (transformer, reactor, etc.).



- **Set**: to which set the bushing belongs to, for which the initial values need to be adjusted.

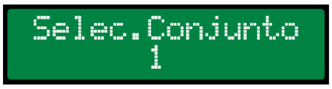
  Adjustment range: Set 1, 2, 3 or All.

Adjustment range: 000.8 a 100 mA.
Default value: 005.0 mA.

Initial Values

This menu contains the initial capacitance and tangent delta values for each monitored bushing, obtained from the bushing's identification plate (in the case of new bushings) or through offline measurements taken during the installation of the monitoring system.

The programming of the initial values is carried out by first selecting the bushing to which the adjustments refer, which is done by selecting the bushing set and then the bushing phase:



- **Set:** to which set the bushing belongs to, for which the initial values need to be adjusted.

  Adjustment range: Set 1, 2, 3 or All.

- **Phase:** to which phase of the set selected above the bushing belongs to, for which the initial values need to be adjusted.

  Adjustment range: Phase A, B, C, R (reserve) or All.

- **Capacitance:** initial capacitance value of the bushing selected in the "set" and "phase" items.

  Adjustment range: 50 to 3200.00 pF.
  Default value: 0500.0 pF.

- **Tangent Delta:** initial tangent delta value of the bushing selected in the "set" and "phase" items.

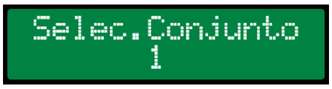
  Adjustment range: 0.010 to 32.000%.
  Default value: 00.300.

Note: Changes to the initial value parameters only take effect if the BM is still in the learning phase of its initial reference. Changes made after this period will only take effect if the YES option is selected in the **Recalculate Reference** menu.

Bushing monitoring

Allows you to start or stop monitoring the bushings of each of the three-phase sets being monitored for possible tests or maintenance. First, you must select the desired set:

- **Conjunto**: which set you want to stop or start monitoring.

  Adjustment range: Set 1, 2, 3 or All.

- **Sampling**: selection of the operating state of the selected set.

  Adjustment range: Running, Stopped.

Bushing Replacement

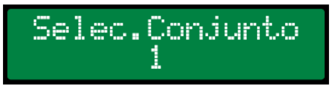
Through this menu, you can change the parameters of the bushings in operation, allowing you to switch to the spare bushing without losing the parameters of the bushings that are not being monitored, in any of the following situations:

- Start-up of the reserve unit;
- Shutdown of the reserve unit and return to normal unit operation;
- Replacement of any bushing being monitored by a new bushing.

This feature is particularly useful in applications with single-phase equipment banks, since the unit's reserved data can be pre-programmed in the BM, and when it enters or exits service, this condition only needs to be indicated in the Bushing Replacement menu.

First, the desired three-phase set must be selected.

- **Set**: which assembly the bushing you want to replace belongs to.

  Adjustment range: Set 1, 2, 3 or All.

- **Bushing Replacement**: selection of bushings that will remain in operation.

  Adjustment range:

  ABC - Bushings A, B, and C in operation, Reserve bushing out of service;

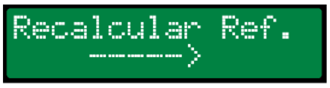
  ABR - Bushings A, B and Reserve in operation, C out of service);

  ARC - Bushings A, Reserve and C in operation, B out of service);

RBC - (Reserve bushing, B and C in operation, A out of service).

When a bushing needs replacing, the Bushing Monitor will automatically proceed to the **Recalculate Reference** parameter. Bushing replacement will only be effective if the YES option is confirmed in this parameter.

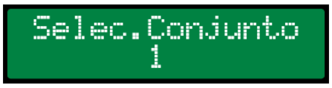
Recalculate Reference



Through this menu, you can recalculate the initial reference, either due to bushing replacement or to perform a new parameterization of the initial capacitance and tangent delta values. To do this, you must first select the desired three-phase assembly.

- **Set**: which set where the learning of the initial reference will be restarted.

  Adjustment range: Set 1, 2, 3 or All.



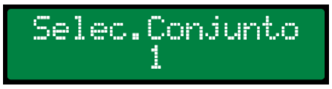
- **Recalculate Reference**: confirmation.

  Adjustment range: YES, NO.

Reset Averages

Through this menu, you can reset the readings due to bushing replacement or any error that resulted in unwanted data. This resets the BM to the data obtained during its learning cycle. To do this, you must first select the bushing set you wish to reset.

- **Set:** which set will be reset for learning.
  Adjustment range: Set 1, 2, 3 or All.



- **Reset Averages:** Confirmation.

  Adjustment range: YES, NO.

5.2.6 Clock Adjustment Menu

Internal clock

Once the clock settings menu is opened, if the internal clock option is selected, the clock will reset with the seconds starting at zero.

The date format is determined by the language selected in the language menu:

- Português and Español: *DD/MM/AA*;
- English: *MM/DD/YY*.

The day of the week is calculated automatically by the BM.

5.2.7 Advanced Configuration Menu

Allows adjustment of advanced Bushing Monitor settings.

5.2.7.1 Settings

Select using the keys ↑ and ↓ between General Settings or Serial Communication Settings and press the key ↵ in the Settings option.

Screen scrolling

This feature allows you to choose the display mode for the BM information screens.

Adjustment ranges:

- **NO**: The last viewed screen will remain indefinitely on the display.
- **YES**: All measurement screens will be displayed cyclically on the screen, with an approximate interval of 15 seconds between each screen.

Default value: NO.

RTD settings

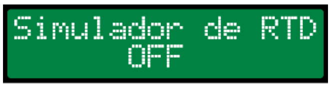
Selection of the connection option for the Pt100Ω at 0 °C type temperature sensor(s).
Note: When selecting the “RTD B Only” option, verify that a jumper is present as per the wiring diagram, see Figure 15.

Adjustment range:

- A and B Off;
- Only RTD A;
- Only RTD B;
- A and B On.

Default value: A and B Off.

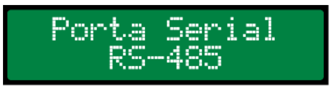
RTD Simulator



Used to verify Pt100 inputs using an electronic RTD simulator. During normal system operation, this parameter should be set to “OFF”. Each time the device is switched off and on again, this parameter returns to the “OFF” setting.

Adjustment range: ON or OFF.

Serial port



Selection of the serial port used for parameterization and remote data acquisition.
Adjustment range: RS-232 or RS-485.

Baud rate

Selects the baud rate for the RS-485 serial communication port.

Adjustment range:

- 38400 bps;
- 19200 bps;
- 9600 bps;

Address

Defines the BM address on the RS-485 communication port, for communication with data acquisition or parameterization systems.

Adjustment range: 1 to 247, in steps of 1.

Protocol

Here you select the standard protocol to be used for communication with the data acquisition or parameterization system.

Adjustment range:

- Modbus;
- DNP3.

Default value: Modbus.

Relay operating hysteresis

Determines a value, expressed as a percentage of the alarm setpoint, that will be adopted as hysteresis for the alarm relays to return to normal, in order to prevent the alarm relay from repeatedly opening and closing due to small fluctuations in the measurements.

For example: If the high tangent delta alarm is triggered at 0.70% and high capacitance at 300 pF, and the hysteresis is set to 1%, the alarm relays will only return to their normal state when the tangent delta and capacitance measurements return to values below 0.693% and 297 pF, respectively.

Adjustment range: 0.0 to 20.0%, in 0.1 steps;
Default value: 00.5 %.

Log interval

Time interval for recording measurements in mass memory (recordings are also made in the event of any alarm).

Adjustment range: 1 to 720 hours.
Default value: 012h.

Mass memory reset

Allows you to reset the mass memory, erasing all stored data. The user will be prompted to confirm the procedure.

Adjustment range: YES,   NO.

New password

Programming a new password to control access to the BM programming menus. The factory default password is “000”.

Adjustment range: 0 to 999 in steps of 1.

Observação: O número inicial mostrado no campo senha quando do acesso ao menu de programação pode ser utilizado para recuperar a senha em caso de esquecimento. Informar este número ao nosso departamento de suporte técnico para decifrá-lo.

5.2.7.2 Alarms

Minimum value for high delta tangent

If the BM is in automatic mode, this parameter will be the minimum value for triggering an alarm due to a high tangent delta; it must be at least 0.700 or twice the calculated tangent delta.

Default value: 00.700.

Example: As illustrated in the graph below, if the minimum value parameterized here is 0.7, **the high tangent delta alarm parameter**, in automatic mode, is set to 100%, and the **initial value** parameterized in the **Measurement Module** menu is 0.3, measured tangent delta values above 0.6 (0.3 + 100% of 0.3 = 0.6) should trigger an alarm. However, due to the minimum parameterized value, only values above 0.7 will trigger an alarm.

Adjustment range: 0 to 32%, in 0.001 steps.

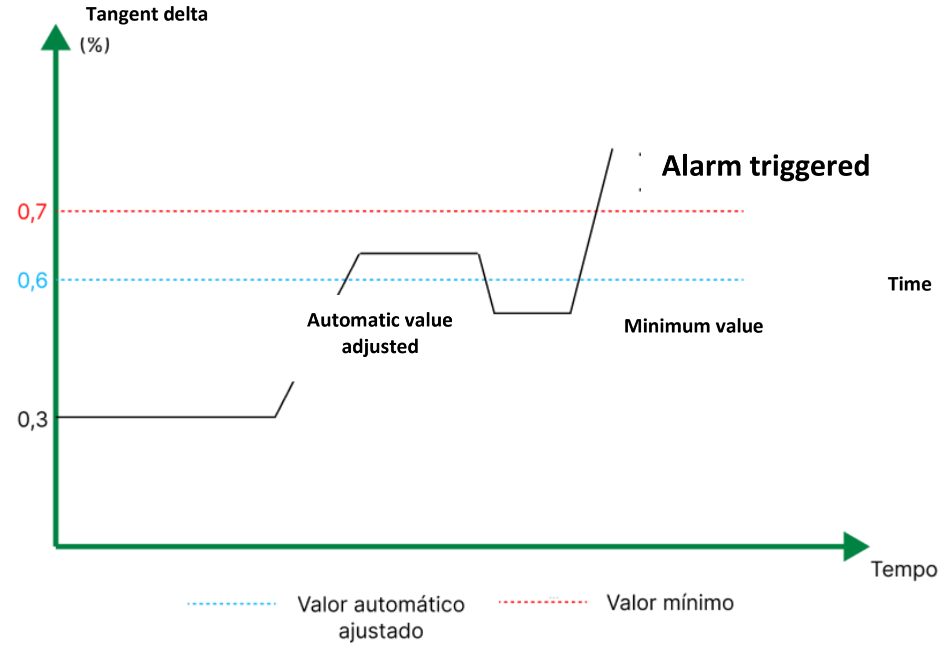


Figure 29 - Tangent delta alarm behavior in automatic mode

Minimum value for a very high tangent delta

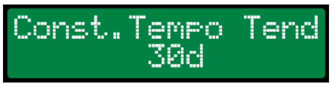
If the BM is in automatic mode, this parameter will be the minimum value for issuing an alarm due to a very high tangent delta; it must be at least 1.050 or twice the calculated tangent delta.

It follows the same logic as the "**Minimum value for high tangent delta**" parameter.

Adjustment range: 0 to 32%, in 0.001 steps.
Default value: 01.050.

5.2.7.3 Measurement module

Trend time constant



Time constant of the first-order digital filter used in the calculation of capacitance and tangent delta evolution trends.

This filter prevents temporary variations in these variables from causing high trend calculations, resulting in undue alarms.

Adjustment range: 0 to 90 days.
Default value: 30d.

5.2.7.4 Analog output

mA Output range

Selection of the current range to be used by the loop outputs for remote indication.

Adjustment range:

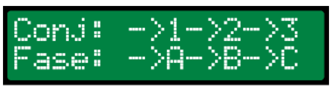
- 0...1 mA
- 0...5 mA
- 0...10 mA
- 0...20 mA
- 4...20 mA

Default value: 0...10 mA.

Analog output

Selection of the analog output to be parameterized.
Each output can indicate values from multiple measurement sets and multiple monitored phases.

Adjustment range: 1 or 2.



- **Set**: selection of bushing sets for indication on the analog output.
- **Phase**: selection of phases for indication on the analog output.

Use the key To advance through the selection of sets and phases. Use the and keys to select or deselect each set and phase. The → sign indicates which sets and phases are selected.

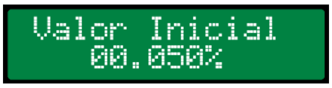
Attention: When selecting more than one set and/or more than one phase for display on the analog output, only the highest value will be represented.

Analog variable

Selection of the variable to be indicated by the selected output.

Adjustment range: Tan (tangent delta) or Cap (Capacitance).
Default value: Cap.

Initial value



Selection of the capacitance value, in pF, or tangent delta, in %, corresponding to the start of the scale of the analog output selected for remote indication.

Adjustment range:

0.00 – 32.000% (if tangent delta is selected);
Default value: 00.050%.

0 – 3200.0 pF (if capacitance is selected).
Default value: 0005.0 pF.

Final value

Selection of the capacitance value, in pF, or tangent delta, in %, corresponding to the full scale of the analog output selected for remote indication.
Adjustment range:

0.00 - 32.000% (if tangent delta is selected);
Default value: 01.000%.

0 – 3200.0 pF (if capacitance is selected).
Default value: 0100.0 pF.

5.2.7.5 Factory only

This menu is for factory and technical support use only.
The factory password will be requested. This menu is for the exclusive use of Treetech technical support and is not available to the equipment user.

6 Procedure for commissioning

Once the equipment has been installed in accordance with Chapter 3 of this manual, commissioning must follow the basic steps below:

- ✓ At the start of Bushing Monitor (BM) operation, it will be necessary to configure the equipment with the current capacitance and tangent delta values of the bushings. For bushings already in operation, it is necessary to measure these parameters conventionally (off-line), with the bushing de-energized;
- ✓ Check the mechanical installation of the tap adapters, in accordance with subchapter 3.2, ensuring that there will be no water ingress into the tap of the bushings;
- ✓ Check the correctness of the electrical connections according to subchapter 3.3 (e.g., through continuity tests), ensuring that the bushing tap is not open and that leakage current will flow to ground through the Measurement Module;
- ✓ If you are going to perform dielectric strength tests on the wiring (applied voltage), disconnect the ground cables connected to terminal 17 of the Interface Module and to terminal 1 of the Measurement Module, and disconnect the plug from the tap adapter, keeping its casing isolated from any grounded part, in order to avoid destroying the overvoltage protections inside the devices. These protections are internally connected between the input/output terminals and ground, clamping the voltage at values below 350 V. Applying high voltages for a long period (e.g., 2 kV for 1 minute) would destroy these protections;
- ✓ Check that the intermediate measuring terminals of the bushings are not short-circuited;
- ✓ Power the BM-MM Measurement Modules with a voltage of 38 to 265 Vac/Vdc;
- ✓ Power the Interface Module - BM-HMI with a supply voltage of 38 to 265 Vac/Vdc;
- ✓ Complete all the parameter settings for the Measurement Module(s) according to the instructions in subchapter 5.2.5;
- ✓ Complete all the parameter settings for the Interface Module, according to the instructions in Chapter 0. The completed parameter settings can be recorded in the form provided on the following page;
- ✓ Consult the leakage current measurements of the bushings for phases A, B, and C of each monitored set. Verify that the readings are consistent with the approximate theoretical value calculated using the formula:

$$Leakage\ Current = 6.28.(Frequency) \times (Phase\ Voltage - Ground) \times (Capacitance\ C1)$$

- ✓ Check the serial communication between the Interface Module and the data acquisition system, if it exists;
- ✓ Check the operation of the analog outputs and programmable output contacts, if used;

- ✓ Using an ohmmeter, check the continuity of the three current input circuits of the Measurement Modules by measuring their resistance. The measurement will vary continuously, due to the internal reading process of the Measurement Module, within the approximate range shown in the following table:

Table 11 - Measurement range of the Measurement Module

Measurement performed between the terminals:	Expected variation:
7 and 10 (of the measurement module)	10 to 2200 Ω
8 and 10 (of the measurement module)	10 to 2200 Ω
9 and 10 (of the measurement module)	2200 Ω

7 Troubleshooting

If you encounter difficulties or problems operating the system, we suggest consulting the possible causes and simple solutions presented below. If this information is not sufficient to resolve the problem, please contact Treetech technical support or your authorized representative.

7.1 The BM-HMI displays self-diagnosis messages on its screen

The self-diagnosis function implemented in the BM-HMI allows for the detection and diagnosis of any external defects or internal failures, enabling the user to quickly identify and correct problems in most cases.

Upon detecting a problem, the BM-HMI will activate its self-diagnosis contact and display an error screen showing the fault code, as illustrated in the figure below.

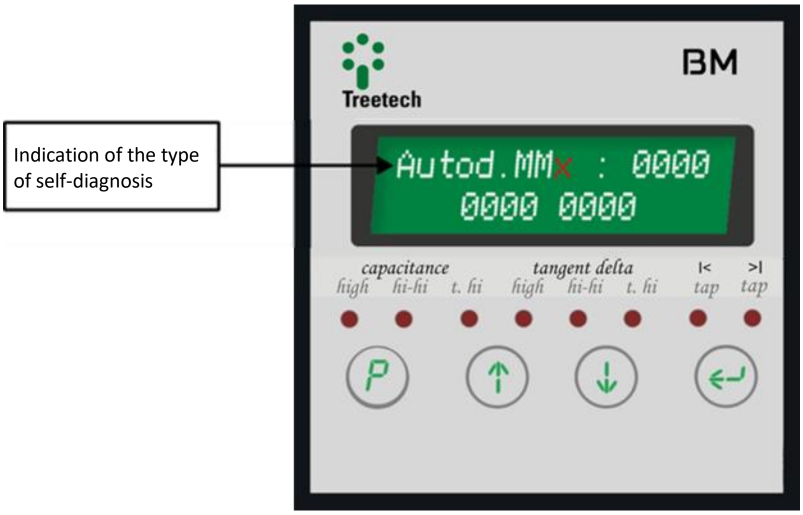


Figure 25 - Self-diagnosis indicator screen

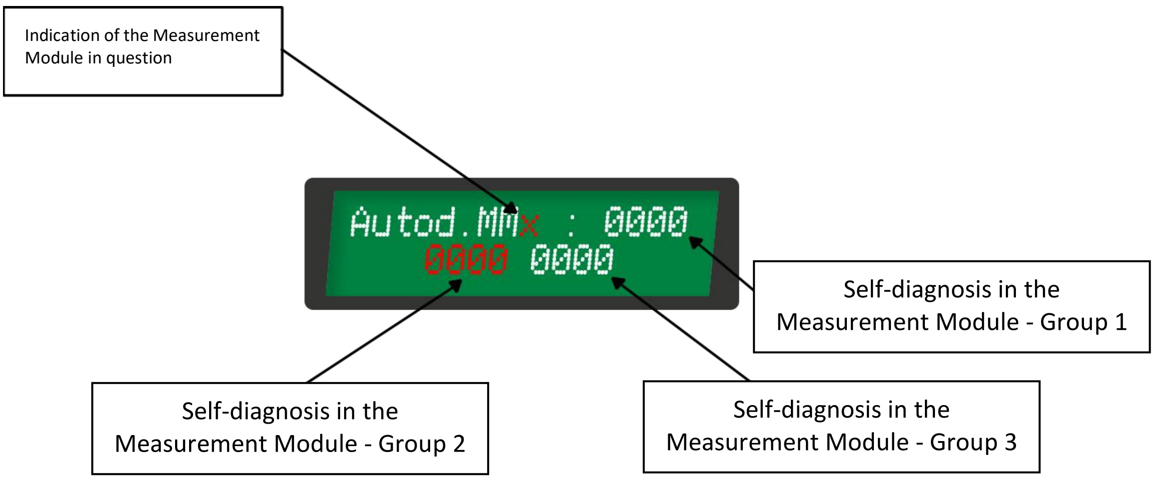


Figure 26 - Detailed explanation of self-diagnosis codes

The meaning of the fault codes is shown in the following tables, respecting the display digit where the code appears. The code indication system is in hexadecimal encoding, where the allowed character set is S = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F}. Individual errors are indicated by the set M = {1, 2, 4, 8}. In case of simultaneous faults, the number indicated in a given digit will be the sum of the individual errors, thus indicated by the complementary set N = {3, 5, 6, 7, 9, A, B, C, D, E, F}.

To check the procedure in case of self-diagnosis and possible errors generated by the BM, follow the instructions by clicking the link below or scanning the QR code to be redirected to Treetech's Customer Service.

Self-diagnosis

FAQ:

7.2 Firmware version query and self-diagnosis message memory

To view the firmware version, simply press the key during the measurement screen. To exit the firmware version display screen, simply press the key again. The figure below shows the screen that will be displayed indicating the installed firmware version.

All self-diagnosis messages identified by the BM are stored and can be viewed by the user on the front screen of the device.

To view the self-diagnosis memory, simply press the and keys simultaneously. The figure below shows the screen that will be displayed indicating the self-diagnosis codes that occurred.

Note: The number of screens in the MM self-diagnosis tool will depend on the number of BMMs in the network.

The value shown for each digit in the self-diagnosis memory is the sum of the values of every error that has ever occurred for that position, not just those that are currently active. This allows you to know all the errors that have occurred since the last time the memory was reset.

To reset the values stored in memory, press the keys and .

8 Technical data and type tests

8.1 Technical data

8.1.1 Interface Module - BM-HMI

Table 12 - Interface Module - BM-HMI

Condition	Range / Description
Supply voltage	85 to 265 Vac/Vdc - 50/60 Hz
Maximum consumption	< 8 W
Operating temperature	-40 to +85 °C
Protection rating	IP 20
Connections - Removable terminals	0.3 to 2.5 mm², 22 to 12 AWG
Mounting	Panel mounting
Temperature Measurement	
Sensor	Pt100Ω at 0 °C with continuous autocalibration
Measuring range	-55 to +200 °C
Maximum error at 20 °C	0.2% of full scale
Maximum deviation due to temperature variation	20 ppm/°C
Connection options	Up to two three-wire sensors
Outputs	
Relay outputs	Potential-free contacts
Type and functions (Standard)	7 configurable (NO or NC) and one fixed NC for self-diagnostics
Maximum switching power	70 W(dc) / 220 VA (ac) - resistive load
Maximum switching voltage	250 Vdc / Vac
Maximum convection current	5 A
Analog current loop outputs	2 with common positive
Maximum error	0.5% of full scale
Output range	Programmable (0-1, 0-5, 0-10, 0-20 and 4-20 mA)
Maximum load	0...1 mA, 10 kΩ 0...5 mA, 2 kΩ 0...10 mA, 1 kΩ 0...20 mA, 500 Ω 4...20 mA, 500 Ω
Communication	
Serial communication ports	1 RS-485 for BM-MM + 1 RS-485/RS-232 for supervisory system
Communication protocols	Modbus-RTU and DNP3
Memory	
Mass memory	Non-volatile, FIFO (First In First Out) type
Capacity	712, 420 or 297 records (for 1, 2 or 3 connected BM-MMs)
Recording interval	1 to 720 hours

8.1.2 Measurement Module - BM-MM

Table 13 - Measurement Module - BM-MM

Condition	Range / Description
Supply voltage	85 to 265 Vac/Vdc - 50/60 Hz
Maximum consumption	5 W
Operating temperature	-40 ... +85 °C
AC current measurement input	3 for bushing leakage current (0...100 mA)
Protection rating	IP 20
Mounting	35 mm DIN rail mounting
Serial communication port	RS-232 for connection to BM-HMI
Connections (except mA inputs)	0.3 to 2.5 mm², 22 to 12 AWG
Connections (mA inputs)	1.5 to 2.5 mm², 16 to 12 AWG using appropriate ring terminals
Monitored Quantities	
Capacitance	0...6500 pF
Maximum variation	0.5%
Tangent delta	0...9.999%
Maximum absolute variation	0.05%
Leakage current	0...100 mA
Maximum measurement variation	0.5% of full scale
Minimum current for phase shift calculation	< 1.3 mA
Outputs	
Relay outputs	1 NC for self-diagnosis
Maximum switching power	70 W(cc) / 220 VA(ac)
Maximum switching voltage	250 VDC / 250 Vac
Maximum conduction current	5A

8.1.3 Tap adapter

The mechanical construction of the tap adapter varies depending on the bushing model and manufacturer. Tap adapters are equipped with tap opening protection that prevents dangerous voltages from developing in case of disconnection of the cable carrying the leakage current to the Measurement Module.

Table 14 - TAP adapter

Condition	Range / Description
Maximum voltage developed in case of cable disconnection	14 ± 2 Vca
Continuous conduction capability at 125°C with cables disconnected	2 x 250 mA (redundant protection)
Operating temperature	- 25 °C to 120 °C
Degree of protection	IP 65 (NEMA 4)
Cable gauge	0.3 to 1.5 mm² (22 to 14 AWG)
Maximum tightening torque	15 N.m
Maximum vertical effort	20 kg

8.2 Type tests

The BM is a device built on the Smart Sensor 2 platform, which has undergone the following type tests:

Table 15 - Tests performed

Type Tests	
Immunity to Outbreaks (IEC 60255-22-5)	
Phase-to-neutral surges: Phase-to-ground and neutral-to-ground surges:	1 kV, 5 per polarity (+/-) 2 kV, 5 per polarity (+/-)
Immunity to Electrical Transients (IEC 60255-22-1 e IEEE C37.90.1)	
Peak value 1st cycle: Frequency: Time and repetition rate: 50% decay:	2.5 kV 1.1 MHz 2 seconds, 400 bursts/sec. 5 cycles
Voltage Impulse (IEC 60255-5)	
Waveform: Amplitude and energy: Number of pulses:	1.2 / 50 sec. 5 kV 3 negative and 3 positive, 5s interval
Applied Voltage (IEC 60255-5)	
Power-frequency withstand voltage:	2 kV 60 Hz 1 min. against ground
Immunity to Radiated Electromagnetic Fields (IEC 61000-4-3 / IEC60255-22-3)	
Frequency: Field strength:	26 to 1000 MHz 10 V/m
Immunity to Conducted Electromagnetic Disturbances (IEC 60255-22-6)	
Frequency: Field strength:	0.15 to 80 MHz 10 V/m
Electrostatic Discharges (IEC 60255-22-2 e IEEE C37.90.3)	
Air mode: Contact mode:	8 kV, ten discharges/polarity 6 kV, ten discharges/polarity
Immunity to Fast Electrical Transients (IEC60255-22-4 e IEEE C37.90.1):	
Test of power supply, inputs, and outputs: Test of serial communication:	4 kV 2 kV
Climate Test (IEC 60068-2-14)	
Temperature range: Total test time:	-40 to +85 °C 96 hours
Response to Vibration (IEC 60255-21-1)	
Application Mode: Amplitude: Duration:	3 axes (X, Y and Z), sinusoidal 0.075 mm from 10 to 58 Hz 1G from 58 to 150 Hz 8 min/axis
Resistance to Vibration (IEC 60255-21-1)	
Application Mode: Frequency: Intensity: Duration:	3 axes (X, Y, and Z), sinusoidal 10 to 150 Hz 2 G 160 min/axis

9 Specifications for ordering

The Bushing Monitor - BM is a universal device, with its features selected through its programming menus via its front panel or through the RS-232 or RS-485 ports. The power input is universal.
Therefore, in the purchase order for the device, **it is only necessary to specify**:

1. Product name

Bushing Monitor:

- Interface module - BM-HMI
- Measurement module - BM-MM

Adapters for bushing tap.

2. Quantity

- **Number** of **Measurement Modules BM-MM** (each BM-MM measures 3 bushings from the same three-phase set);
- **Number** of **Interface Modules BM-HMI** (one to three BM-MM measurement modules can be connected to each BM-HMI);
- **Number** of **Bushing tap adapters** with the respective manufacturers, bushing models and tap types (test or tension). The mechanical construction of the tap adapter varies according to the bushing model and manufacturer. Treetech has ready-made adapters for several common bushing models on the market, and other adapter models are readily developed whenever necessary.

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