English

www.treetech.com.br

# USER MANUAL

## BUSHING MONITOR

# BM

Treetech

Praça Claudino Alves, 141 - Atibaia - SP - Brasil   CEP: 12940-800  - Tel./Fax: 55 11 4413-5787

# Summary

# Figure List

# Table List

# 1 Foreword

## 1.1 Legal Information

Treetech Sistemas Digitais LLC reserves the right to change components without prior notice in all products, circuits and functionalities described herein, with the purpose to improve their reliability, function or project. Treetech Digital Systems will not accept any liability resulting from application or use of any product or circuit described herein, and will also not transfer any licenses or patents belonging to it or to third parties.

Treetech Sistemas Digitais Ltda. may possess patents or other types of records and intellectual property described herein. The possession of this document by any person or entity does not confer to that person or entity any right to those patents or records.

## 1.2 Presentation

This manual includes all recommendations and instructions to install, operate and maintain of the Bushing Monitor BM.

## 1.3 Typographic Conventions

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

**Bold type**: Symbols, terms and words in bold type are the most important in different contexts. Therefore, pay attention to those words and terms.

*Italics*: Foreign terms, alternative words or words not used in formal situations are in italics.

## 1.4 General and Safety Information

In this section some relevant aspects on safety, installation and maintenance of the BM will be covered.

### 1.4.1 Safety Symbols

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

**Caution**

The **Caution** symbol is used to alert the user against an operating or maintenance procedure that may be potentially dangerous, which demands more care while being performed Mild or moderate Injuries can occur, as well as equipment damage. .

**Warning**

The symbol of **Warning** is used to alert the user to an operational or maintenance procedure that is potentially dangerous, in which extreme caution should be exercised. Severe injuries or death may occur. Possible damage to the equipment will be irreparable

**Risk of Electric Shock**

The symbol for **Risk of Electric Shock** is used to alert the user against an operating or maintenance procedure that, if not strictly observed, may result in an electric shock. Mild and moderate injuries, severe injuries or death may occur.

### 1.4.2 General Symbology

This manual uses the following symbols for general purposes:

**Important**

The symbol for **Important** is used to highlight relevant information.

**Hint**

The symbol for **hint** represents instructions that facilitate the use of the BM's functions or the access to those functions.

### 1.4.3 Minimum recommended profile for the operator and maintenance person in charge of the BM

The installation, maintenance and operation of equipment in substations of electric energy demand cares special and, therefore all the recommendations of this manual, applicable norms, procedures of security, practices of good and dependable work judgment should be utilized during all the phases of handling of the Bushing Monitor BM.

For the purposes of using this manual, an authorized and trained person knows the inherent risks – both electric and environmental – to handling the BM.

Only authorized and trained personnel – operators and maintenance crew – should handle this equipment.

a) The operator, or the person in charge of maintaining the equipment, must be trained and authorized to operate, ground, and turn the BM o and off, following the maintenance procedures according to the established safety practices, under complete responsibility of the operator and the maintenance crew of the BM;
b) Be trained in using PPEs and CPEs and first aid;
c) Be trained on the BM working principles, as well as its configuration.
d) Follow the regulatory recommendations about interventions in any kind of equipment in an Electric Power System.

### 1.4.4 Environmental and Voltage Conditions required for installation and operation

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

**Table 1 - Operation Conditions**

| Condition | Interval / Description |
|---|---|
| Application | Equipment should be sheltered inside substations, industrial environments and similar |

| | |
|---|---|
| Indoor / Outdoor use | Indoor Use |
| Degree of Protection (IEC 60529) | IP 20 |
| Altitude* (IEC EN 61010-1) | Up to 2000 m |
| Temperature (IEC EN 61010-1) | |
| Operation | -40 °C to +85 °C |
| Storage | -50 °C to +95 °C |
| Relative Humidity (IEC EN 61010-1) | |
| Operation | 5% to 95% – Not Condensed |
| Storage | 3% to 98% – Not Condensed |
| Voltage Fluctuation of the Power Supply (IEC EN61010-1) | Up to ±10% |
| Overvoltage (IEC EN 61010-1) | Nominal Voltage II |
| Pollution Degree (IEC EN 61010-1) | Degree 2 |
| Atmospheric Pressure** (IEC EN 61010-1) | 80 kPa to 110 kPa |

* At altitudes over 2000m there are already successful applications.
** At pressures under 80 kPa there are already successful applications.

### 1.4.5 Installation and Testing Instructions

**This manual must be made available to the ones that are responsible for the installation, maintenance and users of the Bushing Monitor BM.**

In order to ensure safety for users, as well as equipment protection and correct operation, the following minimum recommendations must be followed while installing and maintaining the BM:

1. Read this manual carefully before installing, operating or maintaining the BM. Errors in the installation, maintenance or in the settings of the BM can cause inappropriate operations of the OLTC unsatisfactory voltage regulation, inappropriate alarms or can also prevent the activation of relevant alarms.
2. The installation, settings and operation of the BM should be done by trained personnel familiarized with power transformers or voltage regulators, control devices and substation equipment command circuits.

Special attention should be paid to the installation of the BM (Chapter 0 -

3. Project and installation), including the kind and gauge of the ends and terminals used, as well as to the startup procedures, including correct parameterization of the equipment (Chapter 4 - Operation).

The BM must be installed in a shelter of some kind, (a panel without doors in a control room or a closed panel if installed outdoors) that does not exceed what has been specified for the equipment.

The BM should not be installed next to heat sources such as heating resistors, incandescent bulbs or high voltage devices or devices with heat sinks. Also it is not recommended to install it near to vents or in places where it can be hit by a flow of forced air, such as the discharge or intake of cooling fans or forced ventilation ducts

### 1.4.6 Cleaning and Decontamination Instructions

Be careful when cleaning the BM. Use ONLY a clean cloth with soap or detergent diluted in water to clean the cabinet, front panel or any other part of the equipment. Do not use abrasive cleaning materials, polishing products or aggressive chemical solvents (such as alcohol or acetone on any of its surfaces.

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

### 1.4.7 Inspection and Maintenance Instructions

When inspecting or maintaining the BM, the following recommendations must be followed:

Do not open your equipment. It does not contain any parts the user can fix. Leave the repairs to Treetech's tech support, or to engineers or technicians authorized by the manufacturer.
This equipment is completely maintenance-free, and any inspections, operating or visual, periodic or not, can be carried out by the user. These inspections are not mandatory.

Opening the BM at any time shall imply loss of product warranty. In the cases where product was unduly opened, Treetech will also not be able to guarantee its correct operation, regardless of the warranty expiration date.

All the part of this equipment should be supplied by Treetech, or by one of its accredited suppliers, as per Treetech's specifications. If the user desires to purchase the parts from another source they should strictly follow the specifications Treetech has provided. Then the performance and safety for the user and the equipment will not be compromised. If these specifications will not go successions, the user and the equipment may be exposed to unnecessary and unexpected risks.

## 1.5 Technical Support

In order to obtain tech support for the BM or any other Treetech product, contact us at the address below:

**Treetech Sistemas Digitais LLC - Tech Support**
Rua José Alvim, 100 – Salas 03 e 04 – Centro
Atibaia – São Paulo – Brasil
ZIP CODE: 12.940-800

Corporate Tax ID: 74.211.970/0002-53
State Registration: 190.159.742.110
Phone: +55 (11) 2410-1190 x201
FAX: +55 (11) 2410-1190 x702
Email: *suporte.tecnico@treetech.com.br*
Site: *http://www.treetech.com.br*

## 1.6 Warranty Terms

The Bushing Monitor -BM shall be covered by Treetech's warranty for 2 (two) years, counting from the date of purchase, exclusively against eventual manufacturing defects or quality flaws that may prevent it from being used regularly.
The warranty does not cover damage undergone by the product as a consequence of accidents, mishandling, incorrect installation and application, inadequate tests or broken warranty seal.
The eventual need for technical support must be communicated to Treetech or to its authorized representative, and the equipment should be shipped back to them with the respective sales receipt.
No express or implied warranty, in addition to those mentioned above, is provided by Treetech. Treetech does not guarantee that the BM will be adequate for any particular application.
The seller will not be liable for any type of damage to property or any losses and damages that may happen, be connected, or result from purchasing this equipment, from its performance or any service that may be supplied together with the BM.
Under no circumstances the vendor will be deemed liable for losses that may occur, including, but not limited to: losses of profits or earnings, impossibility of using the BM or any equipment associated to it, costs of capital, costs of acquired energy, equipment costs, installations or replacement services, stoppage costs, complaints by clients or crew members of the buyer, regardless of the aforementioned damages, complaints, or losses are based on contract, warranty, warranty against negligence, violation or any other.
Under no circumstance shall the vendor be deemed liable for any personal damage, of any sort.

## 1.7 Revision History

**Table 2 - Revision History**

| *Revision* | *Date* | *Description* | *By* |
|---|---|---|---|
| *0* | *2004-02-04* | *Original emission* | ***Marcos Alves*** |
| *1* | *2004-08-17* | *Revised Modbus register map from register 23 to 104. Added registers 186 to 200 in Modbus register map (for firmware version 1.02). Revised chapters 6.1.2 and 6.2.1.b and illustrations 6.6, 6.8, 6.9 and 6.10.* | ***Marcos Alves*** |
| *2* | *2005-01-14* | *Revised Measurement Module BM-MM: supply voltage, address setting, position of connection terminals. Revised chapters 6.1.2, 6.2.1.a and 7. Revised appendix A.2. Revised illustrations 5.1, 6.3, 6.5, 6.8, 6.10, 7.1 and 7.2. Added chapter 7.2. Added illustration 7.3.* | ***Marcos Alves*** |
| *3* | *2006-11-28* | *Adaptation of Manual for new Interface Module, BM-HMI.* ***This Manual is not applicable to the previous version of Interface Module, BM-HMI.*** | ***Marcos Alves*** |
| *4* | *2011-11-16* | *Updated Modbus Register Map and DNP 3.0 Point List. Added Feature: Detection of defects in the bushings with short evolution times.* ***This Manual is not applicable to versions below 1.10 of Interface Module, BM-HMI.*** | ***Daniel Carrijo*** |

| | | | |
|---|---|---|---|
| 5 | 2011-12-07 | *Improved description of feature: Detection of defects in the bushings with short evolution times.* ***This Manual is not applicable to versions below 1.10 of Interface Module, BM-HMI.*** | ***Daniel Carrijo*** |
| 6 | 2013-01-15 | *Self-Diagnostic screen update. Protocols update. Addition of "Submenu I Leakage Alarms" screen and submenu structure. Protocol separation.* | ***Heber Pedrosa*** |
| 7 | 2014-07-01 | *Inclusion of new parameters "Recalculate averages", "Tan Delta H Min" and "Tan Delta VH Min". General revision.* ***This Manual is not applicable to versions below 2.05 of Interface Module BM-HMI and 6.07 of Measurement Module BM-MM.*** | ***Rodrigo Gennari*** |
| 8 | 2015-05-20 | *Design and logos revised. Summary, Table list and Figure List updated. Connection Diagrams updated. International representatives updated. Text review.* ***This Manual is not applicable to versions below 2.05 of Interface Module BM-HMI and 6.07 of Measurement Module BM-MM.*** | ***João Victor Miranda*** |
| 9 | 2015-12-09 | *Subchapter 2.1 updated* | ***João Victor Miranda*** |
| 9.01 | 2016-01-08 | *Item 3.2.1 updated* | ***João Victor Miranda*** |
| 9.10 | 2016-08-26 | *Item 3.2.2 added* | ***João Victor Miranda*** |
| 9.11 | 2018-02-05 | *Item 2.5 updated* | ***João Victor Miranda*** |
| 9.12 | 2018-04-27 | *Item 7.2 updated* | ***João Victor Miranda*** |

# 2 Introduction

Bushings are accessories used in high-voltage equipment for the purpose of providing safe passage for electric current from the external environment to the interior of the equipment, as well as providing the necessary insulation in relation to the casing of the equipment. A few of the more common examples can be found on power transformers, shunt reactor, current transformers and high-voltage circuit breakers of the dead-tank type.
Despite being accessory to the different equipment types mentioned, and in general being of much lower unit cost as compared to the overall cost of the equipment, bushings perform a function that is essential in operating the equipment.
On the other hand, bushings are subject to considerable dielectric strains, and a failure in their insulation may result, not only in damage to the bushing itself, but also to the entire equipment to which it is associated. In extreme cases, a dielectric failure in a bushing can result in total destruction of the high-voltage equipment (in power transformers, for instance, losses stemming from an event of this type can be worth a few hundred times the unit cost of the bushing that originally caused the problem).
reetech's BM Bushing Monitor allows this to be performed on-line, with bushings energized, monitoring of capacitance and dissipation factor (tangent delta) for the insulation of the bushing, important variables in early detection of deterioration of the insulation. This way, potentially catastrophic failures can be avoided by detecting the problem still in its incipient phases.

**Figure 1-Bushing Monitor BM**

## 2.1 Application Field

Among the different existing types of bushings, the condensive bushing stands out in high and extra high-voltage applications. In these bushing the insulating body is made up of a staggered arrangement of several concentric cylindrical layers of insulating material and layers of conducing materials for the purpose of making the electric field as uniform as possible. The innermost conducing layer may be connected to the main lead, in order to increase the radius and reduce the electric field in this region (also reducing the intense electric fields that may be caused by surface roughness on the main lead). The outermost conducing layer is connected to the flange of the bushing that, in its turn, is grounded. The intermediate conducing layers are insulated, with floating potential. For outdoor applications, the entire set must be placed inside a waterproof container, frequently made of porcelain. The connection of the last conducing layer (or of one of the outermost layers) to ground is usually performed by way of removable connection close to the base of the bushing, called voltage tap or test tap. Check Figure 2.

The set described in the previous paragraph acts electrically like several capacitors connected in a series array, forming a capacitive voltage splitter. In this way, the total potential differential for the main lead in relation to ground is shared equally among the different capacitors.

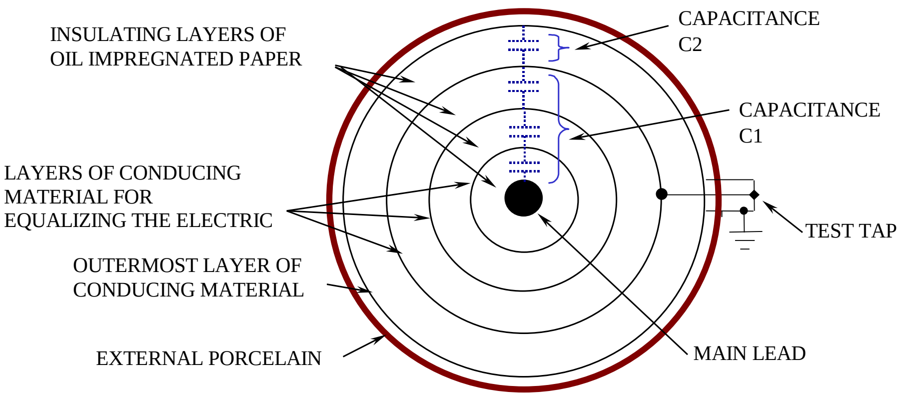



**Figure 2 - Construction details of a condensive bushing.**

When the operating voltage is applied to a condensing bushing, a current known as the leakage current, begins circulating through the insulation, due mainly to their capacitance, and in much lower proportion due to the dielectric losses (expressed by the dissipation factor or delta tangent). Figure 3 depicts this situation; in it we can see the electrical equivalent obtained with the construction shown in Figure 2, with the bushing energized.

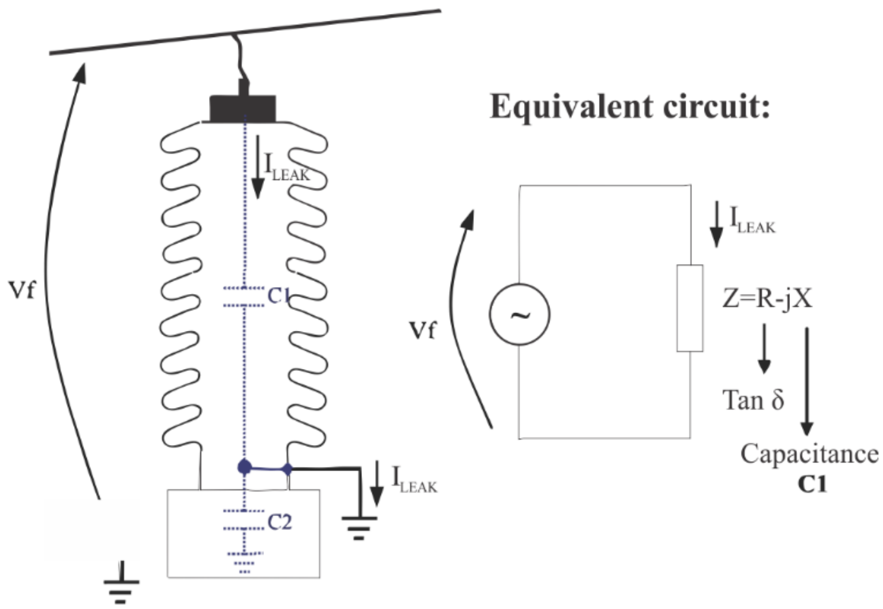



**Figure 3- Equivalent circuit for an energized condensive bushing.**

The objective of on-line monitoring of condensing bushings is detection of changes in the insulation of the bushing while still in the initial phase, pointing to the development of conditions that may lead to a dielectric failure in the equipment, providing information for analysis and decision support. To achieve this it is necessary to detect, with the bushing energized, changes in capacitance and in delta tangent values of the insulation, that is to say, changes in the “Z” impedance of the insulation of the bushing.

## 2.2 Main Features

- Autonomous monitoring system, to be installed on the body of the equipment (transformer, reactor, etc.). Does not require installation of computers and/or special software for operation;
- Connection through adapters to Test Taps or Voltage Taps of capacitive bushings, besides the innovative capability of monitoring capacitive bushings through DPBs (Bushing Potential Devices);
- Operating temperatures -40...+85ºC;
- Universal voltage input, 38 to 265Vdc/Vac;
- Spare bushings pre-programmed for operation in case of single-phase transformer banks;
- Modular system: configurable for monitoring of 3, 6 or 9 bushings;
- Protection against bushing tap opening, with activation indicated by an alarm;
- Inputs for 2 Pt100Ω 0°C temperature sensors, allowing recording and correlation of insulation variation with changes in ambient temperature, oil temperature or others;
- 8 output contacts, 1fixed (NC) for auto diagnostic and 7 configurable (5 NO and 2 NC) for alarms by absolute values, high evolution trends or low leakage currents. Operation mode programmable NO or NC;
- 2 programmable analog outputs for remote readings of capacitances and tangent delta. Configurable output range: 0...1mA, 0...5mA, 0...10mA, 0...20mA or 4...20mA;
- Internal clock and non-volatile memory for storage of history of capacitance and tangent delta data and alarm events;
- Serial communication port selectable RS485 or RS232 with Modbus RTU and DNP3.0 protocols;
- Communication via fiber optic cable, using external electrical-optical converter;
- Simplified programming divided into basic settings (sufficient for most applications) and advanced parameters;

## 2.3 Methodology

In each bushing, the leakage current I leakage flows through capacitance C1 to ground, passing through the test tap, with this current being a function of the phase-ground voltage and the impedance of the insulation. Thus, any change in the impedance of the insulation (capacitance or dissipation factor) will be reflected in a corresponding alteration in the value of the leakage current that, in theory, could be used in detecting the change that occurred in the impedance.

However, one of the obstacles found in detecting using the process described above is the order of magnitude of the changes that must be monitored. Changes as small as an algebraic increment of 0.3% in the dissipation factor of a bushing may represent the difference between a new bushing, in good conditions, and a borderline acceptable bushing. It is clear that such a slight change in the dissipation factor will cause a practically insignificant change in the leakage current of the bushing, making unfeasible detecting this only by way of monitoring each bushing's leakage current.

One of the techniques that allow the practical limitation shown to be overcome is using the vector sum of the leakage currents of the three bushings deployed in a three-phase system. In an arrangement of this sort, the three currents will have a phase difference in relation to each other of approximately 120º, and usually will be of the same order of magnitude once, in principle, the three bushings will have insular capacitances and the voltages of the three phases will be close to balanced. This way, the sum of the three leakage currents tends to a value quite a bit lower than for each of the leakage currents taken individually, as shown in Figure 4(a) for a given initial condition of capacitances and dissipation factors.

Now, let's suppose that a change has occurred in the capacitance and in the dissipation factor of the bushing for phase A, as shown in Figure 4(b), the Change Vector, that expresses de displacement of current Ia from its initial value to the final one, is also reflected in the sum current, which is altered in relation to its initial value according to the same Change Vector. This Change Vector has a practically insignificant weight if compared to the magnitude of leakage current of phase A. However, the same does not happen when this vector is compared to the sum current, which allows its detection and, consequently, detection of the change that took place in the impedance of this bushing. Changes detected in the sum current are always attributed to just one of the bushings on three-phase sets, selected as a function of the angle of the Change Vector in relation to bushing leakage currents. This selection takes into account the fact that the probability of their occurring simultaneous changes in two or three of the bushings comprising a set is very low.

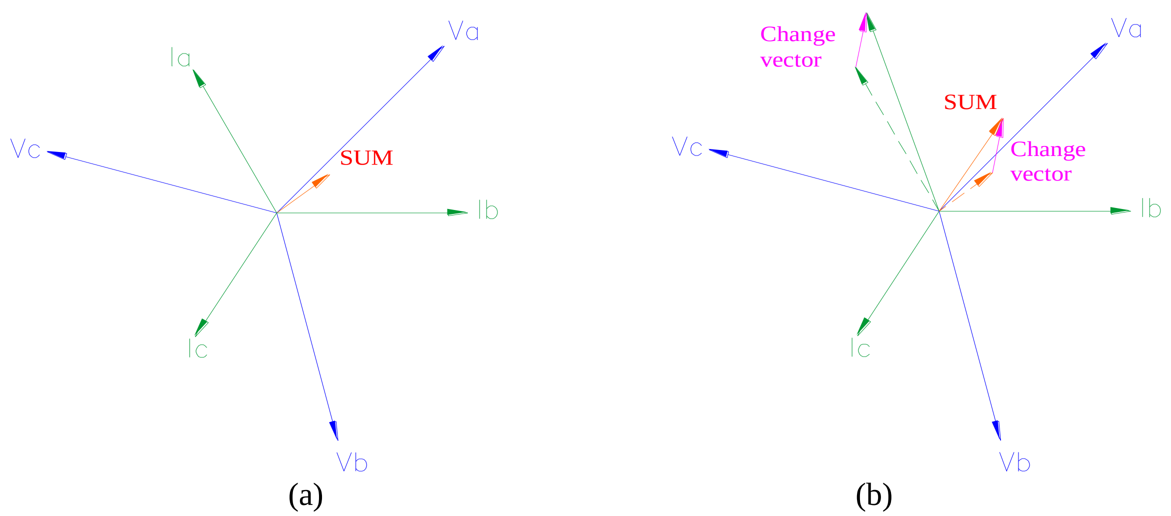



**Figure 4 - Leakage current in three bushings of a three-phase system and their vector sum; (a) for a given initial condition; (b) with alteration in the capacitance and dissipation factor of the bushing**

- An initial reference set of currents must be defined for the system, so that subsequently these can be compared to the new readings obtained on-line, in order to determine the changes occurred in the bushing's capacitance and dissipation factor;
- Absolute values for capacitance and delta tangent of bushings are not measured, rather what is measured instead are the variations that occur in these parameters. However, once the initial values for capacitance and delta tangent are known for each bushing (values found when the initial reference current set is defined), measuring the variations that take place allows the existing values for capacitance and delta tangent to be known;
- For new bushings, the initial values can be defined as the rated values supplied by the manufacturer on the equipment plaque for capacitance and delta tangent. However, for bushings in operation, it is advisable that, while installing the on-line monitoring system, these parameters should be measured using conventional methods, with de-energized bushings. This ensures the monitoring system will use correct values for the initial reference set.

- In case of alarms for high capacitance or tangent delta in one of the bushings, not just one, but all three bushings in the three-phase set must be checked, for instance, by way of off-line measurements for capacitance and tangent delta.

Another issue, that has not been dealt with so far, is that leakage currents and the sum current are not only influenced by changes in the capacitance and delta tangents of the bushings, but also by changes in the phase-ground voltage in each bushing. This influence is eliminated by way of mathematical and statistical treatments performed on the readings. This is also the reason for determining the initial reference set of currents during the adjustable period of 1 to 10 days following the beginning of operation of the monitoring system. Likewise and for the same reasons, the process of measuring the changes occurred has an identical time response to reach stabilization at the final value after a change in capacitance and tangent delta.

As expounded in the above introduction, the bushing's physical construct creates a capacitive voltage divider, with its lower end normally being short-circuited grounding the tap of the bushing, so that the tap's voltage in relation to ground is zero volts. In order to be able to measure the leakage current for the bushing, this direct grounding is removed and replaced by the leakage current measurement circuit. Due to this circuit's low impedance, the tap's voltage in relation to ground remains close to zero. We should bear in mind the fact that, in case of accidental interruption of this circuit, the capacitive voltage divider will generate a voltage on the tap of the bushing that will normally display values higher that the tap's dielectric rigidity in relation to ground, risking damaging the bushing.

In order to avoid this event, the connection adapter of the tap of the bushing has a voltage limiting device that becomes conducive in case the measuring circuit opens, thus supplying the leakage current with a low impedance path, so that the tap's voltage to ground remains on the order of a few volts. This limiter device is not subject to wear of mechanical or electrical natures, allowing it to carry the leakage current for indeterminate time. For total safety purposes, each adapter is equipped with two protections connected in parallel, in a redundant configuration.

## 2.4 Detection of defects in the bushings with short evolution times

Electric industry experts have defended the premise that the evolution of defects in condensing bushings is slow, taking place over days. Given this premise, the monitoring system's response time to variations in capacitance and Tangent Delta would not present any problem for the detection of defects developing in the bushings, allowing enough time for the user to take action when an evolving defect is detected. Experiments with periodic off-line measurement of capacitance and tangent delta and with online monitoring support this notion.

In fact, this premise has proven to be true in several cases. However, one should take into account that evidence accumulated from bushing maintenance experience originates from periodic offline measurements, with measurement intervals of several years. Whereas in most cases offline measurements will only be able to detect defects in evolution and prevent slow evolving bushing failures, it is natural, therefore, that it would seem like all failures evolve slowly. In cases where bushings fail in the interval between offline tests it was impossible to understand the failure evolution speed, hence several failures may have evolved quickly.

With the popularization of online monitoring, recently evolved, continuous monitoring of the evolution of changes in Capacitance and Tangent Delta has allowed the observation of many instances where the failure evolution was slow. Others instances were observed where the evolution was very rapid. This establishes the need for mechanisms in the online monitoring systems to be able to detect and send an alarm to the user

whenever defects of a fast nature occur. Simultaneously, one must not lose the ability to detect capacitance and tangent delta slow evolving defects, available with the current technique, the vector sum of leakage currents.
To meet this need Treetech has developed a method (with patents filed internationally) for the detection (and alarm) of fast evolving defects as a result of the bushing insulation short-circuiting (increasing its capacitance) and evolving toward an imminent failure.
The immediate effect when bushing insulation short-circuits and evolves toward complete failure is an increase in the leakage current, due to the equivalent increase in capacitance when insulation layers are short-circuited.
In this case threshold values are programmed in the bushing monitor for an alarm to trigger for high and very high leakage current. This provides two levels of alarm with different severity levels. To prevent spurious alarms as a result of transient overvoltage, alarms have user adjustable timing.

In this case the monitoring system would also act as a protection system, requiring high confidence that the measurement indicative of impending failure is correct. The same need also exists in the case that the decision by the shutdown is manual and not automatic, since the decision of the operators will be grounded in the information provided by the bushing monitor.

To ensure the reliability of the measurement and eliminating the possibility of false alarms due to faulty hardware, for example, a strict consistency check is performed by the bushing monitor.

Any changes in the leakage currents of bushings are also reflected in the vector sum of the currents. With this, the truth of an occurrence of high leakage current in one phase can be verified before the before the alarm generation of high or very high leakage current, comparing the current measurements of individual escape with measuring the vector sum, which should always be consistent.

If a measurement of high current leakage does not find confirmation in measuring the sum of the currents, the issuance of the alarm is blocked. Instead of alarm, the bushing monitor emits then a self-diagnosis warning alerting you to the existence of inconsistency in measurements.

Such a procedure, with required patents, guarantee the reliability of alarms for high current leakage, causing the users the confidence to, based on this information, take actions that may be drastic in many cases, as the immediate shutdown of the transformer.

## 2.5 Procedures in case of alarms issued by Bushings Monitor BM

Below are presented some guidelines to settings support Bushings Monitor BM.
The objective is not to suggest adjustments BM, but provide guidance on how to proceed in case of alarms. However, the information is interesting because the suggested adjustments end up being shown implicit form and based on IEEE standard.

To answer questions, suggestions implied adjustments in the text are:

- High Capacitance: 2 to 3% increase.
- High High Capacitance: 5% increase.
- High Delta Tangent: 100% increase.
- High High Delta Tangent: 200% increase.
- Alarms for trend: these alarms have greater freedom to adjust, so they are not mentioned in the manual, but it is always suggested an adjustment 7-14 days.

Based on IEEE Standard C57.19.100-1995 and 2012 (IEEE Guide for Application of Power Apparatus Bushings) some procedures can be recommended in case of a warning from the on-line bushing monitoring.

Although the standard refers to capacitance and tangent delta tests performed off-line, as was the common practice at the time it was written, the application of the general guidance to on-line monitored bushings is direct, as shown on the table below. Texts in “IEEE Recommendation” column are extracted from section 10.2.1 of C57.19.100-1995. Texts in “Application to On-line Monitoring” column are the Treetech’s suggestions.

**Table 3- General guidance to on-line monitored bushings**

<table>
<tr><th colspan="3">Capacitance</th></tr>
<tr><th>Normative recommendations</th><th colspan="2">Application to On-line Monitoring</th></tr>
<tr><td rowspan="5">IEEE C57.19.100-1995:<br>Bushing capacitance should be measured with each power or dissipation factor test and compared carefully with both nameplate and previous tests in assessing bushing condition. This is especially important for capacitance-graded bushings where an increase in capacitance of 5% or more over the initial/nameplate value is cause to investigate the suitability of the bushing for continued service.</td><td colspan="2">• Bushing capacitance is being monitored on-line and compared with alarm thresholds, which are based on the nameplate or previous tests values plus a margin.<br>• If the capacitance increases by 5% from its initial value it will be indicated be the “Very High Capacitance” alarm in the bushing monitor (unless this alarm is programmed in a different way by users).<br>• If a very high capacitance alarm happens the bushing should be removed from service.</td></tr>
<tr><td colspan="2">• In addition to the above mentioned for capacitance, the bushing monitor has two additional levels of warning before the “very high capacitance” alarm.<br>• First one is “Trend of Capacitance Increase” alarm, which is an advanced warning indicating that a “capacitance high” alarm may come in the future. In this case, watch for the evolution of capacitance to see if it will reach the high capacitance level.<br>• Second one is “Capacitance High” alarm, which is normally set in 2% to 3% above initial capacitance. In this case it is suggested to make a schedule for off-line measurements. If the high capacitance is confirmed it would be advisable to make a schedule for removing the bushing from service.</td></tr>
<tr><th colspan="2">Recommended practices</th></tr>
<tr><td>HIGH ALARM</td><td>Default: 3%<br>Recommended: 3%</td></tr>
<tr><td>VERY HIGH ALARM</td><td>Default: 5%<br>Recommended: 5%</td></tr>
</table>

| ***Delta Tangent*** |
|---|

<table>
<tr><th>Normative recommendations</th><th colspan="2">Application to On-line Monitoring</th></tr>
<tr><td rowspan="6">IEEE C57.19.100-1995:<br>If any bushing exhibits an increase in power or dissipation factor over a period, the rate of change of this increase should be monitored by more frequent tests.<br>If the power or dissipation factor measurement of a bushing doubles from its initial reading, then the test frequency should be increased or the bushing should be removed from service.<br>If the power or dissipation factor measurement triples the initial test reading, then the bushing should be removed from service.<br><br>IEC 60137:2008<br>The maximum allowed value for delta tangent measured at the factory is 0.7% absolute, with the typical bushing being 0.35% absolute.</td><td colspan="2">• The rate of change in power factor is monitored by the “Trend of Tangent Delta” in the bushing monitor.<br>• If a high trend alarm happens, “more frequent tests” are already being performed on-line.<br>• Watch for the evolution of tangent delta to see if it will double from initial value. This is the criteria normally used to program the “high tangent delta” alarm threshold.</td></tr>
<tr><td colspan="2">• If the power factor doubles from its initial value it will be indicated be the “High Tangent Delta” alarm in the bushing monitor (unless this alarm is programmed in a different way by users).<br>• If a high tangent delta alarm happens, “more frequent tests” are already being performed on-line.<br>• It is up to the user to decide to remove the bushing from service. However, as both tangent delta and capacitance are being monitored on-line, it may be reasonable to make a schedule for removal of service instead of an immediate, unplanned outage.</td></tr>
<tr><td colspan="2">• If the power factor triples from its initial value it will be indicated be the “Very High Tangent Delta” alarm in the bushing monitor (unless this alarm is programmed in a different way by users).<br>• If a very high tangent delta alarm happens the bushing should be removed from service. the double of the initial value</td></tr>
<tr><td colspan="2">Recommended practices</td></tr>
<tr><td>HIGH ALARM</td><td>Default: 100%<br>Recommended: The double of the initial value (100%) or 0,700% in absolute value, the highest.</td></tr>
<tr><td>VERY HIGH ALARM</td><td>Default: 200%<br>Recommended: The triple of the initial value (200%) or 1.050% in absolute value, the highest.</td></tr>
</table>

**Important**

The minimum values are based on recommendations for a typical bushing with initial delta tangent of 0.350%, in accordance with IEC 60317: 2018.

The absolute minimum value recommended for "high delta tangent alarm" of 0.7% is based on IEC 60137: 2008 and is justified by the fact that naturally occurring variations in the delta tangent calculation can trigger undue alarms if the alarm configuration, based on a 100% increase over the initial value, result in a very low absolute value.

The absolute minimum value recommended for "very high delta tangent alarm" of 1.05% is suggested in order to maintain consistency and proportionality with the minimum recommended value for the "high delta tangent alarm" (0.7 %).

# 3 Project and installation

## 3.1 System Topology

The Bushing Monitor BM is composed of three basic parts (Figure 5):

- Adapter for test tap or voltage tap – provides electrical connection to the tap of the bushing, ensuring its mechanical rigidity and weather seal. This component also incorporates protection against overvoltage and overcurrents due to transient phenomenon as well as accidental opening of the measurement circuit, thus preventing the tap from remaining open. The mechanical construction of the adapter is variable, keeping pace with the different bushing tap designs found on the market;
- Measurement Module BM-MM – receives the leakage currents from three bushings in a three-phase set, measures these currents and performs a first level of mathematical and statistical data processing, making them available for the Interface Module (BM-HMI) through a serial communication port RS485;
- Interface Module BM-HMI – receives data from one, two or three measurement modules (BM-MM), displaying these results as current capacitance and tangent delta values for each bushing on the front panel displays. Also supplies analog outputs (mA), alarm contacts and serial communication ports RS485 and RS232, which are available for the user.

Figure 6 shows the connections between these components.

The following items are also necessary for the implementation of the BM Bushing Monitoring system:

- Twisted, shielded cables for connection between serial communication ports of the Measurement Module BM-MM and the Interface Module BM-HMI;
- Twisted, shielded cables for connection between the bushing tap adapters and the measurement module BM-MM.


**Figure 5 - Figure Component parts of the Bushing Monitors BM. (a) Adapter for Test or voltage tap; (b) Measurement Module BM-MM; (c) Interface Module BM-HMI**

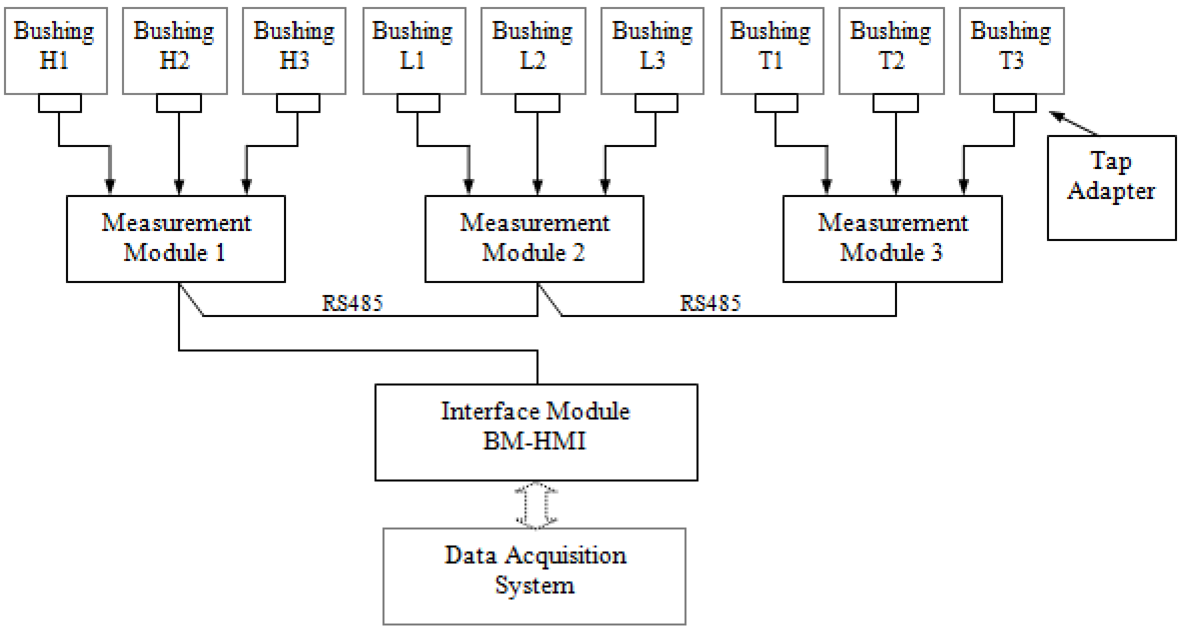



**Figure 6 - Interconnection block diagram**

## 3.2 Mechanical Installation

Except for the bushing TAP adapter, the equipment of the Bushing Monitoring System must be installed protected from the weather, sheltered inside panels. An anti-dew (condensation) system must be available.

### 3.2.1 Tap Adapter

When beginning to operate the BM bushing monitor, it will be necessary to define equipment parameters to current values for capacitance and tangent delta of the bushings. In the case of bushings already in operation, these parameters will have to be measured using a conventional procedure, with de-energized bushings. These readings can be taken with the tap adapters already installed on the bushings, as long as during the voltage reading process voltage on the tap does not exceed the peak of 9V.

The Bushing Measurement Tap Adapter comes in a variety of sizes, due to the different mechanic constructs used by the different manufacturers or even between different models of the same make.

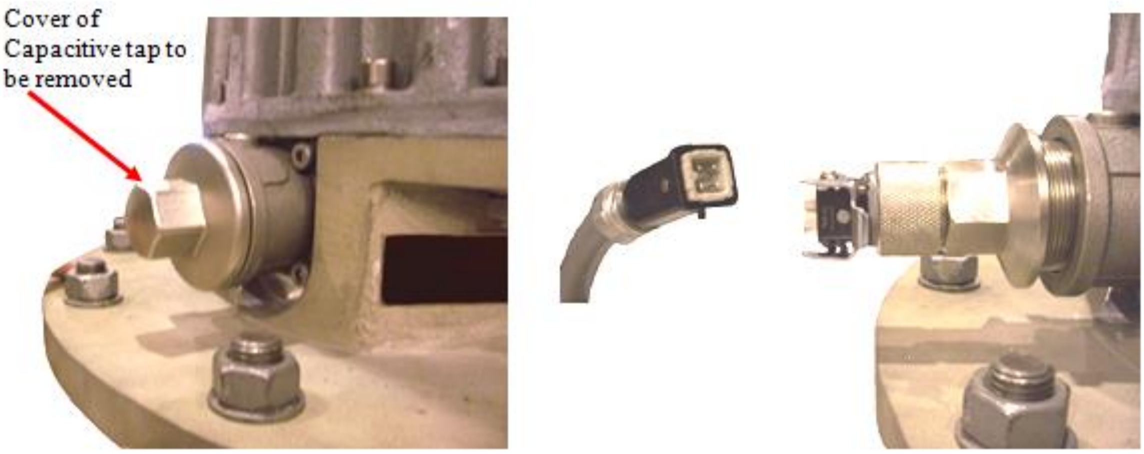



**Figure 7 - Assembly of the Capacitive Tap Adapter**

The adapter must be installed with the transformer off line (de-energized). After reaching the base of the bushing with cabling, connect the cables to the connection outlet, minding the numbering found on it. The rear cable entrance of the outlet has a Pg 11 thread for a cable gland.

After the outlet is assembled, remove the cover to the capacitive tap and connect the Adapter to the tap, with the outlet unplugged, Figure 7. The use of force in the adapter connection is not necessary and can damage the tap of the bushing.

After fixing the adapter, it should be connected to the outlet, Figure 8. After this procedure has been carried out, perform the start up procedure described in Figure 5 of this manual.

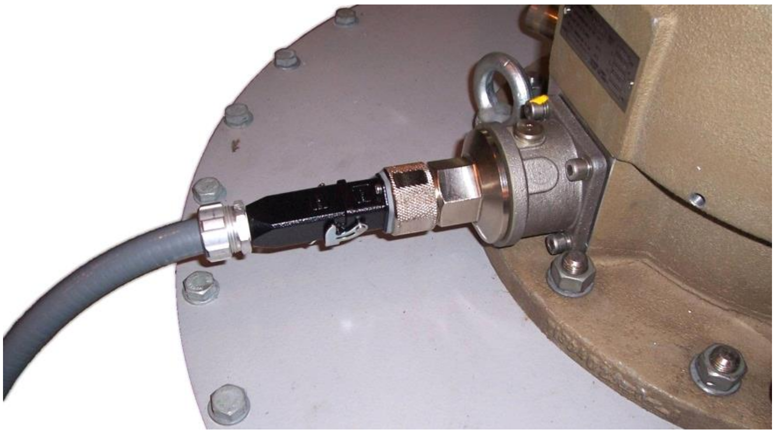


**Figure 8 - Tap Adapter Installed**

### 3.2.2 BSP x PG Thread Adapter

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

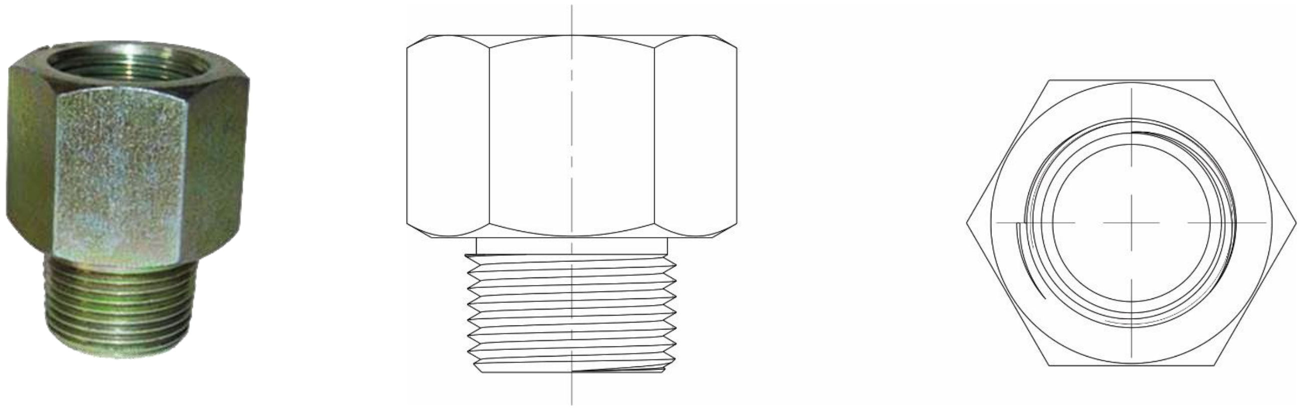


**Figure 9 – BSP x PG Thread Adapter**

Material: Nickel-plated Brass
Male Thread PG11
Female Thread BSP ½"

### 3.2.3 Measurement Module BM-MM

The Measurement Module is suitable for being installed in standard DIN 35mm track, and can be placed, for instance, in assembly boards inside panels. Figure 10 shows the main dimensions of the equipment.

Once the recommendations for grounding the shield of measurement cables are observed (Figure 12), the Measurement Module BM-MM can be installed up to 500 meters far from the bushings. As a rule of thumb, the Measurement Module must be placed as close as possible to the bushings it will monitor, so the ideal site for installing the Measurement Module is inside the transformer's control panel on transformer tank or inside the centralizing panel for single-phase transformer banks.

Connection terminals are installed in the front panel of the BM-MM. 22 to 12AWG cables (0.5 to 2.5mm²) cables can be used, bare or with pin-type terminals for power supply and serial communication circuits. For the cables used in measuring leakage currents from the taps of the bushings, eyelet-type terminals of up to 12AWG (2.5mm²) must be used.

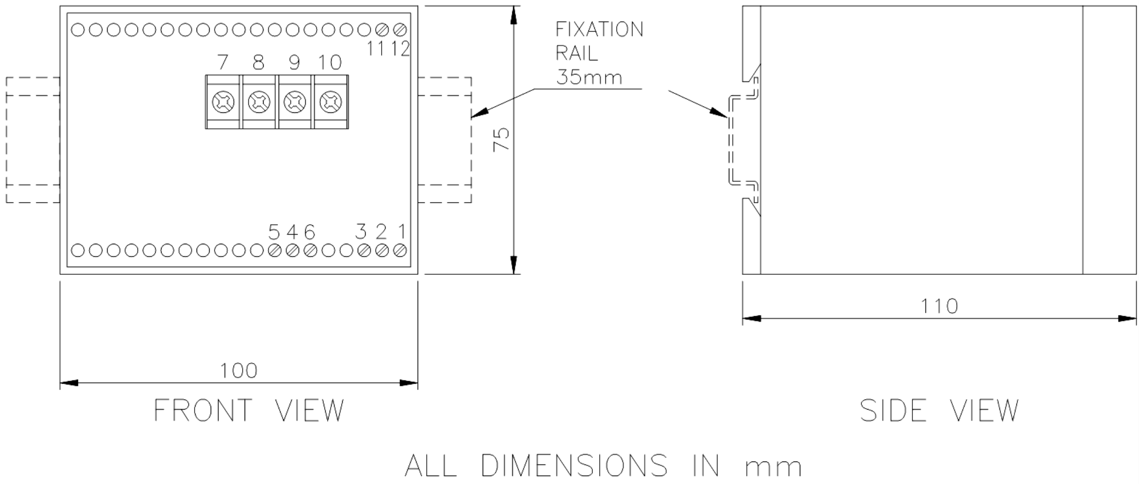



**Figure 10 - Dimensions of Measuring Module – BM-MM**

### 3.2.4 Interface Module – BM-HMI

The Interface Module – BM-HMI is suited for built-in type installations and can be fixed to, for instance, doors or face plates of panels. Fixing clips are supplied with the Module. Figure 11 shows the main equipment dimensions, as well as the dimensions of the cutout needed on the plate for insertion of the equipment. Special attention must be given to the thickness of the paint coat where the cutout is made, since in some cases, when high-thickness paint is used, reduction in the cutout area may even keep the equipment from fitting.

Connection terminals are installed on 2 removable connectors at the rear of the BM-HMI, in order to facilitate connections. 22 to 12AWG (0.5 to 2.5mm²) cables can be used, bare or with pin-type terminal.

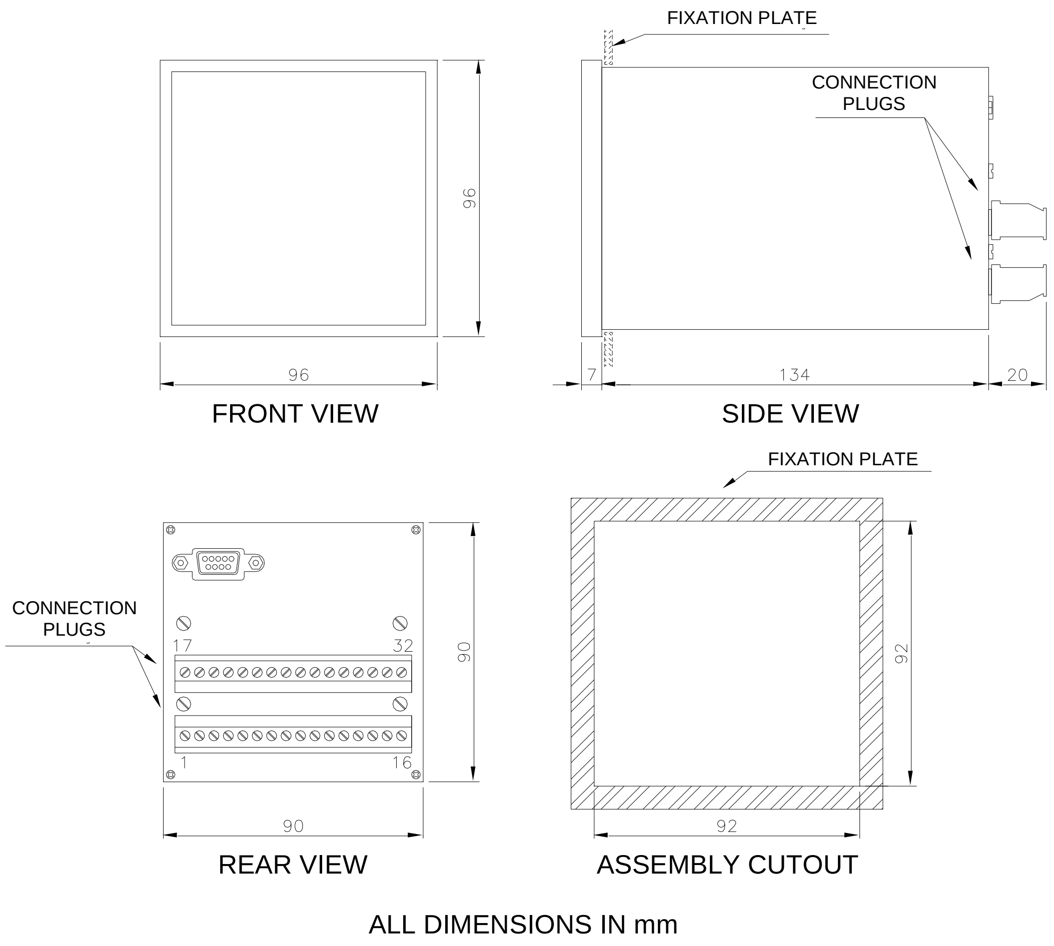



**Figure 11 Dimensions of Interface Module – BM-HMI**

## 3.3 Electrical Wiring

### 3.3.1 Measurement Module BM-MM

**Table 4 - Measurement Module BM-MM**

| INPUTS | TERMINALS OF BM-MM |
|---|---|
| 1) Auxiliary power feed and grounding:<br>Input for universal power feed<br>38 to 265 Vdc/Vac, 50/60Hz, 5W | 1 – ground<br>2 – cc/ca<br>3 – cc/ca |
| 2) Leakage current measurement inputs:<br>Receives leakage currents from the bushings, coming from the tap adapters. There are three inputs in total, one for each phase of a set of three-phase bushings. Current return to ground occurs by way of a common terminal for all three phases. | 7 – Phase A<br>8 – Phase B<br>9 – Phase C<br>10 – Common |

## 1) Auxiliary power feed and grounding

The BM has universal auxiliary power input (38 ~ 265 Vac / 38 ~ 275 VAC, 50/60Hz) independent of the TP measuring input. It is possible, however, to use the secondary voltage of the TP itself to feed equipment via an external jumper connecting in parallel the input of the measuring and feeding. In this case should be taken into account the consumption of equipment (8W) and the potency of TP.

Feeding the BM from the auxiliary services of the substation is advisable especially when it is integrated into a serial communication network for the purpose of collecting data for supervisory or monitoring systems.

## 2) Leakage current measurement inputs

**Risk of Electric Shock**

ATTENTION: Under no circumstances can the bushing tap be open with the bushing energized. For this reason, **it is highly advisable** that the cables coming from the tap adapter are NOT connected directly to the measurement modules. Intermediate, short-circuitable terminal blocks must be used (similar to those used in current transformer circuits). See illustration 6.5. This makes short-circuiting the intermediate terminal blocks possible and, in this way, reroute the leakage currents, allowing the measurement module to be removed from service even with the bushings energized.
The connection cable between the Tap Adapter and the Measurement Module must be of the shielded, twisted pair type. In order to ensure mechanical resistance for this cable, it is not advisable to use very small gauges, so as to reduce the chance of accidental opening of the bushing tap. Gauges around 18AWG or 0.75mm2 are indicated..

Shielding on connection cables between tap adapters and the Measurement Module must also go through terminals, avoiding interrupting the shielding. The stretch of cable left without shielding must be as short as possible and shielding should be grounded only at one end, preferably at the tap adapter (Figure 12). If the measurement module is installed on the control panel found on the casing of the transformer tank, shielding can be grounded on the control panel.

**Table 5 – BM-MM Outputs**

| OUTPUTS | TERMINALS OF BM-MM |
|---|---|
| 3) Port RS485 – Interface Module:<br>Connection to the RS485 port of the Interface Module is performed by way of shielded, twisted pair. Up to three Measurement Modules can be connected to the same Interface Module. | *4 ( + )*<br>*5 ( – )* |
| 4) Self-diagnostic relay:<br>Potential free contact (NC), signals failure in power feed, internal or connection cable failure, as well as low leakage current (possible disconnection from the bushing tap). When energizing the Bushing Monitor, this contact changes state, returning to the rest position in the event of a failure. | *11 e 12* |

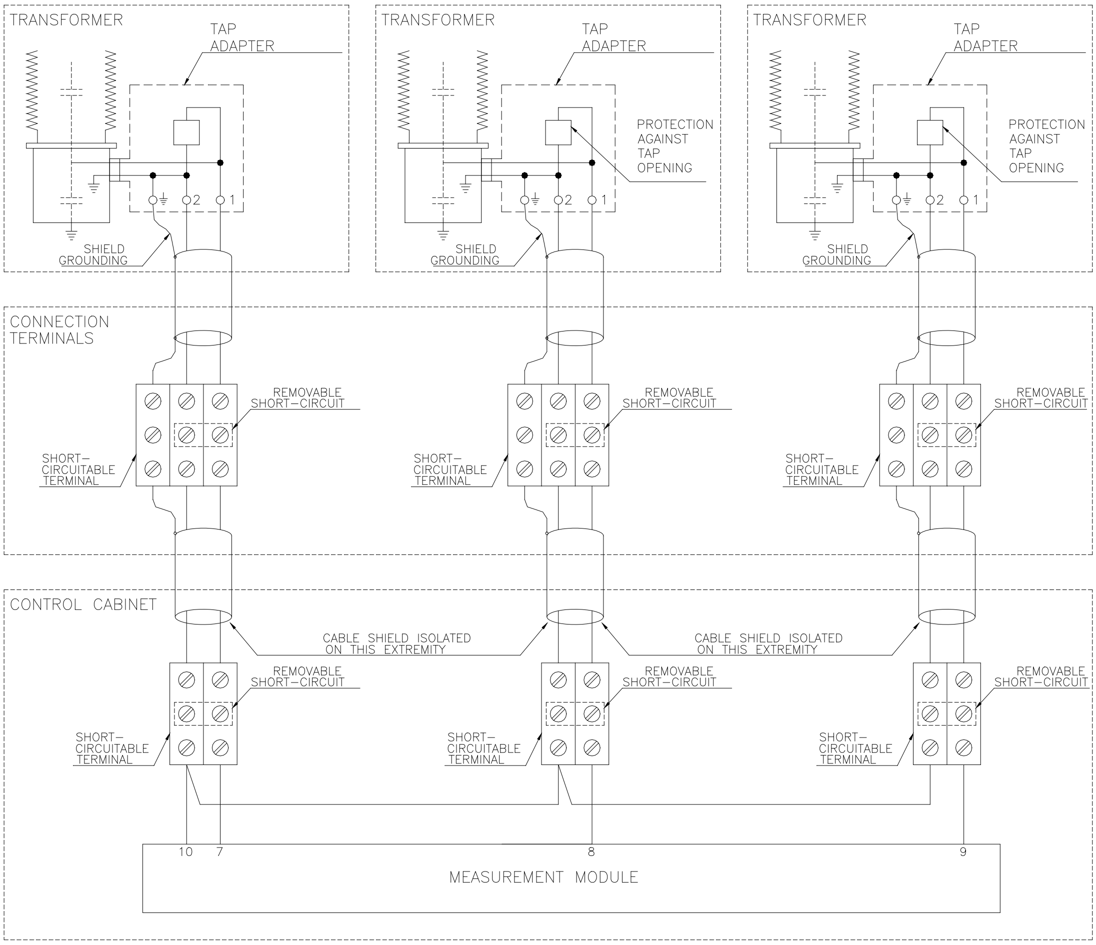



**Figure 12 - Details of the connection and grounding for the shielding of the measurement cables for leakage currents.**

### 3) RS485 Port – HMI

Serial communication Ports RS485 for every measurement module must be linked by way of shielded, twisted-pair cable, preserving the shield unbroken all the way to its grounding point close to the BM-HMI Interface Module.

Any unshielded stretches resulting from patching must be as short as possible.

### 3.3.2 Interface Module BM-HMI

The following inputs and outputs are available in this Module:

**Table 6 – BM-HMI Inputs**

| INPUTS | TERMINALS OF BM-HMI |
|---|---|
| **1) Auxiliary power feed and grounding:**<br>Universal power feed inputs<br>38 to 265 Vdc/Vac, 50/60Hz, 8W | 17 – ground<br>18 – dc/ac<br>19 – dc/ac |
| **2) RTD Inputs:**<br>Allow up to two RTD (Pt100) sensors for free deployment to be connected, for example, for measuring ambient temperature, oil temperature or others. Using these inputs is optional. When only RTD B is used, an external jumper must be placed between terminals 26 and 27 of BM-HMI, as shown in the wiring diagram. | RTD A<br>26, 27 and 28<br>RTD B<br>26, 27, 29 and 30<br>(see wiring diagram) |
| **3) Port RS485 – Measuring Modules:**<br>Connection to the RS485 port(s) of the Measurement Module(s) is performed by way of shielded, twisted pair. One, two or three Measurement Modules can be connected to the same Interface Module. | 20 ( + )<br>21 ( – ) |

If intermediate terminal blocks have to be used in the Serial communication connection RS485 between the measurement Modules and the Interface, and/or the RTD sensor, make sure the shielding of this cable also shields the terminal blocks, thus keeping the shielding uninterrupted and unbroken (see Figure 13 and Figure 14Figure 2). The unshielded length of cable, due to the patching, must be as short as possible.
Maximum distance between ends of the RS 485 serial communication network is of 1300 meters, with a 120-ohm termination resistor being used at each end.

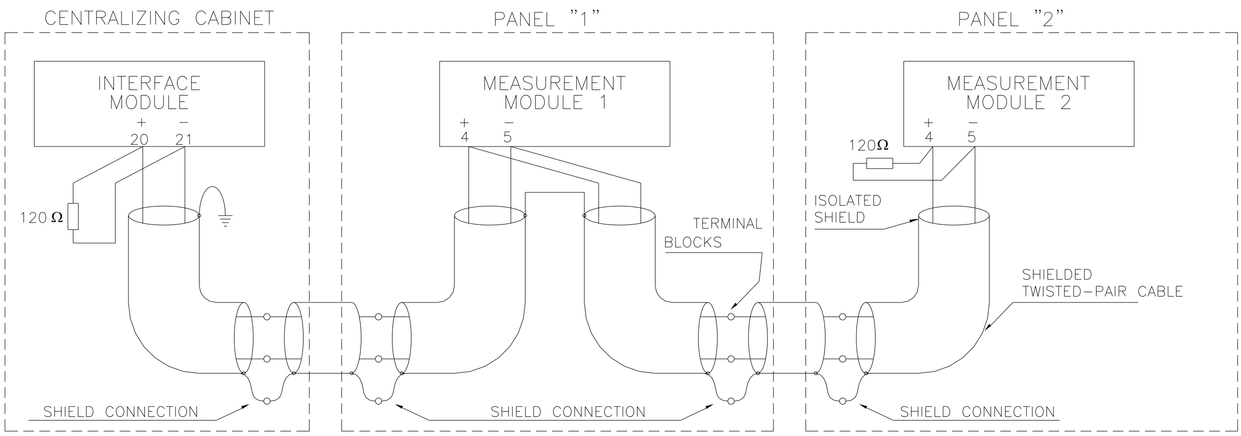



**Figure 13 - Details of connections and grounding of the shielding for the connection cables between the Measurement and Interface Modules.**

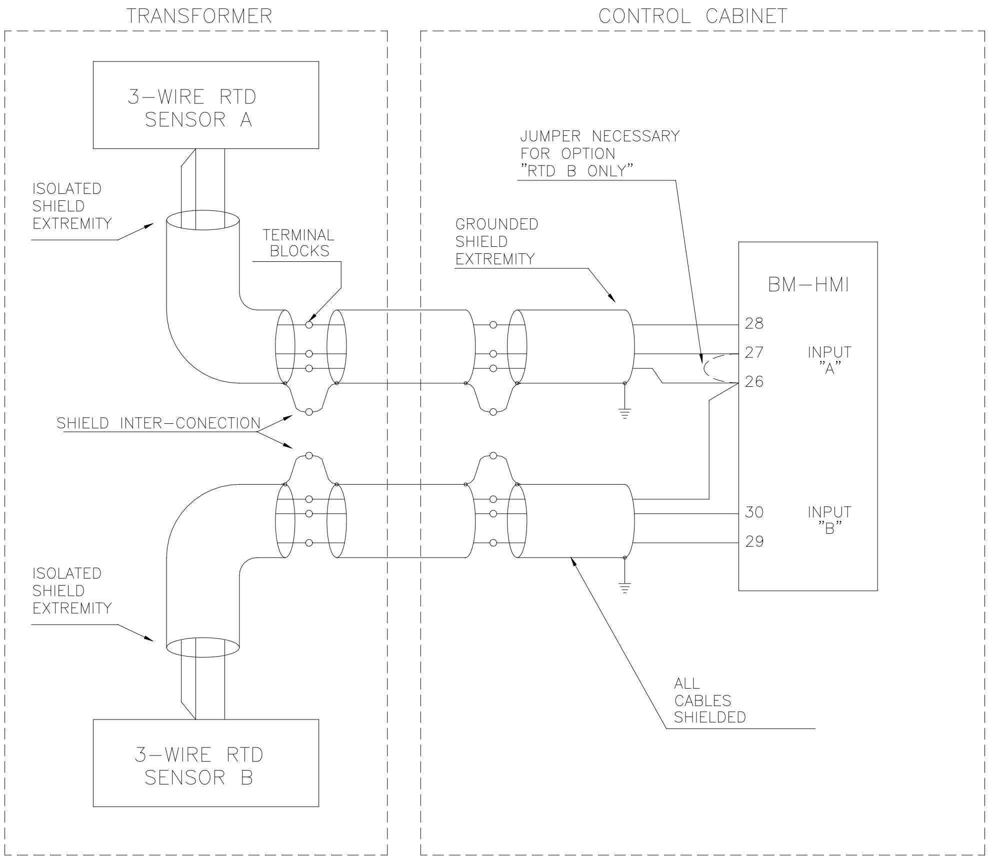



**Figure 14 - Details of connection and grounding of shielding for cables between Pt100 and BM-HMI.**

**Table 7 - BM-HMI outputs**

| OUTPUTS | TERMINALS OF BM-HMI |
|---|---|
| **4) Current Loop Output:**<br>Programmable outputs for remote reading of current values for capacitance and tangent delta of bushings.<br>Output Standard selected by user (0...1, 0...5, 0...10, 0...20 or 4...20 mA). | **22( + ) common**<br>**23( – )**<br><br>**24( + ) common**<br>**25( – )** |
| **5) Self-diagnostic relay:**<br>Potential free contact (NC), signals failure in power feed, internal or connection cable failure. When energizing the Bushing Monitor, this contact changes state, returning to the rest position in the event of a failure. | **15 and 16** |
| **6) Programmable signal relays (NC):**<br>Potential free contact (NC), with programmable operation function and mode (NO or NC).<br>Alarms for high, very high values, as well as for high rise trends for capacitance and/or tangent delta, programmable via menu. | **5 and 6 - relay 3**<br>**7 and 8 - relay 4** |
| **7) Programmable signal relays (NO):**<br>Potential free contact (NO), with programmable operation function and mode (NO or NC).<br>Alarms for high, very high values, as well as for high rise trends for capacitance and/or tangent delta, programmable via menu. | 1 and 2 - relay 1<br>3 and 4 - relay 2<br>9 and 10 - relay 5<br>11 and 12 - relay 6<br>13 and 14 - relay 7 |

| | |
|---|---|
| **8) Port RS485 / RS232 – Scada:** Connection with data acquisition system, protocols Modbus RTU or DNP3.0, via shielded, twisted pair cable (RS485) or rear DB9 (RS232). | 31 ( + )<br>32 ( – )<br>or<br>Connector DB9<br>(rear panel) |

## 3.4 Connection Diagrams

- The BM bushing monitoring system has a modular concept, meaning that one Interface Module can host up to three Measurement Modules. This concept allows several different application combinations to be made on three-phase or single-phase transformers, reactors, CTs or combinations thereof. The following illustrations feature some examples of possible wiring schemes for Tap Adapters, Measurement Modules and Interface Module.
-

**Important**

Please note that, if there are back up transformers or reactors, their bushings will only be monitored when they effectively are in use. To this end, cables coming from the tap adapter of the bushing on back up unit must be connected to the measurement module in the position previously occupied by the bushing that is being removed from operation.

**Warning**

ATTENTION – Special care must be taken to ensure that none of the taps on the bushings in service is left open, as this is a risk of severe damage to the bushing or operator injury. Even in out-of-service bushings, it is advisable to maintain the tap duly grounded, and remove the grounding only when it is to be reconnected to the measurement module

.

- Whenever a bushing that is being monitored is replaced, the BM must update initial values for tangent delta and capacitance for bushings starting to operate as well as reinitialize the initial reference acquisition process. In order to facilitate these operations, “Bushing Exchange” menu can be used. This procedure should be carried out in any of the situations shown below:
- Entrance in operation of back up unit;
- Exit from operation of back up unit with return of regular unit to operations;
- Replacement of any bushing being monitored by a new one.

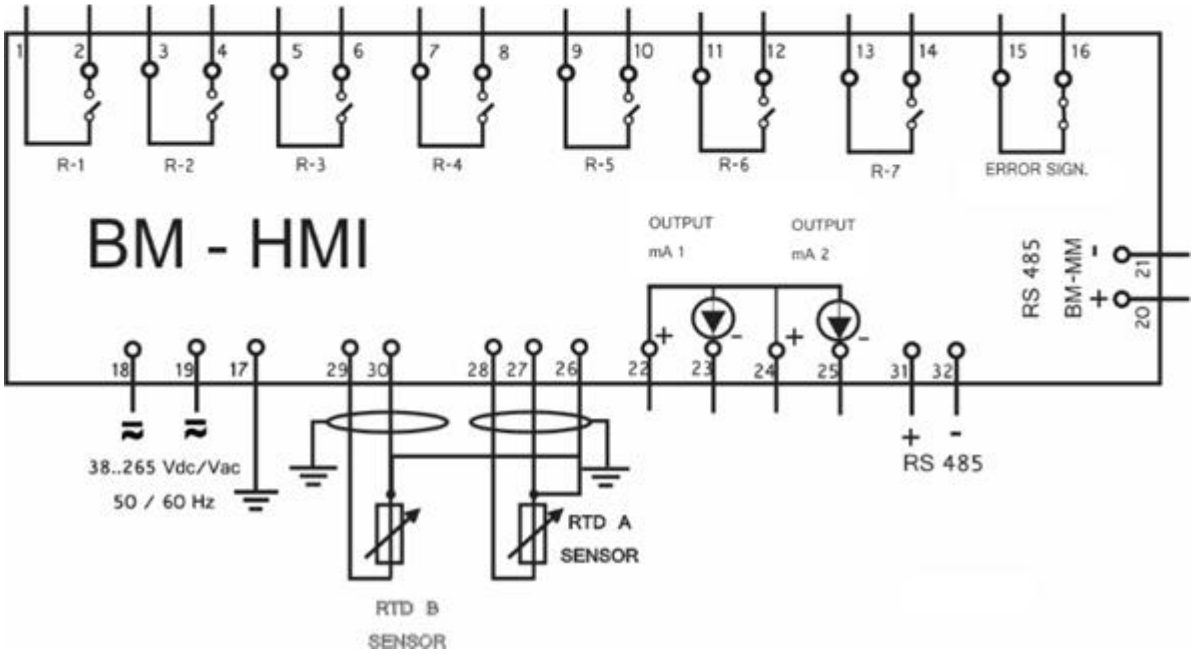



**Figure 15 – BM -HMI interface module connection diagram**

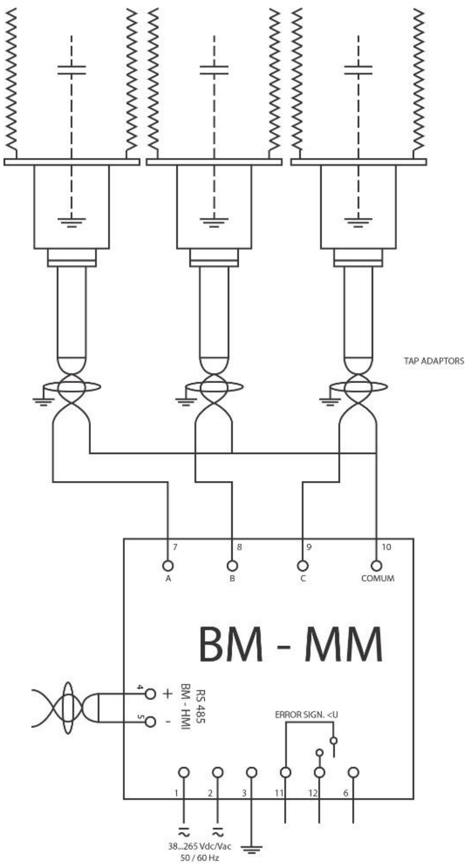



**Figure 16 – BM-MM connection diagram**

### 3.4.1 Application suggestions

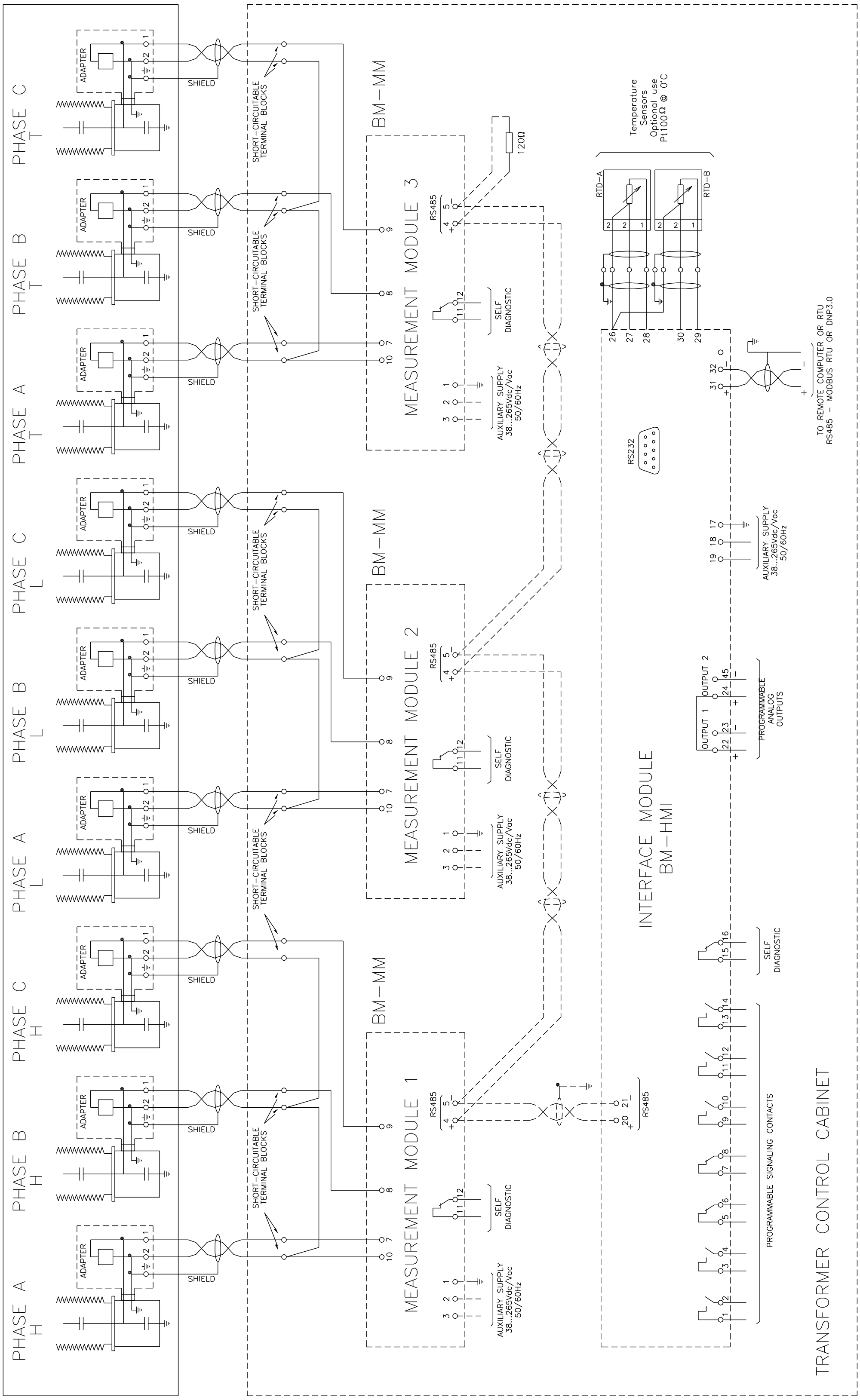



**Figure 17 - Basic Wiring Diagram for application on one three-phase transformer monitoring 3 sets of bushings.**

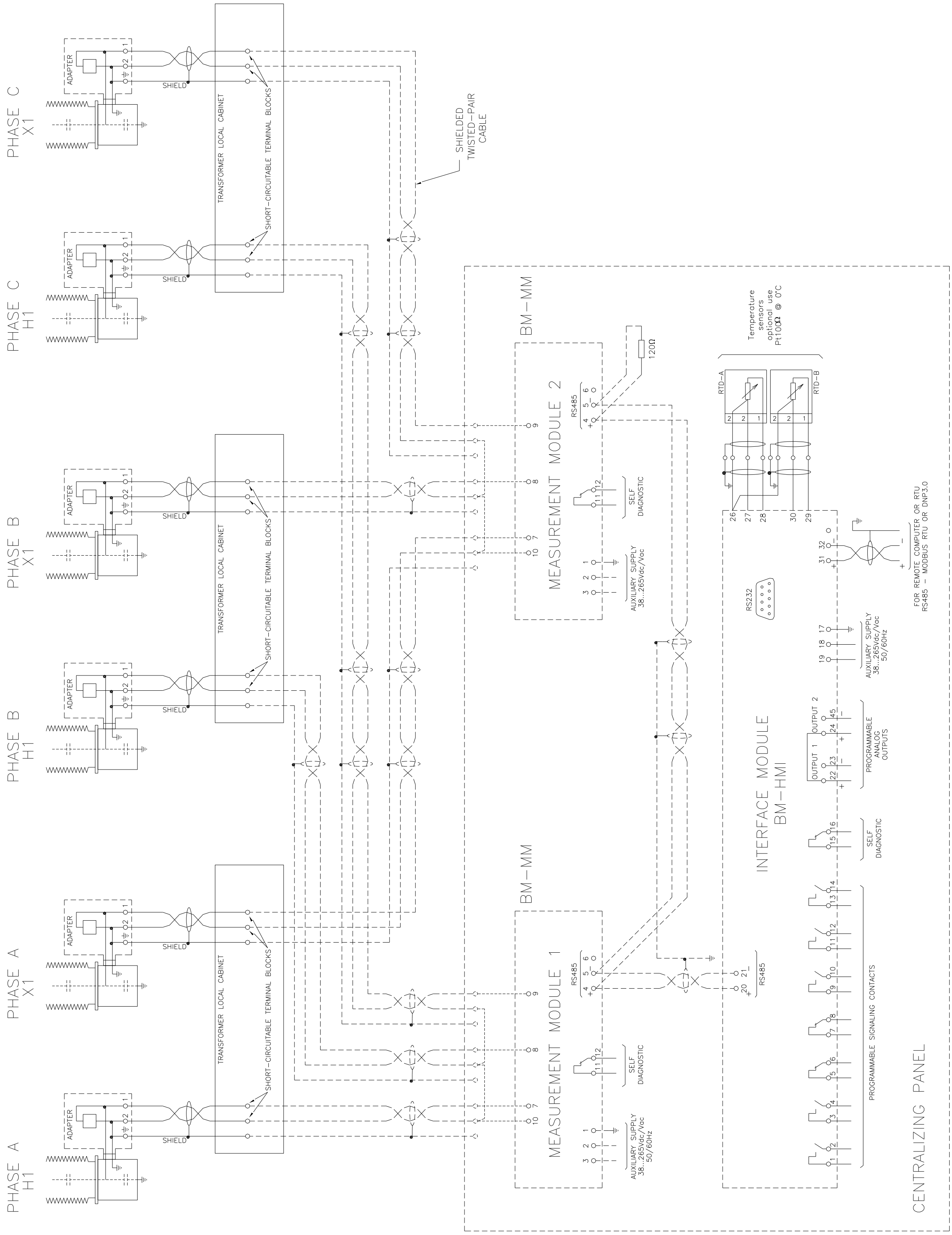

PHASE C X1
PHASE C H1
PHASE B X1
PHASE B H1
PHASE A X1
PHASE A H1
ADAPTER
SHIELD
TRANSFORMER LOCAL CABINET
SHORT-CIRCUITABLE TERMINAL BLOCKS
SHIELDED TWISTED-PAIR CABLE
BM-MM
MEASUREMENT MODULE 2
MEASUREMENT MODULE 1
RS485
120Ω
SELF DIAGNOSTIC
AUXILIARY SUPPLY 38...265Vdc/Vac
AUXILIARY SUPPLY 38...265Vdc/Vac 50/60Hz
Temperature sensors optional use Pt100Ω @ 0°C
RTD-A
RTD-B
RS232
INTERFACE MODULE BM-HMI
OUTPUT 1
OUTPUT 2
PROGRAMMABLE ANALOG OUTPUTS
PROGRAMMABLE SIGNALING CONTACTS
FOR REMOTE COMPUTER OR RTU RS485 - MODBUS RTU OR DNP3.0
CENTRALIZING PANEL

**Figure 18 - Basic Wiring Diagram for application on bank of single-phase transformers monitoring 2 sets of bushings.**

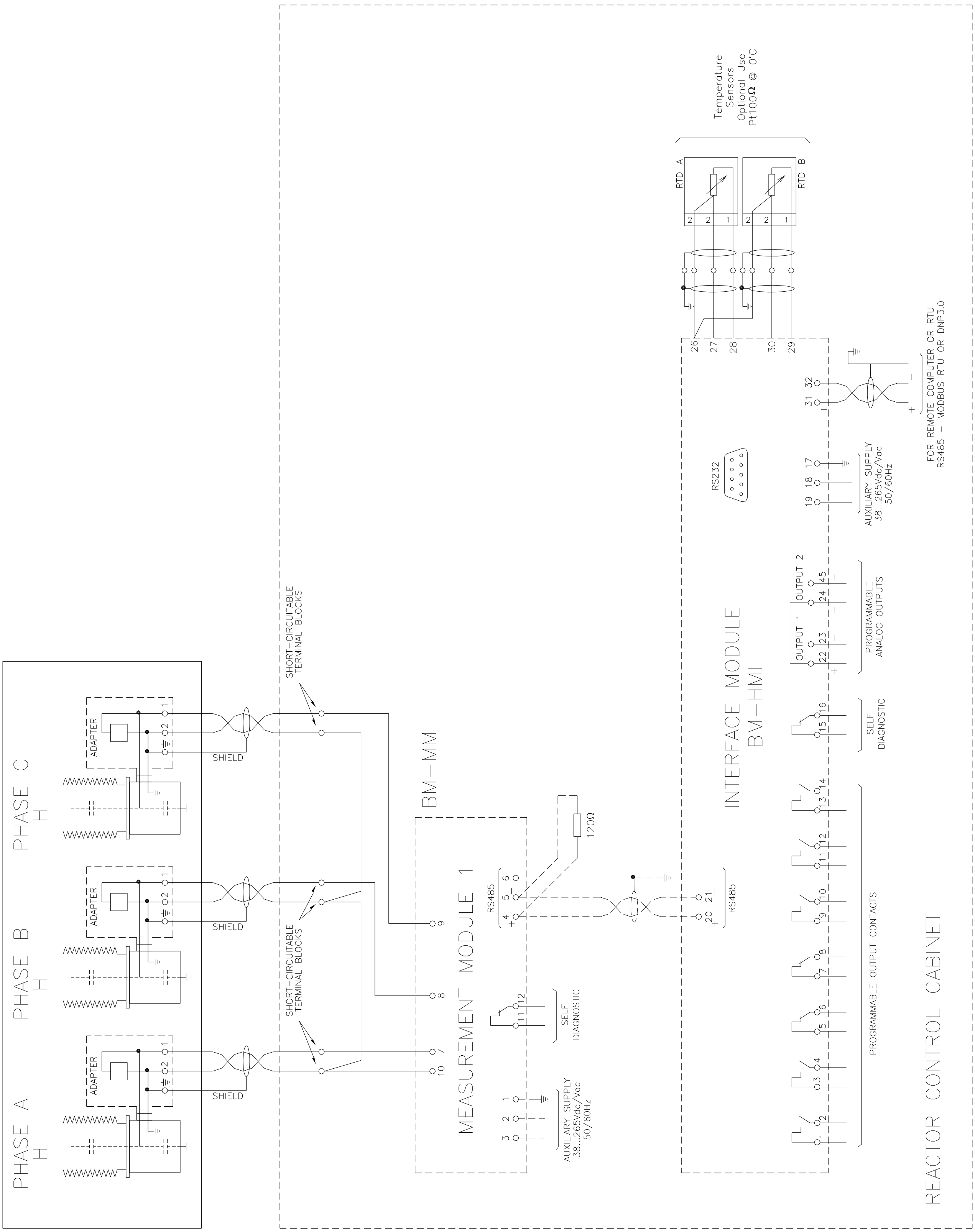



**Figure 19 - Basic wiring diagram for application on a three-phase reactor, monitoring 1 set of bushings**

# 4 Operation

## 4.1 Parameter definition for Measurement Module BM-MM

Each Measurement Module connected to the same Interface Module must have a unique address, without repetition. The addresses must be programmed according to the bushing set connected to the module, as shown in the table below:

**Table 8 – Programming addresses**

| Bushing Set | Address of Measurement Module |
|---|---|
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |

In case there are only two measurement modules only addresses 1 and 2 will be programmed, address 3 will not exist. In a similar way, if there is only one measurement module only address 1 will be programmed, addresses 2 and 3 will not exist.

The address programming in a measurement module is affected by pressing the push-button at the upper left corner, as shown in figure below

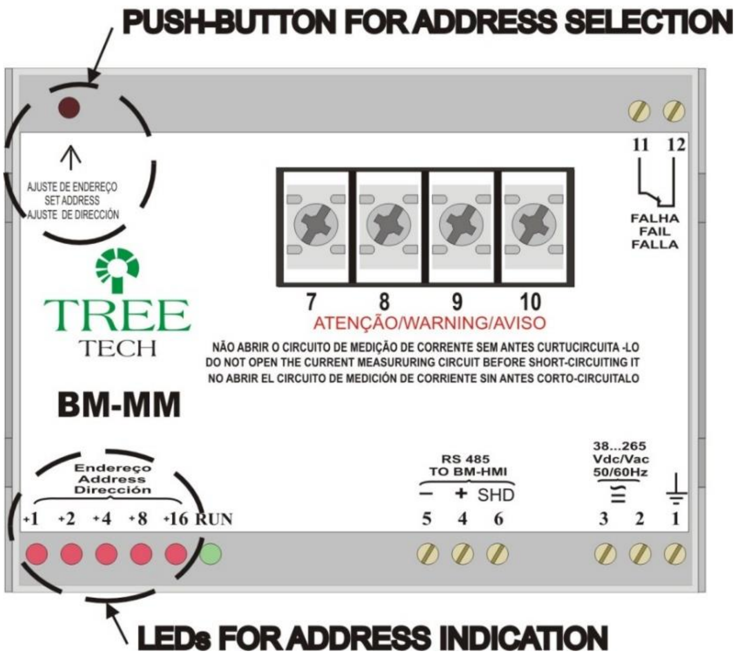



**Figure 20 - Programming of address in Measurement Module**

To change the address, press and hold the push-button. After 3 seconds the address will begin to increment at one unit per second. Release the button when the correct address is reached. After maximum address (31) is reached, a new increment will make address return to minimum (1).

The address selected is visualized by the combination of LEDs situated at the lower left corner (see Figure 18), as shown in the following table. Addresses 4 to 31 are reserved for future use.

**Table 9 - Possible combinations of LEDs**

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

## 4.2 Local operation of the Bushing Monitor BM

All query and programming operations for the Bushing Monitor can be carried out through the front panel of the Interface Module BM-HMI, shown in Figure 19.

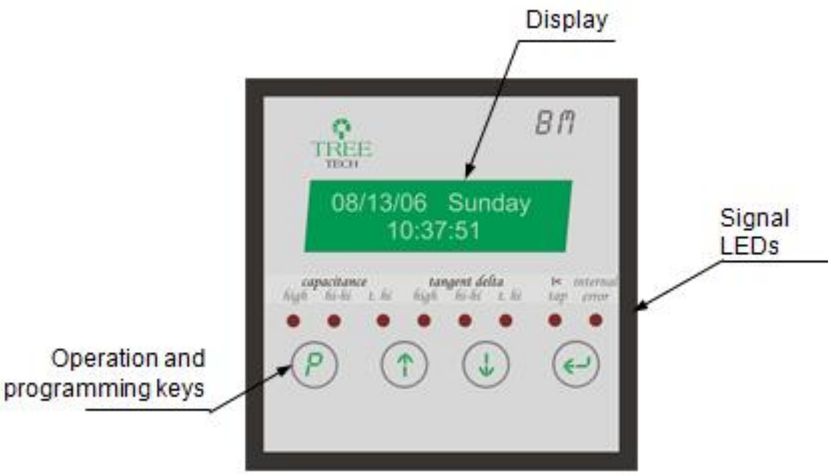



**Figure 21 - Front Panel of the Interface Module BM-HMI**

## 4.3 Signal LEDs

Signal LEDs allow easy visualization of eventual alarms and warnings, as shown in Figure 21.

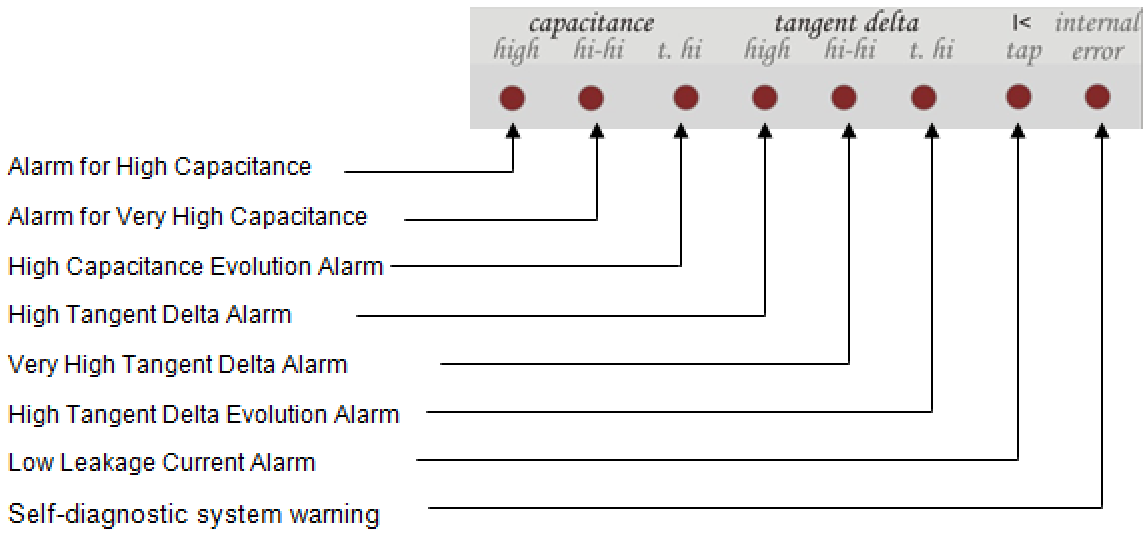



**Figure 22 - Signal LEDs for Interface Module BM-HMI**

## 4.4 Operation and Programming Keys

The keys have the following functions:

**Programming Key:** The reading screens allow queries about equipment firmware version as well as access password for access to the programming menu. In the programming menus, it quits current menu and return to the menu for the previous level. If actuated during a parameter change, they return to the menu for the previous level without saving any changes made.

**Up key:** Navigation between reading screens and menu screens and programming parameters. When editing a parameter, this key increments value programmed.

**Down key:** Navigation between reading screens and menu screens and programming parameters. When editing a parameter, this key decrements value programmed.

**Enter key:** Alternates groups of reading screens, selects menus and saves values programmed. It also allows control and set of display brightness.

## 4.5 Display

When in normal operation mode, the display of the Interface Module BM-HMI will display readings measures or date and time of internal clock, according to programming by user, between the following options:

1. Standard screen, where user defines screen to be displayed,
2. Sequential display mode, where readings screens are alternated at intervals of approximately 10 seconds.

Regardless of the display mode programmed, it is possible to query reading screens manually using the and keys.

The BM's readings screens are divided into two groups: Main Readings and Auxiliary Readings. The change between groups of readings can be performed using the key.

The screen sequence in both reading groups can be seen in illustrations below.

In case an abnormal condition occurs, the corresponding Error code will be shown on the display (see Troubleshooting, chapter 6).

## 4.6 Setting the Contrast of the Display

The BM offers seven different settings for level of brightness set using the keys on the front panel. Follow the steps shown below to set the desired contrast level:


In the initial reading screen, press and hold : the brightness set screen will be displayed.


Use keys: and to increase or reduce brightness, respectively.

By pressing the or keys, the new setting will be saved and the display returns to the readings screens.

## 4.7 Indications Screen

During normal working operation, the BM indicates the measured quantities or the date and time of the internal clock, as programmed by the user. The presentations can be:

1) *Default screen*, where the user determines which screen should be indicated;

2) Sequentially, where the seven measurement screens are shown with intervals of approximately 15 seconds;

3) Static way, where one screen is shown for an indeterminate time.

When using the option default or static for the presentation screen, the BM will reverse (text in negative) and intermittently normalize the illumination of display points to prevent premature wear of the display, which would be caused by the presentation of the same image for a long time.

Regardless of the programmed mode, the measurement screen can be manually consulted using the keys ↑ and ↓. The screens of optional functions will only be shown if the function is available.

See below which are the BM consultation screen:

| | |
|---|---|
| DateDay of the week<br>**Hour**-GMT | 11/26/12 Monday<br>21:15:30 |
| Capacitance per phase of the measuring set 1 | Set 1 pF A:000.0<br>B:000.0 C:000.0 |
| Tangent Delta per phase of the measuring set 1 | Set1 TD% A:000.0<br>B:000.0 C:000.0 |
| Time for alarm of High Capacitance of the measurement set 1 | Set 1 Cap. High<br>Phase A > 90 days |
| Time for alarm of Very High Capacitance of the measurement set 1 | Set 1 Cap. Hi Hi<br>Phase A > 90 days |
| Time for alarm of High Tangent Delta of the measurement set 1 | Set 1 TanD High<br>Phase A > 90 days |
| Time for alarm of Very High Tangent Delta of the measurement set 1 | Set 1 TanD Hi Hi<br>Phase A > 90 days |
| Capacitance per phase of the measuring set 2 | Set 2 pF A:000.0<br>B:000.0 C:000.0 |
| Tangent Delta per phase of the measuring set 2 | Set2 TD% A:000.0<br>B:000.0 C:000.0 |

| | |
|---|---|
| Time for alarm of High Capacitance of the measurement set 2 | `Set 2  Cap. High`<br>`Phase A > 90 days` |
| Time for alarm of Very High Capacitance of the measurement set 2 | `Set 2 Cap. Hi Hi`<br>`Phase A > 90 days` |
| Time for alarm of High Tangent Delta of the measurement set 2 | `Set 2  TanD High`<br>`Phase A > 90 days` |
| Time for alarm of Very High Tangent Delta of the measurement set 2 | `Set 2  TanD Hi Hi`<br>`Phase A > 90 days` |
| Capacitance per phase of the measuring set 3 | `Set 3 pF A:000.0`<br>`B:000.0  C:000.0` |
| Tangent Delta per phase of the measuring set 3 | `Set3 TD% A:000.0`<br>`B:000.0  C:000.0` |
| Time for alarm of High Capacitance of the measurement set 3 | `Set 3  Cap. High`<br>`Phase A > 90 days` |
| Time for alarm of Very High Capacitance of the measurement set 3 | `Set 3 Cap. Hi Hi`<br>`Phase A > 90 days` |
| Time for alarm of High Tangent Delta of the measurement set 3 | `Set 3  TanD High`<br>`Phase A > 90 days` |
| Time for alarm of Very High Tangent Delta of the measurement set 3 | `Set 3  TanD Hi Hi`<br>`Phase A > 90 days` |

## Auxiliary screens Indications

| | | |
|---|---|---|
| Daily increase of capacitance | Set1 pF/d A:0.00<br>B:0.00 C:0.00 | ↑ ↓ |
| Daily increase of Tangent Delta | Set1 %/d A:0.000<br>B:0.000 C:0.000 | ↑ ↓ |
| Phase Voltage | Set 1 kV A:000.0<br>B:000.0 C:000.0 | ↑ ↓ |
| Line Voltage | Set 1 kV AB:00.0<br>BC:00.0 CA:00.0 | ↑ ↓ |
| Current | Set 1 mA A:00.00<br>B:00.00 C:00.00 | ↑ ↓ |
| Leakage Current ABC | Set 1 ILeak ABC<br>0° 000.0° 000.0° | ↑ ↓ |
| Sum of Current and angle | Set 1 As:000.0°<br>Is: 00.000 mA | ↑ ↓ |
| Number of Samples | Set 1 Calc.<br>Sample: 0000 | ↑ ↓ |
| Daily increase of capacitance | Set2 pF/d A:0.00<br>B:0.00 C:0.00 | ↑ ↓ |
| Daily increase of Tangent Delta | Set2 %/d A:0.000<br>B:0.000 C:0.000 | ↑ ↓ |
| Phase Voltage | Set 2 kV A:000.0<br>B:000.0 C:000.0 | ↑ ↓ |
| Line Voltage | Set 2 kV AB:00.0<br>BC:00.0 CA:00.0 | ↑ ↓ |
| Current | Set 2 mA A:00.00<br>B:00.00 C:00.00 | ↑ ↓ |
| Leakage Current ABC | Set 2 ILeak ABC<br>0° 000.0° 000.0° | ↑ ↓ |
| Sum of Current and angle | Set 2 As:000.0°<br>Is: 00.000 mA | ↑ ↓ |

| | |
|---|---|
| Number of Samples | Set 2 Calc.<br>Sample: 0000 |
| Daily increase of capacitance | Set3 pF/d A:0.00<br>B:0.00 C:0.00 |
| Daily increase of Tangent Delta | Set3 %/d A:0.000<br>B:0.000 C:0.000 |
| Phase Voltage | Set 3 kV A:000.0<br>B:000.0 C:000.0 |
| Line Voltage | Set 3 kV AB:00.0<br>BC:00.0 CA:00.0 |
| Current | Set 3 mA A:00.00<br>B:00.00 C:00.00 |
| Leakage Current ABC | Set 3 ILeak ABC<br>0° 000.0° 000.0° |
| Sum of Current and angle | Set 3 As:000.0°<br>Is: 00.000 mA |
| Number of Samples | Set 3 Calc.<br>Samples: 0000 |

## 4.8 Alert Screens

The BM can display text alert on your display in order to inform the user about the occurrence of certain events, such as notices of maintenance for the switch, alarms or errors parameter. The warning screens and procedures to adopt will be shown in Item 6 - Troubleshooting, because the function that originated them.

### Self-diagnostic IHM

A The self-diagnostic function implemented on the BM-HMI allows detection and diagnosis of defects external to the equipment or even internal failures, allowing users to quickly identify and correct problems in the majority of cases.

```
Autod. IHM
0000
```

### Self-diagnostic MM

Indicates that an error in one of the MMs modules, indicated by the module number and the code of the corresponding error occurred.

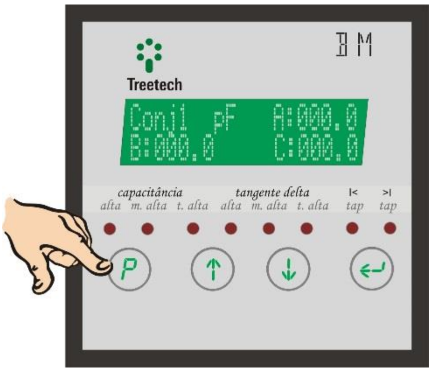
```
Autod. MM1: 0000
0000 0000
```

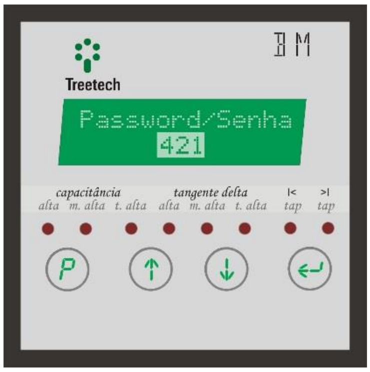
## 4.9 Parameters Menus

In order to ensure the correct operation of the system several parameters must be adjusted on the Interface Module BM-HMI, which will supply the equipment with the information needed for its operation. Adjustments can be carried out using the front keyboard, helped by the display, or through serial communication ports RS232 or RS485, available to users on the device's rear panel.

Programmable parameters are organized into different submenus, inserted into one main, password protected access menu. In each submenu, users will be able to access a set of parameters that will have to be set to meet the needs of each application and the characteristics of the transformer/condensive bushing.

In order to Access the programming menu for the Interface Module, follow the procedure below:



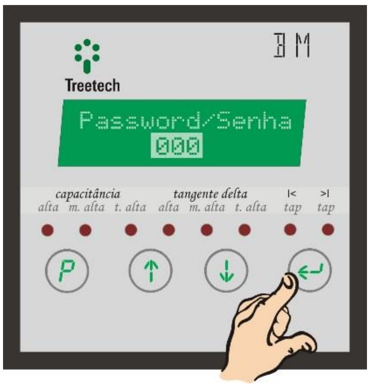

The initial number shown on this screen can be used to recover the password in case it is forgotten. Inform our Technical Assistance Number for decoding, in case of need.

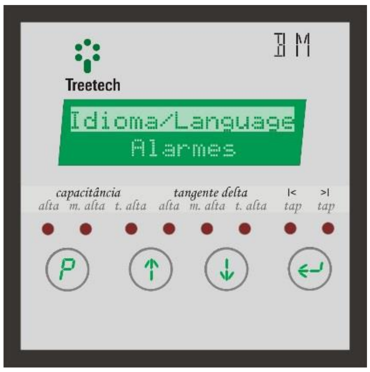
**1)** On any reading screen, press and hold for 5 seconds

**2)** The password Access screen will be displayed.

**3)** Use the and , keys to set the password for access to the main menu (set range = 0 to 999).

Factory setting for the password is 0 (zero). This value can be changed by the user (see menu configuration).




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

**5)** Submenus available are shown, two at a time. Use and to navigate among them. The submenu selected is shown in highlight (in the illustration above the submenu selected is "Idioma/Language"). Press to access the desired submenu.

There are five basic programming submenus and one for advanced configuration. In most applications, just basic programming will be enough for operating the Bushing Monitor:

- Idioma / Language;
- Alarms;
- I Leakage Alarms (Optional)
- Relay Configuration;
- Measurement Module;
- Set clock;
- Advanced configuration;
  - Configuration;
  - Measurement module;
  - Analog output;
  - Factory only;
  - Firmware Update.

The Factory Only submenu is for use only by the technical assistance service, and is blocked by exclusive manufacturer password.

The Firmware Update submenu is used for up-dating firmware for the BM, and it is password protected to avoid accidental access. Consult Treetech in case of need to up-date your BM's firmware.

## To access a Menu

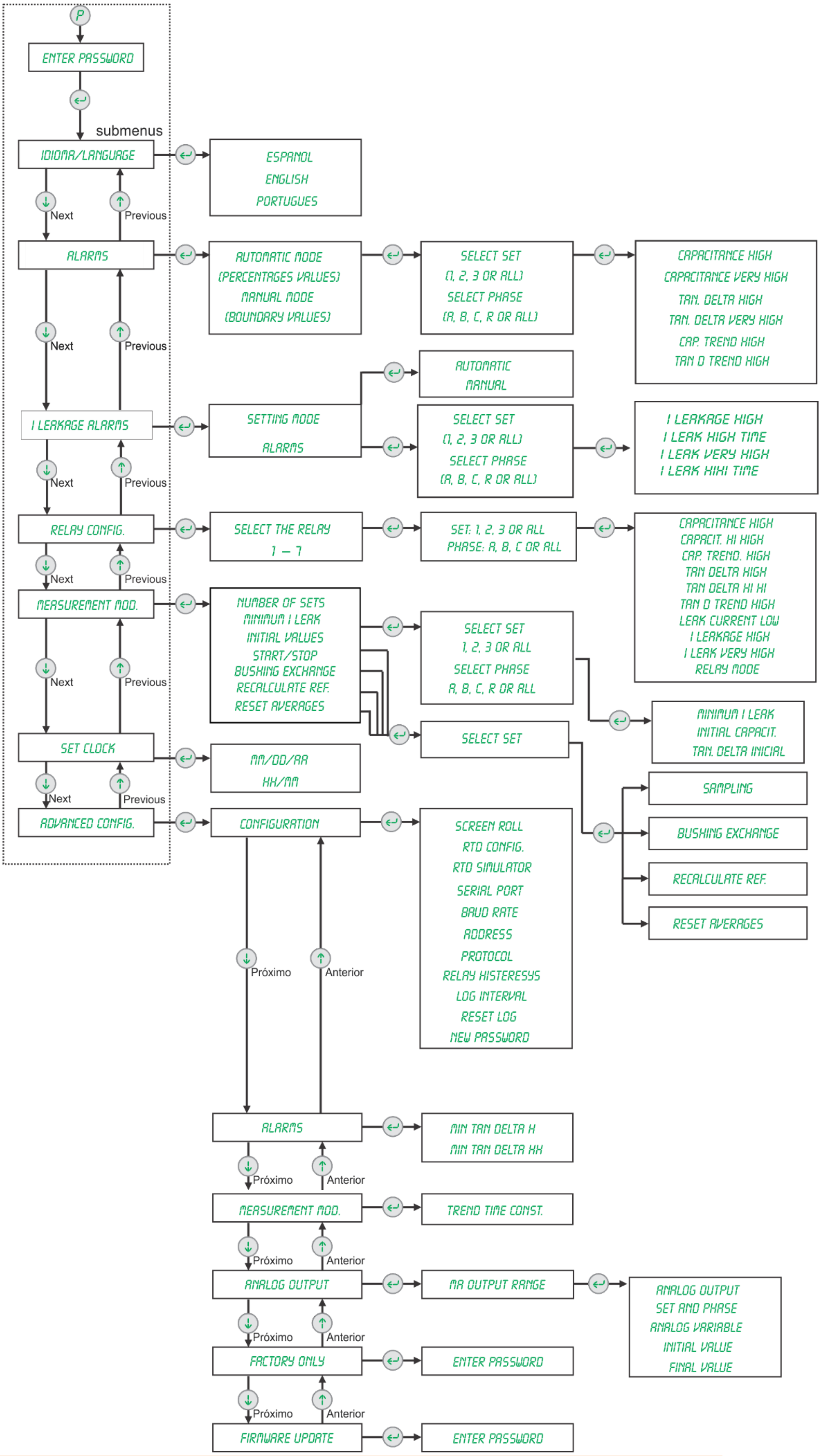
- Use ↵ to select a menu or parameter;
- Inside a menu, use ↓ and/or ↑ to navigate between parameters and/or adjust them after selected;
- To return to a previous parameter or leave the menu, use P;

Menus related to optional functions will only be displayed if the corresponding optional function is available.

## After accessing the desired submenu:

- Use ↑ and ↓ to navigate between submenu parameters;
- Press ↵ to select the parameter for adjusting /
- Use ↑ and ↓ to set the desired value for the parameter;
- Press ↵ to save change made to parameter;
- Press P to quit parameter without saving changes made or to return to the menu of the level immediately above

Below, details of submenus are given:



P
ENTER PASSWORD
submenus
IDIOMA/LANGUAGE
ESPAÑOL
ENGLISH
PORTUGUES
Next
Previous
ALARMS
AUTOMATIC MODE
(PERCENTAGES VALUES)
MANUAL MODE
(BOUNDARY VALUES)
SELECT SET
(1, 2, 3 OR ALL)
SELECT PHASE
(A, B, C, A OR ALL)
CAPACITANCE HIGH
CAPACITANCE VERY HIGH
TAN. DELTA HIGH
TAN. DELTA VERY HIGH
CAP. TREND HIGH
TAN D TREND HIGH
AUTOMATIC
MANUAL
I LEAKAGE ALARMS
SETTING MODE
ALARMS
SELECT SET
(1, 2, 3 OR ALL)
SELECT PHASE
(A, B, C, A OR ALL)
I LEAKAGE HIGH
I LEAK HIGH TIME
I LEAK VERY HIGH
I LEAK HIHI TIME
RELAY CONFIG.
SELECT THE RELAY
1 – 7
SET: 1, 2, 3 OR ALL
PHASE: A, B, C OR ALL
CAPACITANCE HIGH
CAPACIT. HI HIGH
CAP. TREND. HIGH
TAN DELTA HIGH
TAN DELTA HI HI
TAN D TREND HIGH
LEAK CURRENT LOW
I LEAKAGE HIGH
I LEAK VERY HIGH
RELAY MODE
MEASUREMENT MOD.
NUMBER OF SETS
MINIMUM I LEAK
INITIAL VALUES
START/STOP
BUSHING EXCHANGE
RECALCULATE REF.
RESET AVERAGES
SELECT SET
1, 2, 3 OR ALL
SELECT PHASE
A, B, C, A OR ALL
MINIMUM I LEAK
INITIAL CAPACIT.
TAN. DELTA INICIAL
SELECT SET
SET CLOCK
MM/DD/AA
HH/MM
SAMPLING
BUSHING EXCHANGE
RECALCULATE REF.
RESET AVERAGES
ADVANCED CONFIG.
CONFIGURATION
SCREEN ROLL
RTD CONFIG.
RTD SIMULATOR
SERIAL PORT
BAUD RATE
ADDRESS
PROTOCOL
RELAY HISTERESYS
LOG INTERVAL
RESET LOG
NEW PASSWORD
Próximo
Anterior
ALARMS
MIN TAN DELTA H
MIN TAN DELTA HH
MEASUREMENT MOD.
TREND TIME CONST.
ANALOG OUTPUT
MA OUTPUT RANGE
ANALOG OUTPUT
SET AND PHASE
ANALOG VARIABLE
INITIAL VALUE
FINAL VALUE
FACTORY ONLY
ENTER PASSWORD
FIRMWARE UPDATE
ENTER PASSWORD

### 4.9.1 Language Menu

Selection of interface language used by the device in displaying subtitles:


- Portugues;
- English;
- Espanol.

### 4.9.2 Alarms Menu

Gives access to Alarm submenu. This submenu contains the programming for the alarm issuance values (thresholds).

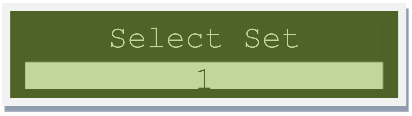
- With display showing submenu Alarms in highlight, press .


## Programming Modes:

**Set Range:**


**Automatic Mode (recommended):** Alarms are set as percentages of increase of capacitance and tangent delta in relation to their initial values. Before using the automatic mode, initial values must be set. **Manual Mode**: Programming mode used to inform boundary values in absolute values for capacitance (pF) and tangent delta (%).

After choosing the programming mode, each alarm is set by first selecting the bushings related to the alarms, which is done by selecting the bushing set and the phase of the bushing:





- Set

Select the set of bushings for which the alarm is being set.
Set range: set 1, 2, 3 or All.

- Phase

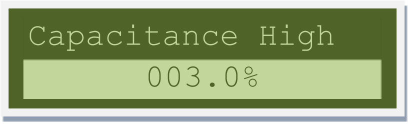
Select the phases of the set(s) selected to which the bushing for which the alarms are being set belong.
Set range: phase A, B, C or All.

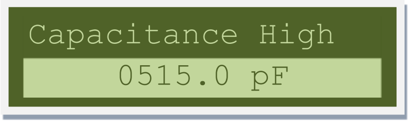
**Hint**

In order to make more agile setting alarm values, use programming in mode “Automatic”, selecting option “All” in choosing sets and phases. In this way, with only six alarm set definitions the 54 alarms for the bushings are set (9 bushings x 6 alarms = 54 alarms)..

## Parameters set:

### Capacitance High




Select values desired for issuance of alarm for high capacitance value.

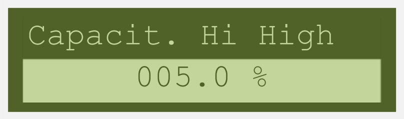
**Set Range:**

Automatic Mode: 00,0 – 20,0% of initial capacitance values

Manual Mode: 0000.0 – 3200.0 pF

**Default: 003.0 %**

### Capacitance Very High





Select values desired for issuance of alarm for very high capacitance value.

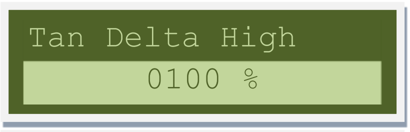
**Set Range:**

Automatic Mode: 00.0 – 20.0% of initial capacitance values

Manual Mode: 0000.0 – 3200.0 pF

**Default: 003.0 %**

### Tangent Delta High





Select values desired for issuance of alarm for high tangent delta.

**Set Range:**

Automatic Mode: 0 – 500% of initial tangent deltas

Manual Mode: 0.000 – 6.500% (tangent delta in %)

**Default: 0100 %**

**Hint**

Recommended values: twice the initial value (0100% - automatic, or 0.700% - manual) in absolute value, whichever is greater.

### Tangent Delta Very High



Select values desired for issuance of alarm for very high tangent delta.

**Set Range:**

Automatic Mode: 0 – 500% of initial tangent deltas

Manual Mode: 0.000 – 6.500% (tangent delta in %)

**Default: 0200 %**

**Hint**

Recommended values: three times the initial value (200% - automatic, or 1.050% - manual) in absolute value, whichever is greater.

### Capacitance Trend High


Set alarm for increasing trend in Capacitance, issued if the number of days required to reach high or very high capacitance values is inferior to value set here.

**Set Range:**

Automatic Mode / Manual: 0 – 365 days

**Default: 014 days**

### Tangent Delta Trend High

Set alarm for increasing trend in Tangent Delta, issued if the number of days required to reach high or very high tangent delta is inferior to value set here.
**Set Range:**
Automatic Mode / Manual: 1 – 365 days
**Default: 014 days**

### 4.9.3 I Leakage Alarms Menu

Gives access to Leakage Current Alarms submenu. This submenu contains the programming for the leakage current alarm issuance values (thresholds). This process involves patented mathematical and statistical structures.

With display showing submenu I Leakage Alarms in highlight, press .


**Programming Modes:**

Setting Mode

Automatic Mode (recommended)

Alarms are set as percentages (%) of increase of the typical leakage current, obtained during the BM learning process. All Sets and Phases are configured with the same percentages, choose by this parameter.

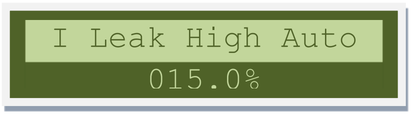


Manual Mode

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

I Leak High Auto (Used only by automatic mode)

Set the high alarm in percentage (%) of increase of the leakage current,
**Set Range:** 0.0 % – 200.0%
**Default: 15.0 %**




I Leak High Time

Adjust the delay of the alarm I Leak High Time (s).
**Set range:** 10 s – 1800 s
**Default: 60 s**


I Leak HiHi Auto (Used only by automatic mode)

Set the very high alarm in percentage (%) of increase of the leakage current,
**Set Range**: 0.0 % – 200.0%
**Default: 25,0%**


I Leak HiHi Time

Adjust the delay of the alarm I Leak High Time (s).
**Set range:** 10 s – 1800 s
**Default: 60 s**

### Alarms


In this submenu are possible do see the values calculated by automatic mode, change them or set newer values in manual mode.
The "I Leakage High Time" and "I Leakage HiHi Time" are used by both setting modes.
Each alarm is set by first selecting the bushings related to the alarms, which is done by selecting the bushing set and the phase of the bushing:

- **Set**


Select the set of bushings for which the alarm is being set.
**Set range:** set 1, 2, 3 or All.

- **Phase**

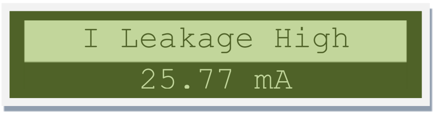

Select the phases of the set(s) selected to which the bushing for which the alarms are being set belong.
**Set range:** phase A, B, C or All.

**Hint**

In order to make more agile setting alarm values, use programming in mode "Automatic". If used the "manual" mode, you can choose the option "All" in choosing sets and phases. In this way, with only four alarms set definitions the 36 alarms for the bushings are set (9 bushings x 4 alarms = 36 alarms)..

### Parameters set:

#### I Leakage High (Used only by manual mode)




Set the high alarm in direct value (mA) of the leakage current,
**Set Range:** 0.01 mA – 99.99 mA
**Default: 80.00 mA**

#### I Leakage High Time


Set the high alarm time delay in seconds (s).
**Set Range:** 10 s – 1800 s
**Default: 60 s**

#### I Leakage Very High (Used only by manual mode)


Set the very high alarm in direct value (mA) of the leakage current,
**Set Range:** 0.01 mA – 99.99 mA
**Default: 90.00 mA**

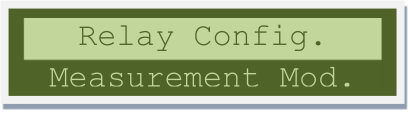
#### I Leakage HiHi Time


Set the very high alarm time delay in seconds (s).
**Set Range:** 10 s – 1800 s
**Default: 60 s**

## 4.9.4 Relay Configuration Menu

Gives access to relay programming submenu. In this submenu, we will find the setup for the desired sets and phases, as well as alarm and operation mode for each relay.

- With display showing submenu Relay Config. in highlight, press



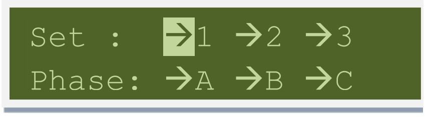

## Parameters set:

### Select Relay


The relay to be programmed must be selected.
Set Range: 1 – 7
Each relay can issue alarms for the three measurement sets as well as the three phases monitored.

**Set:** Select set of bushings for indication of alarm on relay.

**Phase:** Selection of phases for indication of alarm on relay.




Use to move forward in selecting sets and phases.
Use and to select or cancel the selection of each set or phase.
The signal → indicates the sets and phases selected.
Each relay can be actuated by one or several types of alarms, selecting "YES" or "NO" for each of the following parameters:

- Capacitance High
- Capacitance Very High
- Capacitance Trend High
- Tangent Delta High
- Tangent Delta Very High
- Tangent Delta Trend High
- Leakage Current Low
- Leakage Current High
- Leakage Current Very High


**Set Range:** YES, NO

### Operation mode


Select relay operation logic, Normal Open or Normal Closed, regardless of the relay's physical configuration.
Set Range: Normally Open / Normally Closed

## 4.9.5 Measurement Module Menu

Gives access to configuration submenu for measurement modules.

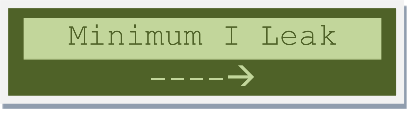
- With display showing submenu Measurement Module in highlight, press .


## Parameters set:

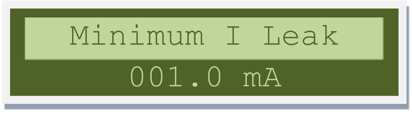

### Number of Sets

Select the number of three-phase bushing sets being monitored. Reflects the number of Measurement Modules connected to the Interface Module.
**Set Range:** 1 – 3

## Minimum Leakage Current




Minimum value for leakage current, below which there will be an alarm for Low Leakage Current. The alarm for Low Leakage Current can be an indication of opening in cables or current measurement circuit, and must be immediately checked. The BM does not issue this alarm if all three phases present low leakage current simultaneously, for considering that this is due to de-energizing of the equipment (transformer, reactor, etc.).
Set Range: 0 to 100mA.


- Select Sets: Selects the bushing set for which initial values are being adjusted.

**Set Range:** set 1, 2, 3 or All

## Initial Values

This menu contains programming for initial values of capacitance and tangent delta for each bushing monitored, obtained from the bushing's id plate (for new bushings) or through off-line readings taken when installing the monitoring system.
Initial values are programmed by first selecting the bushing related to the adjustments, which is done by selecting the bushing set and then the phase of the bushing:


- Select Set: set to which the bushing, for which the initial values are being set, belongs.


**Set Range:** set 1, 2, 3 or All

- Select Phase: phase of the set selected above to which the bushing, for which the initial values are being set, belongs.


**Set Range:** phase A, B, C, R (back up) or All

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

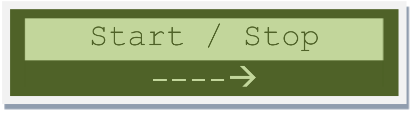

**Set Range:** 50 to 3000 pF

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


**Set Range:** 0.010 to 3.000 %

**Important**
Changes made to parameters for initial values are only valid if the BM is still in its initial reference acquisition phase. Changes made after this period will only be effective when the option YES has been selected in the menu Recalculate Reference.

## Start / Stop




Allows bushing monitoring to be started or stopped for each of the three-phase sets being monitored for eventual testing or maintenance operations. First, the desired set must be selected:


- Select Set: set that we wish to start or stop monitoring.

**Set Range:** set 1, 2, 3 or All


- Sampling: selection of operation state for the set selected.

**Set Range:** Running, Stopped

## Bushing Exchange

This menu allows parameters to be changed for bushings in operation, allowing these to be changed for the parameters of the backup bushing without losing the parameters of the bushings temporarily removed from monitoring, in any of the following situations:
Entrance in operation of back up unit;
Exit from operation of back up unit for return of regular unit;
Replacement of any bushing being monitored by a new one.
This feature is particularly useful in applications with single-phase equipment banks, once the data for a backup unit can be pre-programmed on the BM, and when it enters or leaves operation, merely inform this condition on the Bushing Exchange menu.
First select the desired three-phase set.


- Select Set: set to which the bushing that is going to be changed belongs.

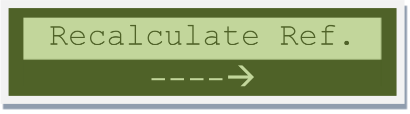

**Set Range:** set 1, 2, 3 or All

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


**Set Range:**
ABC (bushings A, B and C in operation, Back Up not),
ABR (bushings A, B and Back Up in operation, C not),
ARC (bushings A, Back Up and C in operation, B not), or
RBC (bushings Back Up, B and C in operation, A not).

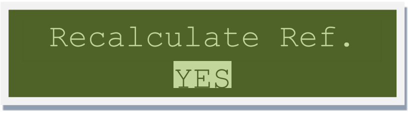
Whenever there is a change of bushing, the bushing monitor will automatically move to parameter Recalculate Reference. The exchange of bushings will only be confirmed, is option YES is chosen in this parameter.

### Recalculate Reference




This menu allows a new initial reference to be calculated, when there is a change of bushings, or to carry out a new definition of parameters for the initial capacitance and tangent delta values. To this end, first select the desired three-phase set.


Select Set: The set where acquisition of initial reference will be performed.
**Set Range:** set 1, 2, 3 or All




Recalculate Reference: confirmation.
**Set Range:** YES, NO.

### Reset Averages


Through this menu you can reset the calculation of averages, for instance due to some fault that has caused acquisition of incorrect measurements, so the BM is reset to the data obtained in its learning period. To perform this command, first select the set of bushings you want to reset.


Select Set: bushing set that will be reset to the learning phase.
**Set Range:** 1, 2, 3 or All


Reset Averages: Confirmation
**Set Range:** YES, NO

## 4.9.6 Set Clock Menu

### Set Clock:

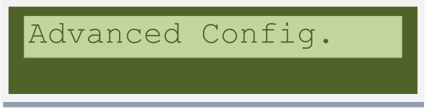
Use and to set the value indicated in highlight, and press to navigate between the fields for day, month, year, hour and minute. Once the desired values have been set, press to return to main menu. At this point in time, the clock will be re-started with seconds beginning in zero.


When the day, month and year are set, the device automatically sets the day of the week.
Date format changes according to the interface language selected:

- Portuguese and Spanish: *DD/MM/YY,*
- English: *MM/DD/YY.*

### 4.9.7 Advanced Configuration Menu

Sets the advanced configuration settings for the Bushing Monitor.




With display showing submenu **Advanced Configuration** in highlight, press .

#### 4.9.7.1 Configuration

Select using and enter General Configuration or Serial Communication Configuration and press the option *Configuration*.

## Screen Roll

Allows choice of form of display for the BM's information screens. When enabled (option YES), the BM will display screens sequentially reading and calendar / clock screens, at intervals of approximately 15 seconds between screens.
**Set Range:** YES, NO.


## RTD Configuration

Selection of connection option for temperature sensor(s) type Pt100Ω at 0ºC.

Note: When the option selected is "Only RTD B", check for jumper as shown in wiring diagram of Figure 13.


**Set Range:**

- ✓ A e B OFF
- ✓ RTD A Only
- ✓ RTD B Only
- ✓ A e B ON

## RTD Simulator

Used to check Pt100 inputs using an electronic RTD Simulator.
With the system in regular operation, this parameter must be selected to "OFF". Every time the device is switched OFF and the ON again, this parameter assumes position "OFF".
**Set Range:** ON or OFF.


## Serial Port

Selection of serial port used in parameter definition and remote data acquisition.
**Set Range:** RS232 or RS485


## Baud Rate

Baud rate for serial communication ports.
Set Range:

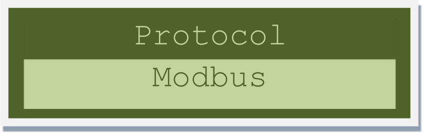
- ✓ 38400 bps
- ✓ 19200 bps

- ✓ 9600 bps

## Address


Address of BM at RS232 and RS485 serial communication ports.
**Set Range:** 1 to 31, in steps of 1.

## Protocol




Here you select the default protocol used for communication with the data acquisition system or parameterization. In the BM, the standard protocol is Modbus RTU. Optional 1 If available, the DNP 3.0 communication protocol will be another option in this item.

## Relay Hysteresis


Determines a value, in percentage of alarm set point, to be used as hysteresis for return to normal status of alarm relays, in order to keep alarm relay from opening and closing repeatedly due to small fluctuations in readings. For example: if High Tangent Delta alarm is actuated at 0.70% and High Capacitance at 300pF and the hysteresis is set in 1%, alarm relays will only return to the normal state when readings for tangent delta and capacitance return to values below 0.693% and 297pF, respectively.
**Set Range:** 0.0 – 20.0 %

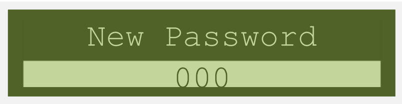
## Log Interval


Time interval for recording readings on mass memory (recordings are also made for any alarm events).
**Set Range:** 1 – 720 h

## Reset Log


Allows mass memory to be re-initialized, erasing all the data stored. User confirmation will be requested before this procedure is carried out.

## New Password




Programming new menu access control password for the BM. Factory set password is “000”.
**Set Range:** 0 to 999 in increments of 1.

**Important**

Observation: The initial number displayed in the password field when accessing the programming menu can be used to recover the password in case it is forgotten. Inform this number to our Technical Assistance Department for decoding..

### 4.9.7.2 Alarms

#### Minimum Tan. Delta High

Minimum value for high tangent delta alarm threshold when alarms are programmed in Automatic mode, so as to avoid very low alarm settings when tan delta initial values are low, thus avoiding unnecessary alarms due to normal variations. Recommended value 0.700 %, based on IEC60137.

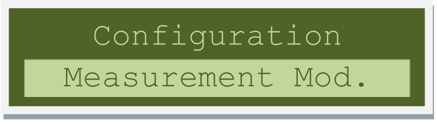

#### Minimum Tan. Delta Very High

Minimum value for very high tangent delta alarm threshold when alarms are programmed in Automatic mode. Suggested value 1.050 %, so as to keep consistency and proportionality with parameter “Tan Delta H Min” (see above).


### 4.9.7.3 Measurement Module

Sets advanced configuration parameters for the BM’s measurement module.

- With display showing submenu Measurement Module in highlight, press .




## Parameters set:

#### Trend Time Constant

Time constant for the first order digital filter used in calculating the evolution trend for capacitance and tangent delta. This filter prevents temporary variations from causing high trend calculations, leading to undue alarms.

**Set Range:** 0 – 30 days


### 4.9.7.4 Analog Output

This menu contains the general configuration parameters for the analog outputs of the BM bushing monitoring system.

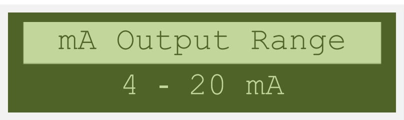
With display showing submenu Analog Output in highlight, press .


## Parameters Set:

#### mA Output Range

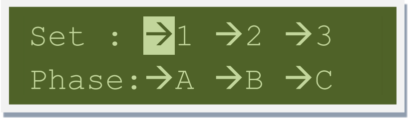
Selection of current range to be used by the current loop outputs for remote readings

**Set Range:** 0 – 1 mA
0 – 5 mA
0 – 10 mA
0 – 20 mA
4 – 20 mA



### Analog Output


Selection of Analog Output for which parameter is being set.
**Set Range:** 1 or 2
Each output can deliver values from several measurement sets as well as of several phases monitored.

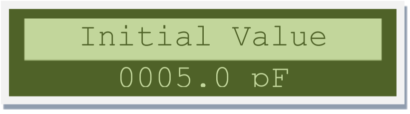



Set: Selection of bushing sets to be informed via the analog output.
Phase: Selection of phases to be informed via analog output
Use to move forward in selecting sets and phases.
Use and to select or cancel selection for each set and phase.
The signal → indicates the sets and phases that have been selected.

### Analog Variable


Selection of analog variable to be indicated by the output selected.
**Set Range:** Tan (tangent delta) or Cap (capacitance).

### Initial Value

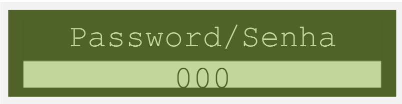



Selection of capacitance value, in pF, or tangent delta, in %, corresponding to the beginning of the scale for the analog output selected for remote reading.
**Set Range:** 0.00 – 6.50 % (if tangent delta is selected) or
0 – 3200 pF (if capacitance is selected)

### Final Value


Selection of capacitance value, in pF, or tangent delta, in %, corresponding to end of scale for the analog output selected for remote reading.
**Set Range:** 0.00 – 6.50 % (if tangent delta is selected) or
0 – 3200 pF (if capacitance is selected)

## 4.9.7.5 Factory Only

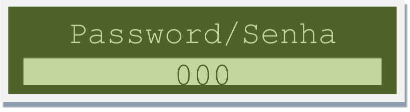

This menu is for use exclusively by plant and technical assistance staff.
With display showing submenu Factory Only in highlight, press .
The factory password will be requested.
This menu is for use exclusively by Treetech technical assistance staff, and is not available to users of the equipment.

## 4.9.7.6 Firmware Update

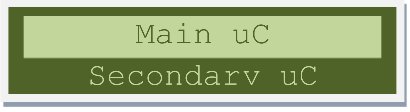
Gives access to functionality for up-dating firmware (resident software in micro-controllers of the BM) through serial communication ports.


With display showing submenu Firmware Update in highlight, press .
When this submenu is selected, the access password will be requested again, the same one used to access the main menu.

Confirmation by password targets avoiding accidental access of this menu.




Once confirmed the password, a submenu with the options “Main uC” and “Secondary uC” will be displayed, for selection of the micro-controller (uC) that will receive the new firmware. After selecting the micro-controller, the BM paralyzes the execution of its normal program and remains waiting for transmission of the new firmware by the PC connected to the serial port RS232. If the option selected is “Main uC”, the message “Ready to receive new firmware” will remain fixed on the display. If the option selected is “Secondary uC”, the message displayed will be “Uploading”. For transmission of the new firmware, specific software supplied by Treetech must be used.




If you want to quit this process before beginning transmission of the firmware, the BM must be restarted (switched off and then on again).

# 5 Start up procedure

- Once the equipment has been installed in accordance with Part III of this manual, beginning of operations must follow the basic steps described below:

- At onset of operations of the bushing monitor BM, it will be necessary to define and set equipment parameters to current values for bushing capacitance and tangent delta. For bushings already in service, these parameters must be measured using conventional methods (off-line), with de-energized bushings;

- Check mechanical installation of the Measurement Adapters, in compliance with chapter 6.1.1, making sure that it will be impossible for water to penetrate the taps on the bushings.

- Check that electrical wiring schemes are correct in compliance with chapter 6.2 (for example, by way of continuity tests), ensuring that bushing taps are not open and that leakage currents will flow to ground through the measurement module;

- If dielectric rigidity test are to be performed on the wiring (applied voltage), disconnect grounding cables connected to terminal 17 of the Interface Module and to Terminal 1 of the Measurement Module and disconnect the plug for the Tap Adapter, maintaining the casing insulated from any grounded parts, in order to avoid damaging the overvoltage protection systems found inside the equipment. These protections are connected internally between the input/output terminals and ground, stapling the voltage at values below 350V. Application of high tensions for long periods (for example 2kV for 1 minute) would destroy these protections.

- Make sure that the intermediate bushing measurement blocks are not short-circuited (see sub-chapter 6.2.1);

- Energize Measurement Modules BM-MM with voltage of 38 ~ 265Vdc/Vac;

- With an ohm-meter, check continuity of the three current input circuits of the Measurement Modules, by measuring their resistance. The readings will vary continually, due to the internal measurement process, within the range given in the table below:

**Table 10 -- Measurement modules range**

| Readings between terminals: | Expected variation: |
|---|---|
| 7 and 10 (of the measurement module) | 10 to 2200 ohms |
| 8 and10 (of the measurement module) | 10 to 2200 ohms |
| 9 and 10 (of the measurement module) | 10 to 2200 ohms |

- Energize the Interface Module BM-HMI with input voltage of 38 ~ 265Vdc/Vac;
- Perform settings for the Measurement Module(s), in accordance with the instructions given on sub-chapter 0;
- Perform parameter definition and setting for the Interface Module, in accordance with the instructions given on sub-chapter 4.9.7.1. Parameter definition used can be noted on the form given in the next pages;
- Consult readings obtained for leakage currents of the bushings for phases A, B and C of each set being monitored, as described in sub-chapter 0. Make sure the readings obtained are coherent with the approximate theoretical value obtained by applying the formula:
- Leakage Current = 6.28 . (Frequency) . (Phase-ground voltage) . (Capacitance C1)
- Check serial communication between the Interface Module and the data capture system, if applicable.

- Check that analog outputs and programmable output contacts are working properly, when they are used.

# 6 Trouble shooting

If difficulties or problems are found in operating the system, we suggest consulting the possible causes and simple solutions presented in this unit. If this information is not enough to solve the difficulty, please contact Treetech's technical assistance or its authorized representative.

## 6.1 The BM-HMI displays self-diagnostic messages on its display

Upon detecting a problem, the BM-HMI with actuate its self-diagnostic contact and display an Error screen, showing the code relative to the failure underway, as shown in illustration 8.1. The meaning of failure codes is shown on the following tables, respected the digit of the display where the code is exhibited. In the event of simultaneous failures, the number displayed by a given digit will be the sum of the individual Errors.

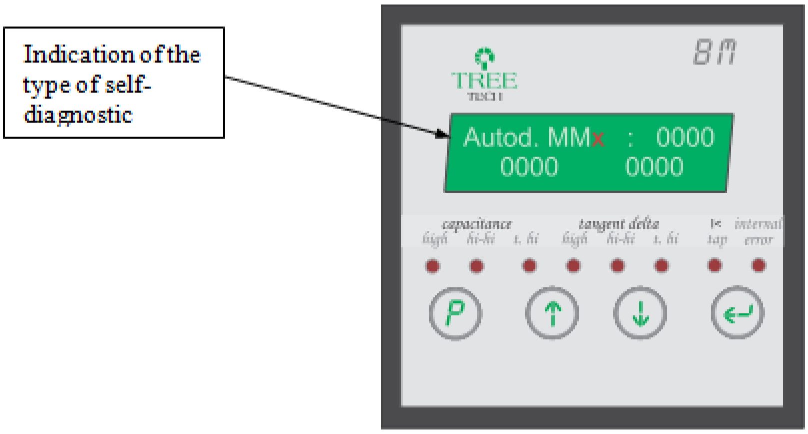
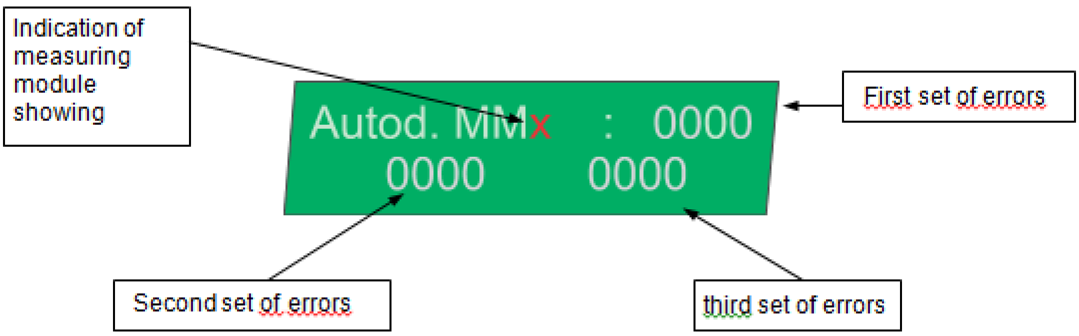



**Figure 23 - Self-diagnostic indication screen**



Autod. IHM:
0000

**Figure 24 - Detailing of Self-diagnostic codes MM/IHM**

The meanings of fault codes are shown in the following table, respecting the digit of the display in which the code appears. The indicator system of codes are in hexadecimal encoding, in which 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}. If simultaneous failures occur, the indicated number in a given digit will be the sum of the individual errors and is thus indicated by the additional set C = {3,5,6,7,9, A, B, C, D, E, F}. Below is a table with the possible combinations of errors in each digit.

**Table 11 Table of possible assets errors combination**

| | | |
|---|---|---|
| 0 → None Diagnostics assets | 6 → Diagnostics 2 + 4 assets | C → Diagnostics 4 + 8 assets |
| 1 → Diagnostics 1 asset | 7 → Diagnostics 1 + 2 + 4 assets | D → Diagnostics 1 + 4 + 8 assets |
| 2 → Diagnostics 2 asset | 8 → Diagnostics 8 asset | E → Diagnostics 2 + 4 + 8 assets |
| 3 → Diagnostics 1 + 2 assets | 9 → Diagnostics 1 + 8 assets | F → Diagnostics 1 + 2 + 4 + 8 assets |
| 4 → Diagnostics 4 asset | A → Diagnostics 2 + 8 assets | |
| 5 → Diagnostics 1 + 4 assets | B → Diagnostics 1 + 2 + 8 assets | |

## 6.2 Self-diagnostic codes for the BM-HMI Interface

**Table 12 - Self-diagnostic codes for the BM-HMI Interface**

| Autodiag. IHM 0000 | | ***BM-HMI Interface*** | |
|---|---|---|---|
| ***Code*** | ***Description*** | ***Probable causes*** | ***Actions recommended*** |
| ***0000*** | *No failure* | - | - |
| ***0001*** | *RTD Measurement Overflow* | *Internal Failure* | *- Reset the BM-HMI by removing and reconnecting the power supply*<br>*-If the action above doesn't clear the diagnostic indication or it happens again after a while, contact Treetech Technical Assistance.* |
| ***0002*** | *Internal Error – Memory EEPROM* | *Internal Failure* | *- Reset the BM-HMI by removing and reconnecting the power supply*<br>*-If the action above doesn't clear the diagnostic indication or it happens again after a while, contact Treetech Technical Assistance.* |
| ***0004*** | *Communication Error between micro-controllers.* | *Internal Failure* | *- Reset the BM-HMI by removing and reconnecting the power supply*<br>*-If the action above doesn't clear the diagnostic indication or it happens again after a while, contact Treetech Technical Assistance.* |
| ***0010*** | *Communication Error with* | *Bad contact in communication cables* | *- Check for existence of bad contact or inversion in cables connected to terminals* |

| | | | |
|---|---|---|---|
| | *Measurement Module 1.* | *between interface module and measurement module.* | *20 and 21 of BM-HMI and terminals 4 and 5 of BM-MM 1.* |
| | | *Use of inadequate cables for communication connection.* | *- Use shielded, twisted-pair cable for connection between BMs, see figure 12.* |
| ***0020*** | *Communication Error with Measurement module 2.* | *Bad contact in communication cables between interface module and measurement module.* | *- Check for existence of bad contact or inversion in cables connected to terminals 20 and 21 of BM-HMI and terminals 4 and 5 of BM-MM 2.* |
| | | *Use of inadequate cables for communication connection.* | *- Use shielded, twisted-pair cable for connection between BMs, see figure 12.* |
| | | *Measurement set 2 is enabled, but not in use.* | *- Disable this measurement module in parameter Number of sets, sub-chapter 4.9.7.1.* |
| ***0040*** | *Communication Error with Measurement module 3.* | *Bad contact in communication cables between interface and measurement modules.* | *- Check for existence of bad contact or inversion in cables connected to terminals 20 and 21 of BM-HMI and terminals 4 and 5 of BM-MM 3.* |
| | | *Use of inadequate cables for communication connection.* | *- Use shielded, twisted-pair cable for connection between BMs.* |
| | | *Measurement set 3 is enabled, but not in use.* | *- Disable this measurement module in parameter set number.* |
| ***0080*** | *Failure in temperature reading – sudden change, more than 5°C, between two consecutive temperature readings.* | *Bad contact or disconnection in cables connected to interface module. See Figure 13.* | *Check for existence of bad contact along the entire path of the cable connected to interface module, BM-HMI, including connection to sensor and passage terminals.* |
| | | *Use of unshielded cables in the connection of sensors to BM-HMI.* | *Check if three-way, shielded cable is being used in connecting RTD sensors to interface module, BM-HMI.* |
| | | *Shielding of connection cables from BM-HMI to sensors not grounded or grounded in more than point.* | *Check that shielding of connection cables from BM-HMI to RTD sensors are grounded only on one end of the connection and the other end insulated, as shown in Figure 14.* |
| | | *After checking and correcting the cause for the failure in the reading, reset the Error by pressing and holding P and ↑ for about 2 seconds. ATTENTION: when this reset is carried out, you will be informing the BM that the current temperature reading is correct.* | |
| ***0100*** | *Failure in reading from RTD A.* | *Bad contact on cable connected to terminal 28 of the interface module. See Figure 13.* | *Check for existence of bad contact along the entire path of the cable connected to terminal 28 of the interface module, BM-HMI, including connection to sensor and passage terminals.* |
| | | *Failure of temperature sensor RTD A.* | *Replace defective sensor Pt100.* |
| ***0200*** | *Failure in reading from RTD B.* | *Bad contact on cable connected to terminal 29 of the interface module. See Figure 13.* | *Check for existence of bad contact along the entire path of the cable connected to terminal 29 of the interface module, BM-HMI, including connection to sensor and passage terminals.* |

| | | | |
|---|---|---|---|
| | | *Failure of temperature sensor RTD B.* | *Replace defective sensor Pt100.* |
| ***0400*** | *Failure in reading from RTD A.* | *Bad contact on cable connected to terminal 26 and/or 27 of the interface module. See Figure 13.* | *Check for existence of bad contact along the entire path of the cable connected to terminal 26 and/or 27 of the interface module, BM-HMI, including connection to sensor and passage terminals.* |
| | | *Failure of temperature sensor RTD A.* | *Replace defective sensor Pt100.* |
| | | *RTD A is not in use, but is enabled.* | *Disable reading for this sensor in parameter RTD Configuration, sub-chapter 4.9.7.1.* |
| ***0800*** | *Failure in reading from RTD B.* | *Bad contact on cable connected to terminal 26 and/or 30 of the interface module. See Figure 13.* | *Check for existence of bad contact along the entire path of the cable connected to terminal 26 and/or 30 of the interface module, BM-HMI, including connection to sensor and passage terminals.* |
| | | *Problem with jumper between terminals 26 and 27 of the interface module.* | *Check for bad contact or absence of jumper between terminals 26 and 27 of the interface module, when option only RTD B has been selected.* |
| | | *Failure of temperature sensor RTD B.* | *Replace defective sensor Pt100.* |
| | | *RTD B is not in use, but is enabled.* | *Disable reading for this sensor in parameter RTD Configuration, sub-chapter 4.9.7.1.* |

## 6.3 Module diagnostic codes for Measurement Modules BM-MM

**Table 13 - Indications Grouping 1**

| Autod. MMx: 0000<br>0000 0000 | | ***Measurement Module 1, 2 or 3 (Grouping 1)*** | |
|---|---|---|---|
| ***Code*** | ***Description*** | ***Probable causes*** | ***Actions recommended*** |
| ***0000*** | *No failure* | *-* | *-* |
| ***0001*** | *Leakage current A measurement failure* | *See diagnostic details indicated at parts 2 and 3 of self-diagnostic code* | *See diagnostic details indicated at parts 2 and 3 of self-diagnostic code* |
| ***0002*** | *Leakage current B measurement failure* | *See diagnostic details indicated at parts 2 and 3 of self-diagnostic code* | *See diagnostic details indicated at parts 2 and 3 of self-diagnostic code* |
| ***0004*** | *Leakage current C measurement failure* | *See diagnostic details indicated at parts 2 and 3 of self-diagnostic code* | *See diagnostic details indicated at parts 2 and 3 of self-diagnostic code* |
| ***0008*** | *Sum current measurement failure (Is > 2mA)* | *See diagnostic details indicated at parts 2 and 3 of self-diagnostic code* | *See diagnostic details indicated at parts 2 and 3 of self-diagnostic code* |
| ***0010*** | *Period out of bounds* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| ***0020*** | *Difference between the Channels period* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |

| | | | |
|---|---|---|---|
| **0040** | *Current close to ADC saturation* | *Current close to ADC saturation* | *Contact Treetech Technical Assistance.* |
| **0080** | *Offset beyond the limits* | *Internal failure.* | *Replace defective BM and Contact Treetech Technical Assistance.* |
| **0100** | *Combination of several measurement errors* | *Internal failure.* | *Contact Treetech Technical Assistance.* |
| **0200** | *Difference between the channels of self-calibration* | *Internal failure.* | *- Reset the BM-HMI by removing and reconnecting the power supply<br>-If the action above doesn't clear the diagnostic indication or it happens again after a while, contact Treetech Technical Assistance.* |
| **0400** | *Reference voltage out of bounds* | *Internal failure.* | *- Reset the BM-HMI by removing and reconnecting the power supply<br>-If the action above doesn't clear the diagnostic indication or it happens again after a while, contact Treetech Technical Assistance.* |
| **0800** | *Phase sequence error* | *Bushings connected to the measuring module does not correspond to phases A, B and C of the same tri-phase set* | *Check the connecting cables between BM-MM and tap adapter. Each module must be connected to each of the TAPs of the three-phase set of bushings.* |
| **1000** | *Overflow error* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| **2000** | *Internal access error to the memory E2P* | *Internal failure.* | *- Reset the BM-HMI by removing and reconnecting the power supply<br>-If the action above doesn't clear the diagnostic indication or it happens again after a while, contact Treetech Technical Assistance.* |
| **4000** | *Access to external RAM* | *Internal failure.* | *- Reset the BM-HMI by removing and reconnecting the power supply<br>-If the action above doesn't clear the diagnostic indication or it happens again after a while, contact Treetech Technical Assistance.* |
| **8000** | *Less than 99% of the measurement samples are good or failure in the external E2P memory.* | *Internal failure.* | *- Reset the BM-HMI by removing and reconnecting the power supply<br>-If the action above doesn't clear the diagnostic indication or it happens again after a while, contact Treetech Technical Assistance.* |

**Table 14 - Indications Grouping 2**

```
Autod. MMx: 0000
  0000 0000
```

### 6.3.1 Measurement Module 1, 2 or 3 (Grouping 2)

| ***Code*** | ***Description*** | ***Probable causes*** | ***Actions recommended*** |
|---|---|---|---|
| **0001** | | *Internal or external failure* | *Contact Treetech Technical Assistance.* |

| | | | |
|---|---|---|---|
| | *Period of channel 0 out of bounds* | | |
| ***0002*** | *Difference between Channel 0 period greater than the limits* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| ***0004*** | *Current of the channel 0 close to ADC saturation* | *Current of the channel 0 close to ADC saturation* | *Contact Treetech Technical Assistance.* |
| ***0008*** | *Offset from channel 0 beyond the limits* | *Internal failure.* | *Replace defective BM and Contact Treetech Technical Assistance.* |
| ***0010*** | *Period of channel 1 out of bounds* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| ***0020*** | *Difference between Channel 1 period greater than the limits* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| ***0040*** | *Current of the channel 1 close to ADC saturation* | *Current of the channel 1 close to ADC saturation* | *Contact Treetech Technical Assistance.* |
| ***0080*** | *Offset from channel 1 beyond the limits* | *Internal failure.* | *Replace defective BM and Contact Treetech Technical Assistance.* |
| ***0100*** | *Period of channel 2 out of bounds* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| ***0200*** | *Difference between Channel 2 period greater than the limits* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| ***0400*** | *Current of the channel 2 close to ADC saturation* | *Current of the channel 2 close to ADC saturation* | *Contact Treetech Technical Assistance.* |
| ***0800*** | *Offset from channel 2 beyond the limits* | *Internal failure.* | *Replace defective BM and Contact Treetech Technical Assistance.* |
| ***1000*** | *Period of channel 3 out of bounds* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |

| | | | |
|---|---|---|---|
| **2000** | *Difference between Channel 3 period greater than the limits* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| **4000** | *Channel 3 current close to ADC saturation* | *Current of the channel 3 close to ADC saturation* | *Contact Treetech Technical Assistance.* |
| **8000** | *Offset from channel 3 beyond the limits* | *Internal failure.* | *Replace defective BM and Contact Treetech Technical Assistance.* |

**Table 15 - Indications Grouping 3**

```
Autod. MMx: 0000
0000 0000
```

### 6.3.2 Measurement Module 1, 2 or 3 (Grouping 3)

| Code shown | Description | Probable causes | Actions recommended |
|---|---|---|---|
| **0000** | *No failure* | - | - |
| **0001** | *Period of channel 4 out of bounds* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| **0002** | *Difference between Channel 4 period greater than the limits* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| **0004** | *Current of the channel 4 close to ADC saturation* | *Current of the channel 4 close to ADC saturation* | *Contact Treetech Technical Assistance.* |
| **0008** | *Offset from channel 4 beyond the limits* | *Internal failure.* | *Replace defective BM and Contact Treetech Technical Assistance.* |
| **0010** | *Period of channel 5 out of bounds* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| **0020** | *Difference between Channel 5 period greater than the limits* | *Internal or external failure* | *Contact Treetech Technical Assistance.* |
| **0040** | *Current of the channel 5 close to ADC saturation* | *Current of the channel 5 close to ADC saturation.* | *Contact Treetech Technical Assistance.* |
| **0080** | *Offset from channel 5* | *Internal failure.* | *Replace defective BM and Contact Treetech Technical Assistance.* |

| | | | |
|---|---|---|---|
| Check | *beyond the limits* | | |

## 6.4 Problems with no indication in self-diagnosis:

If you encounter difficulties or problems in the operation of the BM, we suggest consulting the possible causes and solutions listed below. If this information is not sufficient to remedy the trouble, please contact technical support Treetech or his authorized representative

**Table 16 - BM does not read or reads incorrect values for capacitances or tangent delta of bushings:**

| ***Probable Causes*** | ***Actions recommended*** |
|---|---|
| *Check parameter definition for measurement modules and interface module.* | *Check addresses of measurement modules;*<br>*Check programming for the following parameters on submenu Measurement Module (4.9.7.3):*<br>*Number of Sets;*<br>*Initial Values (Capacitance. / Tan. Delta);*<br>*Start / Stop (Sampling).* |
| *Bad contact, disconnection or inversion in one of the connection cables between the Measurement Module and Bushing Adapters.* | *Check for bad contact points, disconnections or inversions in the entire path of cables connected to terminals 7, 8, 9 and/or 10 of the Measurement Module, including connection to Bushing Adapters and to passage terminals. See Figure 12.* |
| *Use of unshielded cable, ungrounded or incorrectly grounded shielding in connection between Bushing Adapters and Measurement module.* | *Use shielded cable, connected according to recommendations of sub-chapter 3.3.* |
| *Bad contact, disconnection or inversion in connection cables between Measurement Module and Interface Module.* | *Check for bad contact points, or inversions in cables connected to terminals 20 and 21 of BM-HMI and terminals 4 and 5 of BM-MM.* |
| *Use of unshielded cable, ungrounded or incorrectly grounded shielding in connection between Measurement module and Interface Module.* | *Use shielded cable, connected according to recommendations of sub-chapter 3.3* |
| *Failure of Measurement module* | *Replace defective Measurement Module and Contact Treetech Technical Assistance.* |

**Table 17 - BM does not read or reads incorrect values for temperatures of RTDs:**

| ***Probable Causes*** | ***Actions recommended*** |
|---|---|
| *Measuring function of RTD sensor(s) is not enabled in parameter Configuration RTD.* | *Enable temperature measurement function of sensor(s) in parameter RTD Configuration, 4.9.7.1.* |
| *Poor contact point in one of the cables connected to measurement terminals of the RTDs in Interface Module.* | *Check for bad contact points along the entire path of cables connected to terminals of interface module, to passage terminals and to RTD sensor. See Figure 13.* |
| *Use of unshielded cable, ungrounded or incorrectly grounded shielding in connection between sensor and Interface Module.* | *Use shielded cable, connected according to recommendations of sub-chapter 3.3 and Figure 13.* |
| *Failure of interface module* | *Replace defective Interface Module and Contact Treetech Technical Assistance.* |

**Table 18 - BM does not communicate with data acquisition system::**

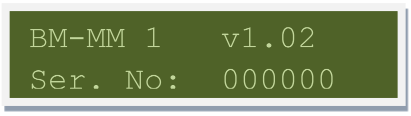
| ***Probable Causes*** | ***Actions recommended*** |
|---|---|
| *Incorrect programming of serial communication parameters on Interface Module.* | *Check for correct programming of the following parameters on submenu Configuration (4.9.7.1):*<br>*Serial Port*<br>*Baud Rate*<br>*Address*<br>*Protocol* |
| *Bad contact, disconnection or inversion in serial communication connection cables.* | *Check for bad contact points, disconnections or inversions in the entire path of serial communication cables, including connection to Interface Module, to passage terminals and to data acquisition system. See Figure 13.* |
| *Use of unshielded cable, ungrounded or incorrectly grounded shielding in connection between data acquisition system and Interface Module.* | *Use shielded cable, connected according to recommendations of submenu 3.3 and Figure 13.* |
| *Use of incorrect cable type* | *Communication cable must be twisted-pair, shielded type. See submenu 3.3.* |
| *Distance between ends of communication network in excess of 1300 meters* | *If circuit overall distance exceeds 1300 meters, repeater modules or fiber optic cables must be used.* |
| *Failure of Interface Module* | *Replace defective Interface Module and Contact Treetech Technical Assistance.* |

**Table 19 - Incorrect remote reading from Analog output:**

| ***Probable Causes*** | ***Actions recommended*** |
|---|---|
| *Incorrect programming for parameters related to current output* | *Check programming of the following parameters in submenu Analog Output (4.9.7.4):*<br>*Current output range;*<br>*Selection of sets for readings;*<br>*Selection of phases for readings;*<br>*Selection of analog variable for readings;*<br>*Value for beginning of scale;*<br>*Value for end of scale.* |
| *Incorrect connection of cabling* | *Check for correct connection of cables (polarity, eventual short-circuits, open links, grounding) between BM and measurement system. See Figure 13.* |
| *Maximum load allowed exceeded* | *Check maximum load allowed for each output standard selected (see 7.2 Attachments B – Technical Data).* |
| *Failure of Interface Module* | *Replace defective Interface Module and contact Treetech Technical Assistance.* |

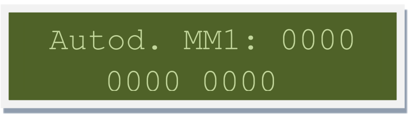
## 6.5 Consulting Firmware and Memory of Self-diagnosis Messages

To view the firmware version just press the key at the measurement screen. To exit the Firmware Version screen display, just press the key again. The figure below shows the screen that will appear indicating the firmware version installed.


Every self-diagnostic message identified by BM is stored and can be consulted by the user on the equipment front screen.

To view the self-diagnosis memory just press multiple keys simultaneously and . The figure below shows the screen that will be displayed indicating the self-diagnosis codes occurring.


The value shown for each digit of the memory self-diagnostic is the value of the sum of the values of each error that has already occurred for that position, not just those that are currently active. So it is possible 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 .

# 7 Attachments

## 7.1 Attachments A – Parameters tables

**Table 20 - Bushing Monitor BM-HMI – Parameter Definition Sheet 1**

| Serial No. of Interface Module: | | Date: | |
|---|---|---|---|

| Menu | Description | Value Set | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ALARMS | Set | 1 | | | 2 | | | 3 | | |
| | Phase | A | B | C | A | B | C | A | B | C |
| | High Capacitance | | | | | | | | | |
| | Very High Capacitance | | | | | | | | | |
| | High Capacitance Trend | | | | | | | | | |
| | High Tangent Delta | | | | | | | | | |
| | Very High Tan. Delta | | | | | | | | | |
| | High Tan. Delta Trend | | | | | | | | | |
| | Low Leakage Current | | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| I LEAKAGE ALARMS | Setting Mode | Automatic | | | | Manual | | | | |
| | I Leak High Auto | | | | | | | | | |
| | I Leak HiHi Auto | | | | | | | | | |
| | Alarms | | | | | | | | | |
| | Set | 1 | | | 2 | | | 3 | | |
| | Phase | A | B | C | A | B | C | A | B | C |
| | I Leak High | | | | | | | | | |
| | I Leak High Time | | | | | | | | | |
| | I Leak Very High | | | | | | | | | |
| | I Leak HiHi Time | | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| RELAY CONFIGURATION | Relay Selected | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | Set | □ 1<br>□ 2<br>□ 3 | □ 1<br>□ 2<br>□ 3 | □ 1<br>□ 2<br>□ 3 | □ 1<br>□ 2<br>□ 3 | □ 1<br>□ 2<br>□ 3 | □ 1<br>□ 2<br>□ 3 | □ 1<br>□ 2<br>□ 3 |
| | Phase | □ A<br>□ B<br>□ C | □ A<br>□ B<br>□ C | □ A<br>□ B<br>□ C | □ A<br>□ B<br>□ C | □ A<br>□ B<br>□ C | □ A<br>□ B<br>□ C | □ A<br>□ B<br>□ C |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **High Capacitance** | | | | | | | |
| | **Very High Cap.** | | | | | | | |
| | **High Cap. Trend** | | | | | | | |
| **RELAY CONFIGURATION** | **High Tan Delta** | | | | | | | |
| | **Very High TanDelta** | | | | | | | |
| | **High T.Delta Trend** | | | | | | | |
| | **Low Leak Current** | | | | | | | |
| | **I Leakage High** | | | | | | | |
| | **I Leak Very High** | | | | | | | |
| | **Operation Mode** | □ **NO**<br>□ **NC** | □ **NO**<br>□ **NC** | □ **NO**<br>□ **NC** | □ **NO**<br>□ **NC** | □ **NO**<br>□ **NC** | □ **NO**<br>□ **NC** | □ **NO**<br>□ **NC** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MEASUREMENT MODULE** | **Number of sets** | | | | | | | | | | | |
| | **Initial Values** | **Set** | **1** | | | **2** | | | **3** | | | |
| | | **Phase** | **A** | **B** | **C** | **A** | **B** | **C** | **A** | **B** | **C** | |
| | | **Capacitance** | | | | | | | | | | |
| | | **Tan. Delta** | | | | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **ADVANCED CONFIGURATION** | **Configuration** | **Screen Rolling** | □ YES | □ NO | | | |
| | | **RTD Configuration** | □ RTD A and B | □ RTD A | □ RTD B | □ OFF | |
| | | **RTD Simulator** | □ ON | □ OFF | | | |
| | | **Serial Port** | □ 485 | □ 232 | | | |
| | | **Baud Rate** | □ 9600 | □ 19200 | □ 38400 | | |
| | | **Address** | | | | | |
| | | **Protocol** | □ MODBUS | □ DNP 3.0 | | | |
| | | **Relay Hysteresis** | | | | | |
| | | **Log Interval** | | | | | |
| | | **New Password** | | | | | |
| | **Meas. Mod.** | **Trend Time Constant** | | | | | |
| | | **Minimum I Leakage** | | | | | |
| | **Alarms** | **Tangent Delta High** | | | | | |
| | | **Tangent Delta Hi High** | | | | | |
| | **Analog Output** | **mA Output Range** | □ 0...1 | □ 0...5 | □ 0...10 | □ 0...20 | □ 4...20 |
| | | **Analog Output** | 1 | | | 2 | |
| | | **Set** | □ 1 □ 2 □ 3 | | | □ 1 □ 2 □ 3 | |

| | | | | |
|---|---|---|---|---|
| | | **Phase** | □ A □ B □ C | □ A □ B □ C |
| | | **Analog variable** | □ Capacit. □ Tan. Delta | □ Capacit. □ Tan. Delta |
| | | **Initial value** | | |
| | | **Final value** | | |

## 7.2 Attachments B – Technical Data

**Table 21 - Interface Module BM-HMI**

| Test | Interval / Description |
|---|---|
| **Input Voltage:** | 38 to 265 Vac/Vdc 50/60Hz |
| **Maximum Consumption:** | <8 W |
| **Operating Temperature:** | -40 to +85°C |
| **Degree of Protection:** | IP 20 |
| **Fixation:** | Panel fixation |
| **Connections – Removable Terminals:** | 0,3 a 2,5mm², 22 a 12 AWG |
| **Temperature Measurement** | |
| Sensor: | Pt100 at 0°C with ongoing self-calibration |
| Measurement Range: | -55 to +200°C |
| Maximum Error at 20°C: | 0.2% from end of scale |
| Deviation for temperature variation: | 20ppm/°C |
| Connection options: | Up to 2 three-wire sensors |
| **Output Relays:** | Potential free contacts |
| Type and functions (standard): | 5NO (configurable) + 3NC (2 configurable + 1 self-dig.) |
| Maximum switching power: | 70W (dc) / 220VA (ac) |
| Maximum switching voltage: | 250 Vdc / Vac |
| Maximum conduction current: | 5 A |
| | |
| **Analog outputs:** | |
| Variables: | 2 programmable with common positive |
| Maximum Error: | 0.5% from end of scale |
| Output range: | Programmable (0-1,0-5,0-10,0-20 and 4-20mA) |
| Maximum load: | 0-1mA 10kΩ , 0-5 mA 2kΩ , 0-10mA 1kΩ<br>0-20mA 500Ω , 4-20mA 500Ω. |
| **Serial Communication Ports:** | 1 RS485 (for BM-MM)+1 RS485 / RS232 (for supervisory)<br>Modbus RTU and DNP 3.0 Level 1 |
| **Communication Protocols:** | |
| **Mass Memory:** | |
| Recording interval: | 1 to 720 hours |
| Capacity: | 712, 420 or 297 records (for 1, 2 or 3 BM-MM connected) |

**Table 22 - Measurement module BM-MM**

| Test | Interval / Description |
|---:|---|
| **Input Tension:** | 38 to 265 Vac/Vdc 50/60Hz |
| **Maximum Consumption:** | 5W |
| **Operating Temperature:** | -40 to +85°C |
| **AC current measurement inputs:** | 3 for bushing leakage currents (0...100mA) |
| **Magnitudes Monitored:** | |
| Capacitance: | 0...6500pF |
| Tangent Delta: | 0...9.999% |
| | |
| **Output to Relay:** | 1(NC) for self-diagnostic |
| Maximum switching power: | 70W (dc) / 220VA (ac) |
| Maximum switching voltage: | 250 Vdc / Vac |
| Maximum conduction current: | 5 A |
| **Protection Level:** | IP 20 |
| **Fixation:** | Assembly on DIN 35mm track |

### Tap Adapter

The mechanical construct for the tap adapter varies in accordance with the model and manufacturer of the bushing. Tap adapters are equipped with protection against opening of the tap thus preventing the occurrence of hazardous voltage levels in case of disconnection of the cable that takes leakage currents to the Measurement Module.

**Installation Precations**

- Screwing by hand without tools.
- Do not support, step on or hang objects on the tap adapter. Always anchor cable or conduit to nearby structure to relieve mechanical stresses in outlet.

**Table 23 – Tap Adapter**

| Test | Interval / Description |
|---:|---|
| **Maximum voltage developed with disconnection of cables:** | 14 ±2 Vac |
| **Permanent conduction cap. at 125°C w/ cables disconnected:** | 2 x 250mA (redundant protection) |
| **Operating Temperature:** | -25 to +120 °C |
| **Degree of Protection:** | IP 65 |
| **Cable section:** | 0.3 to 1.5 mm² (22 to 14 AWG) |
| **Maximum tightening torque:** | 15 N.m |
| **Maximum vertical load:** | 20 kg |

## 7.3 Attachment C – Order Specifications

The BM Bushing Monitor is a universal equipment item, with features being selected from programming menus through its front panel or RS232 or RS485 ports. Power input is universal. Therefore, in placing orders for this device, it is only necessary to specify:

- Number of Measurement Modules BM-MM (with one BM-MM receiving signal from 3 bushings on the same three-phase set);
- Number of Interface Modules BM-HMI (with one BM-HMI being able to connect to 1, 2 or 3 BM-MM modules);
- Number of Tap Adapters, model and manufacturer of each bushing and type of tap (test tap or voltage tap). The mechanical construction of the adapter varies according to the model and manufacturer of the bushing. Treetech has available adapters ready for the different bushing models commonly found on the market, and others models of adapters can be quickly developed, if required.

Example of specification:
For a transformer (or bank of transformers) where three 500kV and three 230kV bushings are going to be monitored:
2 Measurement Modules BM-MM;
1 Interface Module BM-HMI;
3 Tap adapters for Bushings make ABB, type GOE with voltage tap;
3 Tap adapters for Bushings make Trench, type COT with test tap.

## 7.4 Attachment D – Tests Performed

**Table 24 Tests performed**

| Test | Interval / Description |
|---|---|
| **Surge Immunity (IEC 60255-22-5)** | |
| phase-neutral surges: | 1 kV, 5 per polarity (+/-) |
| phase-ground and neutral-ground surges: | 2 kV, 5 per polarity (+/-) |
| **Immunity to Electrical Transients (IEC 60255-22-1 and IEEE C37.90.1)** | |
| 1st cycle peak value | 2,5 kV |
| frequency: | 1,1 MHz |
| time and repeat rate: | 2 seconds, 400 surges/sec. |
| drop off to 50%: | 5 cycles |
| **Voltage Impulse (IEC 60255-5)** | |
| waveform: | 1,2 / 50 microseconds |
| amplitude and energy: | 5 kV |
| number of pulses: | 3 neg. e 3 pos., interval 5s |
| **Applied Voltage (IEC 60255-5)** | |
| Tolerable voltage at industrial frequency: | 2 kV 60Hz 1 min. to ground |
| **Immunity to Irradiated Electromagnetic Fields (IEC 61000-4-3 / IEC60255-22-3)** | |
| Frequency: | 26 to 1000 MHz |
| Field intensity: | 10 V/m |
| **Immunity to Conduced Electromagnetic Disturbances (IEC 60255-22-6)** | |
| Frequency: | 0,15 to 80 MHz |
| Field intensity: | 10 V/m |

| | |
|---|---|
| **Electrostatic Discharges (IEC 60255-22-2 e IEEE C37.90.3)** | |
| Air mode: | 8 kV, ten discharges/polarity |
| Contact mode: | 6 kV, ten discharges/polarity |
| **Immunity to Fast Electrical Transients (IEC60255-22-4 e IEEE C37.90.1):** | 4 kV |
| Input test, input and output: | |
| Test in serial communication: | 2 kV |
| **Climate Tests: (IEC 60068-2-14)** | |
| Temperature range: | -40 to +85ºC |
| Total test time: | 96 hours |
| **Response to vibration: (IEC 60255-21-1)** | |
| Mode of Application: | 3 axis (X, Y e Z), sinusoidal |
| Amplitude: | 0,075mm from 10 to 58 Hz<br>1G from 58 to 150 Hz |
| Duration: | 8 min/axis |
| **Resistance to vibration: (IEC 60255-21-1)** | |
| Mode of Application: | 3 axis (X, Y e Z), sinusoidal |
| Frequency: | 10 to 150 Hz |
| Intensity: | 2G |
| Duration: | 160 min/axis |

BRAZIL
Treetech Sistemas Digitais Ltda
Praça Claudino Alves, 141, Centro
CEP 12.940-000 - Atibaia/SP
+ 55 11 2410-1190
comercial@treetech.com.br
www.treetech.com.br