SINGLE-PHASE VOLTAGE REGULATOR

TRANSFORMER TYPE | BY STEPS

INSTRUCTION MANUAL

MIR-001 | ENGLISH

REV202412

itb®
EQUIPAMENTOS ELÉTRICOS

INDEX

SAFETY AND LIFE IMPORTANCE

ITB, as a manufacturer of electric equipment, takes all measures to ensure safety of people who may come into contact with its products, other equipment that may be connected to them and the environment in which They are installed.

Our main references to guarantee these safety levels are the official norms that represent experiences accumulated in several different conditions and for enough time to be adopted as good practices of operational, contingency and efficiency.

We consider our obligation to actively promote conscious and safe practices, both in choosing the most suitable equipment for each application, as well as in its correct handling and proper maintenance, just as we understand that spreading the knowledge involved, through technical service and training programs, are the most efficient means of continuous improvement of both our products and services and the set of these good practices.

We recommend observing all safety procedures stipulated by local regulations, approved, instituted and required, as well as the use of all safety equipment, individual or global, recommended for activities around equipment and high voltage lines.

SECURITY INFORMATION

The instructions contained in this manual are not intended to replace the proper training and accumulation of experience necessary for the safe installation, maneuver and operation of the single-phase voltage regulator. Only competent technicians who are familiar with networking equipment should install, operate and maintain it.

A competent technician for such functions must meet the following qualifications:

- Be familiar with these instructions;
- Be trained in safe operation, procedures and practices accepted by the high and low voltage industry;
- Be trained according to regulatory standards and authorized to energize, de-energize and manipulate power distribution equipment.
- Be trained in the proper care and use of personal protective equipment, such as: flame-retardant clothing, goggles, visors, helmets, rubber gloves, hot sticks, etc.;
- Be trained in the installation and use of ladders on poles, necessary signs on public roads and the related legislation.

For installation and operation of this equipment, be sure to read and understand all warnings and cautions.

This manual contains three types of warning phrases:

DANGER: Indicates an imminently hazardous situation which, if not avoided, will result in death or injury of any kind to the operator or bystanders near the network or equipment.

CAUTION: Indicates a potentially critical situation which, if not avoided, could result in operational damage to equipment, the network, or people in the vicinity.

NOTICE: a potentially unwanted situation which, if not avoided, could result in equipment malfunction.

General Security Information

In general, we suggest taking into account the following information when installing, operating, maintaining or maneuvering devices installed on high voltage networks:

DANGER: Dangerous voltage. Contact with high voltage will cause death or serious injury. Follow all approved safety procedures when working around high voltage lines and equipment.

NOTICE: Before installing, operating, maintaining or testing the equipment, carefully read and understand the contents of this manual. Improper operation, use or maintenance can result in damage to the equipment or the network where it is installed.

DANGER: Power distribution equipment must be properly selected for the intended application. They must be installed and maintained by competent personnel, trained and aware of proper safety procedures. These instructions are written for such persons and are not a substitute for proper formal training or experience in safety procedures. Failure to properly choose, installation, configuration, and maintenance electrical distribution equipment can result in death, serious personal injury, and equipment damage.

INTRODUCTION

This manual is intended to provide instructions for installation, operation and maintenance of ITB voltage regulators, model RAV-2.

NOTICE: A complete reading of this manual will assist in proper installation, safe handling, efficient operation of the equipment, and maintenance of the equipment in a safe and reliable condition.

ADDITIONAL INFORMATION

This manual does not intend to cover all the details or variations of the equipment and its respective control systems, procedures or processes in general, nor to guide on all the practices required for installation, operation and maintenance. If you need more information, contact a technical representative from ITB Equipamentos Elétricos Ltda.

MANUFACTURING STANDARDS

The regulators of ITB Equipamentos Elétricos Ltda. are designed, manufactured and tested in accordance with the latest versions of ABNT® NBR 11809 or IEEE Std C57.15 ™ standards.

INTEGRATED MANAGEMENT POLICY

Our high standard of quality, preservation of the environment and personal well-being are endorsed by ISO 9001 Quality Management System, ISO 14001 Environmental Management System and ISO 45001 Occupational Health and Safety Management System.

RECEIPT

Prior to packaging, the regulator is factory tested and inspected. Upon receipt, another inspection must be carried out to locate damage that may result from transport. The external position indicator, control box, lightning rod, radiators, bushings, electrical cables and other external components must be rigidly fixed to the regulator body, intact and free from cracks and deformations. The packaging must also not show signs of tampering, impact or dropping.

Any irregularity found, before proceeding with the unloading, immediately inform the representative or the after-sales department of ITB Equipamentos Elétricos Ltda.

UNLOADING, STORAGE AND TRANSPORT

Any and all handling of the equipment must be carried out carefully by qualified personnel and with the necessary protections. The regulator must not be hoisted over people or objects.

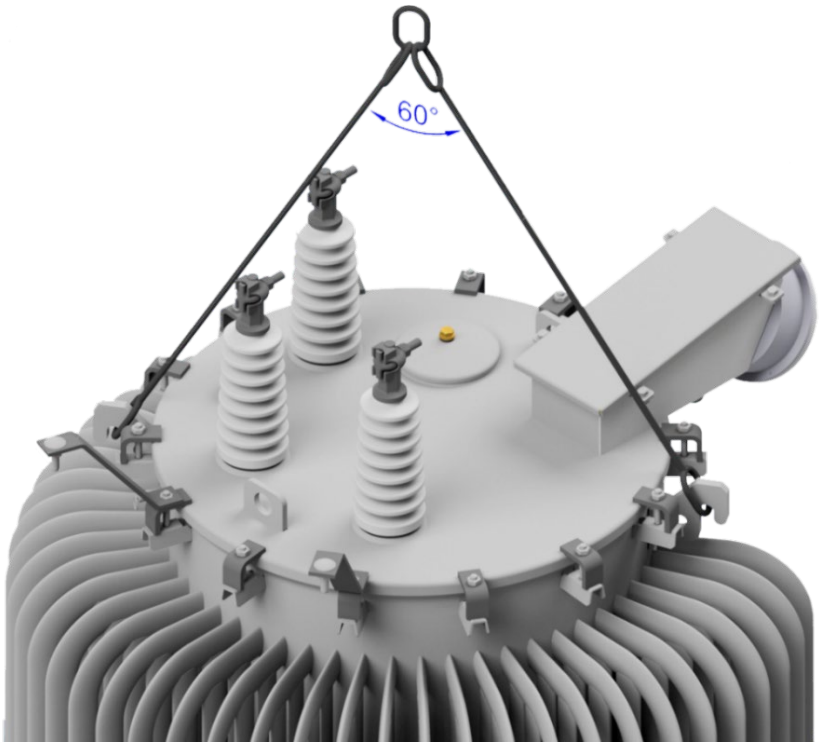
Lifting the regulator must be done levelly, with cables or chains and through the suspension hooks fixed on the side of the tank.

Do not use the lifting eyes installed on the equipment cover to lift the complete regulator. These lifting eyes are only intended for removing the active part that is attached to the cover.

CAUTION: DO NOT USE the eyebolts on the cover to lift the complete equipment. The cover could break, causing equipment damage, serious personal injury, and even death.

The cable or chain to be used must be intact, have the capacity to support the weight of the regulator and be of sufficient length so that the angle formed between each cable run, with the apex on the hook, is a maximum of 60º, as shown in Figure 1.

Figure 1: Method of total suspension.



CAUTION: The use of cables, straps or very short chains, which provide angles greater than 60º, will cause permanent deformation in the regulator tank and rupture of the lifting handles, causing damage to equipment, serious bodily injury and even death.

If the regulator is temporarily discharged, the equipment must be stored, preferably in its original packaging, in a ventilated place, with a leveled floor, away from heat sources, protected from sparks and where there is no possibility of mechanical damage.

When transporting the regulator to the installation site, in order to maintain the product warranty, preventive measures must be taken to avoid constant shocks and sudden movements. It is necessary to ensure that the equipment is well fixed to the transport vehicle and that the speeds of this vehicle are limited according to Table 1.

Table 1: Transport speed limit values.

Type of Transport Route	Maximum Speed Recommended [km/h]
Paved	80
Not paved	40

NOTICE: It is recommended that the transport vehicle has a tachograph installed to control the maximum transport speed.

VOLTAGE REGULATOR - OVERVIEW

The voltage regulators RAV-2 from ITB Equipamentos Elétricos Ltda. aim to keep voltage levels within the programmed limits, significantly improving the quality of electrical energy distribution.

The regulator is an autotransformer equipped with an on-load tap-changer, which together with a transition reactor, regulates the line voltage, correcting deviations of up to ±10% with steps of 0.625% of the rated voltage. The steps are distributed in 33 leads, 16 for raising, 16 for lowering and 1 neutral position. For more details, see the section: *Erro! Fonte de referência não encontrada.*

Serial Items

The regulators are arranged in unitary construction and have the following standard features:

- Base with holes for platform installation;
- Terminal block on the cover;
- Bushings suitable for rated voltage and current levels;
- On-load tap-changer suitable for rated voltage and current levels;
- ABNT® or IEEE™ grounding connector;
- Top connection for filter-press and thermo-vacuum (1.1/2" thread);
- Sealed tank construction;
- Regulator full suspension hooks;
- Oil level indicator with nominal and minimum marking;
- Suspension eyelids of the active part;
- External series lightning arrestor;
- Stainless steel nameplate;
- Filled with type II insulating mineral oil, in accordance with ASTM D3487;
- ABNT® or IEEE™ pole fixing bracket (for regulators with mass ≤1.500 kg);
- Inspection cover;
- Internal pressure relief valve;
- Válvula de drenagem com dispositivo para coleta de amostra de óleo.

Optional Items

Depending on the most diverse technical specifications met by ITB Equipamentos Elétricos Ltda., optionally, the following characteristics can be met:

- Shielded control cable from 2 to 10 meters (1 meter pitch);
- Control cable with quick disconnect from 2 to 10 meters (1 meter pitch);
- Control cable from 2 to 10 meters (1 meter pitch);
- Auxiliary junction box for single control connection;
- Stainless steel control box;
- NEMA type bushing connectors;
- Single-phase control, model CTR-2, from ITB Equipamentos Elétricos Ltda.;
- Single-phase control, model SEL-2431, from Schweitzer Engineering Laboratories Inc.;
- Three-phase control, model CTR-3, from ITB Equipamentos Elétricos Ltda.;
- Alternative finishing colors;
- Adjustable lifting frame in galvanized steel for installing the regulator;
- Oil level indicator with alarms;
- External analog position indicator, model TCPI-1, from ITB Equipamentos Elétricos Ltda.;
- Vacuum and pressure gauge;
- Oil of vegetable origin;
- External stainless-steel screws;
- Line external lightning arrestor;
- Identification plate on the cover of the control box;
- Bushing protectors;
- Control box heating system.
- Parallel surge arrester mounting bracket (shunt)
- Top oil thermometer with or without alarms;
- Independent external PT for source-side measurement (only for individual control);
- Internal pressure relief valve with alarm.

Voltage Regulator RAV-2 - External Characteristics

With a simple and intuitive design, for easy installation and maintenance, the voltage regulator has all the fundamental components for its proper operation. The location and description of each of these components can be seen in Figure 2 and Table 2.

NOTICE: The following details are not intended to cover all possibilities of external construction of a voltage regulator. Details intrinsic to each project must be consulted during the technical feasibility analysis and purchase order approval phase.

NOTICE: For more details on voltage regulator controls manufactured by ITB Equipamentos Elétricos, visit our website and download the latest versions of the instruction manuals.

Figure 2: External components of the RAV-2 regulator.

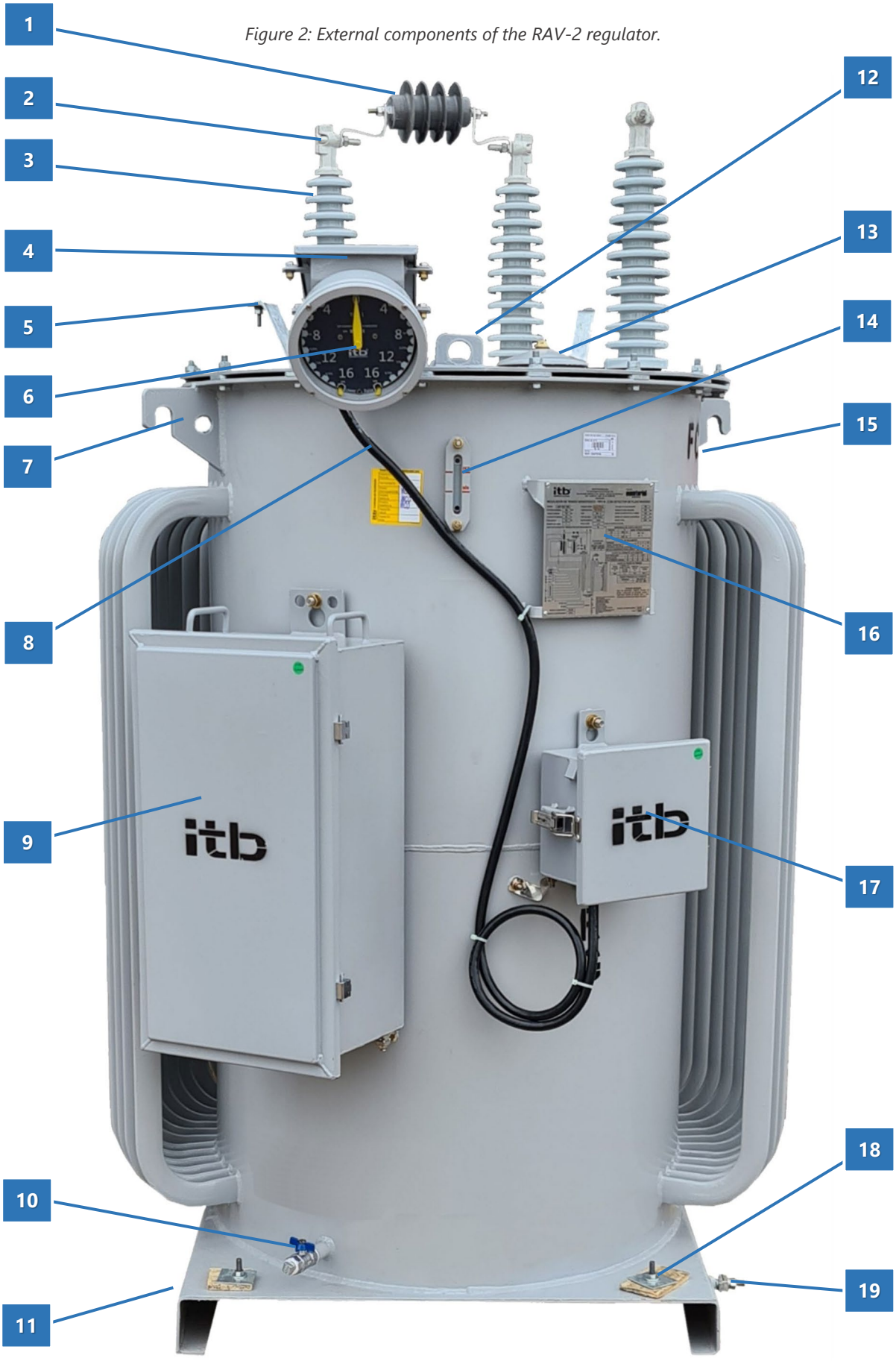


Table 2: External components of the RAV-2 regulator.

Item	Description
1	Zinc oxide polymeric lightning arrestor for series winding protection
2	Line connectors
3	Isolator
4	Terminal block box
5	Parallel lightning arrester mounting bracket (shunt)
6	External mechanical position indicator model TCPI-1
7	Regulator full suspension hooks
8	Control cable
9	Control box (according to customer specified)
10	Drain valve with oil sampling device
11	Drilled base for platform installation
12	Active part suspension eyes
13	Inspection cover
14	Oil level indicator with nominal and minimum marking
15	Internal pressure relief valve (rear of regulator tank)
16	Stainless steel nameplate
17	Auxiliary junction box for single control connection (if applicable)
18	Provision of 4 round holes with a diameter of 20mm for fixing the base to the platform
19	ABNT® grounding connector

Line terminal identification

The line terminals of the regulators are identified as specified by the customer and in accordance with the nomenclature described by ABNT® or IEEE™. These identifications are indelibly marked on the regulator cover in low relief and reinforced with paint. Figure 3 represents the markings according to ABNT® nomenclature and Figure 4, according to IEEE™.

Figure 3: Nomenclature ABNT®.

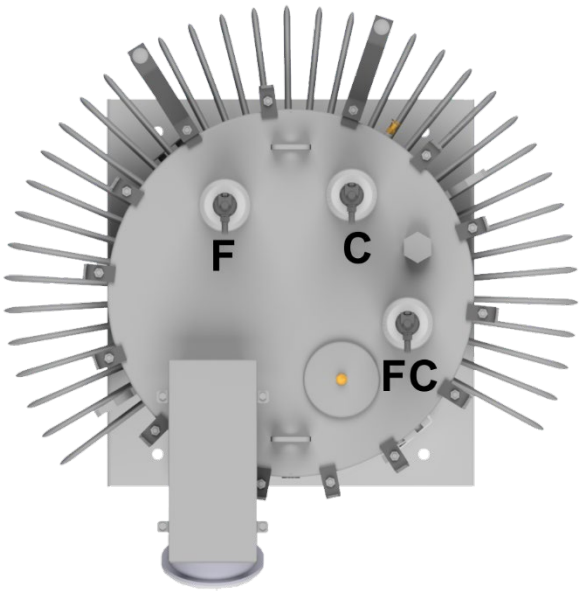
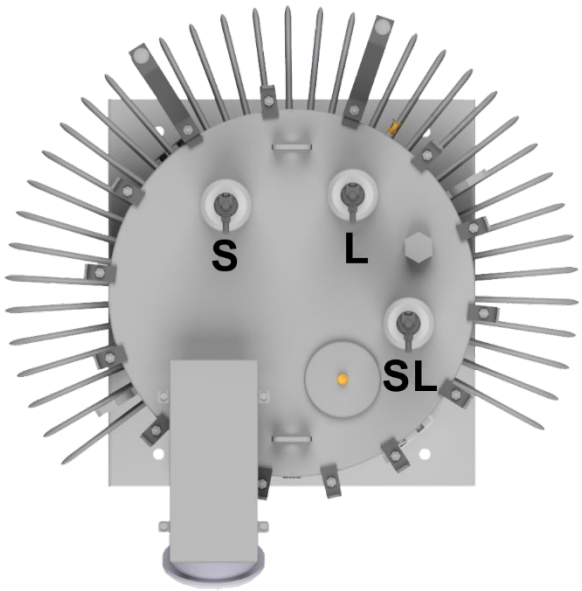


Figure 4: Nomenclature IEEE™.



The terminal connected to the system source is identified by the letter F (source), or S (source), and is positioned to the left of the regulator, when viewed from above. The terminal connected to the system load is identified by the letter C (load), or L (load), and is positioned in the center of the regulator. The common terminal that is connected to the reference is designated by the letter FC (source-load) or SL (source-load), and is positioned to the right of the regulator.

DESCRIPTION - MAIN ACCESSORIES

For the operation of voltage regulators to be full and safe, some accessories are necessary. These accessories are described below:

Auxiliary enclousure

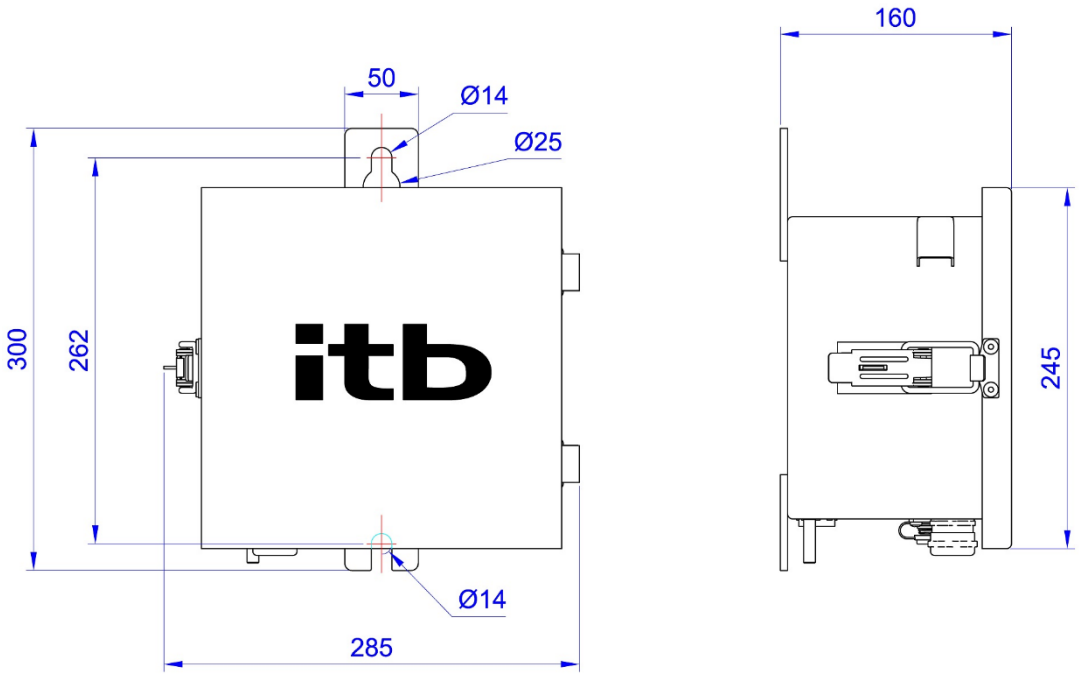
When voltage regulators are supplied without control, or if specified by the customer, an auxiliary junction box will be available for interfacing between the chosen control system and the voltage regulator.

All the components of this box are housed in a metallic cubicle, made of carbon steel and coated with a liquid or powder coating system, in light gray color, MUNSELL N. 6.5 notation, or in accordance with the standard painting of the voltage regulator.

Upon request, or in accordance with the customer's technical specification, it is possible to change the finish system and material of the housing.

The box has fixing straps for mounting on the regulator body and, if necessary, can also be used to fix the box to the pole. The dimensions and details of the handles are illustrated in Figura 5.

Figura 5: External dimension of the auxiliary passage box.



The auxiliary crossing box has the following characteristics:

- Motor capacitor (20 µF / 400 V);
- Alternate engine start switch;
- Knife-type key to short-circuit the CT, ensuring safe removal of the control system;
- 6-Digit electromechanical cumulative operations counter;
- Protection devices for motor actuation signals;
- Additional input for external PT and CT signal;
- Degree of protection IK9 against external mechanical impacts;
- IP54 protection degree ready to work in the weather;
- Printed circuit board with spring terminals for input and output and signals;
- M8 threaded terminal for grounding;
- Connection terminal for primary voltage selection;
- Standard 18-way male circular socket.

Internal components

The passage auxiliary box has components necessary for the wide standardized interfacing between the control system and the voltage regulator, the location and description of each of these can be seen in Figure 6 and Table 3Table 3: Components inside the auxiliary box..

Figure 6: Components inside the auxiliary passage box.

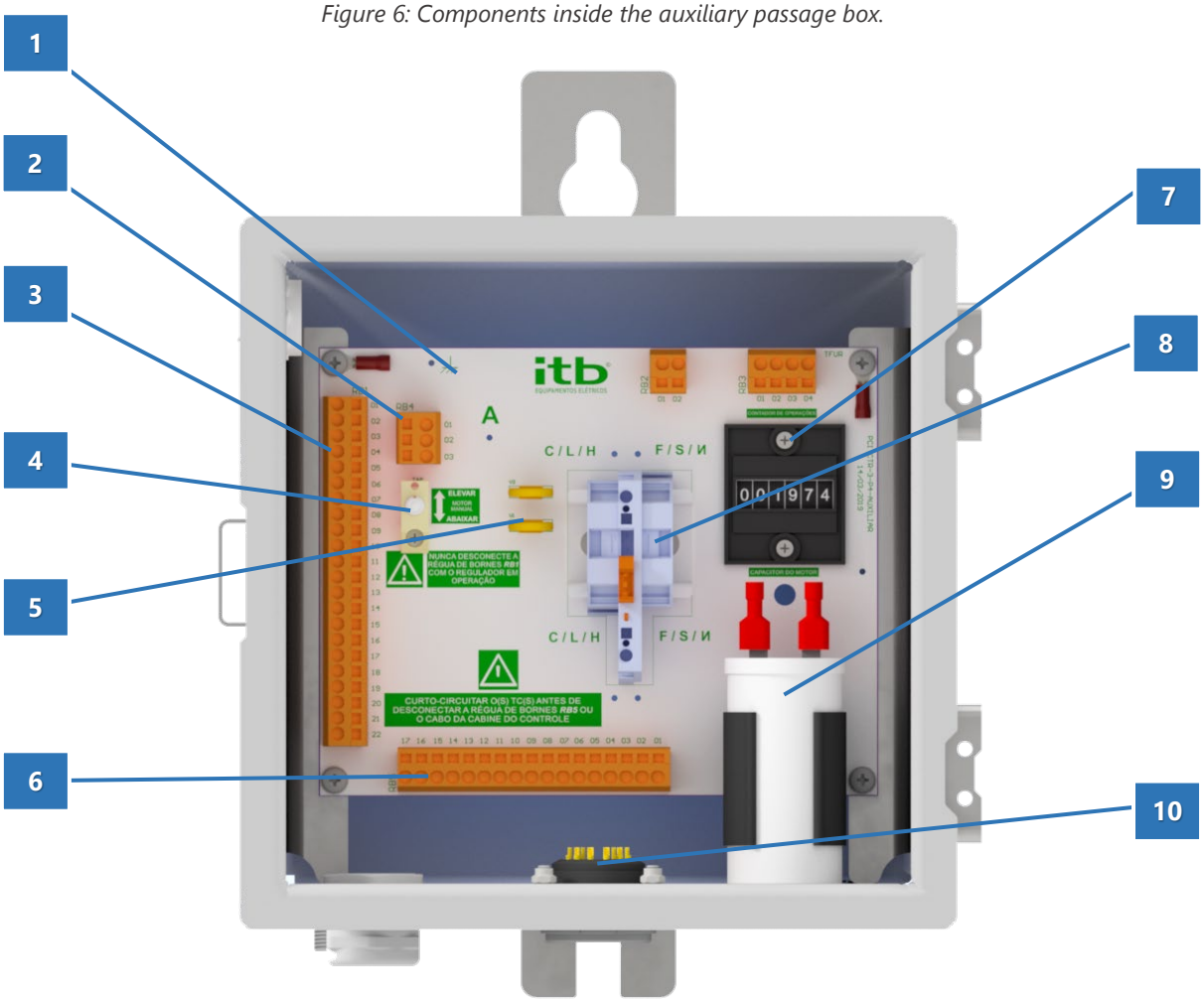


Table 3: Components inside the auxiliary box.

Item	Description
1	PCI CTR-3 Printed circuit board - P4 – AUXILIARY
2	Connection terminal for primary voltage selection (washer A)[1]
3	Input terminal for voltage regulator signals
4	Alternate engine start switch
5	Protection devices for motor actuation signals
6	Voltage regulator signals output terminal for standard male circular socket
7	6-digit electromechanical accumulative operations counter
8	Knife-style switch for shorting the CT secondary
9	Motor capacitor (20 µF / 400 V)
10	Standard 18-way male circular socket

Standardized interface

The connection between the chosen control system and the voltage regulator auxiliary box is made through a standardized interface, according to item 10 of Table 3. This interface has standardized signals, which meet the most diverse technical specifications of the market, according to Table 4.

Table 4: Standard pins for interfacing

Pins	Description
1	Neutral (grounded)
2	Operations counter
3	Neutral Light
4	Current measurement phase
5	Voltage measurement phase
6	Motor drive in the lifting motion
7	Motor drive in the lowering motion
8	Position indicator reset
9	Engine retention
10	- No connection -
11*	Polarity indicator
12*	Bit 0 for encoder reading
13*	Bit 1 for encoder Reading
14*	Bit 2 for encoder reading
15*	Bit 3 for encoder reading
16*	Bit 4 for encoder reading
17*	Voltage measurement phase for auxiliary PT
18*	Voltage measurement phase for auxiliary CT

CAUTION: In order to avoid problems, even the control system burning, the points indicated with * MUST be opened if using control systems not manufactured by ITB Equipamentos Elétricos Ltda.

For more information on adjusting the primary voltage, see the section: ***Adjusting the primary voltage.***

The interface fixed to the auxiliary box is of the 18-way male circular socket type. The interface that must be connected to the auxiliary box must be of the 18-way female circular socket type, as shown in Figure 7.

Figure 7: 18-way female circular socket.

Alternative engine drive

The alternative motor actuation switch is located on the printed circuit board called PCI CTR-3 - P4 - AUXILIARY, and in the TAP position, according to item 4 of Table 3.

This switch allows the operation of raising or lowering the tap-changer position only with the presence of a control system connected to the auxiliary box.

The switch is of the 3-position momentary type, one normally off and the ones that activate the lifting and lowering motor, according to the direction indicated in the serigraphy of the PCI CTR-3 - P4 - AUXILIARY.

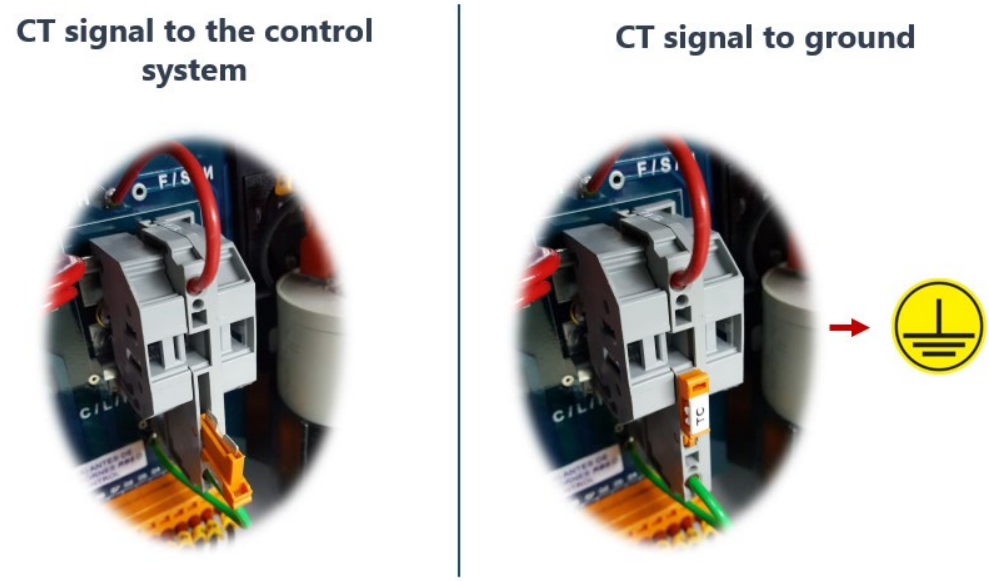
DANGER: DO NOT OPERATE this function on voltage regulators without an external mechanical position indicator.

DANGER: Alternative engine start must be performed carefully, because inside the auxiliary box there are several energized points.

CT short circuit

To avoid overvoltage on the CT secondary, before removing the chosen control system, it is necessary to short-circuit the current signal. This operation must be carried out through the knife type key, fixed on the printed circuit board called PCI CTR-3 - P4 - AUXILIARY, inside the auxiliary passage box. Figure 8 illustrates this procedure.

Figure 8: Procedure for short-circuiting the CT.



CAUTION: DO NOT REMOVE the connector from the standard circular outlet without first shorting the CT. The CT circuit MUST be short-circuited when withdrawing from the control system. Failure to follow these instructions will result in equipment damage.

External mechanical position indicator model TCPI-1

The external mechanical position indicator, model TCPI-1 for voltage regulators RAV-2 from ITB Equipamentos Elétricos Ltda., is a device that allows to obtain the positioning information of the tap-changer in real time, through its connection through a flexible shaft directly connected to the mechanism of the tap-changer under load.

It is fixed to the regulator cover and has an inclination that makes it visible from the ground. The TCPI-1 has a display graduated in 16 steps to raise, 16 steps to lower and neutral position, the steps have indications for even taps only.

This display, simultaneously, is able to indicate the current, maximum and minimum position reached during the regulator operation. The pointers indicating the maximum and minimum positions are of the drag type, for their re-establishment (reset) the corresponding button must be used in the chosen control system.

Capacity of the rated supplementary currents in continuous mode (load bonus)

Standardized by ABNT® NBR 11809 and IEEE Std C57.15 ™, single-phase voltage regulators must be able to work with supplementary rated currents in continuous mode (load bonus), provided that this current does not exceed 668 A. Adjustment details are in Table 5.

Table 5: Load bonus adjustment table.

Voltage Regulation Range [%]	Adjustment Position [TAP]	Supplementary Nominal Current in Continuous Regime [%]
±10,00	±16	100
±8,75	±14	110
±7,50	±12	120
±6,25	±10	135
±5,00	±8	160

To fulfill this function, the TCPI-1 indicator is equipped with limit switches that allow controlling the operating range limit (load bonus control) for the raising and lowering sides. The location and description of each of these keys, and of the other TCPI-1 items, can be seen in Figure 9 and Table 6.

Figure 9: Indicator TCPI-1.

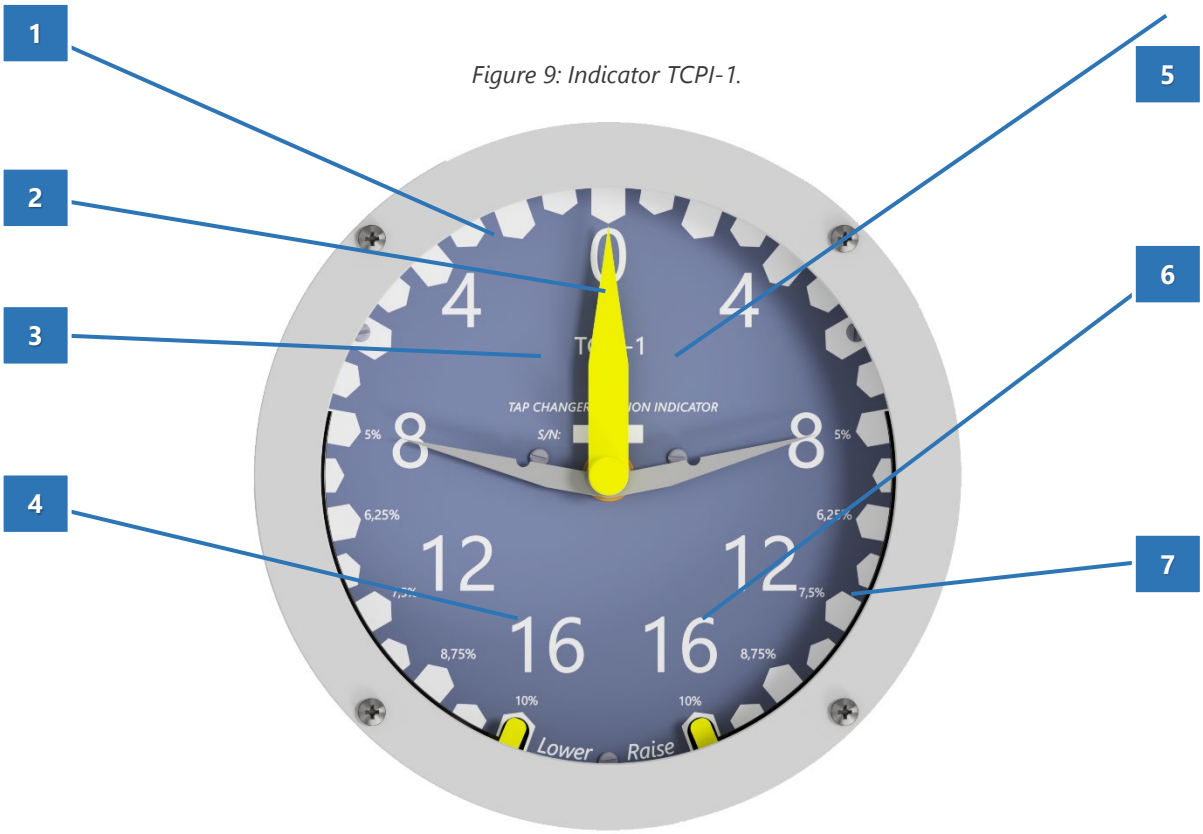


Table 6: TCPI-1 indicator components.

Item	Description
1	Graduated display with position indication
2	Current position indicator pointer
3	Pointer indicated from the minimum position
4	Minimum position load bonus limit switch adjustment lever (downward direction)
5	Maximum position indicator pointer
6	Maximum position load bonus limit switch adjustment lever (lift direction)
7	Screw for front panel removal and access to load bonus adjustment levers

Adjustment of limit switches (load bonus)

The load bonus function in the RAV-2 regulators allows the addition of the supplementary current carrying capacity by reducing the regulation range. This operation must be adjusted through the settings of the TCPI-1 position indicator limit switches, or through the digital function available in the chosen control system, so that it can limit the working range of the on-load tap-changer in both directions.

NOTICE: Make sure the current position indication pointer is not outside the intended adjustment range before adjusting the lock levers.

NOTICE: NEVER manipulate current position indication pointer.

If necessary, operate the tap changer manually into the required bandwidth before activating the load bonus function.

To program the limit switch levers, proceed with the following steps:

1. Use a #2 Phillips screwdriver to loosen the 4 screws that secure the front of the TCPI-1 indicator;
2. 2. Push the levers to the new required load bonus range, note that every 2 adjustment steps, between ±8 to ±16 positions, there will be a small click, indicating the correct positioning;
3. 3. Close the front cover of the indicator and tighten the 4 fixing screws;
4. 4. Make sure the seal of the indicator cover with its body has been re-established.

NOTICE: Setting the load bonus directly on the TCPI-1 indicator takes precedence over the digital settings, as it electrically interrupts the tap-changer motor circuit.

DANGER: For safety, when supplying voltage regulators without the control system, only with the bypass box, it is recommended that the TCPI-1 indicator be specified on the purchase order.

Series lightning arrestor (by-pass)

The RAV-2 voltage regulators are equipped with lightning arresters, metal oxide varistor type (Zno, zinc oxide), with silicone polymer encapsulation, for series winding protection, connected between the source terminals (F or S) and load (C or L), according to item 1 of Table 2. This device has the objective of limiting the voltage that will pass through the series winding of the regulator during atmospheric surges, switching surges or any other line problem. Table 7 details the specifications of the series surge arrester used as a function of the rated voltage of the regulator.

Table 7: Series surge arresters (by-pass).

Basic Characteristics	Rated Voltage of the Regulator ≤19.92 kV	Rated Voltage of the Regulator >19,92 kV
Rated voltage (kV)	3,0	6,0
Maximum continuous operating voltage (kV)	2,55	5,1
Nominal frequency (Hz)	50/60	50/60
Rated discharge current 8/20µs (kA)	10	10
Energy absorption capacity (kJ/kV)	1,8	1,8

Para-raios paralelo (shunt)

To protect the parallel winding (excitation or shunt) of the regulator, it is recommended to install parallel lightning arrestors on all ungrounded terminals of the regulator.

If specified, the voltage regulator may come with supports for installing these lightning arresters close to the regulator terminals. Connect the arrester directly to earth, using the shortest possible length of cable[2].

Table 8 details the specifications of the parallel lightning arrester as a function of the rated voltage of the regulator.

Table 8: Parallel lightning arrester (shunt).

Rated Voltage of the Regulator [V]	Recommended Parallel Lightning Arrestor	
	Rated voltage [kV]	Maximum Continuous Operating Voltage [kV]
6.600	9,0	7,65
7.620	10,0	8,40
7.967	10,0	8,40
8.660	12,0	10,20
10.000	15,0	12,70
11.000	15,0	12,70
13.800	18,0	15,30
14.400	18,0	15,30
15.000	21,0	17,00
19.920	27,0	22,00
20.000	27,0	22,00
22.000	30,0	24,40
23.100	30,0	24,40
30.000	36,0	30,60
33.000	36,0	30,60
34.500	36,0	30,60

NOTICE: Table 8 is for information purposes only, it is recommended that protection studies should be carried out for case-by-case validation of the voltage regulator protection system.

[2] *For more details on installing parallel lightning arresters, check the section: System connection possibilities.*

INSTALLATION AND OPERATION

The following approaches are crucial for the safe installation and operation of the RAV-2 voltage regulators from ITB Equipamentos Elétricos Ltda.

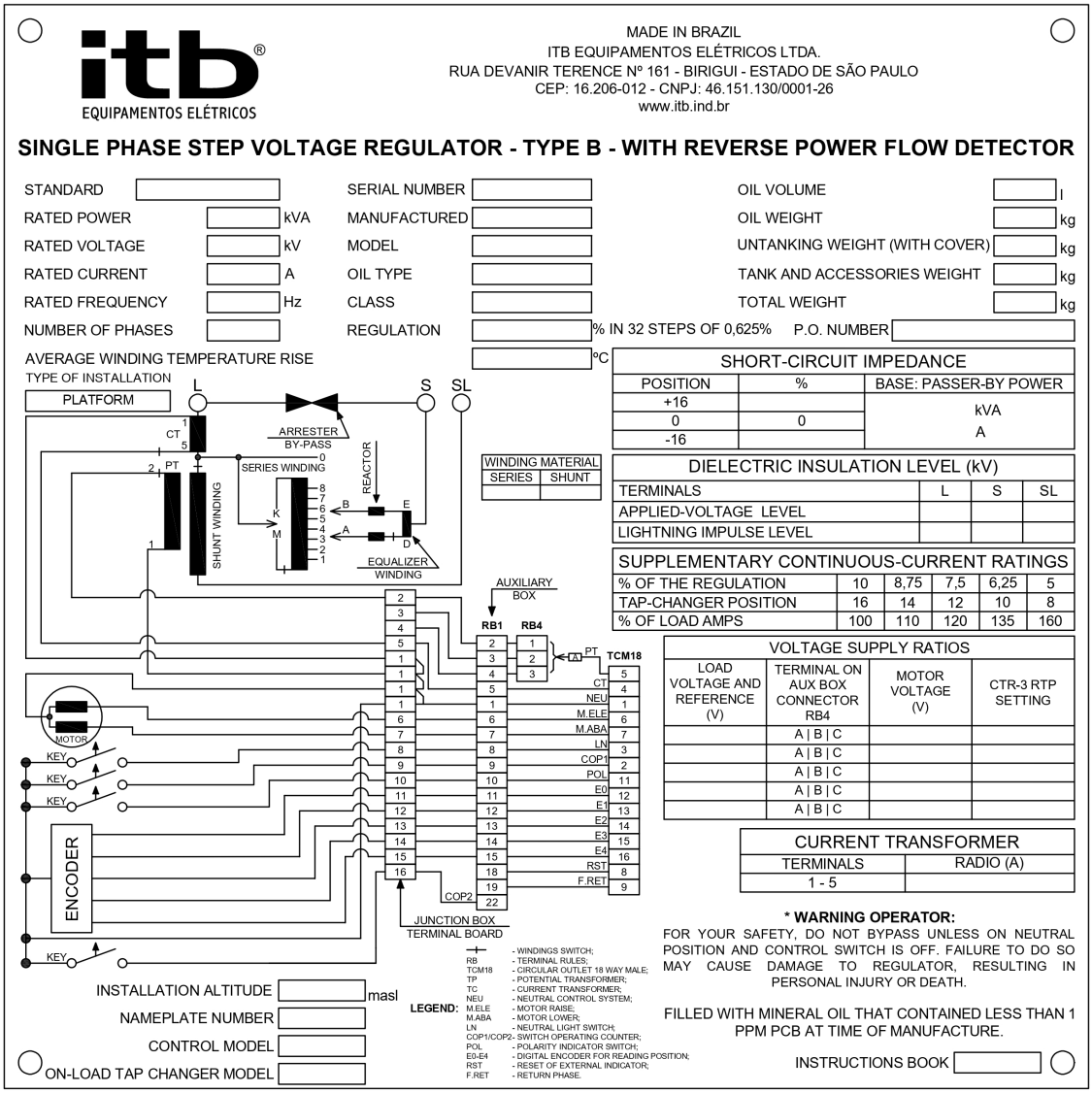
Identification plate

Before installation and operation, it is essential to read all data on the regulator nameplate. By default, each regulator has a nameplate, made of stainless steel, and affixed to the tank. In Figure 10, a typical model of this plate can be seen.

It brings data inherent to the regulator project, information necessary for the proper use of the equipment. It also has the serial number, manufacturing date, customer code (if applicable) and heritage (if applicable) engraved.

When contacting the technical support of ITB Equipamentos Elétricos Ltda., always have the serial number at hand, so that our team can consult all the information related to the equipment in question.

Figure 10: Typical nameplate.



Primary voltage adjustment

On all RAV-2 voltage regulator nameplates, there is a table titled PRIMARY VOLTAGE ADJUSTMENT. This table is specific for each type of control system, and brings the necessary changes that must be made so that the rated working voltage of the regulator is compatible with the rated voltage of the line to be regulated. It is necessary to observe:

- When the regulator has the auxiliary passage box, the adjustment must be made on the terminal identified with "A", which is connected to the RB4 terminal block, located on the printed circuit board called PCI CTR-3 - P4 – AUXILIARY. This adjustment may vary between positions 1, 2 or 3 of the ruler;
- When the regulator has the single-phase control model CTR-2, without a circuit board inside (old version of the box), and the compensation PT, the adjustment must be made on the terminals identified with "A", "B" and "C" on the main terminal block of the box. Adjustment "A" may vary between positions 2, 3 or 4. Adjustments "B" and "C", between positions 30 to 35. If the control system does not have a compensation PT, only adjustment "A" must be performed, adjustments "B" and "C" must be kept in their original positions;
- When the regulator has the single-phase control model CTR-2, with a circuit board inside, and the compensation PT, the adjustment must be made on the terminals identified with "A", "B" and "C". Terminal "A" is connected to the RB4 terminal block, while the "B" and "C" terminals are connected to the RB5 terminal block. Both rulers are located on the printed circuit board labeled PCI CTR-P1 – FUNDO. Adjustment "A", may vary between positions 1, 2 or 3. Adjustments "B" and "C", between positions 1 to 8. If the compensation PT is not available inside the box, only the adjustment "A" must be performed, adjustments "B" and "C" must be kept in their original positions;
- When the regulator has the SEL-2431 single-phase control, the adjustment must be made on the terminal identified with "A", which is connected to the X1 ruler. Adjustment "A" may vary between positions 2, 3 or 4.

To adjust the nominal working voltage, proceed with the following steps:

1. Identify the correct position of the reconnect terminals to select the proper voltage;
2. Use a terminal screwdriver (1/8") to loosen the screws (old CTR-2 control box) or the spring (auxiliary box and CTR-2 control box) from the terminal strips;
3. Proceed with the necessary reconnections;
4. Tighten the screws or release the spring from the terminal strips. Check the connections!

NOTICE: If the regulator is energized and it is necessary to adjust terminals "B" and "C", referring to the compensation PT, open terminal "A" first, to avoid the risk of electric shock.

DANGER: If the regulator is energized and it is necessary to adjust the primary voltage, the operation must be carried out carefully, as there are several energized points inside the box.

NOTICE: If the regulator has the auxiliary junction box and single-phase control box CTR-2, the adjustment of the primary voltage must be performed only on the auxiliary junction box. Do not remove terminal "A" from its original position on the CTR-2 control box.

Rated power depending on altitude

Due to the effect of the reduction in air density due to the elevation of the installation's altitude, the temperature rise of the regulators is increased, since they depend on air to dissipate their losses. For this reason, in order to keep the temperature, rise limits within the projected, the regulators installed above 1,000 meters above sea level (m.a.s.l.), have a reduced rated power, as specified by the standards ABNT® NBR 11809 and IEEE Std C57.15™.

To determine the new nominal power value, a reduction factor of 0.4% is used for every 100 meters of elevation over 1,000 meters. **Example**: Regulators with their own rated power of 276 kVA and designed for a maximum altitude of 1,000 msnm, if installed at 2,000 msnm, will have their rated power reduced to 265 kVA, a reduction of 4%.

NOTICE: In order not to reduce the rated power of the regulator as a function of altitude, during the process of technical specification of the request for quotation, it is necessary to inform the altitude (in msnm) of installation of the regulators.

Inspections before installation

Before putting the regulator into operation, proceed with the following inspections:

1. Check if the voltage regulator selected is compatible with the characteristics of the network where it will be installed;
2. Make sure the oil level is below the minimum mark. In case of insufficiency, check for visible signs of leakage, if not, promote adequate replacement with compatible oil;
3. Inspect the bushings for damage or signs of leaks in the seals. If there is suspected infiltration, remove the inspection cap to check for traces of oxidation or water in the oil. Once infiltration is confirmed, contact ITB Equipamentos Elétricos Ltda. to indicate the appropriate procedure;
4. If the regulator remains stored for some time, check the dielectric strength of the oil in accordance with ABNT® NBR IEC 60156. If the value found is below 55 kV, filter the oil and proceed with additional tests in order to verify its integrity;
5. Check that there is no damage to the series lightning arrestor and its conductors;
6. Check if the regulator line terminal markings are in accordance with what is presented in the section: **Line terminal identification;**
7. Check the dielectric strength between the bushing terminals and the tank using a 5 kV megohmmeter. The minimum value read must be 1,000 MΩ at room temperature;
8. Check if the position indicator is free from damage and in the neutral position and, if not, proceed with the external power supply, functional test at low voltage and place the tap changer in the neutral position;
9. Check that the primary voltage adjustment is adequate for the line voltage that the regulator will work with, as indicated in the section: **Primary voltage adjustment;**
10. Check that all parameter settings are correctly programmed in the chosen control system, according to the pre-established commissioning script.

CAUTION: If there is a need to dry the active part or subject the oil to heated processes, make sure that the tap-changer does not reach temperatures above 90°C. This can damage the microswitches responsible for the on-load tap-changer signals.

NOTICE: Refer to the chosen control system manufacturer's manual for general details of its functions, adjustments and operation.

System connection possibilities

The voltage regulators RAV-2 from ITB Equipamentos Elétricos Ltda. can work in different system configurations, providing a wide possibility of connection and regulation. The type of connection of the regulator to the system will be decisive for the definition of its nominal voltage.

This manual will cover the following connection and adjustment possibilities:

- Single-phase regulation, phase-neutral, multi-grounded, one regulator, two-wire;
- Single-phase, phase-to-phase regulation, one regulator, two wires;
- Three-phase regulation, phase-to-phase, two regulators, three-wire open delta;
- Three-phase, phase-to-phase regulation, three regulators, three-wire leading closed delta;
- Three-phase regulation, phase-to-phase, three regulators, three-wire lagging closed delta;
- Three-phase regulation, multi-grounded phase-neutral, three regulators, four-wire star.

DANGER: Connect the source (F or S) terminal of the regulator to the source side of the system, and the load (C or L) terminal of the regulator to the load side of the system. For star connections, connect the common (FC or SL) terminal of the regulator to the system neutral. For delta connections, connect the common terminal (FC or SL) of the regulator to the load terminal (C or L) of the reference regulator. Incorrect connections can cause equipment damage, serious personal injury, and even death.

DANGER: If the common terminal (FC or SL) of the voltage regulator is open, that is, without reference, and is out of the the neutral position, depending on the load current, high voltages may be induced, which may cause damage to the equipment, serious bodily harm and even death. Therefore, DO NOT INSTALL automatic cutout devices (fuse or recloser) on the common terminal (FC or SL) of voltage regulators.

NOTICE: Connection diagrams show individual switches for bypass and disconnect functions. However, by-pass switches can be used on each regulator to perform simplified sequential operations.

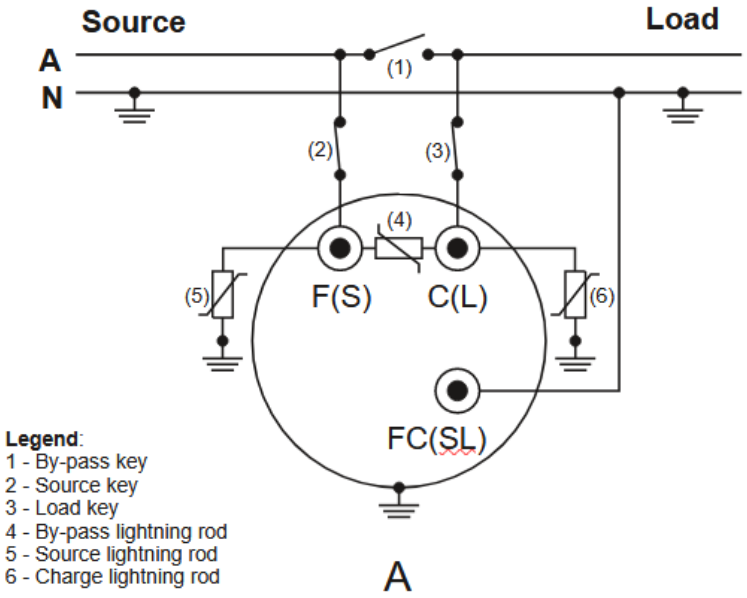
NOTICE: Check the manufacturer's manual of the chosen control system for general details of its functions, adjustments and operation for the correct treatment of power flow in the most diverse possibilities of connections.

Single-phase regulation between phase-neutral and multi-grounded

The single-phase, multi-grounded phase-to-neutral, one-wire, two-wire regulation is wired as shown in Figure 11 and has the following basic characteristics:

- Regulator rated voltage is equal to the system phase-neutral rated voltage;
- Maximum effective regulation of up to ±10% of the phase-to-neutral voltage;
- Current is measured in phase only;
- The difference between voltage and current will be 0º;
- It can regulate both directions of power flow, as long as the chosen control system is able to do so.

Figure 11: Phase-to-neutral single-phase line connection.



DANGER: Due to possible neutral fluctuation and excessive reference search operations, a regulator must not be installed in a one-wire circuit.

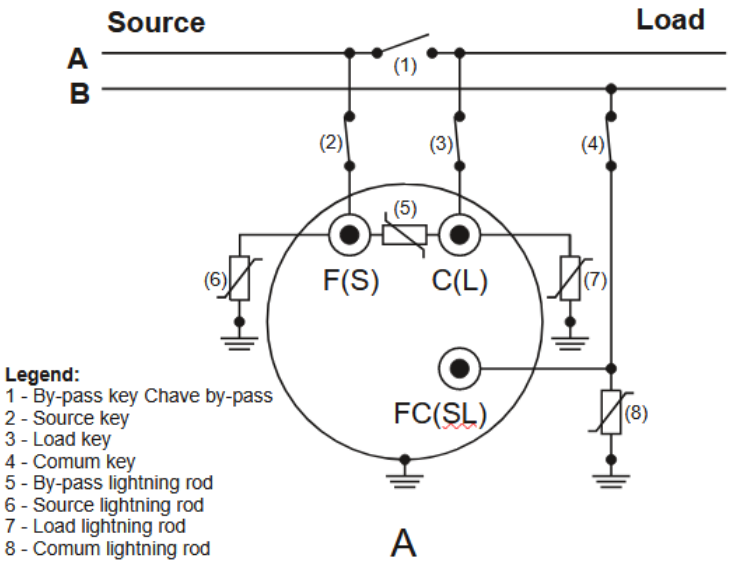
Single-phase regulation between phase-phase

The single-phase, phase-to-phase regulation with one regulator, two wires, is wired as shown in Figure 12 and has the following basic characteristics:

- Regulator rated voltage is equal to the system phase-to-phase rated voltage;
- Maximum effective regulation of up to ±10% of the voltage between phases;
- Current is measured in only one of the two phases;
- Difference between voltage and current will be -30 or +30º, depending on the phase sequence;

- It can regulate both directions of power flow, as long as the chosen control system is able to do so.

Figure 12: Phase-to-phase single-phase line connection.

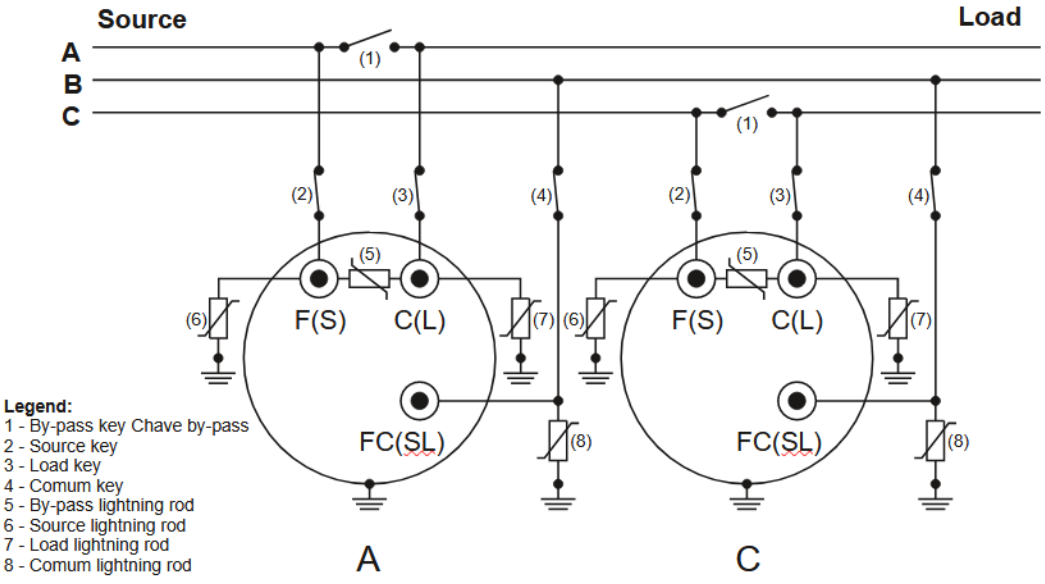


Three-phase regulation – open Delta

The three-phase, phase-to-phase, two-regulator, open delta, three-wire regulation is wired as shown in Figure 13 and has the following basic characteristics:

- Regulator rated voltage is equal to the system phase-to-phase rated voltage;
- Maximum effective regulation of up to ±10% of the voltage between phases;
- Current is measured in only two of the three phases;
- difference between voltage and current will be -30º for one regulator and +30º for the other.
- It can regulate both directions of power flow, as long as the chosen control system is able to do so.

Figure 13: Three-Phase Line Connection - Open Delta.

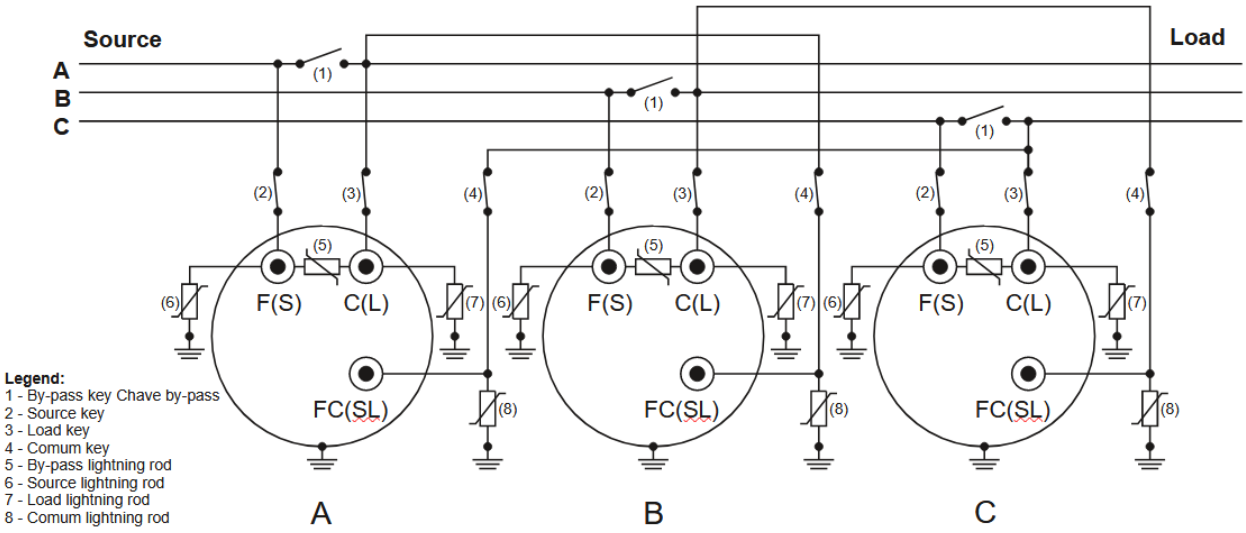


Three-phase regulation – Leading Delta closed

The three-phase, phase-to-phase regulation with three regulators, Leading closed delta, three wires, is wired as shown in Figure 14 and has the following basic characteristics:

- Regulator rated voltage is equal to the system phase-to-phase rated voltage;
- Maximum effective regulation of up to ±15% of the voltage between phases;
- The current is measured in the three phases;
- The difference between voltage and current will be +30º, for all regulators;
- When the control system chosen is of the single-phase type, and it is able to do so, it is possible to regulate both directions of the power flow, as long as the reverse flow is caused by a small generator system (cogeneration);
- When the control system chosen is of the single-phase type, and this is able to do so, to regulate the reverse flow of power caused by the closing of ring networks, or by switching the main sources, the use of an independent external PT will be mandatory. This PT must have its primary connected between the source terminal (F or S) of the regulator that will use its reference and the source terminal (F or S) of the reference phase regulator. Understood as reference phase, the phase where the common terminal (FC or SL) of the regulator is connected, thus respecting and maintaining the same phase sequence and polarity. The secondary terminal of the PT must be connected to the additional voltage signal input of the chosen control system.

Figure 14: Three-Phase In-Line Connection – Leading Closed Delta



NOTICE: The independent external PT for measuring the voltage between phases on the source side is optional, if necessary, specify it during the quote request process.

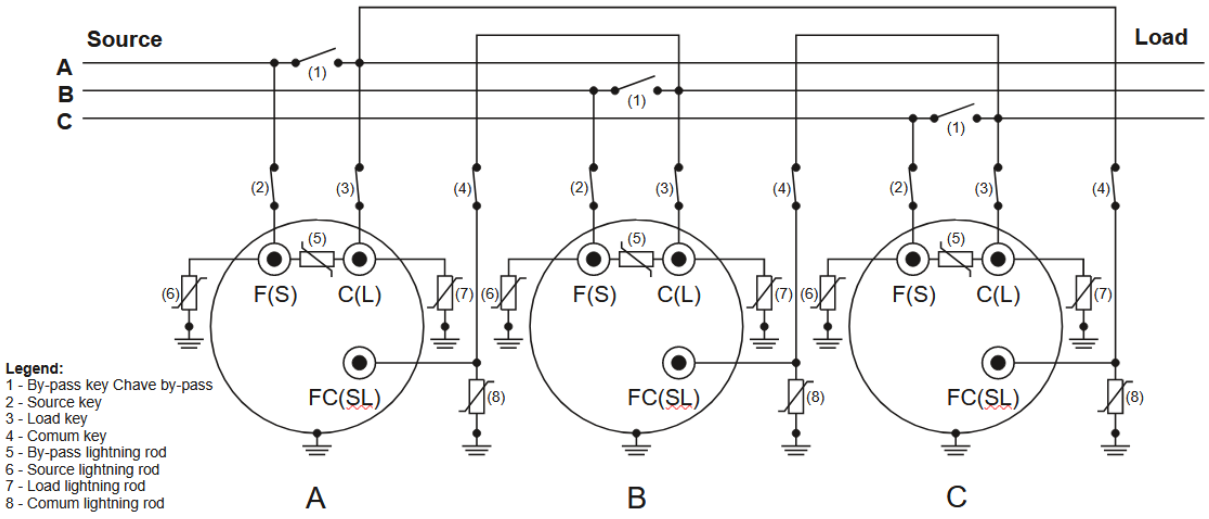
NOTICE: When using the three-phase control, model CTR-3, there is no need to use the independent external PT to regulate the bidirectional flow in a closed delta connection.

Three-phase regulation – Lagging closed delta

Three-phase, phase-to-phase, three-regulator, lagging closed delta, three-wire regulation is wired as shown in Figure 15 and has the following basic characteristics:

- Regulator rated voltage is equal to the system phase-to-phase rated voltage;
- Maximum effective regulation of up to ±15% of the voltage between phases;
- Current is measured in all three phases;
- The difference between voltage and current will be -30º, for all regulators;
- When the control system chosen is of the single-phase type, and it is able to do so, it is possible to regulate both directions of the power flow, as long as the reverse flow is caused by a small generator system (cogeneration);
- When the control system chosen is of the single-phase type, and this is able to do so, to regulate the reverse flow of power caused by the closing of ring networks, or by switching the main sources, the use of an independent external PT will be mandatory. This PT must have its primary connected between the source terminal (F or S) of the regulator that will use its reference and the source terminal (F or S) of the reference phase regulator. Understood as reference phase where the common terminal (FC or SL) of the regulator is connected, thus respecting and maintaining the same phase and polarity sequence. The secondary terminal of the PT must be connected to the additional voltage signal input of the chosen control system.

Figure 15: Three-Phase Line Connection - Lagging Closed Delta.



NOTICE: The independent external PT for measuring the voltage between phases on the source side is optional, if necessary, specify it during the quote request process.

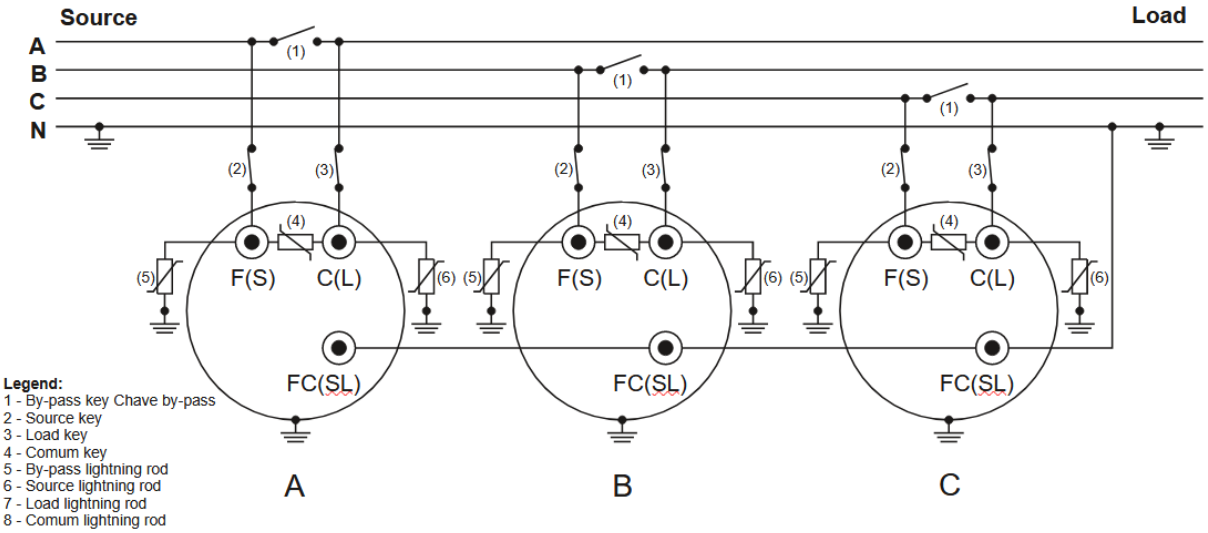
NOTICE: When using the three-phase control, model CTR-3, there is no need to use the independent external PT to regulate the bidirectional flow in a closed delta connection.

Three-phase regulation – multi-grounded star

The three-phase, phase-to-neutral, with three regulators, multi-grounded star, four wires, is wired as shown in Figure 16 and has the following basic characteristics:

- Rated voltage of the regulator is equal to the rated phase-neutral voltage of the system;
- Maximum effective regulation of up to ±10% of the voltage between phase-neutral;
- Current is measured in all three phases;
- The phase shift between voltage and current will be 0º for all regulators;
- It can regulate both directions of power flow, as long as the chosen control system is able to do so.

Figure 16: Three-phase line connection - multi-grounded star.



DANGER: Due to possible fluctuation of neutral and excessive operations in search of reference, three regulators in star connection must not be installed in three-wire circuits.

Independent external PT connection

When there is a need for regulation in both directions of power flow, with single-phase voltage regulators installed to the three-phase electrical system through the closed delta connection, and the use of the single-phase voltage regulator control system, is mandatory the use of an external PT independently linked between regulators' sources.

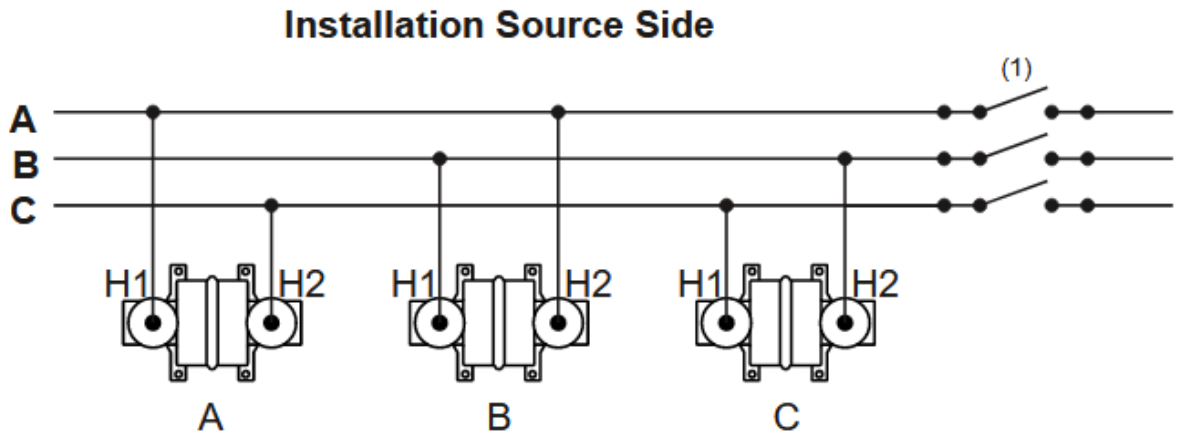
The following topics will illustrate the primary connections of this independent external PT to the delta-connected banks of regulators. The secondary connections of the PT must be in accordance with the recommended by the manufacturer's manual of the chosen control system.

NOTICE: If the independent external PT is provided by ITB, connect the terminals X1 (phase) and X2 (neutral), of its secondary, in the single-phase voltage regulator control of the corresponding phase.

closed Leading Delta-Connected Regulators

Figure 17 details the connection of the independent external PT, for measuring the voltage on the source side of the regulators, in a Leading Delta-Connected Regulators

Figure 17: Independent external PT connection – Delta Leading Delta-Connected Regulators.

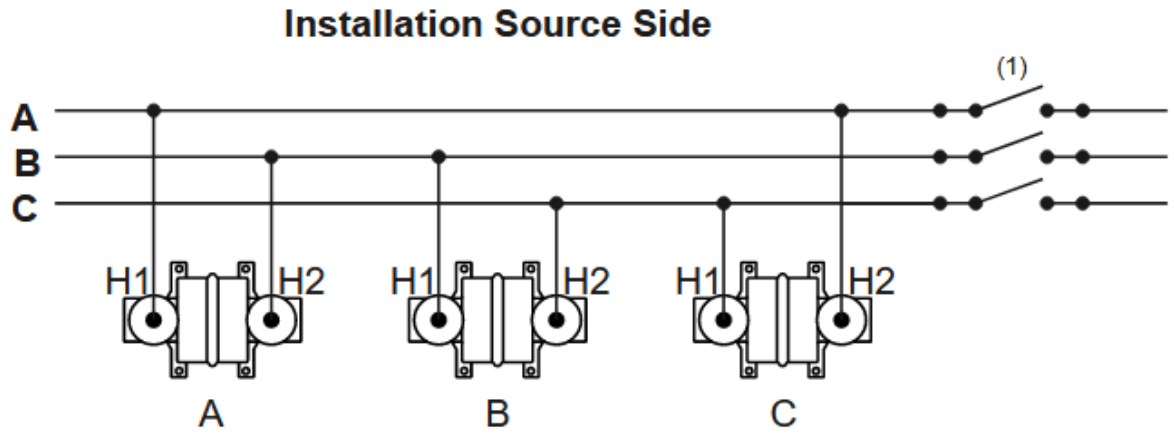


Legend:
1 - Regulators by-pass switches

Banks in Lagging Delta-Connected Regulators

Figure 18 details the connection of the independent external PT, for measuring the voltage on the source side of the regulators, in a Lagging Delta-Connected Regulators.

Figure 18: Independent external PT connection – lagging closed delta bank.



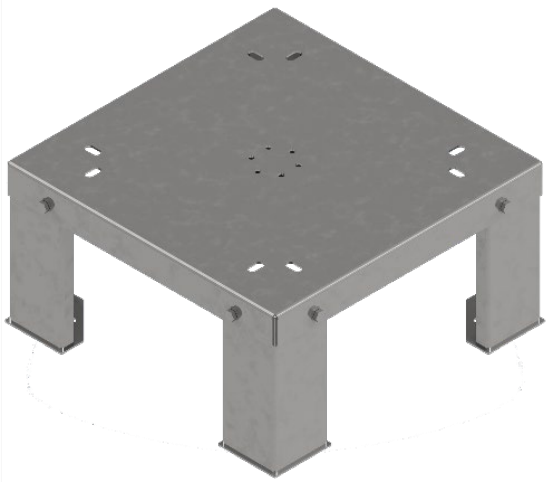
Legend:
1 - Regulators by-pass switches

Mounting, fixing and support

Regulators with a total mass of up to 1,500 kg can be installed both on platforms and on poles. Above this weight, we recommend mounting exclusively on platforms. In either case, they must remain leveled.

If required as a special accessory, the mounting and fixing of the regulators can be carried out on an elevated structure to simplify installation in substations, where a specific spacing between phase and ground is required. Figure 19 details the standard geometry of an elevation structure.

Figure 19: Elevating base for substation.



Regulators are designed to operate in the weather and rely on ambient air for cooling. Although sheltered installations can be used, they must have sufficient ventilation and free space to allow operation, inspection and maintenance of the equipment. For more information, consult ABNT® NBR 14039.

Grounding in bank of regulators

Proper grounding for a bank of single-phase voltage regulators must ensure ground resistance in accordance with ABNT® NBR 14039.

DANGER: Do not put into operation banks of regulators with high ground resistance. The possible potentiation of the frame or the common terminal (star bank) of the equipment can generate failures in the absorption of atmospheric surges or transitory maneuvers, causing damage to the equipment, serious bodily injuries and even death.

Bank of regulators in cascade

We define cascade regulation as the series installation, on the same feeder, of two or more banks of regulators. Under these conditions, problems of operational interaction between the banks may arise, which must be carefully examined to determine their adjustments and installation locations, under penalty of causing large voltage fluctuations in the network.

For a correct analysis of cascade regulation, it is necessary to take into account that changes in the taps of the regulators are perceived both downstream, by changing the voltage, and upstream, by changing the current.

In the case of delta connections, there is still an additional complicating factor, as there are current deviations between phases at the point, in the network, where each bank is installed, and their effect depends on the switch position, the passing currents and the impedances of the network up to that point.

Overvoltage effect due to fault

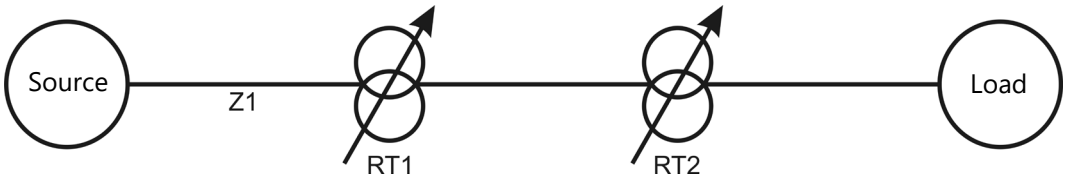
A distribution network where N banks are installed in cascade, can find itself in a critical condition in which all regulators of all banks are promoting maximum elevation, that is, 15%, for delta connection. If, in this condition, there is a power failure, at the time of return and for a few moments, the loads would be off, but the switch positions would still be maintained as they were at full load. As the losses would be smaller, overvoltages of up to 1.15N times the rated voltage may occur on the load of the last bank.

NOTICE: In order to avoid this problem, we recommend using the three-phase control CTR-3 equipped with a no-break system (UPS), which has the capacity to neutralize a voltage regulator bank in the event of a power failure.

Effect of excess operations (avalanche)

Analyzing the operation of 2 banks of regulators, RT1 and RT2, connected in series as shown in the diagram in Figure 20, we can see that the most downstream bank, RT2, perceives any tap switching of the most upstream bank, RT1, by the variation that this promotes in tension. It is also observed that RT2 tap changes will be perceived by RT1, due to the variation it promotes in the current. The current variation, as a function of the network impedance from the source to RT1, Z1, causes variation in the voltage of RT1.

Figure 20: Regulators bank in cascade



Changing the taps of one of the RT2 regulators in order to raise, for example, can cause a current increase that causes, in the regulator of the same phase of the RT1 bank, a difference in level greater than the insensitivity programmed in it. If this occurs, the RT1 regulator control will detect this unevenness and correct it by switching the tapes in the upward direction. This commutation in RT1 will increase the phase voltage and the control of one of the RT2 regulators will measure this elevation, which may be greater than its insensitivity and, therefore, will cause commutations in the sense of lowering the voltage, restarting the interaction cycle.

What then happens is a large number of operations sequenced between the serial regulators, which we call an avalanche of operations. This interaction presents voltage and current variations along the network of increasing amplitude, which may reach harmful levels of unbalance between phases, triggering the protection system due to high neutral current.

For delta banks, the avalanche can occur between different phases and with greater intensity and frequency because of the greater regulation and interaction between phases.

Coordination of insensitivity eliminates the possibility of avalanche of operations.

NOTICE: Banks of voltage regulators connected in series (cascade) must have a coordinated timing function in order to minimize interactions between them (switching avalanche). It is recommended that the regulator closest to the source respond to variations in less time and the others, downstream of the circuit, have timing adjustments with a minimum difference of 15 seconds more than their predecessor.

Line terminal connections

Connections to the line terminals of the regulators must be carried out in such a way that the rated voltage between the load (C or L) and common (FC or SL) terminals does not exceed the rated value indicated on the nameplate.

The cable connections in the bushings must be tight enough to eliminate any possibility of bad contact and hot spot between terminal and cable.

The cables and terminations must be sufficiently flexible to prevent mechanical efforts caused by wind, by the expansion and contraction of networks, cables and terminations, from impacting the regulator terminals, since such impacts can damage the porcelain of the insulators, as they are, these are very limited in terms of resistance to shocks, blows and mechanical stress in general. For the same reason, the direct connection of the network to the regulator terminals is not allowed without the intermediation of supports for the connection cables to the bushings.

CAUTION: During assembly and connection, no mechanical stress can be transmitted to the porcelains and their conductive rods. Such an effort can cause loosening of internal connections and ruptures in sealing and insulation elements, causing poor contact, heating, rupture of conductors, insulation rupture, oil leaks and loss of electrical insulation.

Putting into operation

If the regulators are assembled with the switchgear as suggested in the **System connection possibilities** section of this manual, commissioning can be done without interrupting the power supply.

The procedures described below are extremely important to make sure that the regulator is ready to be connected to the system.

DANGER: EXPLOSION HAZARD. Before putting into operation, the voltage regulator MUST BE IN NEUTRAL POSITION. The confirmation of the position reading must be done in at least two references, the external position indicator and the chosen control system indication. If the regulator is out of the neutral position during this operation, the series winding will short circuit, causing equipment damage, serious personal injury and even death.

To put the regulator into operation, follow the sequence below:

1. From the nameplate check that the control circuit is configured for the proper voltage;
2. Place the control system main switch in the "**OFF" position**;
3. For regulators connected between phases, **CLOSE** the switch that connects the **COMMON TERMINAL (FC or SL)**;
4. In sequence, **CLOSE** the switch that connects the **SOURCE TERMINAL (F or S)**. The regulator will be excited, but without load;
5. Place the main switch of the control system in the **NORMAL (INTERNAL)** position;
6. Enable **MANUAL** engine command in the chosen control system. Use the **UP** or **DOWN** buttons to operate the switch two or three steps. Then return the switch to the **NEUTRAL POSITION**. When in neutral, check the redundancy of this position: the external indicator will indicate 0 (zero) and the neutral position LED of the chosen control system will light up;
7. With the regulator in the neutral position, place the control system main switch in the **OFF** position;
8. **CLOSE** the switch that connects the **LOAD TERMINAL (C or L);**
9. **OPEN** the **BY-PASS** switch. The regulator will be fully energized;
10. If available, open the current signal short circuit knife switch, see section: CT short circuit;
11. Place the main switch of the control system in the **NORMAL (INTERNAL)** position;
12. If the control system is configured, switch to **AUTOMATIC** operating mode.

NOTICE: STEP 5. Switches that make, in a single operation, source opening, load opening and by-pass closing, do not allow this step and the prior confirmation of the neutral position of the regulator without the use of additional resources.

CAUTION: STEP 5. Some select control systems have Auto Zero function. Even so, due to the risk of a maneuver out of position, although this function is automatic, the sequence of changing positions, its logical order and the reach of the neutral position must be monitored by the operator.

Checking operation and regulation

Before closing the switch that connects the load terminal (C or L) and opening the by-pass switch, according to steps **8** and **9**, respectively, of the section **Putting into operation**, it is possible to check the operating capacity and regulation of the chosen control system.

To perform the test for the need to raise voltage at the regulator output, proceed as follows:

1. Enable the **MANUAL** command of the engine in the chosen control system;
2. Press the electronic control LOWER key until the control leaves the regulated voltage range. This will be identified by the out-of-band LED lighting up;
3. Set the control for operation in **AUTOMATIC** mode;
4. Wait for the time programmed in the first switching time delay function to end;
5. The commutation must be started, in the sense of raising positions, to return the voltage profile value to within the programmed bandwidth;

6. Once in-band, the out-of-band LED will turn off;
7. Return to step **6** of the **Commissioning section**.

To perform the test for the need to lower voltage at the regulator output, proceed as follows:

1. Enable the **MANUAL** command of the engine in the chosen control system;
2. Press the electronic control **RAISE** key until the control leaves the regulated voltage range. This will be identified by the out-of-band LED lighting up;
3. Set the control for operation in **AUTOMATIC** mode;
4. Wait for the time programmed in the first switching time delay function to end;
5. Switching must be initiated, in the sense of lowering positions, to return the voltage profile value to within the programmed bandwidth;
6. Once in-band, the out-of-band LED will turn off;
7. Return to step **6** of the **Commissioning section**.

NOTICE: To avoid subjecting the line to voltage variations, the tests presented in this section must be carried out with the load terminal (C or L) of the regulator disconnected and the by-pass switch closed.

NOTICE: Check the chosen control system manufacturer's manual for general details of its functions, adjustments and operation.

Withdrawing from operation

The procedures described below are extremely important to make sure that the regulator is ready to be removed from the system. Withdrawal from service can be done without interrupting the power supply.

DANGER: EXPLOSION HAZARD. Before taking out of service, the voltage regulator MUST BE IN NEUTRAL POSITION. The confirmation of the position reading must be done in at least two references, the external position indicator and the chosen control system indication. If the regulator is out of the neutral position during this operation, the series winding will short circuit, causing equipment damage, serious personal injury and even death.

To remove the regulator from operation, proceed in the following sequence:

1. Enable the **MANUAL** command of the engine in the chosen control system;
2. Use the **UP** or **DOWN** buttons to reach the **NEUTRAL POSITION**. When in neutral, check the redundancy of this position: the external indicator will indicate 0 (zero) and the neutral position LED of the chosen control system will light up;
3. Place the control system main switch in the **OFF** position;
4. If available, close the current signal short circuit knife switch, see section: **CT short circuit**;
5. **CLOSE** the **BY-PASS** switch;
6. **OPEN** key connecting **LOAD TERMINAL (C or L);**
7. **OPEN** switch connecting **SOURCE TERMINAL (F or S);**
8. For regulators connected between phases, **OPEN** the switch that connects the **COMMON TERMINAL (FC or SL).**

CAUTION: STEP 1. Some select control systems have Auto Zero function. Even so, due to the risk of a maneuver out of position, although this function is automatic, the sequence of changing positions, its logical order and the reach of the neutral position must be monitored by the operator.

CAUTION: STEP 1. Perform the by-pass of a voltage regulator with the line energized only when the NEUTRAL POSITION reach is certain, through the recommended methods of verifying this reach, for at least two redundancies. If this reliable indication is not available, and there is doubt about the real position of the tap changer, the line must be turned OFF to avoid the short circuit of the regulator.

CONSTRUCTION DETAILS AND CONNECTIONS

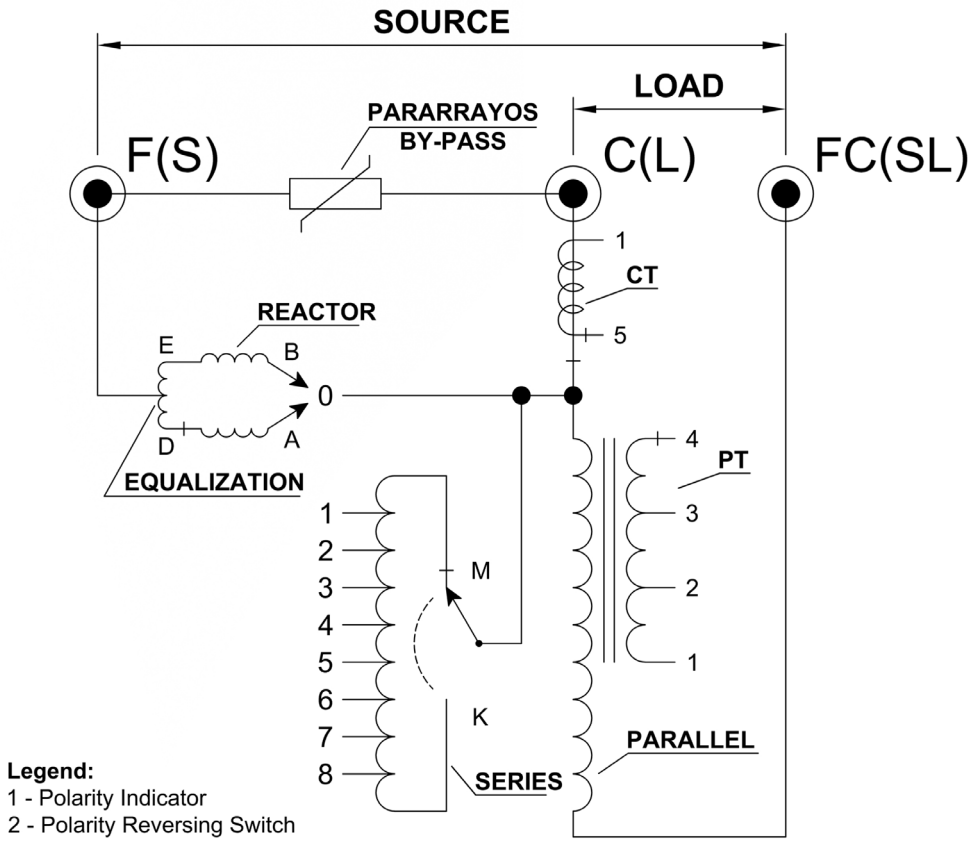
The voltage regulators RAV-2 from ITB Equipamentos Elétricos Ltda. they were designed to be partially or completely removed from the inside of the tank without the need for electrical disconnections, facilitating their maintenance. See section: **Removing the active part of the tank.**

The main winding and the transition reactor assembly have a shell type assembly. The parallel winding is connected to the load side, according to Type B of ABNT® NBR 11809 or IEEE Std C57.15 TM standards.

Winding connection diagram

Figure 21 details the standard circuit of a RAV-2, Type B regulator, which has the parallel winding on the load side.

Figure 21: Winding connection diagram – Type B Voltage Regulator.



Internal arrangement of components

The internal construction of the regulator is made in a unitary way, where all components are fixed directly on the main cover of the regulator. This construction method facilitates its manufacture and maintenance. The details of the arrangement of each internal component can be seen in Figure 22 and Table 9.

NOTICE: The following details are not intended to cover all internal construction possibilities of a voltage regulator. Details intrinsic to each project must be consulted during the technical feasibility analysis and purchase order approval phase.

Figure 22: Internal components of the RAV-2 regulator.

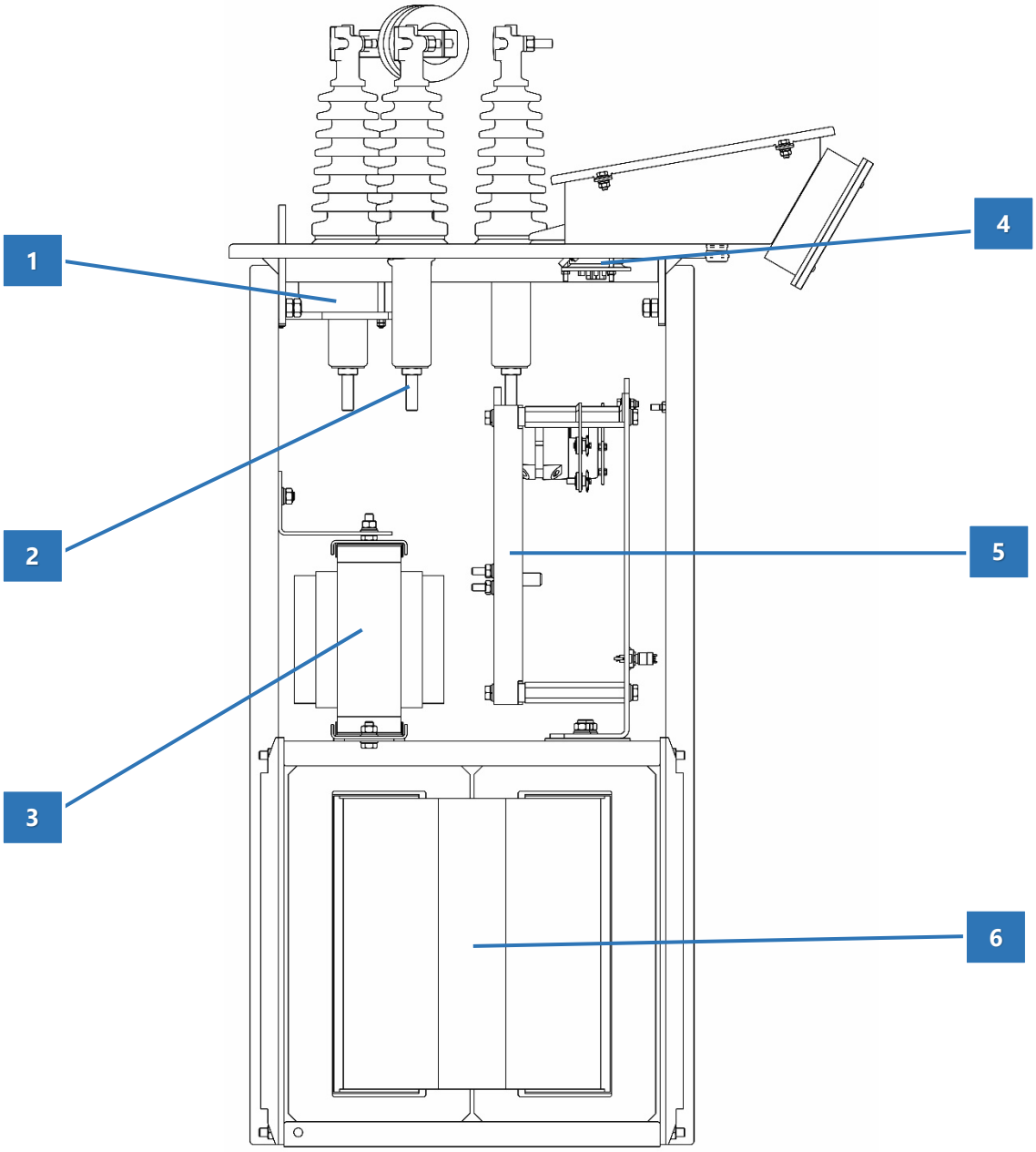


Table 9: RAV-2 Regulator Internal Components.

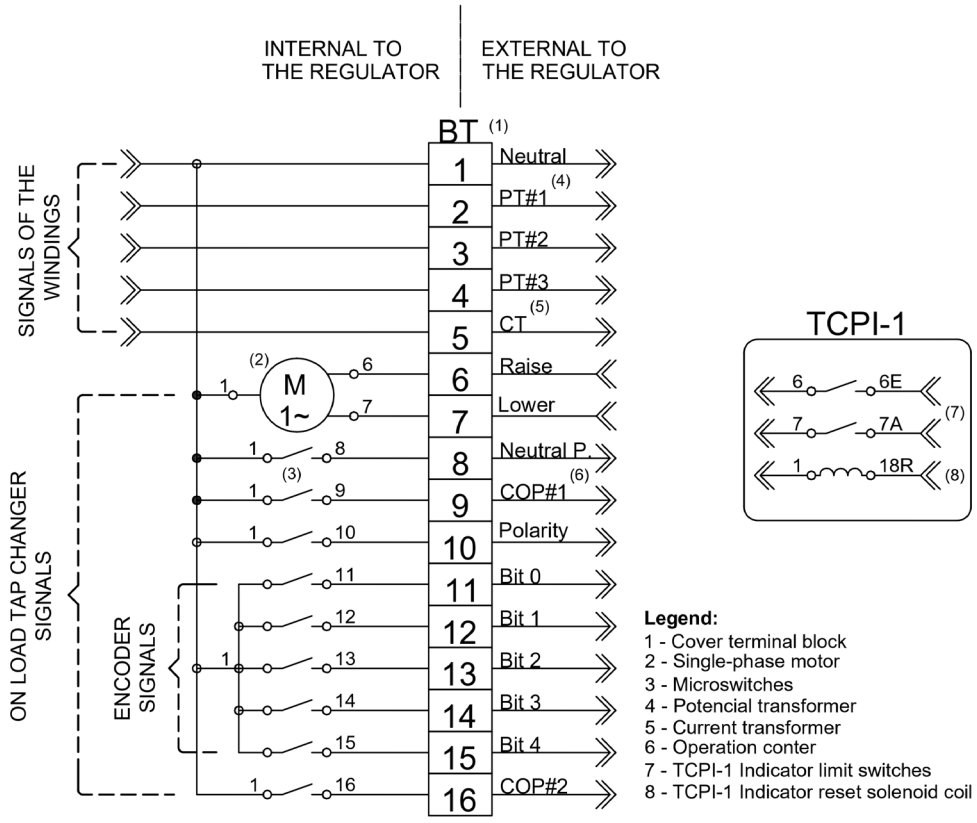
Item	Description
1	Current Transformer (CT)
2	Connection terminals of the bushings
3	Transition reactor
4	Control signal pass-through terminal block
5	On-load tap-changer
6	Main winding (potential transformer (PT), parallel, series, equalization)

Standardized internal wiring diagram

As shown by item 4 of Table 9, by default, all RAV-2 voltage regulators have a pass-through terminal block for control system signals on their cover. This block has a body made of insulating material, resistant to pressure and working temperature, the passage terminals are made of brass. The standardized details of its connection to the internal wiring are shown in accordance with Figure 23.

NOTICE: The following detailing is not intended to cover all internal wiring possibilities of a voltage regulator. Details intrinsic to each project must be consulted during the technical feasibility analysis and purchase order approval phase.

Figure 23: Standardized internal wiring diagram.



Windings

All RAV-2 voltage regulators have at least three sets of independent windings, as follows:

1. A larger set, arranged in the lower part of the regulator, which concentrates the potential transformer (PT), the parallel winding, the series winding and the equalization winding;
2. A winding fixed on top of the main winding which is the transition reactor;
3. A toroidal winding, fixed over the reactor or on the underside of the regulator cover, which is the current transformer (CT).

Each of these windings is built and interconnected according to specific project characteristics, which may vary depending on their application and conditions of use.

Tap-changers

ITB Equipamentos Elétricos Ltda. has a wide range of on-load tap changers, which are manufactured and tested according to ABNT® NBR 8667 and IEEE Std C57.131 TM standards.

The tap-changers used in each project are defined by the voltage and nominal current of the required regulator.

PREVENTIVE MAINTENANCE

The voltage regulator was designed to allow some verification items to be carried out without having to take it out of operation. Maintenance, methodically followed, is an essential factor for the long life of the voltage regulator, in the best operating and performance conditions.

Periodic inspections and maintenance

We recommend that maintenance be carried out periodically, in order to extend the useful life of the equipment. Table 10 and Table 11recommend periodicities (in years), checkpoints, procedures and necessary corrections for the voltage regulator control and for the regulator accessories, respectively. However, the period for these inspections may vary, according to the experiences accumulated by the user.

Table 10: Periodic maintenance for the regulator control.

Period	Checkpoints	Procedure or Item of Verification	Correction
1	Manual activation and maximum and minimum blocking	1. Adjust the position lock and operate the regulator in the upward direction, check that the control raises the position, stopping at the adjusted lock; 2. Adjust the position lock and operate the regulator in the down direction, check that the control lowers position, stopping at the adjusted lock.	Remove control from service and return for maintenance
1	Reference Voltage (Calibration)	1. With the regulator powered, set the compensation (LDC) to 0 V and bandwidth to 1 V: Check if the output voltage of the "VOLTMETER" is equal (±1 V) to the reference after stabilized.	Remove control from service and return for maintenance
1	Automatic regulation	1. Vary the value of the reference voltage to a voltage higher than the net voltage: Check if the motor drives in the RAISE direction after the set time has elapsed; 2. Vary the value of the reference voltage to a voltage lower than the net voltage: Check if the motor drives in the LOWER direction after the set time has elapsed.	Remove the control from service and return it for maintenance.

NOTICE: If the regulator does not operate satisfactorily, a replacement control can be tested before removing the regulator from service.

Table 11: Periodic maintenance for accessories.

Period	Checkpoints	Procedure or Item of Verification	Correction
1	Bushings and terminals	1. Crack in porcelain; 2. Accumulation of impurities in porcelain; 3. Oil leakage; 4. Thermal inspection of terminals.	1. Replace bushing; 2. Wipe with a cloth containing ammonia or carbon tetrachloride and apply a neutralizer; 3. Retighten the joints, or replace the bushing; 4. In case of excessive heating, retighten the terminals when they are loose.
1	Lightning rod	1. Agglomeration of impurities; 2. Thermal inspection.	1. Wash with fresh water and dry with a dry cloth; 2. In case of excessive heating of the terminals, proceed with retightening when they are loose. In case of current conduction, replace the lightning rod.
1	Oil level indicator	1. Crack in the glass display; 2. Oil leak.	1. Replace the display glass; 2. Retighten the gaskets, or replace the sight glass.
1	Drain valve	1. Oil leakage.	1. Retighten or replace drain valve.

DANGER: For safe operation, the verifications shown in Table 11 must be carried out with the equipment out of operation. Use suitable PPE and prevent leaks into the environment.

NOTICE: If repairs cannot be performed in the field, remove the regulator from service and send it in for maintenance.

Mineral insulating oil is used in the regulator to serve two basic functions, insulation and cooling. Monitoring and maintaining oil quality is essential to ensure reliable operation throughout the life of the regulator.

In view of this, we recommend the need for field tests, as shown in Table 12. The tests were typically chosen to obtain a quick estimate of the condition of the oil and to eliminate any possibility of alteration of the sample due to transport to external tests.

Table 13 presents limit values for oil in regulators in use.

Table 12: Periodic maintenance for insulating oil.

Period	Checkpoints	Procedure or Item of Verification	Correction
1	Withdraw sample of insulating oil	Physical-chemical test: 1. Appearance; 2. Dielectric strength; 3. Water content; 4. Loss factor; 5. Neutralization index; 6. Interfacial tension; 7. Flash point; 8. Sediments.	Remove the regulator from service and send it to maintenance if the values found are outside those shown in Table 13.

NOTICE: The sample collected must have a representative volume compared to the oil contained in the equipment. Careless sampling procedures or contamination in the sample container can lead to erroneous conclusions regarding oil quality.

Table 13: Limit values for mineral oil in use.

Tests	Test Method	Acceptance Criteria
Appearance	Visual	Clear, free of suspended materials
Dielectric strength, kV, cap electrode	ABNT® NBR IEC 60156	≥55
Water content, mg/kg	ABNT® NBR 10710	≤40
Loss factor, % at 25 °C at 90 °C at 100 °C	ABNT® NBR12133	 ≤0,5 ≤15 ≤20
Neutralization index mg KOH/g	ABNT® NBR 14248	≤0,20
Interfacial tension at 25°C, mN/m	ABNT® NBR 6234	≥20
Flash point, °C	ABNT® NBR 11341	≥130
Sediments	ABNT® NBR 10576	No sediment or precipitable sludge should be detected. Results lower than 0.02% by mass should be discarded

Removing the active part of the tank

Instructions for safely removing the active part of the regulator from the tank are listed by the following procedure:

1. Remove the regulator from service, following the safety instructions as presented in the section: **Removing from Operation**;
2. Place the regulator in a position where the energized net cannot interfere. It is recommended that the equipment be taken to a maintenance workshop, or somewhere covered, free from high humidity, with a flat and level floor;
3. Wait until the temperature of the insulating oil is less than 40°C;
4. Remove the screws that secure the chosen control system to the main tank;
5. Remove the grounding conductor connected between the control box and the regulator tank;
6. Remove the screws that secure the cover to the tank;
7. Remove the grounding conductor connected between the cover and the regulator tank;
8. Be careful not to damage any device that may be installed in the tank during the removal of the active part;
9. Suspend the active part through the cover eyes, guiding the control box that will be lifted with the cover.

CAUTION: STEP 8. Before removing the active part from the inside of the tank, regulators that have a thermometer, oil level with contacts, or any other accessory that accesses the inside of the regulator, the following procedure must be performed: 1) remove the oil insulation until its level is below the minimum marking on the level indicator device and then 2) remove the accessories. Failure to follow these instructions will cause devices to break, resulting in oil leakage.

CAUTION: STEP 9. Do not rely on the active part lifting device for inspection and maintenance. Place a wedge between the cover and the tank to prevent the cover from lowering with the active part, causing equipment damage, serious personal injury and even death.

CAUTION: STEP 9. Do not lift the control box using its jumper cable to the regulator. The cable is not designed for such an operation and could break, causing equipment damage, serious personal injury and even death.

NOTICE: STEP 9. When opening the regulator, there is the possibility of human and environmental contact with the insulating oil. Use suitable PPE and prevent leaks into the environment.

Placing the active part back in the tank

After performing the services, the replacement of the active part inside the regulator tank must follow the following procedure:

1. If the active part stays out of the oil for more than two hours, dry it before proceeding;
2. Make sure the integrity of the insulation and tightness of all active part terminals;
3. Clean the sealing gasket and position it on the tank flange;
4. Suspend the active part with the lid above the height of the tank;
5. Align the side supports of the active part, fixed on the lid, with the guides inside the tank.
6. Proceed with lowering the unit. Note that there will be a gap between the lid and the tank, even with the active part sitting at the bottom of the tank;
7. Place the cover over the tank and fix all the set sealing screws;
8. Fix the grounding conductor connected between the cover and the regulator tank;
9. Fix the screws that fix the chosen control system to the main tank;
10. Fix the grounding conductor connected between the control box and the regulator tank;
11. Proceed with dielectric, electrical and functional tests.

CAUTION: STEP 1. Make sure that when drying the active part the temperature does not reach marks higher than 90°C.

NOTICE: STEP 6. If necessary, before fixing the cover screws, use a rubber hammer to help accommodate the cover over the tank, in order to avoid possible leaks.

CAUTION: If a new oil filling is necessary, it is recommended that after this process, the vacuum procedure be carried out in the equipment, for at least one hour and at least 100 mmHG. If it is not possible to carry out the vacuum process, do not energize the regulator before the period of seven days after filling.

On-load tap-changer

The on-load tap-changer is a simple device with a long service life, as long as the recommended maintenance, in Table 14, is followed.

Table 14: On-load tap-changer inspections.

Frequency - Number of operations	Recommended Action
125.000	1. Measurement of contact resistance (2,500 μΩ max.); 2. Visual inspection; 3. Analysis of the wear of fixed and moving contacts.
250.000	1. Replacement of fixed and mobile contacts; 2. Verification of the operation mechanism.
1.000.000	1. General review, disassembly and replacement of worn parts.

Resistance measurement test

The contact resistance measurement must be carried out by connecting the microhmmeter terminals between the shaft and slip ring terminals, the most central rods of the commutator insulating plate, identified by the letters A and B. In this condition, the resistance will be given by the association of the current position fixed contact, moving contact, shaft and slip ring. Measurements must be performed at all even positions.

For new tap-changers, measured values cannot exceed 800 μΩ. Due to the natural wear of the contacts, misalignment and gaps in the mechanisms gradually increase this resistance, we consider the value of 2,500 μΩ as the maximum acceptable limit for tap changers in operation.

Checkpoints

When performing periodic inspections of on-load tap changers, we recommend that the points below are always checked:

1. All nuts acting on brass tie rods must be tightened and torqued to 1.2 kgf.m;
2. The drive chain of the main system and the mechanical indication system must have a minimum gap of 15 mm and a maximum of 25 mm, proceed as follows:
    - Pull the current in the downward direction (do not finish the switching);
    - Check the gap in the upper center part of the chain between the crown and the pinion;
    - If the gap is not within 15 to 25mm (total range) adjust the position of the motor or indicator output.
3. ENCODER or STCMS rotor must be synchronized with the movable contacts in such a way that, in the nominal position, none of its contacts are closed, use the reference engraved on the circuit plate for such adjustment;
4. Test the mechanical locks, positions ±16, with the motor energized at 140 VAC;
5. Test the tap-changes of the polarity reversing switch with the motor energized at 95 VAC.

Estimated service life of contacts

It is possible to determine a projection of the life cycle of the tap changer contacts in function of the nominal load and number of operations.

This estimate, shown in Table 15, is based on RAV-2 regulators with on-load tap changers manufactured by ITB Equipamentos Elétricos Ltda.

Table 15: Life expectancy of contacts.

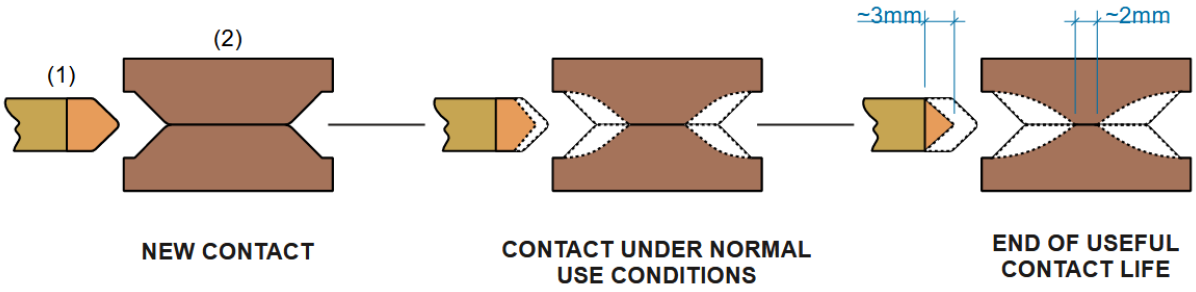
Charging % In	Number of Estimated Operations		
	Mobile Contact	Fixed Contact [Unit]	Fixed Contact [Set]
160	125.000	13.900	125.000
135	177.100	19.700	177.000
120	208.400	23.150	208.500
110	229.200	25.500	230.000
100	250.000	27.800	250.000
90	250.000	37.100	334.000
80	250.000	46.300	417.000
70	250.000	55.600	500.000
60	250.000	64.900	584.000
50	250.000	74.100	666.700
40	250.000	83.400	750.000
30	250.000	92.600	833.400
20	250.000	101.900	916.700
10	250.000	110.000	1.000.0000

NOTICE: Due to mechanical fatigue of the mobile contact compression springs, this contact must be changed after a maximum of 250,000 operations.

NOTICE: The life expectancy of the contacts, as shown in Table 15, does not exclude or limit the user's responsibility to carry out the preventive maintenance described in this instruction manual.

Figure 24 illustrates the projection of wear verified in the fixed contacts in mobile throughout the life of the on-load tap changer.

Figure 24: Contact wear.



LEGEND:
1 - Fixed contact
2 - Mobile contact

SPARE PARTS FOR REPLACEMENT

ITB Equipamentos Elétricos Ltda. is available to supply spare parts for all your equipment. This request can be made by calling +55 (18) 3643-8000, or by e-mail **vendas@itb.ind.br.** For this, if possible, have the ITB code and the description of the component at hand at the time of acquisition.

The complete list of components and accessories is divided into three parts: Tap-changer, Motor and Regulator. The details below are divided by item, description, ITB material code and their respective technical drawings (where applicable).

Tap changer CM-1, CM-1M, CM-2 or CM-2M

Figure 25 and Table 16: CM-1 and CM-2 on-load tap-changer parts list. list the main materials related to the CM-1 and CM-2 on-load tap changers, with their respective variables for the TCPI-1 mechanical indication system.

Figure 25: CM-1, CM-1M, CM-2 or CM-2M on-load tap-changer parts.

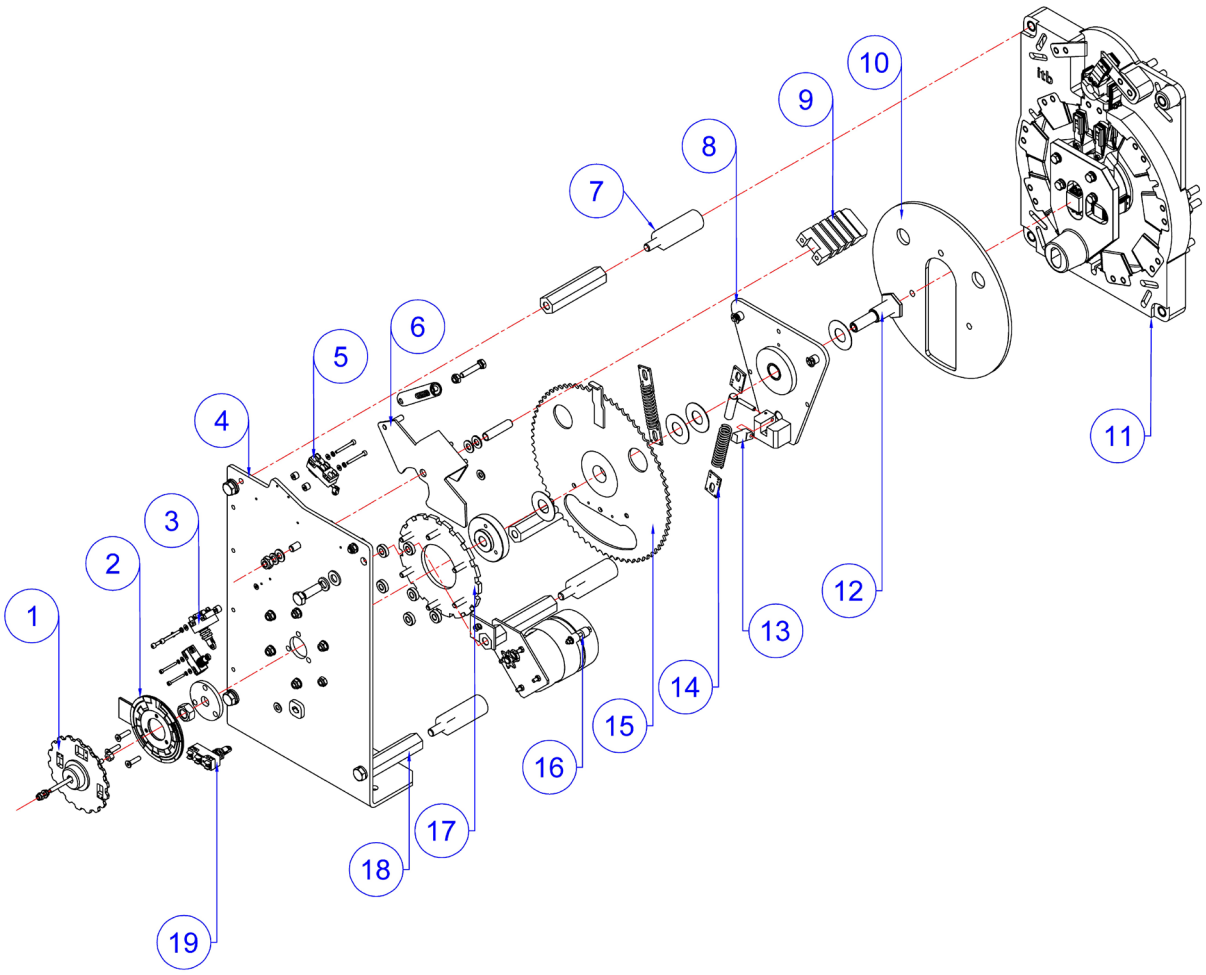


Table 16: CM-1 and CM-2 on-load tap-changer parts list.

Item	Description	Qty.	Code	Drawing
01	ENCODER cam and collector assembly	1	04.018.0997 04.019.0054	8.37.4374 8.37.0120
01	STCMS cam and collector set	1	04.018.0997 04.018.0998	8.37.4374 8.37.4375
02	ENCODER reading device	1	04.018.0299	8.37.2661
02	STCMS reading device		04.018.0996	8.37.4373
03	Operation counter micro switch	1	04.019.0180	N/A
04	Drive mechanism mounting plate	1	04.018.0277	8.37.0012
05	Polarity key micro switch	1	04.019.0179	N/A
06	Inverter switch driver	1	04.019.0090	8.37.0017
07	Mounting plate insulating separator (CM-2 and CM-2M)	4	04.019.0118	8.37.2913
08	Movable contacts trigger set (CM-1 and CM-1M)	1	04.006.0055 04.019.0023 04.019.0070 04.019.0079 04.019.0083 04.019.0084	8.37.0020 8.37.0019 8.37.0044
08	Movable contacts trigger set (CM-2 and CM-2M)	1	04.006.0055 04.006.0062 04.019.0023 04.019.0070 04.019.0079 04.019.0084	8.37.0019 8.37.0020 8.37.0044
09	Inverter switch trigger insulating arm (CM-1 and CM-1M)	1	04.019.0002	8.37.0083
09	Inverter switch trigger insulating arm (CM-2 and CM-2M)	1	04.019.0035	8.37.0082
10	Inertia disk	1	04.006.0098	8.37.1404
11	tap-changer mounted electrical plate	1	04.006.0063	N/A
12	Mechanism shaft	1	04.019.0020	8.37.0023
13	Positioner trigger	1	04.019.0071	8.37.0022
14	Drive spring assembly	1	04.019.0026 04.019.0027 04.019.0028	8.37.0054 8.37.0100 8.37.0285
15	Drive crown assembly	1	04.006.0056 04.019.0022 04.019.0023 04.019.0028 04.019.0068	8.37.0019 8.37.0020 8.37.0039 8.37.0040 8.37.0054
16	Drive motor (CM-1 and CM-1M)	1	07.004.0038	8.46.0008
16	Drive motor (CM-2 and CM-2M)	1	07.004.0044	8.46.0009
17	Positioning disk	1	04.019.0018	8.37.0021
18	Mounting plate separator (CM-1 and CM-1M)	4	04.019.0016	8.37.0013
18	Mounting plate separator (CM-2 and CM-2M)	4	04.019.0080	8.37.0013
19	Neutral position micro switch	1	04.019.0180	N/A
N/A	Roller chain 1/2" R1/8"	1	04.019.0030	N/A
N/A	Mechanical indicator crown (CM-1M and CM-2M)	1	04.019.0109	8.37.0914
N/A	Support, bushing and pinion for mechanical indicator (CM-1M and CM-2M)	1	04.018.1194 04.018.1195	8.37.0911 8.43.0007

Item	Description	Qty.	Code	Drawing
			04.018.1196 04.018.1197	8.43.0008 8.43.0009

CM-3M Tap-changer

Figure 26 and Table 17 list the main materials related to the CM-3M on-load tap changer.

Figure 26: Parts of the CM-3M On Load Tap Changer.

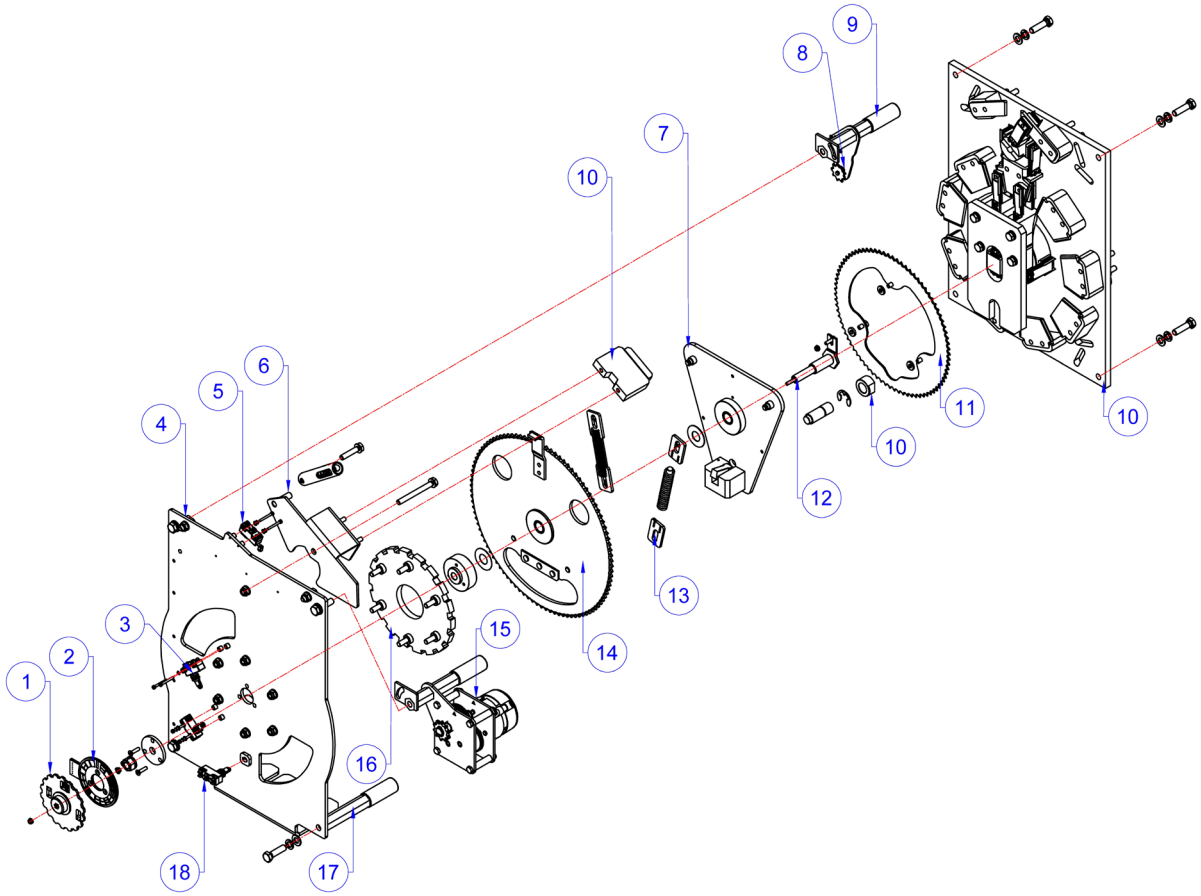


Table 17: CM-3M On Load Tap Changer Parts List.

Item	Description	Qty.	Code	Drawing
01	ENCODER cam and collector assembly	1	04.018.0997 04.019.0054	8.37.4374 8.37.0120
01	STCMS cam and collector set	1	04.018.0997 04.018.0998	8.37.4374 8.37.4375
02	ENCODER reading device	1	04.018.0299	8.37.2661
02	STCMS reading device		04.018.0996	8.37.4373
03	Operation counter micro switch	1	04.019.0180	N/A
04	Drive mechanism mounting plate	1	04.019.0139	8.37.3550
05	Polarity key micro switch	1	04.019.0179	N/A
06	Inverter switch driver	1	04.019.0147	8.37.3558
07	Movable contact trigger set	1	04.019.0146	8.37.3553
08	Support, bushing and pinion for mechanical indicator	1	04.018.1195	8.43.0007

Item	Description	Qty.	Code	Drawing
			04.018.1196 04.018.1197 04.019.0182 04.019.0196	8.43.0008 8.43.0009 8.37.3900 8.37.3561
09	Mounting plate insulating separator	4	04.019.0118	8.37.2913
10	tap-changer mounted electrical plate	1	04.019.0133	N/A
11	Mechanical indicator crown	1	04.019.0181	8.37.3900
12	Mechanism shaft	1	04.019.0151	8.37.3559
13	Drive spring assembly	1	04.019.0138 04.019.0173 04.019.0174	8.37.3569 8.37.3568 8.37.3568
14	Drive crown assembly	1	04.019.0145	8.37.3553
15	CM-3M drive motor	1	07.004.0080	8.46.0010
16	Positioning disk	1	04.019.0143	8.37.3555
17	Mounting plate separator	1	04.019.0153	8.37.3561
18	Neutral position micro switch	1	04.019.0180	N/A
N/A	Roller chain 1/2" R5/16" (main)	1	04.019.0164	N/A
N/A	Roller chain 1/2" R1/8" (mechanical indication)	1	04.019.0030	N/A

Tap-changer motor CM-1, CM-1M, CM-2 or CM-2M

Figure 27 and Table 18list the main materials related to the CM-1 and CM-2 on-load tap changer motors, with their respective variables for the TCPI-1 mechanical indication system.

Figure 27: CM-1, CM-1M, CM-2 or CM-2M tap changer motor parts.

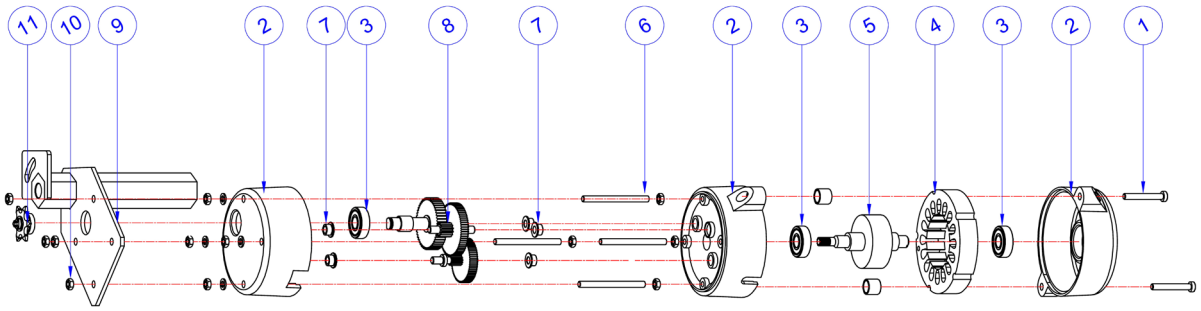


Table 18: CM-1, CM-1M, CM-2 or CM-2M on-load tap-changer motor parts list.

Item	Description	Qty.	Code	Drawing
01	Iron cylindrical head Allen screw M5x35mm	2	04.004.0152	N/A
02	Engine housing set	1	04.019.0094	8.37.0115 8.37.0116 8.37.0117
03	Bearing	3	04.019.0011	N/A
04	Motor stator assembly	1	04.018.0191	8.37.0011 8.37.0119
05	Motor rotor with primary pinion	1	04.019.0061	8.37.0009
06	Iron threaded bar M5x60mm	4	04.004.0144	N/A
07	Engine bushing	5	04.019.0012	8.37.0007

Item	Description	Qty.	Code	Drawing
08	Engine reduction kit	1	04.019.0119	8.37.2843
09	Engine support lock (CM-1 and CM-1M)	1	04.006.0059 04.019.0016	8.37.0176 8.37.0013
09	Engine support lock (CM-2 and CM-2M)	1	04.006.0059 04.019.0080	8.37.0176 8.37.0013
10	Rear frame fixing kit	1	04.004.0035 04.004.0239	N/A
11	Pinion with keyway for chain	1	04.019.0013	8.37.0043

CM-3M tap-changer motor

Figure 28 and Table 19 list the main materials related to the CM-3M on-load tap-changer motor.

Figure 28: CM-3M tap-changer motor parts.

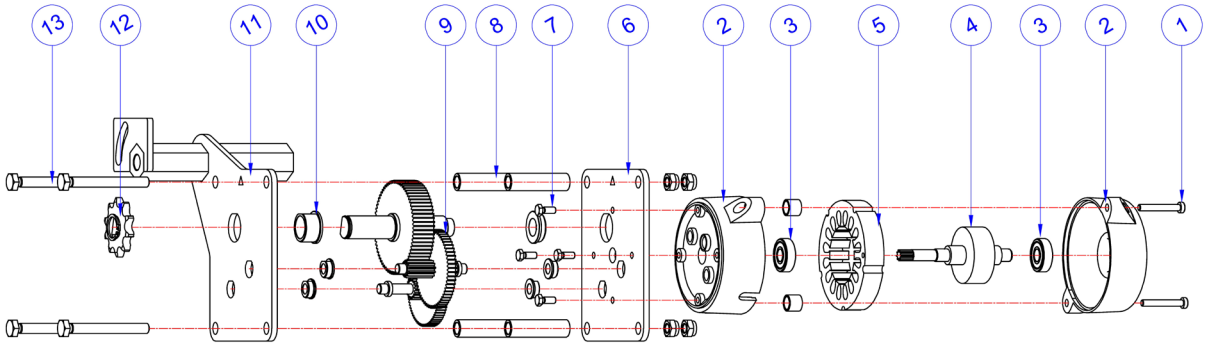


Table 19: CM-3M on-load tap-changer motor parts list

Item	Descrição	Qtde	Código	Desenho
01	Iron cylindrical head Allen screw M5x35mm	2	04.004.0152	N/A
02	Engine housing set	1	04.019.0166	8.37.0115 8.37.0117
03	Bearing	3	04.019.0011	N/A
04	Motor rotor with primary pinion	1	04.019.0162	8.37.3566
05	Motor stator assembly	1	04.018.0191	8.37.0011 8.37.0119
06	reduction mounting plate	1	04.019.0171	8.37.3563
07	M5x12mm hex screw	4	04.004.0967	N/A
08	Reduction mounting plates separator	4	04.019.0154	8.37.3563
09	Engine reduction kit	1	04.019.0158 04.019.0159 04.019.0161	8.37.3565
10	Engine reduction bushing sets	1	04.019.0155 04.019.0156 04.019.0160	8.37.3564
11	Mounting plate with fixing system for the tap-changer	1	04.019.0183	8.37.3561
12	Pinion with keyway for chain	1	04.019.0163	8.37.3567
13	M8x70mm hex screw	4	04.004.0966	N/A

Simplified RAV-2 Regulator

Figure 29 and Table 20 list the main materials related to the general components of the RAV-2 voltage regulators from ITB Equipamentos Elétricos Ltda.

NOTICE: Because each project has its own specific characteristics, the details below were created based on the most commonly used accessories. In case of accessories not listed in this listing, please consult ITB Equipamentos Elétricos Ltda.

Figure 29: Simplified RAV-2 regulator.

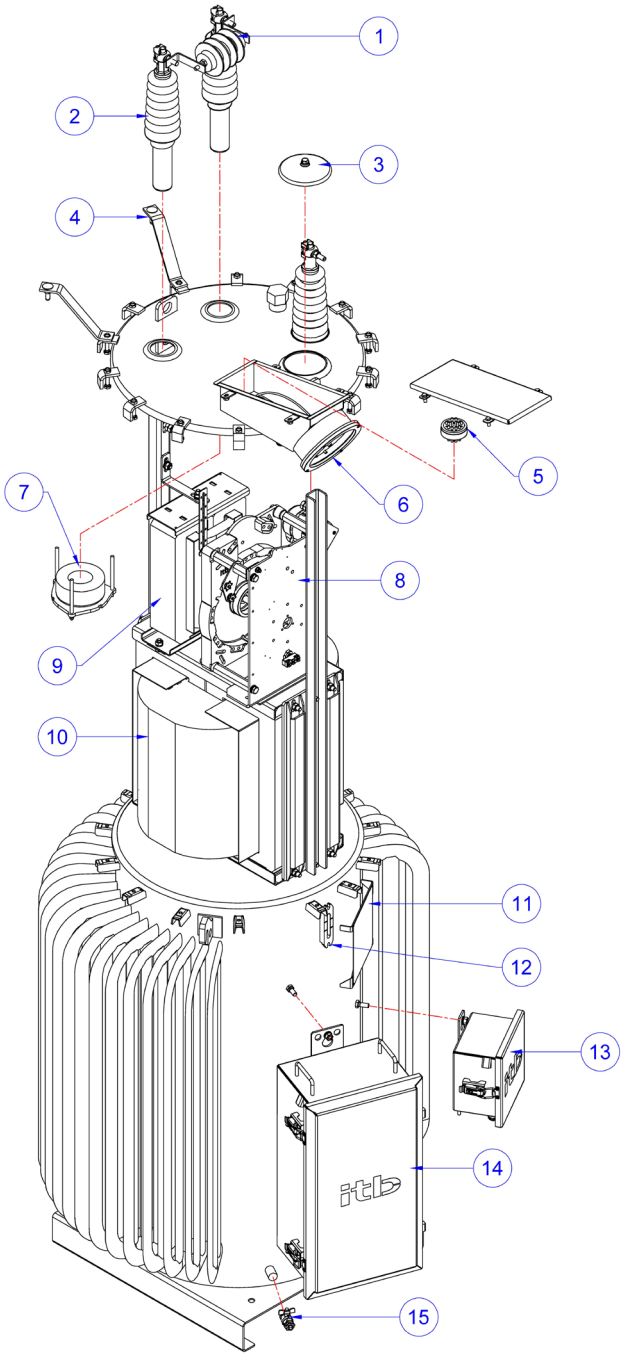


Table 20: Simplified Regulator Parts List.

Item	Description	Qty.	Code	Drawing
01	By-pass type polymeric surge arrester 3kV/10kA	1	04.016.0043	8.37.0817
01	By-pass type polymeric surge arrester 6kV/10kA	1	04.016.0046	8.37.1604
02	ABNT bushings 24.2kV 400A clip	3	07.001.0025	8.37.0142
02	ABNT bushings 24.2kV 800A NEMA special	3	07.001.0030	8.37.0353 8.37.0068
02	ABNT bushings 36.2kV 400A clip	3	07.001.0031	8.37.0059
02	ABNT bushings 36.2kV 800A NEMA special	3	07.001.0034	8.37.0962 8.37.0068
02	ANSI 18kV 400A bushings clip	3	04.007.0074	8.13.0040
02	ANSI bushings 18kV 800A NEMA special	3	04.007.0075	8.13.0060
02	ANSI bushings 36.2kV 400A clip	3	04.007.0046	8.13.0033
02	ANSI bushings 36.2kV 800A NEMA special	3	04.007.0034	8.13.0032
03	Inspection window set	1	07.013.0001	8.05.0001
04	Support for parallel lightning rod	2	07.014.0025	8.12.0335
05	Terminal block	1	04.016.0024	8.37.0105
06	External digital position indicator IRT-1	1	07.017.0003	8.37.2500
06	External analog position indicator TCPI-1	1	04.016.0512	8.43.0001
07	CT coil (variable according to the project)	1	N/A	N/A
08	complete tap-changer CM-1	1	07.004.0046	8.46.0014
08	complete tap-changer CM-1M	1	07.004.0089	8.46.0016
08	complete tap-changer CM-2	1	07.004.0049	8.46.0020
08	complete tap-changer CM-2M	1	07.004.0090	8.46.0022
08	complete tap-changer CM-3M	1	07.004.0148	8.46.0024
09	Reactor coil (variable according to the project)	1	N/A	N/A
10	Main coil (variable according to the project)	1	N/A	N/A
11	210x210mm stainless steel nameplate	1	04.014.0030	N/A
12	Oil level indicator	1	04.016.0021	8.17.0130
13	Auxiliary passage box	1	07.012.0240	N/A
14	CTR-2 single-phase control set and cabinet	1	07.012.0196 07.012.0246	N/A
14	SEL-2431 single-phase control set and cabinet	1	07.012.0253 04.018.1221	N/A
14	CTR-3 three-phase control set and cabinet	1	04.018.1214 07.012.0242	N/A
15	Ball valve with 1/2" butterfly rod	1	04.016.0023	8.17.0131
15	Ball valve with 3/4" butterfly rod	1	04.016.0002	8.17.0133
15	Ball valve with 1" butterfly rod	1	04.016.0027	8.17.0132

ENVIRONMENTAL INFORMATION

Due to its concern for the environment and its support for sustainable consumption, ITB Equipamentos Elétricos Ltda. guides its customers with basic procedures on environmental preservation where its equipment is involved.

Disposal of materials

At the end of the useful life of an electrical equipment, making it unusable, it is advised that the proper disposal of its materials be carried out in accordance with Table 21.

Table 21: Disposal of materials.

Material	Recommended Disposal
Carbon steel	
Silicon steel	
Aluminum	
Copper	
Electronic componentes	
Paper insulators	
Rubber gaskets	
Insulating mineral oil	
Porcelain	
Terminals	

Life cycle

ITB Equipamentos Elétricos Ltda. undertakes to receive and properly dispose of, in accordance with current legislation, the equipment produced by it when these are considered unusable.

Insulating oil – MSDS

Voltage regulators, like many high-voltage electrical devices, have an active part surrounded by insulating oil and coolant. Therefore, they are mounted in airtight tanks with pressure relief devices. In operation, this oil can reach high temperatures and, even at room temperature, it is an agent that can be polluting and aggressive.

We recommend reading the Chemical Product Safety Data Sheet – MSDS, which contains all the information necessary for safe handling, proper disposal, associated risks and measures in case of accidents.

ITB makes itself available for clarification and additional information. ITB reserves the right to revise and update this manual without prior notice. It is not allowed to use the trademark ITB Equipamentos Elétricos Ltda. without its prior consent.

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