USER MANUAL

Treetech

VOLTAGE REGULATOR RELAY

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1 Foreword

1.1 Legal Information

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1.2 Presentation

This manual presents all the recommendations and instructions for installation, operation and maintenance of the Voltage Regulator Relay -AVR.

1.3 Typographical Conventions

Throughout this text, the following typographical conventions were adopted:

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

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

1.4 General and Safety Information

This section presents relevant aspects of safety, installation and maintenance of the AVR.

Safety Symbols

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

Caution

The **Caution** symbol is used to alert the user of a potentially hazardous operating or maintenance procedure that demands greater caution in its conduction. There may be minor or moderate injuries, as well as damages to the equipment.

Warning

The **Warning** symbol is used to alert the user of a potentially hazardous operating or maintenance procedure in which extreme caution must be taken. There may be serious injuries or death. Possible damages to the equipment are irreparable.

Electric Shock Hazard

The **Electric Shock Hazard** symbol is used to alert the user of an operating or maintenance procedure that may result in electric shock if not strictly observed. There may be minor, moderate, serious injuries or death.

General Symbols

This manual uses the following general symbols:

Important

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

Tip:

The **Tip** symbol represents instructions that facilitate use and access of functions in the TM1/TM2.

Minimum profile recommended for the AVR operator and maintainer

Installation, maintenance and operation of equipment in electric power substations require special cares and, therefore, all recommendations of this manual, applicable standards, safety procedures, safe work practices and good judgment must be used during all handling stages of the Temperature Monitor (TM1 and TM2).

For use of this manual, an authorized and trained person has knowledge of the inherent risks – both electrical and environmental – involved in handling the AVR.

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

a) The operator or maintainer must be trained and authorized to operate, ground, turn on and turn off the AVR, following maintenance procedures according to the safety practices established, under the sole responsibility of the AVR operator and maintainer;
b) Be trained in the use of IPEs, CPEs and first-aid;
c) Trained in the working principles of the AVR, as well as its configuration.
d) Follow regulatory recommendations regarding interventions in any type of equipment included in an Electric Power System.

Environmental and voltage conditions required for installation and operation

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

Table 1 – Operating Conditions

Condition	Interval/Description
Application	Equipment for sheltered use in substations, industrial environments and similar.
Internal/External Use	Internal 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% – Uncondensed
Storage	3% to 98% – Uncondensed
MAINS Supply Voltage Fluctuation (IEC EN 61010-	Up to ±10% of the Rated voltage
Overvoltage (IEC EN 61010-1)	Category II
Level of Pollution (IEC EN 61010-1)	Level 2
Atmospheric Pressure** (IEC EN 61010-1)	80 kPa to 110 kPa

Instructions for test and installation

This manual must be available to those responsible for installation, maintenance and users of the Voltage Regulator Relay - AVR

To guarantee user safety, equipment protection and correct operation, the following minimum cares must be followed during the AVR installation and maintenance:

1. Read this manual carefully before installation, operation and maintenance of the AVR. Errors in installation, maintenance or adjustments of the AVR can cause undue operations of the tap changer in load, unsatisfactory voltage regulation, undue alarms or pertinent alarms may also fail to be emitted.
2. The installation, adjustments and operation of the AVR must be done by personnel trained and acquainted with the electric motors, power transformers, tap changers on load or voltage regulators, control devices and control circuits of substation equipment.
3. Special attention must be paid to installation of the AVR, including the type and size of the cables and terminal strips used, as well as the procedures for commissioning, including correct parameterization of the equipment.

The AVR must be installed in a sheltered environment (a panel without doors in a control room or in a closed panel, in cases of outdoor installation) where the temperature and humidity specified for the equipment are not exceeded.

Do not install the AVR near sources of heat like heat resistors, incandescent lamps and devices with high power or with heat dissipaters. Its installation near ventilation orifices or where it can be affected by forced air flow, like outlet or inlet of cooling fans or forced ventilation ducts, is not recommended.

On conducting dielectric strength tests on the wiring (applied voltage), the ground cables connected to terminal 17 of the AVR must be disconnected in order to prevent destruction of the protections against overvoltage existing inside the device due to application of high voltages for a long period (e.g.: 2 kV for 1 minute).

Cleaning and decontamination instructions

Take care when cleaning the TM1/TM2. Use ONLY a cloth wet with soap or detergent diluted in water to clean the cabinet, front plate or any other part of the equipment. Do not use abrasive materials, polishers or aggressive chemical solvents (like alcohol or acetone) on any of its surfaces.

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

Inspection and Maintenance instructions

The following observations must be followed for inspection and maintenance of the AVR:

Do not open the equipment. In it, there are no parts reparable by the user. This should be done by the Treetech technical assistance, or by technicians accredited by it.
This equipment is completely maintenance-free, being that visual and operational inspections, periodical or not, may be conducted by the user. These inspections are not mandatory.

Opening of the TM1/TM2 at any time will imply in loss of the product warranty. In cases of undue opening of the equipment, Treetech will also not be able to warrant its correct functioning, regardless of the warranty period having expired or not.

All parts of this equipment must be supplied by Treetech, or by one of its accredited suppliers, according to its specifications. If the user wishes to purchase it otherwise, he must strictly follow Treetech's recommendations for this. This way, the performance and safety for the user and the equipment will not be compromised. If these specifications are not followed, the user and the equipment may be exposed to unforeseen and unnecessary risks.

1.5 Technical Assistance

To obtain technical assistance for the TM1/TM2 or any other Treetech product, contact us through the address below:

Treetech Sistemas Digitais Ltda. – Technical Assistance
R. José Bonifácio, 661, Jd. Brasil
Atibaia – São Paulo – Brazil
Zip Code: 12940-210
CNPJ [Corporate taxpayer's roll]: 74.211.970/0002-53
IE [State Tax ID]: 190.159.742.110
PHONE: +55 (11) 2410-1190 x201
FAX: +55 (11) 4413-5991
Email: suporte.tecnico@treetech.com.br
Site: http://www.treetech.com.br

1.6 Warranty term

The Temperature Monitor is guaranteed by Treetech for the term of 2 (two) years, counted from the date of purchase, exclusively against eventual manufacture defects or quality vices that render the equipment unfit for use.

The warranty will not cover damages sustained by the product, as a consequence of accidents, improper handling, incorrect installation and use, inadequate tests or in case the warranty seal has been breached.

The eventual need for technical assistance must be informed to TREETECH, or to a technical assistance service appointed by the same, with the equipment being delivered together with the purchase invoice.

Treetech does not supply, nor is liable to, any other warranty, express or understood, in addition to the ones mentioned above. Treetech does not supply any guarantee of suitability of the TM1/TM2 to any specific application.

The dealer is not liable to any claims for damage to property, nor any other form of losses that might occur, in connection to or stemming from the acquisition of the equipment, of the performance of the equipment or of any other service possibly supplied together with the TM1/TM2.

Under no circumstances will the dealer be made responsible for any losses incurred, included but not limited to: loss of profit or revenue, impossibility in using the TM1/TM2 or any other associated item of equipment, costs of capital, costs of energy acquired, costs of replacement equipment, facilities or services, costs of outages, complaints from clients or employees of the buyer, regardless of whether said damages, complaints or losses are based on contracts, warranties, negligence, felony or any other reason.

Under no circumstances can the dealer be made liable for any personal damage of any sort.

1.7 Revision Control

Review	Date	Description	By
0	11/19/2004	*Original issue*	Fco.
1.00	11/26/2004	*Revised firmware version number from 1.0.3 to 1.0.4 (Modbus information).*	M. Alves
2.00	07/07/2008	*Manual in new format. Insertion of optional functions Parallelism by Circulating Current and OLTC Maintenance. Up-date of Modbus and DNP 3.0. tables. Insertion of parameter definition tables.* **Note: *This review of the Manual is applicable only to devices with firmware version* V2.00 and later.**	Tchiarles/ Rafael/ Marcos
3.00	24/07/2015	*New design. International representatives updated*	João V. Miranda
3.10	15/10/2015	*Insertion of "Reversion Flow" in subchapter 6.1*	João V. Miranda
3.20	02/12/2015	*Optional functions updated*	João V. Miranda
3.30	08/06/2016	*Technical Data Review*	João V. Miranda
4.20	03-01-2018	*Inclusion of optional function 4: OLTC checking, and subchapter 3.4; Updating: indication to the self-diagnosis memory; self-diagnosis table and the 2nd delay time and Local Address parameters. Inclusion of "Screensaver" Parameter (replacing "Screen Scrolling") and new layout. Technical Assistance data update. Inclusion of the power flow reversal alarm, error 0200 and the fourth digit. The manual version now corresponds to the Portuguese and Spanish versions.* ***Note: This manual review applies only to devices with firmware version v2.19 and later.***	João V. Miranda

Introduction

In an increasingly more demanding market in terms of Quality of Electric Energy, and with increasingly stricter rules for parameter definition and acceptable supply limits, there is a pressing need for tools capable of adapting to this reality and afford adequate voltage regulation.

Within this context, Treetech's Voltage Regulator Relay AVR offers a solution that goes beyond the traditional and well-known relays "90", equipped with unprecedented resources to afford better control of load voltage limits, allowing addressing of the most exacting regulations in this sector.

1.8 Main Features

- Applicable on power transformers with On Load Tap Changer (OLTC) and Single-phase Voltage Regulators;
- IED (Intelligent Electronic Device), fit for integration with supervision or monitoring systems by way of RS485 and RS232 ports (Modbus standard, DNP 3.0 optional).
- Six independent voltage regulation parameter sets, actuated by hour-based programming (internal clock) or external dry contacts;
- Internal clock with hour, minute and second, and calendar with day, month and year, and day of the week;
- Independent actuation times for voltage above or below the adjusted range;
- Linear temporizing types (defined time) or Inverse Curve;
- Linear temporizing with independent adjustment per range of voltage deviation;
- Line Drop Compensation by adjustment of Resistance (R) and Reactance (X) or by the simplified voltage drop percentage method (Z Compensation);
- Mass memory for recording measured variables (Optional item No. 2);
- Five signal relays with programmable function and operation types (NO/NC). The same relay can be actuated by more than one event ("OR" logic);
- Analog output for remote reading of voltage, current or tap. Configurable output range: 0…1, 0…5, 0…10. 0…20 or 4…20 mA;
- Multiple measurement function: readings of load and transformer voltage, voltage deviation, load current, active, reactive and apparent power, % load, power factor, frequency, current and previous tap position, minimum and maximum tap positions reached (Optional item no.3);
- Phase shift between PT and CT adjustable from 0° to 330° in 30° increment steps, allowing any connection combination between PT and CT;
- Optional item for tap measurement and command selection between automatic (programmed levels of actuation) or manual command to raise or lower tap;
- Optional item for parallelism of up to 6 transformers applying the Minimum Circulating Current Method;
- Optional item for OLTC maintenance, comprised of switching operation counter (including intermediate positions), sum of current switched squared (Ipu^2) and days remaining before OLTC maintenance;
- Blocking of OLTC programmable for overcurrent, undervoltage, overvoltage, OLTC overshoot and high circulating current between transformers in parallel. Programmable actuation for quick voltage reduction in case of overvoltage;
- Optional item for OLTC checking, works by algorithms that identify voltage levels corresponding to the sensitivity of the circuit, identifying activity or not of the switching, signaling the fault (Alarm). It does not require potentiometric transmitter information.
- High brightness VFD (*Vacuum Fluorescent Display*) "*dot matrix*" display with contrast adjustment, legible under most lighting conditions and whole operating temperature range;
- Operating temperature range -40° to +85°C, allowing installation on outdoor panels;

- Universal power input, from 38 to 265Vdc/Vac 50/60 Hz;
- Communication via optic fiber cables, deploying external electric-optical converter;
- User password protected programming menus;
- Parameter definition preserved even in case of long periods without power feed, by way of non-volatile memory without the need for internal batteries;
- Device connection by way of ring-type terminals for CT and PT signals, and detachable connectors for the other circuits;
- Reduced dimensions (96X96X161mm), allowing easy installation in new or existing panels, assembled on transformers or in control rooms.

Figure 1 – Voltage Regulator Relay – AVR

1.9 Optional Functions

According to the order, AVRs can be delivered with one or more of the optional functions listed below. Some combinations of optional items are not simultaneously; consult Appendix C for possible combinations.

Optional item 1 - Protocol DNP 3.0:

User selected communication protocol between Modbus RTU and DNP3.0 level 1.

Optional item 2 – Mass Memory:

Non-volatile memory for storage of readings, operations of the OLTC and alarm event data. User selects the variables to be stored (maximum of 30 variables) and defines whether storage is for instant, average, minimum or maximum values for the interval.

Optional item 3 – Position Reading:

Input for reading OLTC position by potentiometric sensor, with compensation for resistance of cables and detection of errors. Associated functions:

- Current output programming for remote tap reading;
- Manual command of OLTC, local (front panel) and by serial communication;
- Limitation of OLTC excursion range (minimum and maximum tap positions allowed) and memorizing maximum and minimum positions reached since last reset;
- Protection against undue tap operations: blockage of switch in case of operations not initiated by AVR.

Optional item 4 – OLTC Checking:

It works by algorithms that identify voltage levels corresponding to the sensitivity of the circuit, identifying activity or not of the switching, signaling the fault (Alarm). It does not require potentiometric transmitter information.

Optional item 6 – Parallelism by Circulating Current:

Parallelism control for up to 6 transformers using the Minimum Circulating Current Method, with block for excess circulating current.

Optional item 7 – OLTC Maintenance:

Same as for Optional item 3, adding:

- OLTC operation counter, with notice for high number of operations;
- Integration of current switched squared, with notice for high I^2 sum.

1.10 Basic Operating Philosophy

While in operation, the AVR targets maintaining load voltage within a pre-set range of values defined by the user programmed parameters.

To this end, the AVR performs voltage readings at transformer output and load current. By using these two readings and the line drop parameters programmed, the voltage on the load is calculated, which is the voltage that must effectively be maintained within the limits desired as shown in Figure 2.

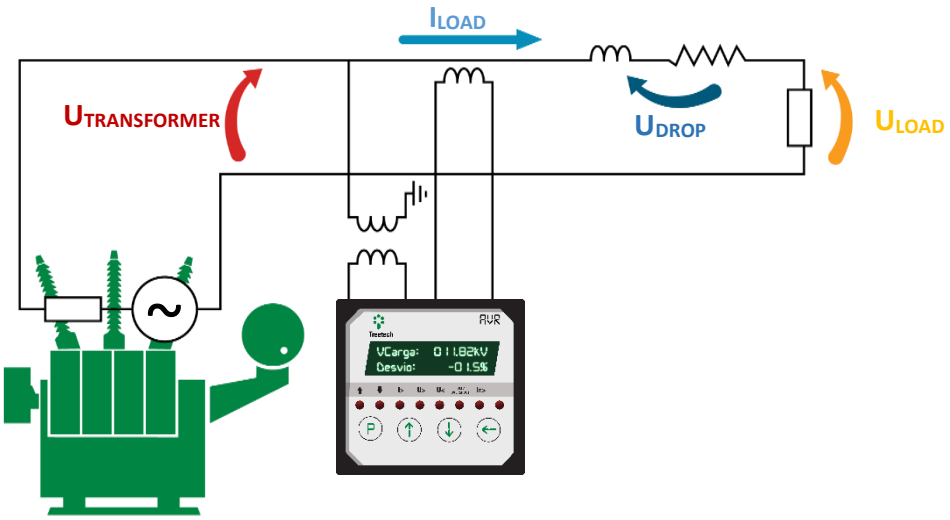


Figure 2 – Deployment diagram for Voltage Regulator Relay - AVR

For more detailed information on the way the AVR acts when regulating voltage. In addition to the basic voltage regulation function, the AVR also acts as protection for the OLTC, blocking its operation in adverse conditions, such as a line short-circuit (over-current/under-voltage) and load protection (over-voltage).

1.11 Control of Parallel Operation using the Circulating Current Method

One of the main concerns when operating power transformers in parallel is avoiding the appearance of currents circulating between windings in parallel. Once transformers operating in parallel feature the same vector groups, voltage, power and impedance levels and that the primary windings are powered from the same source, the main requirement in preventing circulation of current is that transformation ratios be equal.

In transformers with On Load Tap Changers (OLTC), which modify their ratios during operation, this condition can be achieved through a number of different methods. When transformers have the same number of shunt positions, with equal transformation ratios in every position, it is enough for them to always operate from the same tap position, which can be accomplished by applying the “Master-Slave” control philosophy. This is the philosophy adopted in Treetech’s SPS Parallelism Supervisor, which can be deployed together with the AVR Voltage Regulator Relay.

However, it is also possible for transformers to be electrically compatible for operation in parallel, but have different numbers of taps, so that applying the “Master-Slave” philosophy would, in these cases, require a more complex logic. For these cases, an alternative is the use of the Minimum Circulation Current parallelism method, which can be applied using AVR Voltage Regulator Relays equipped with optional function no. 6.

Implementing digitally parallelism by Circulating Current on AVR avoids the inconvenience and complexity faced in the past when applying this method through analog circuits, which required the use of auxiliary CTs and a high number of connection cables. AVRs are installed as usual, adding only the connection between the relays with just one shielded, twisted-pair cable, as shown in Figure 3.

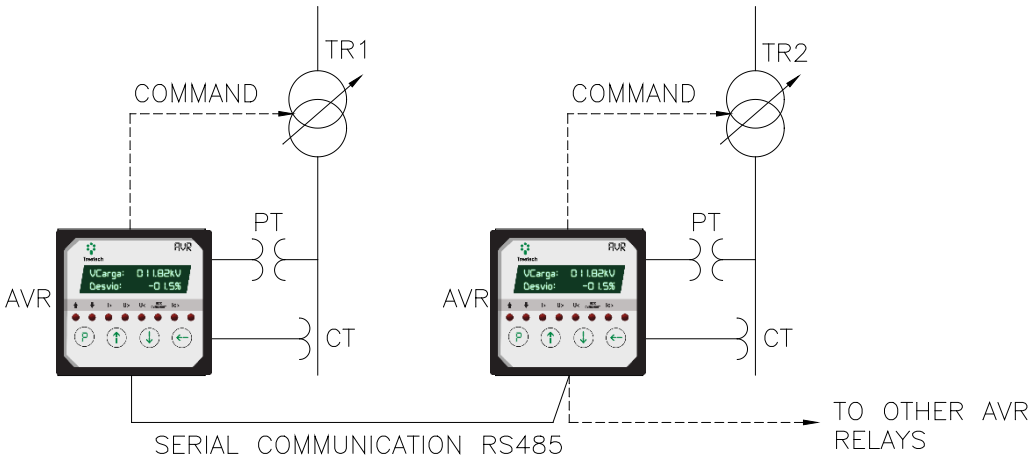


Figure 3 – Application of AVR Voltage Regulator Relay with Parallelism Control by Circulating Current

In the parallelism method by Circulating Current, AVRs control tap changers focusing, not on the tap position, but rather in reducing reactive circulation current between the windings simultaneous to the normal voltage regulation. To do this, relays calculate the circulating current between transformers through data exchange via RS485 serial communication network.

Through a Gain factor, user adjusted between 0 and 100%, a Voltage Correction proportional to the value of the Circulating Current is accomplished, where a gain of 100% corresponds to Correction Voltage equal to reference voltage for a circulating current corresponding to the transformer’s rated power. In transformers acting as generators of circulating current, it will be displayed with a positive sign, as will the correction voltage, and for transformers receiving circulating current, the current will be shown with a negative sign, as will the correction the voltage.

The Correction Voltage obtained in this way is added to the reading at the PT input, used by the relay for regulation, causing a feedback effect that will lead the AVR to a trend to reduce voltage in the transformer generating circulating current (positive Correction Voltage) and/or raise voltage in the receptor (negative Correction Voltage).

The choice between the options informed above – reduce voltage in the transformer generating circulation current or raise it in the transformer receiving – will, in general, be determined by the system voltage level. If the voltage reading is below the reference value, the trend will be for receiving transformers to change tap in order to raise voltage. In the opposite situation, if load voltage is above the reference value, the trend will be for the generating transformer to change tap to reduce voltage.

The Gain adjusted by the user has the purpose of regulating intensity of feedback to reduce circulating current, avoiding excessively weak correction, thus not allowing high circulation currents, or excessively high, causing system instability.

In case of failure in actuation of one or more OLTC, the AVR features protection against excessive circulating current that signals the event through an alarm and blocks the OLTC associated. For correct operation of parallelism, an essential condition is that relays have identical voltage regulation parameter settings, which is automatically checked by AVRs, with alarm issued and blockage of the system if any divergences are found.

This way, control of parallelism by Circulating Current afford a simple way of achieving transformer parallelism in transformers with different numbers of taps, by automatically seeking the tap positions that afford the best voltage regulation and the lowest circulation current.

2 Design and Installation

2.1 System Topology

Basically, the AVR - Voltage Regulation system is comprised of:

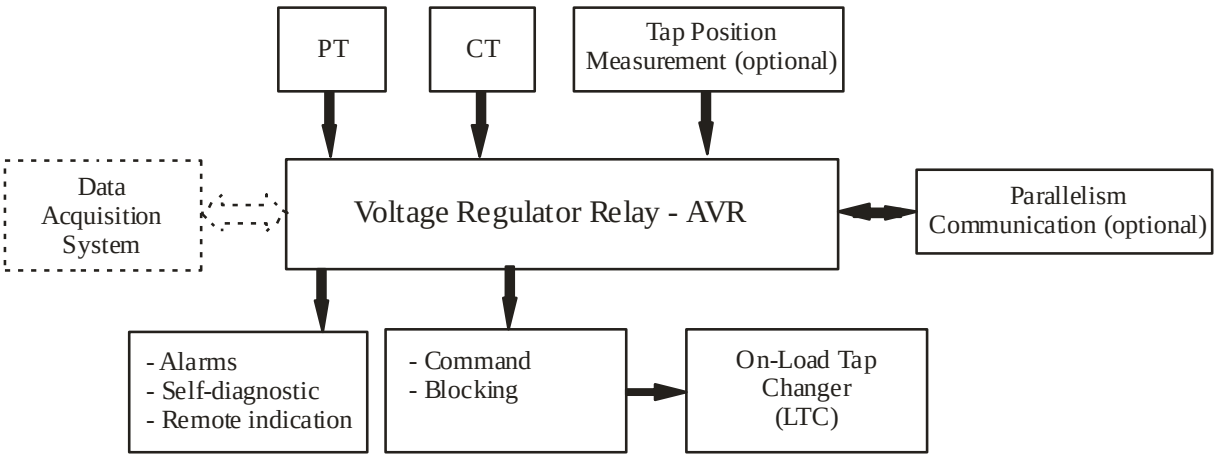


Figure 4 – Composition of the Voltage Regulation system

2.2 Mechanical Installation

The Voltage Regulator Relay - AVR must be installed protected from the weather, inside panels or sheltered in-doors. In any case there must an anti-condensation system.

The AVR is suited for built in type assemblies, and can be fixed, for instance, on doors or front plates of panels. Fixation clips are supplied with the AVR. Figure 5 shows the main dimensions of the equipment, as well as the dimensions of the cut out required on the plate in order to fit the equipment. Special attention must be given to the thickness of the paint coats of the plate at the site of the cut out, because in some cases, high thickness paint may be used and the resulting reduction in the area of the cut out may even keep the equipment from fitting. Connection terminals are installed on the rear part of the AVR, with fixed terminals for the PT and CT connections and 2 detachable connectors for the other connections, in order to facilitate connections. In the detachable terminals, cables between 0.5 and 2.5mm² may be used, bare or with “pin” type connectors (or “needle”) for the detachable connectors, and for the PT and CT terminals, eyelet-type terminals should be used for cables up to 6 mm².

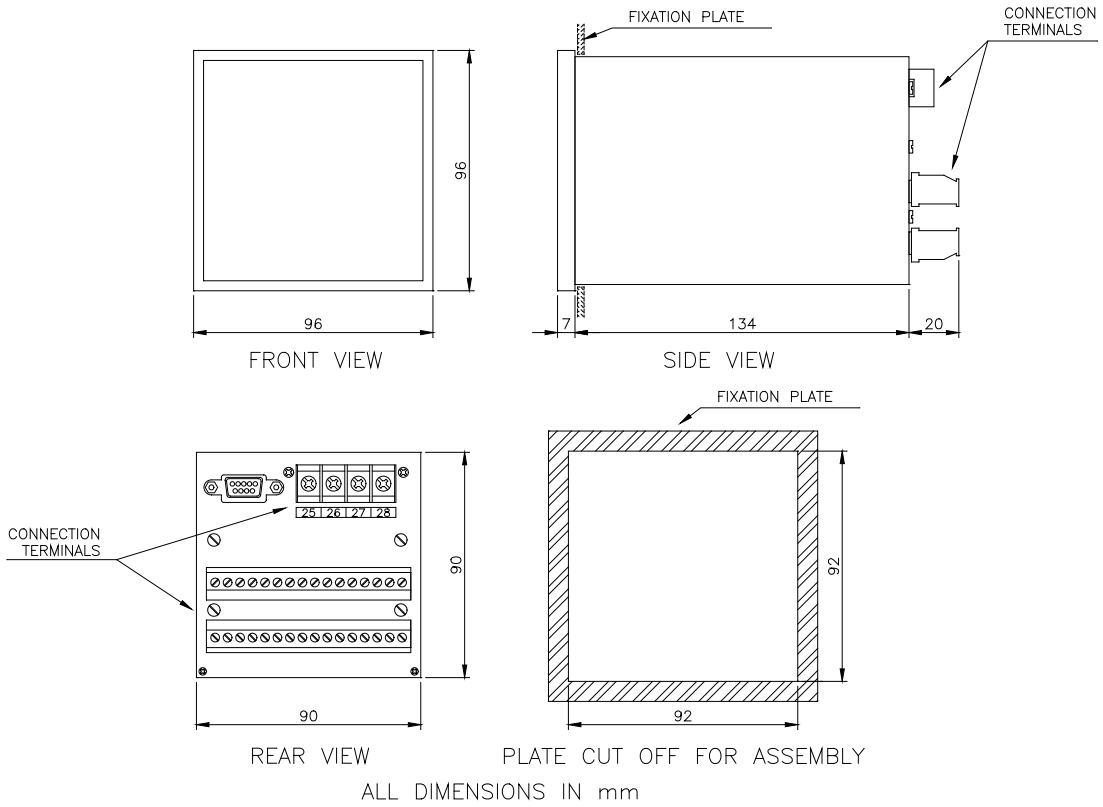


Figure 5 - Dimensions of the Voltage Regulator Relay AVR

2.3 Electrical Installation

Some special care should be taken to the design and installation of AVR, as described below.

A circuit breaker should be used immediately before the power input (Universal Power Supply - 38 ~ 265 Vdc / Vdc, <8 W, 50/60 Hz), which corresponds to the pins, 18 and 19 of the AVR. This circuit breaker must have the number of poles corresponding to the number of phases used in the power supply - the poles must interrupt only the phases and never the neutral or earth - and provide thermal and electrical protection to the conductors that feed the equipment.

The circuit breaker must be close to the equipment and easily operable by the operator. Additionally, it must have an indelible identification showing that it is the AVR's electrical disconnect device.

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

- **AC / DC supply, Neutral-phase:** Single-pole circuit breaker, 1 A ≤ In ≤ 2 A, curve B or C, standards NBR / IEC 60947-2, NBR / IEC 60898 or IEEE 1015-2006**;**
- **AC / DC Power, Phase-Phase:** Bipolar circuit breaker, 1 A ≤ In ≤ 2 A, curve B or C, standards NBR / IEC 60947-2, NBR / IEC 60898 or IEEE 1015-2006.

The minimum insulation for the circuits connected to the AVR is 300 V_{rms} for equipment and auxiliary transducers such as Pt-100 and for equipment with own power up to 50 V_{rms}.

The minimum insulation is 1.7 kV_{rms} for equipment powered up to 300 V_{rms}, in accordance with IEC EN 61010-1.

These values are related to the intrinsic isolation of devices connected to the AVR. Cases where this value does not apply to equipment or devices connected to the AVR will be explicitly reported in this manual.

The AVR Voltage Regulator Relay offers the following inputs and outputs:

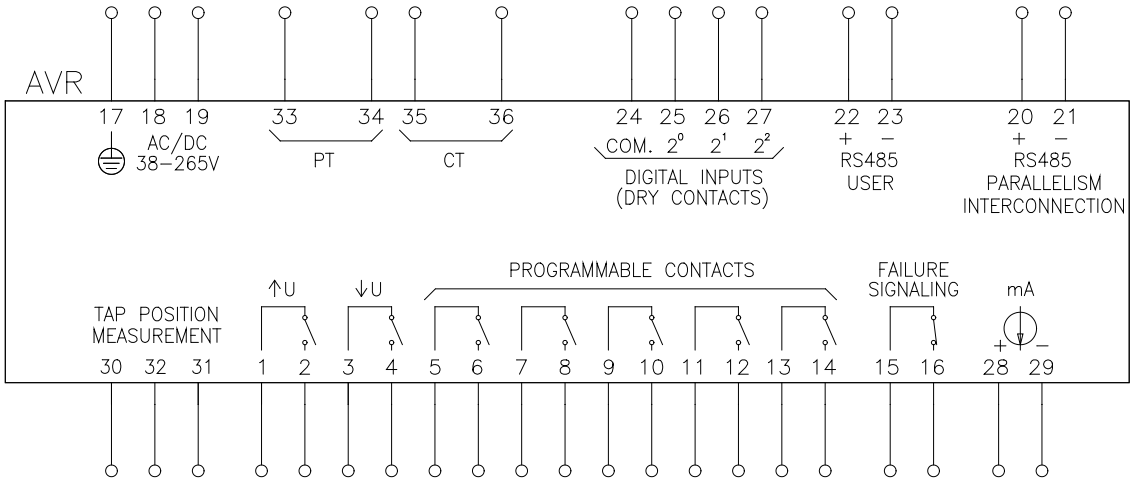


Figure 6 – Input and output terminals of the AVR.

Input Terminals

Table 2 - Input Terminals

INPUT	TERMINALS
1) Auxiliary power input and ground: Input for universal power input (38-265 Vdc/Vac, 8W, 50/60Hz).	*17 – ground* *18 – cc/ca* *19 – cc/ca*
2) RS485 Port - Scada: Connection with the data acquisition system, protocol MODBUS-RTU, DNP 3.0 optional, via shielded, twisted pair cable...	*22 – (+)* *23 – (-)*
3) RS485 Port – AVR connections (Optional item no. 6): Connection for communication with other AVR Voltage Regulator Relays, used only when optional function for Parallelism by Circulating Current is available.	*20 – (+)* *21 – (-)*
4) RS232 Port: Connection to external computer, for parameter definition and data acquisition.	*DB9 Connector (rear panel)*
5) Input for PT: Input for direct measuring of the secondary of the PT. Measuring range 0 to 160Vac (0.5% accuracy from end of 50 to 140V scale).	*33 – (polarity)* *34 –*

6) Input for CT: Input for measuring current of the CT secondary. Measuring range 0 to 10A.	*35 – (polarity)* *36 –*
7) Digital inputs: Input for remote selection of the Regulation Set (1 to 6) to be used in regulating voltage or Parallelism Group by Circulating Current (optional).	*24 – common* *25, 26 and 27 – BCD*
8) Tap reading (Optional items nos. 3 & 7): Input for measuring on load tap changer position through a potentiometric sensor.	*30 –minimum tap* *31 – maximum tap* *32 – Cursor*

1) Auxiliary Power Supply and Ground

The AVR has universal auxiliary power input (38 to 265 Vdc/Vac 50/60 Hz) that is independent of the PT reading input. However, the PT's own secondary voltage can be used to power the equipment, by way of an external jumper connecting in parallel the measuring input and the one used for power input. In this case, the equipment's consumption of 8 W should be taken into account, as well as the PT's power.

It is advisable to power the AVR using the substation's auxiliary services, in particular when the device is integrated in a serial communication network for the purpose of data capture for supervision or monitoring systems.

2) RS485 Port – Supervisory System

The AVR can optionally be connected to a data acquisition system (supervision or monitoring system) using the RS 485 serial communication port. Up to 31 devices can be connected to the same communication network. The communication protocol used is Modbus RTU, with DNP 3.0 being available as optional protocol (other protocols upon consultation). See Appendix F for communication protocol details.

The connection between the AVR and the data capture system must be made by way of shielded, twisted pair cable, with the shielding having to be maintained unbroken along the entire length of the cable. If intermediate connection terminals are necessary for connection of the serial network, pass the cable shielding on the terminal as well, thus keeping it free of interruptions/breaks. The stretch of cable without shielding because of the patch must be kept as short as possible. It is advisable to ground the cable shielding only at one of the ends. A maximum distance of 1300 meters must be maintained between the ends of the communication network.

A 120 ohm termination resistor must be installed at each end of the serial communication net, as well as *pull-up* and *pull-down* resistors in just one point along the net, as shown in Figure 7. 5V direct voltage for powering *pull-up* and *pull-down* resistors can be provided internally to the data acquisition system; note that some communication systems may already have these resistors installed internally, eliminating the need for external resistors.

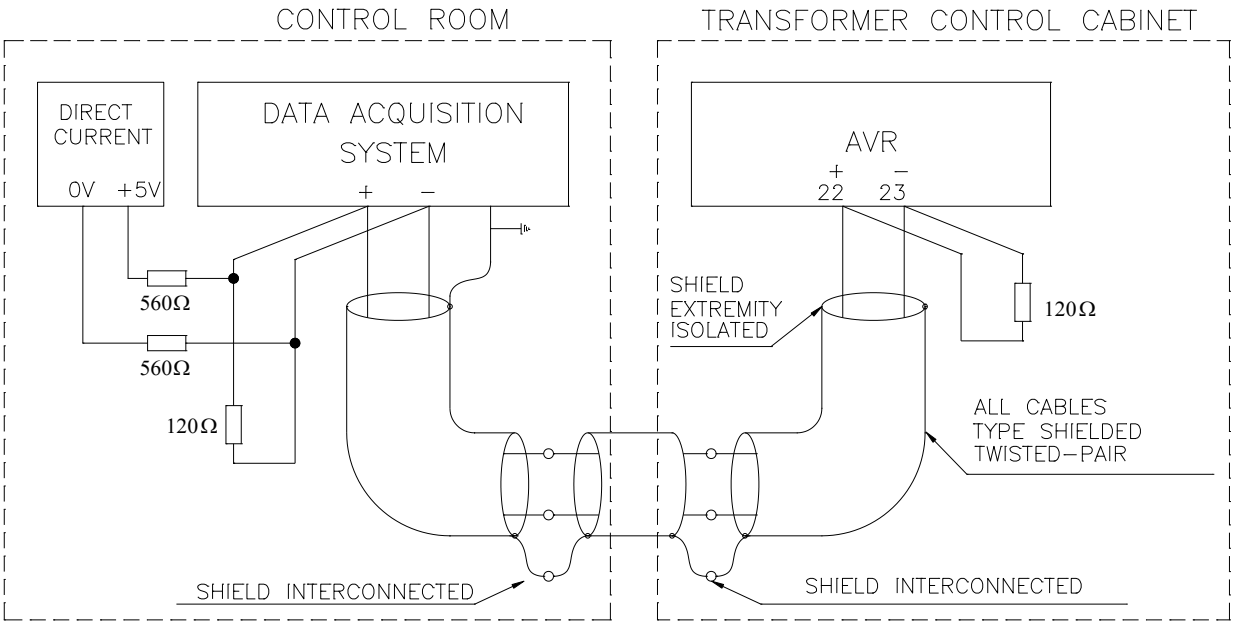


Figure 7 – Connection and grounding of shielding for RS485 serial communication in Data Acquisition

3) RS485 Port – Interconnection between AVRs

The RS485 communication port for linking AVRs is only connected when the Parallelism by Circulating Current (optional item no. 6).

All AVRs participating or that may come to participate in parallelism control must be linked together by simply connecting in parallel their RS485 connection ports using a shielded, twisted pair cable, keeping shield uninterrupted during the whole cable length. If intermediate connection terminals are necessary for connection of the serial network, pass the cable shielding on the terminal as well, thus keeping it unbroken. The stretch of cable without shielding because of the patch must be kept as short as possible. It is advisable to ground the cable shielding only at one of the ends, and that a 120-ohm termination resistor be installed at each extreme of the serial communication, as shown in Figure 8. The RS485 connection ports are already provided with internal *pull-up* and *pull-down* resistors, doing away with the need for external resistors. A maximum distance of 1300 meters must be maintained between the ends of the communication network.

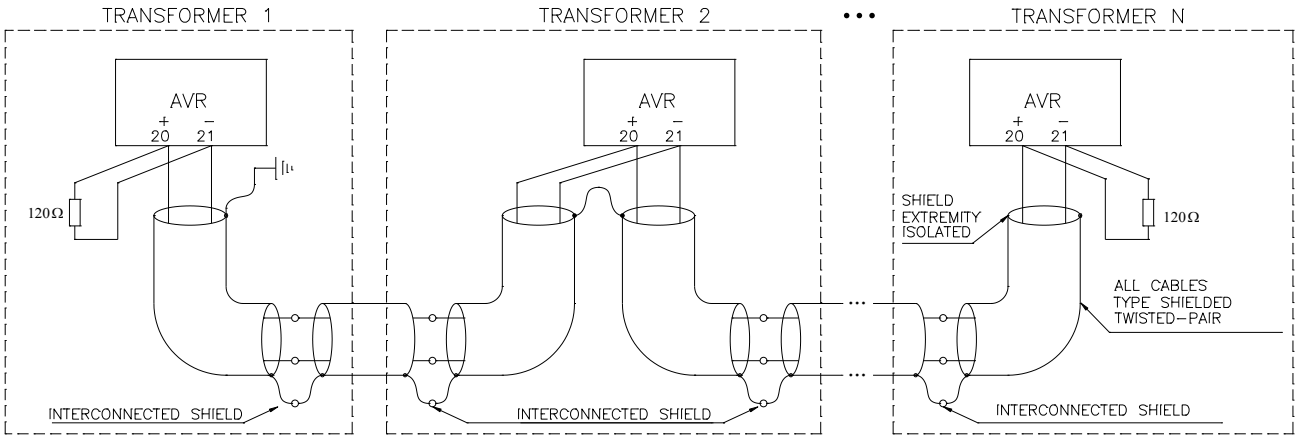


Figure 8 - Connection and grounding of shielding for RS485 serial communication port used in Parallelism control (optional)

4) RS232 Port

The RS232 port available on the rear of the AVR can be used as an alternative to the RS485 port described above. RS485 and RS232 ports cannot be used simultaneously, the port to be used is the port selected in programming the equipment. The RS 232 port uses the same communication protocols as the ones defined above for the RS 485 port – supervision system. Consult **Erro! Fonte de referência não encontrada.** for c ommunication protocol details.

The limitations of the RS232 communication standard in relation to electro-magnetic interference must be observed, maximum distance 50 feet (15 meters) and point to point communication (only 2 devices can be connected to each other).

5) and 6) PT and CT measuring inputs

Measuring ranges for the PT inputs (potential transformer) and CT (current transformer) are 0 to 160 V and 0 to 10 A, respectively, with PT input calibration being guaranteed in the range 50 to 140V. Both inputs perform measurements using the TRUE RMS mode.

Due care must be taken in connecting the CT input, in order to make sure it does not remain open with the transformer in operation. If interventions are made to this circuit with the transformer energized, make sure the CT is short-circuited and grounded at the panel terminal boxes. The short-circuit should only be removed after making sure the AVR's CT input is correctly connected.

There are several possible combinations for the connection of the PT and CT, and each combination generates an angle difference between the signals for voltage and current. In programming the AVR, the phase difference angle is adjusted for the signals between 0° and 330° in 30° steps, which must be compensated for the correct calculation of the power factor.

Below a few examples of possible combinations are shown for connecting the PT and CT. Other combinations are also possible, and the phase difference angle can be easily determined by drawing a phase vector diagram, as shown in the examples.

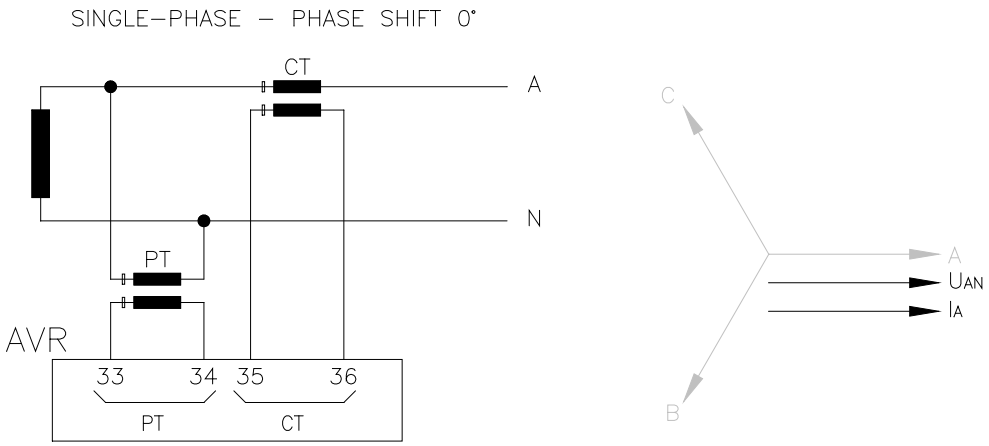


Figure 9 - Single phase PT connection diagram, 0° phase difference angle

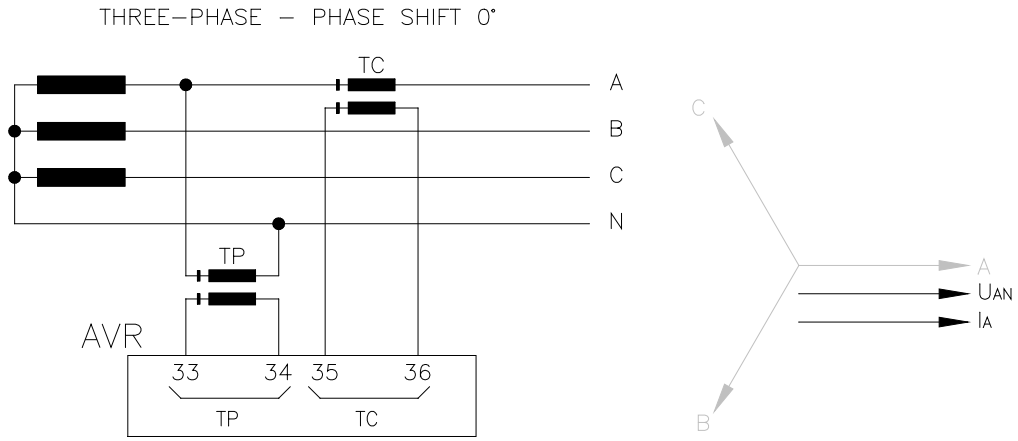


Figure 10 - Phase/Neutral PT connection diagram, 0° phase difference angle

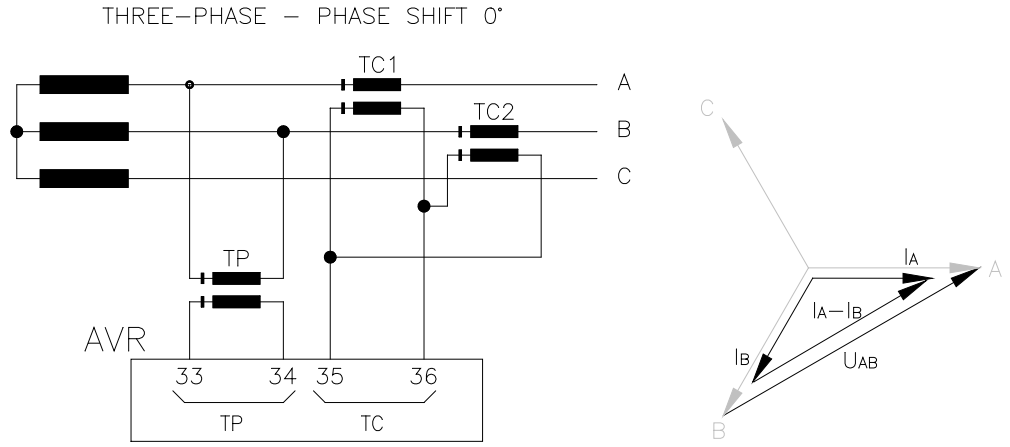


Figure 11 - Phase/phase PT connection diagrams, 0° phase difference angle

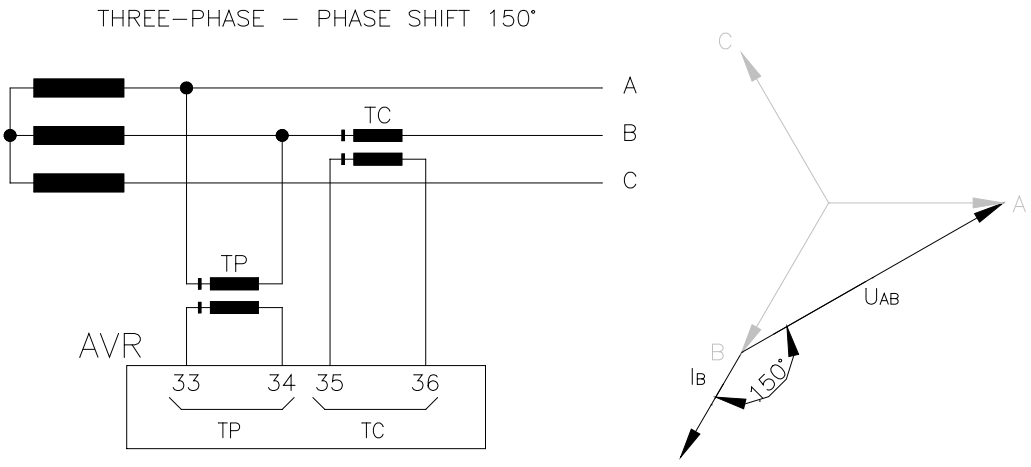


Figure 12 - Phase/phase PT connection diagram, 150° phase difference angle

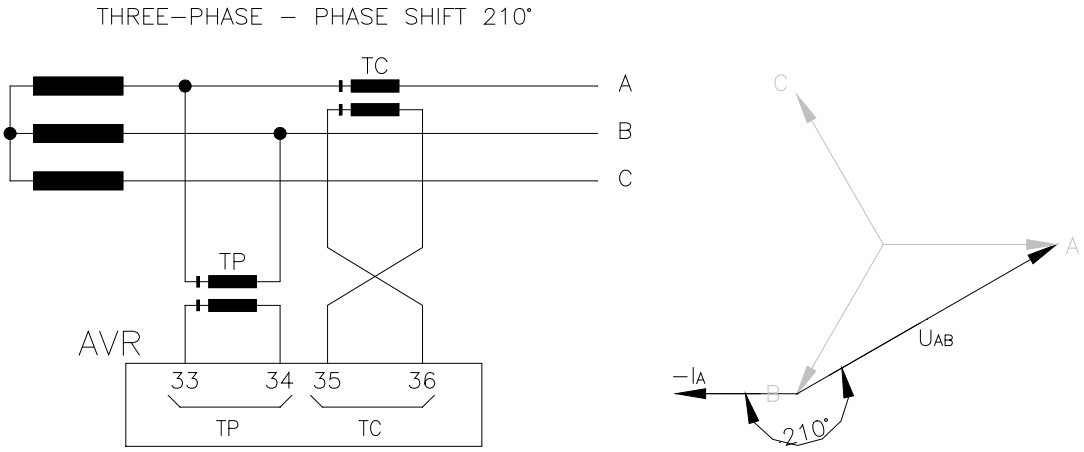


Figure 13 - Phase/phase PT connection diagram, 210° phase difference angle

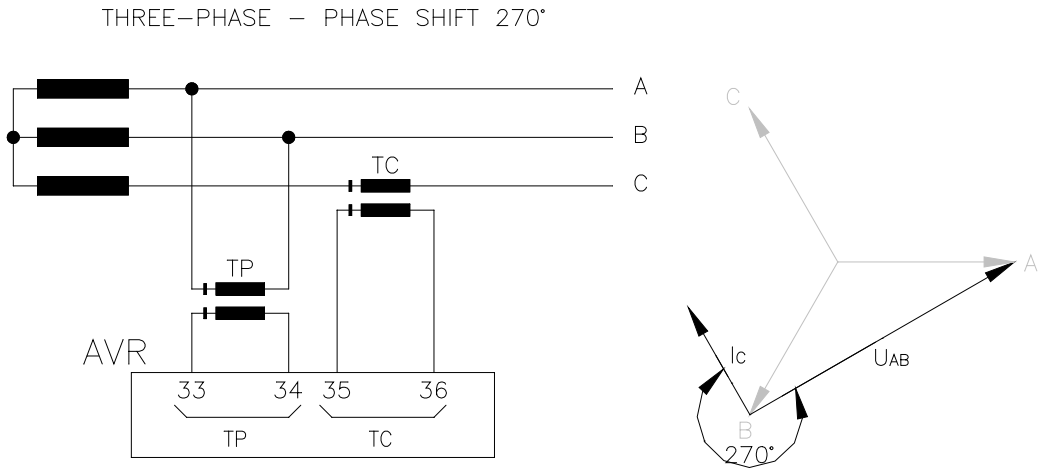


Figure 14 - Phase/phase PT connection diagram, 270° phase difference angle

7) Dry Contact Digital Input

The AVR dry contact digital input can be programmed by users to perform remotely one of the following functions:

- Selection of voltage regulation parameters among the six sets available in the device , or
- Selection of parallelism group to which the AVR belongs, only when the optional item Parallelism by Circulating Current is available.

Table 1 shows the way the AVR interprets contacts connected to this input for both of the deployment options given above.

Contacts connected to these inputs must be free of any external potential, and are energized by way of the AVR's own internal potential, by way of a point common to all contacts (terminal 24).

Table 3 - Selection of voltage regulation parameter set or parallelism group by external contact inputs

INPUT TERMINALS			Regulation Set selected	Parallelism Group selected
27	26	25		
0	0	0	*According to time-based Programming*	*Individual Operation*
0	0	1	*1*	*Group 1*
0	1	0	*2*	*Group 2*
0	1	1	*3*	*Group 3*
1	0	0	*4*	*Not used*
1	0	1	*5*	*Not used*
1	1	0	*6*	*Not used*
1	1	1	*Not used*	*Not used*

Caption: 0 = contact open / 1 = contact closed
Observations:
- Common point: terminal 24
- Regulation Set or Parallelism Group must be selected by the user since both functions cannot be deployed simultaneously.

8) Tap position reading (Optional items no. 3, 7)

Optionally AVRs can read the position of the tap and manually command of the OLTC. Tap position is read by way of a purpose specific input on the AVR for connecting a potentiometric tap position sensor for the OLTC.

- **Cabling for tap position read out**

The connection between the potentiometric OLTC position sensor and the AVR is done through three leads: the cursor, the beginning and end of the potentiometric sensor. The three leads must have the same length and gauge. The lead used in this connection must be shielded along the entire distance between the tap changer and the AVR, with the shielding grounded at a single point.

If the connection is established using more than one length of cable, due to, for example, an intermediate terminal connection, shielding continuity must be ensured by connecting the ends of the shielding of the different cables, as shown in Figure 15. The length of cable without shielding must be as short as possible.

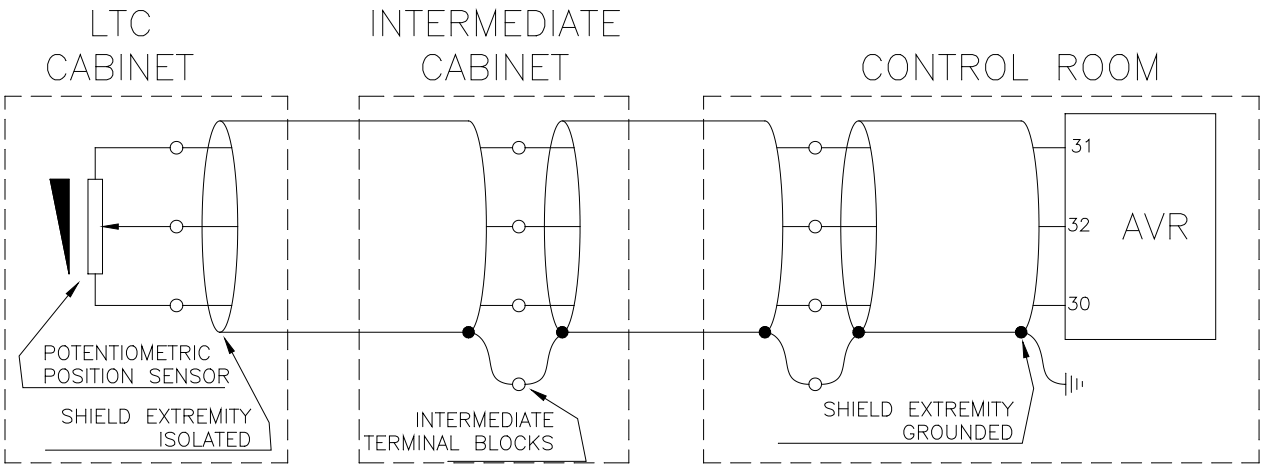


Figure 15 – Connection of shielding on tap position reading cables

The AVR compensates automatically for the resistance of the connection cables from the potentiometric sensor to the AVR, and to this end, the three leads must be the same length and gauge, with maximum admissible resistance for each cable being 8Ω. As a function of this maximum resistance and of the gauge of the cables used, the maximum length for the leads can be calculated. Considering leads with typical resistances of 13.3 Ω/km, 7.98 Ω/km and 4.95 Ω/km for the 1.5mm^2, 2.5mm^2 and 4mm^2 gauge cables, respectively (cables not tinned, cabling class 4), we will obtain the maximum lengths shown in the table below.

Table 4 - Maximum length for each lead gauge used in tap position read out cables

Wire Gauge	Typical Resistance	Maximum Length
0.5 mm^2	39.0 Ω/km	200 m
0.75 mm^2	26.0 Ω/km	300 m
1 mm^2	19.5 Ω/km	400 m
1.5 mm^2	13.3 Ω/km	600 m
2.5 mm^2	7.98 Ω/km	1000 m
4 mm^2	4.95 Ω/km	1600 m

- **Requirements for tap position reading sensor**

The OLTC tap position sensor must be of potentiometric type, with resistance varying between zero and the maximum value for the initial position and the end of the changer, respectively.

In case of tap changers with “intermediate” positions, i.e., transition positions having the same voltage as other adjacent positions, as shown in the following table, resistors of the potentiometer sensor related to these positions must be removed and/or short-circuited, as shown in the example of Figure 16. Every intermediate position (in example, 6A, 6 and 6B) will be shown as tap “6”, since they have the same effective voltage.

Table 5 - Resistance of the potentiometric tap position sensor.

Tap position	Voltage (V)	Current (A)	Resistance between Cursor and Initial Position (example: 10Ω/step)

1	12420	3220.6	*0*
2	12696	3150.6	*10*
3	12972	3083.6	*20*
4	13248	3019.3	*30*
5	13524	2957.7	*40*
6A	13800	2898.6	*50*
6			*50*
6B			*50*
7	14076	2841.7	*60*
8	14352	2787.1	*70*
9	14628	2734.5	*80*
10	14904	2683.8	*90*
11	15180	2635.0	*100*

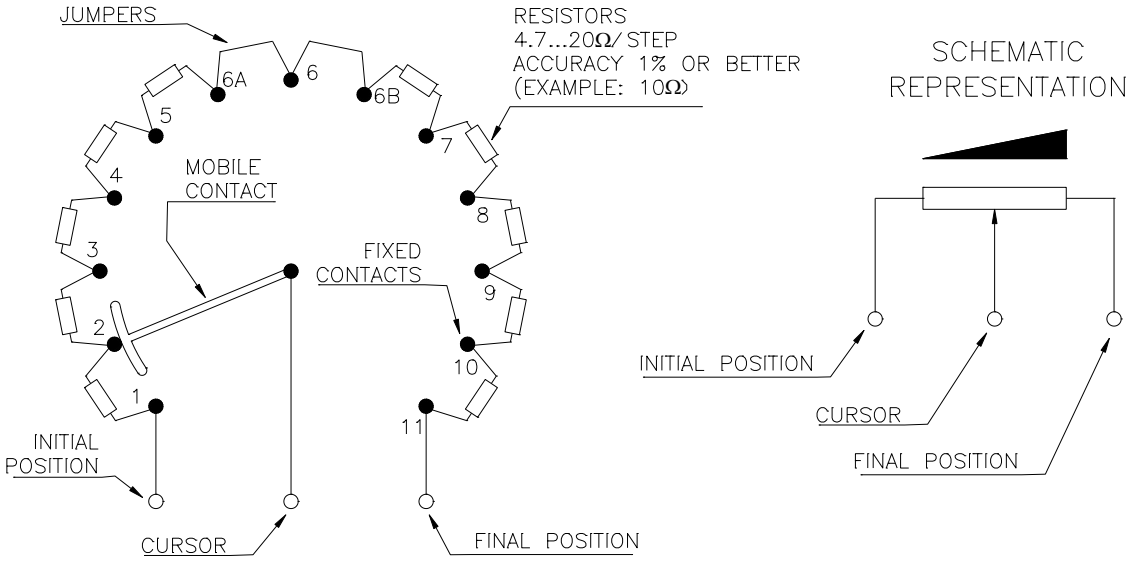


Figure 16 – Configuration of resistors in the potentiometric sensor in intermediate positions of the OLTC

The AVR admits that the resistance for each step of the potentiometric sensor falls in the range of 4.7 to 20Ω, and the total resistance of the sensor between 9.4 and 1000Ω. The value for each individual resistor is shown in Figure 16. The moving contact (cursor) of the potentiometric sensor can be of either “closes before opens” or “opens before closes” types, which is indifferent. The resistances of the potentiometric sensor must be of the precision type, i.e., with error tolerances of 1% maximum.

Current Tap position of the OLTC associated can be informed in simple numeric, bilateral numeric or alphabetical-numeric formats (for example, 1...17, -8...0...8, or 8L...N...8R respectively).

Output Terminals

Table 6 - Output Terminals

OUTPUTS	AVR TERMINALS
1) Current Loop output: Output for remote voltage, current or tap position reading, selected through the program menu. Output standard selected by software (0...1, 0...5, 0...10, 0...20 or 4...20 mA).	*28 – (+)* *29 – (–)*
2) Increase voltage output: Dry contact NO for command of OLTC to raise voltage.	*1, 2*
3) Reduce voltage output: Dry contact NO for command of OLTC to lower load.	*3, 4*
4) Self-diagnostic relay: Dry contact NC for signaling internal AVR failure or to signal lack of auxiliary power input.	*15, 16*
5) Programmable signal relays: Dry contacts (NO), with programmable function and operation mode (NO or NC), for signal, alarm and blockage.	*5 ,6 –Relay 3* *7, 8 –Relay 4* *9, 10 –Relay 5* *11, 12 –Relay 6* *13, 14 –Relay 7*

The characteristics of each output are given below.

1) Current Loop Output

The AVR features an analog output in current loop (mA), which can be programmed by users to offer a remote reading of the value of the voltage or current measured. The output current can also be selected by the user among the options 0-1mA, 0-5mA, 0-10mA, 0-20mA or 4-20mA. Maximum output load in current loop is 10V, which results in the maximum loads in ohms shown in the table below:

Table 7 - Maximum load of current loop output

Output option	Maximum Load	Output option	Maximum Load
0...1 mA	*10000 Ω*	-1...+1 mA	*10000 Ω*
0...5 mA	*2000 Ω*	-5...+5 mA	*2000 Ω*
0...10 mA	*1000 Ω*	-10...+10 mA	*1000 Ω*
0...20 mA	*500 Ω*	-20...+20 mA	*500 Ω*
4...20 mA	*500 Ω*	-	-

If the output is selected to read voltage, beginning and end of scale are, respectively, 0 and 150V, respectively, for current reading, 0 and 10A, respectively, and for tap position reading, minimum and maximum tap, respectively.

Shielded, twisted pair cables, grounded at one end should be used in order to minimize interference.

2) and 3) Raise/Lower Voltage Output Contacts

The AVR's output contacts for Raising or Lowering Tap and/or voltage can be connected directly to the command circuit for the OLTC, acting directly on the coils of Raise/Lower contactors, or may be connected to the corresponding dry contact inputs of the Treetech's PI Position Indicator or SPS Parallelism Supervisor.

These contacts are instant activated, so that for every tap change command issued by the AVR, they will close for approximate time of 0.5 second.

The Raise/Lower voltage output contacts are able to commute loads up to 250Vdc or 250Vac, with maximum power of 70W or 250VA, respectively (for resistive loads). Their continuous conduction capacity (thermal current) is 5A.

Attention must be paid to the fact that output contacts 1-2 always have the function of raising voltage, and output contacts 3-4 always have the function of lowering voltage, and that in some cases raising voltage can mean lowering the tap position and reducing voltage can mean raising the tap.

4) Self-Diagnostic Relay

Potential free NC contact, signals failures in auxiliary power supply or any other internal failure detected by self-diagnostic. On energizing the AVR, this contact changes state (open), and returns to the rest position (closed) in the event of internal failure or power outage.

The self-diagnostic contacts are able to commute loads up to 250Vdc or 250Vac, with maximum power of 70W or 250VA (for resistive loads). Their continuous conduction capacity (thermal current capacity) is 5A.

5) Programmable Output Relays

Five, normal open (NO), potential free contacts programmable by the user to indicate over-current (I>), under-voltage (U<), and over-voltage (U>), in addition to the function of blocking the OLTC. The same contact can signal more than one alarm by deploying an OR logic (for example, I< or U<).

The operation logic for the contacts is selected by the user in the options NO or NC (that is, close when the alarm event occurs or open when it occurs). It is also possible to program more than one relay to signal the same event (multiplication of contacts).

As mentioned above, one or more of the AVR's contacts can be programmed for the function of blocking the OLTC. The conditions that will activate the blockage of the OLTC (following an OR logic) are selected by users among the events of: under-voltage, over-current or over-voltage.

Each programmable output contact is able to commute loads up to 250Vdc or 250Vac, with maximum power of 70W or 250VA (for resistive loads), respectively. Their continuous conduction capacity (thermal current capacity) is 5A.

2.4 Application Diagrams

Below there are two suggestions of wiring diagrams for the Voltage Regulator Relay AVR. The first one is for use together with the changer, and the second one, for use with conventional command selection switches.

Please notice that in both applications, the output contact 5-6 (relay 3) must be programmed for the OLTC blockage function and with normal open (NO) operation mode (0 . In these examples, this relay acts on the coil of an auxiliary contactor that removes power from the command of the OLTC and interrupts commuting in case of over-current or under-voltage, for example. This contact could also act interrupting the power supply to the motor of the OLTC, acting on the coil of a power contactor, whose contacts are connected directly to the power lead for the motor. Another possibility is using this contact to break directly the power supply to

the command of the OLTC, without an auxiliary contactor. In this case the relay should be programmed with operation mode normal closed.

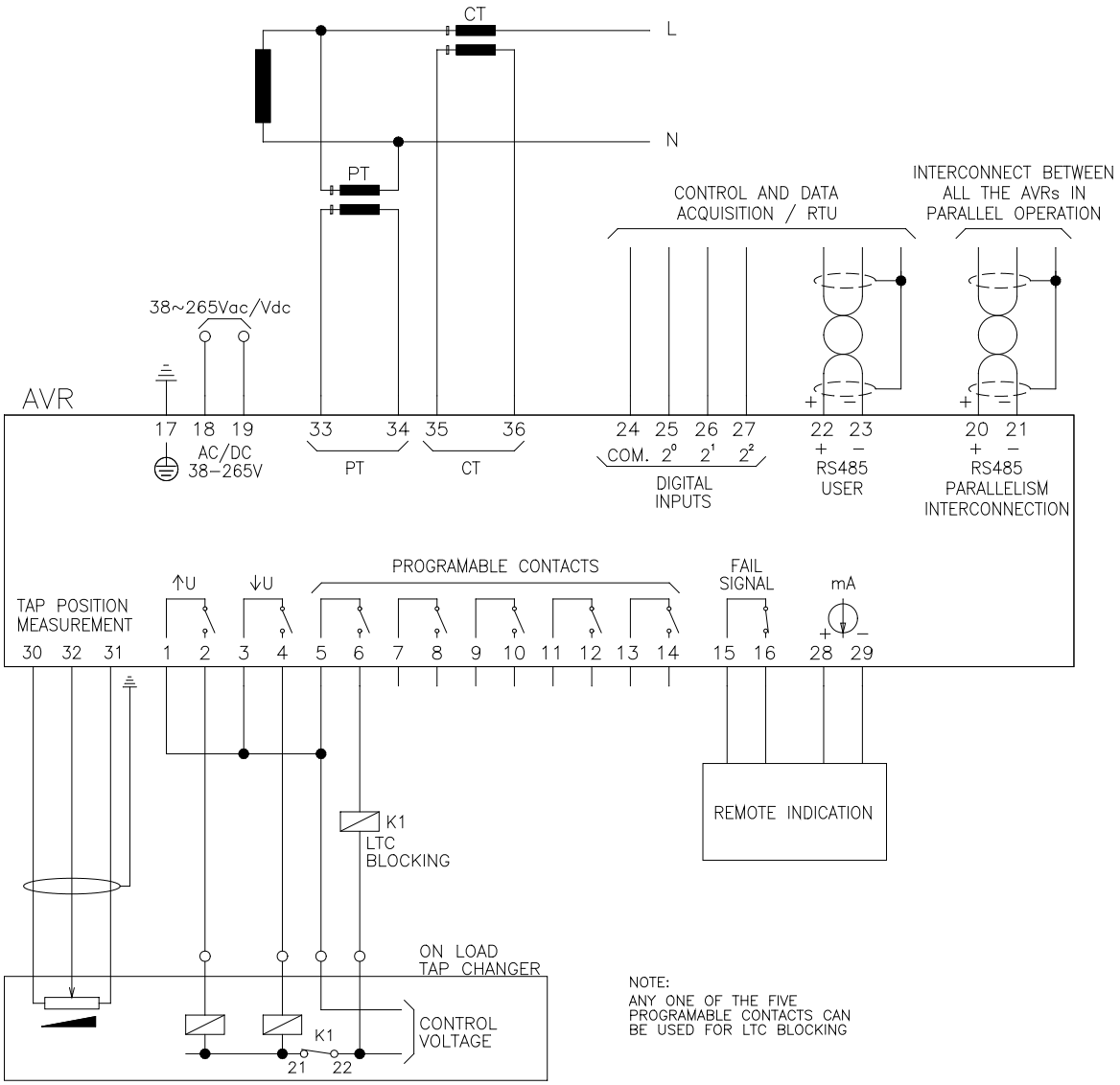


Figure 17 - AVR with tap position reading

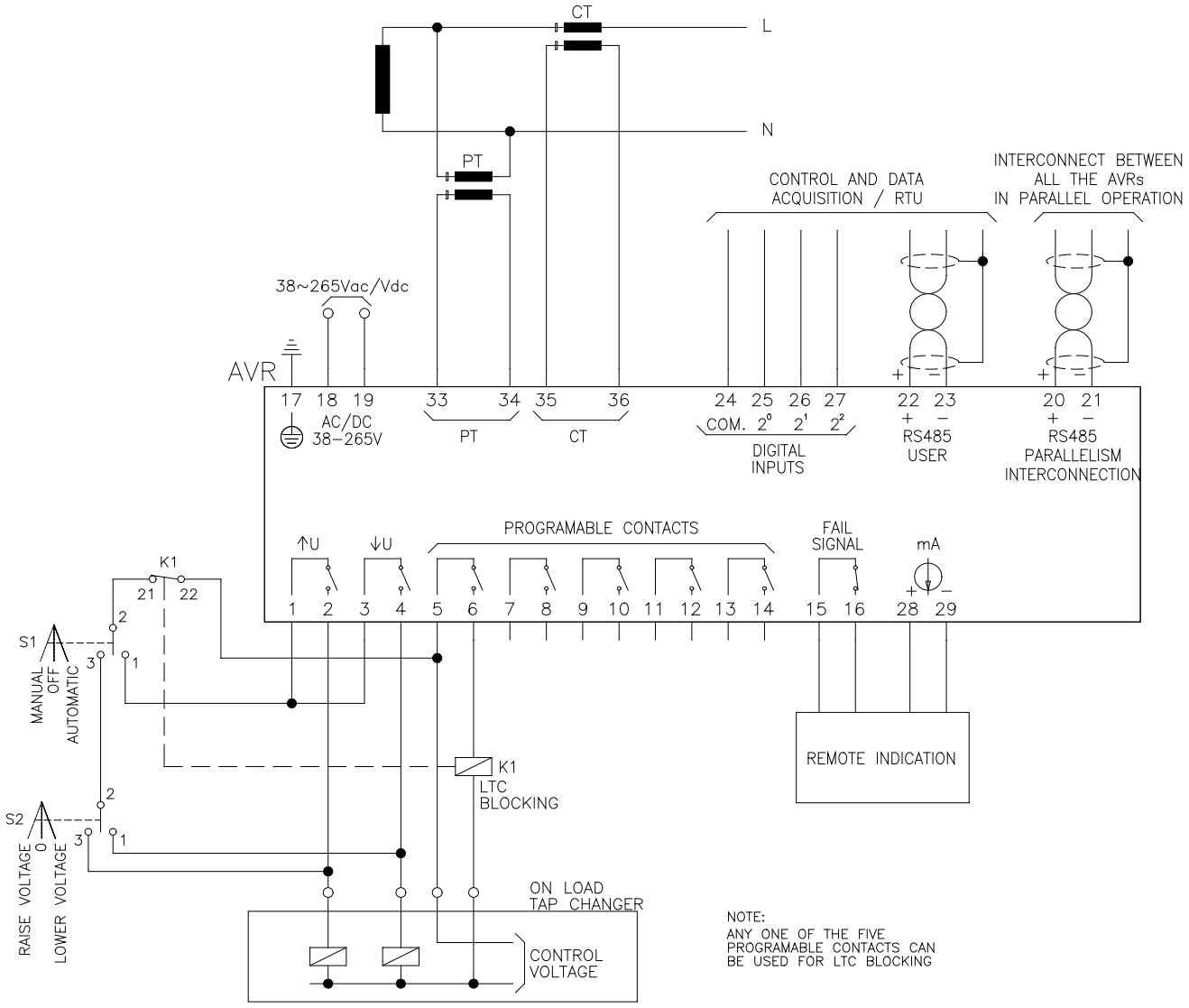


Figure 18 – AVR wiring diagram with external switches

If the optional function for Parallelism by Circulating Current is used, serial communication RS485 ports in terminals 20 and 21 of all AVRs must be connected in parallel, as shown in figure 6(b).

3 Operation

All reading consultations and programming operations for the Voltage Regulator Relay AVR are performed using the display and keyboard on the front panel. Any eventual alarms are also displayed through the front panel display.

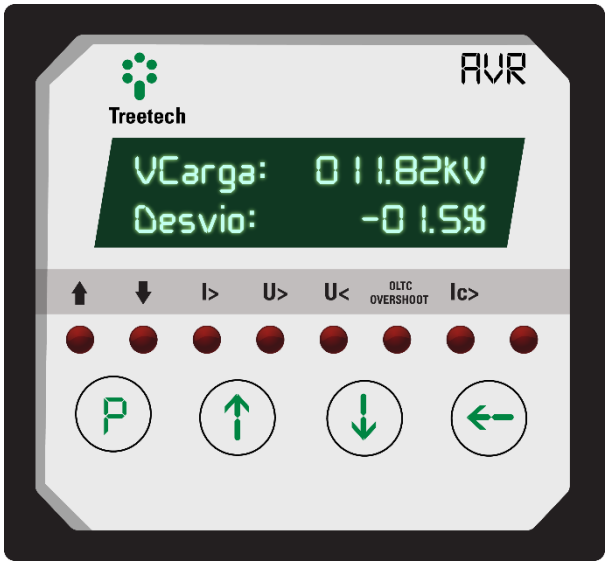


Figure 19 – Front display of the AVR

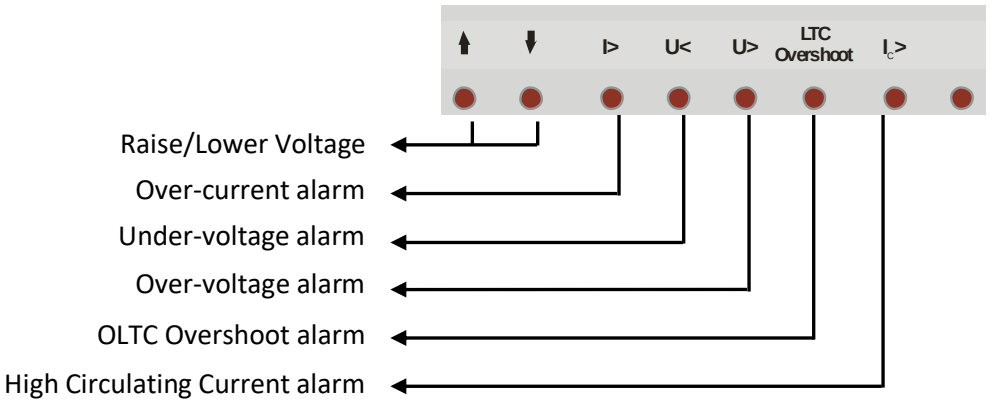
3.1 Functions of Keys and LEDs:

Program Key: On reading screens, allows access to the password for the program menu. In programming menus, exits current menu and return to the previous level menu. If pressed after a parameter change, returns to the preceding level menu without saving the new value for the parameter.

Up Key: navigate between menus and parameters and increment values programmed.

Down Key: navigation between menus and parameters and decrement values programmed.

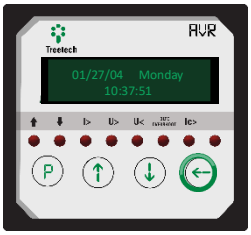
Enter Key: Select menus and parameters for display, saves values programmed.



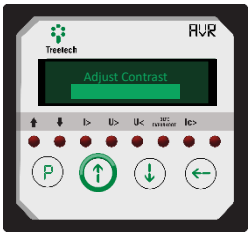
3.2 Contrast Adjustment:

The AVR allows 7 levels of brightness on the display to be adjusted using the keyboard on the front panel.

Follow the steps below to adjust contrast:



On the initial readings screen, press the key: the contrast adjustment screen will be displayed.



Use the keys: and to increase and reduce light intensity, respectively.

Press the or key to store the adjustment and the display will return to the reading screen.

Figure 20 – Adjusting display brightness

3.3 Readings Screens

During regular operation, the AVR will display readings measured or date and time of the internal clock, according to users programming.

Forms of display can be:

1) Default screen, user defined screen option;

2) Sequential format, where the reading screens are shown in sequence, at intervals of approximately 15 seconds;

3) Static format, where a given screen is displayed without change.

When the default or static display screen options are used, the AVR will intermittently invert (text in negative) and normalize display pixels lighting with a view to avoiding the early wear of the display screen by displaying the same message for long periods.

Regardless of the mode programmed, readings screens can be queried manually using the and keys. Optional function screens are only displayed when the function is available. See Appendix C for possible simultaneous optional item combinations.

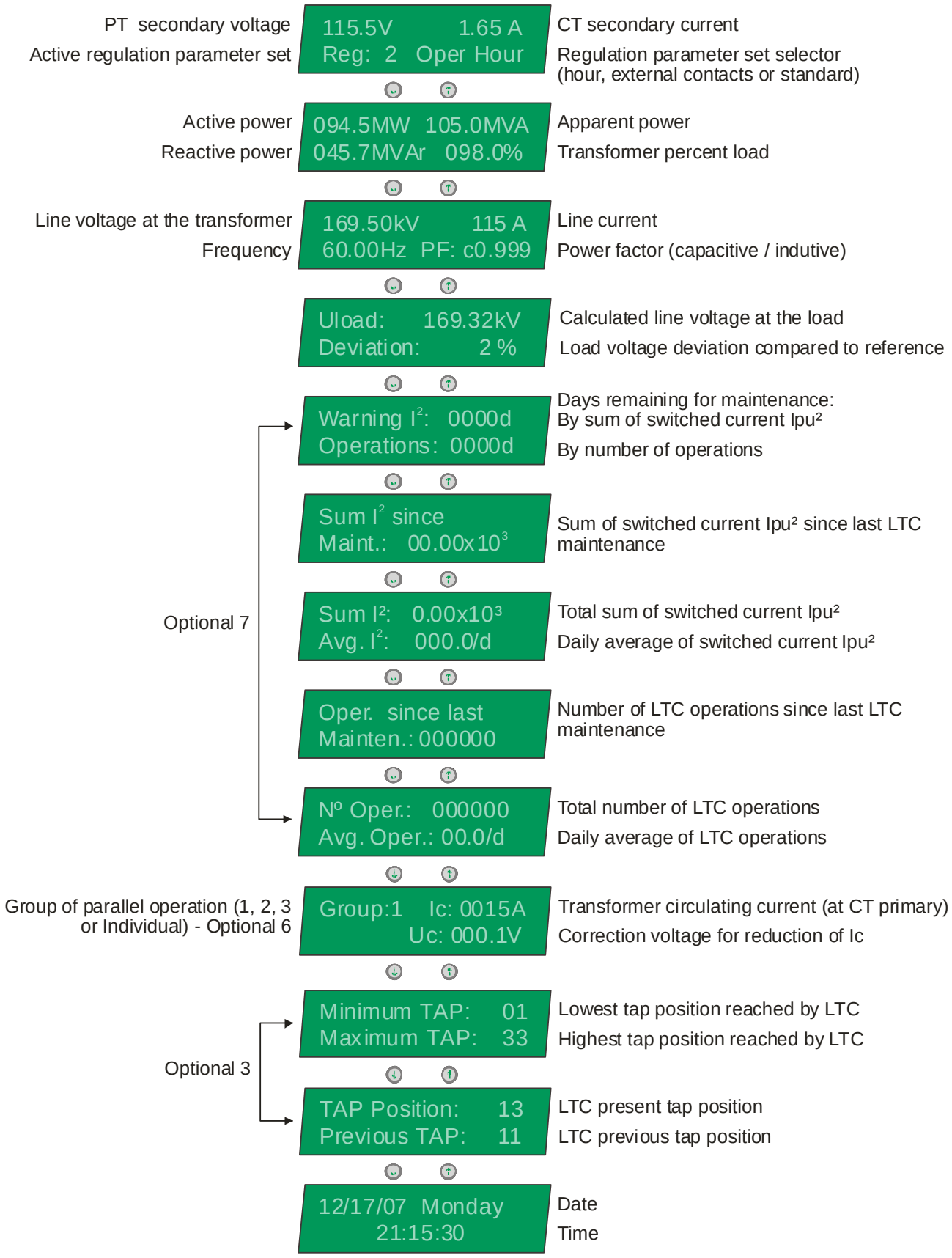


Figure 21 – Readings screens: variables shown on the display of the AVR

In case of any abnormal condition occurring, the corresponding self-diagnostic code will be shown on the display (Chapter 5.1 – Self-diagnostic Messages – Probable Causes and Possible Solutions).

3.4 Alert screens

The AVR can display alert texts on the display for the purpose of informing users on the occurrence of certain pre-programmed events, such as maintenance notices for the changer, alarms or parameter definition errors. Alert texts and procedures to be adopted are shown below.

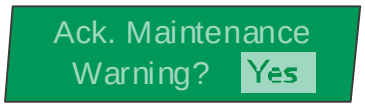
Maintenance Function for OLTC

The alert screens below are shown only if the Tap Changer Maintenance function (optional item no. 7) is available.

OLTC Maintenance Notice in xxx Days due to Number of Operations

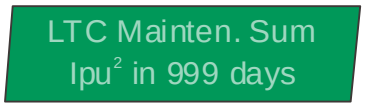
Informs that, based on the daily average operations of the OLTC, the number of operations required for maintenance will be reached in the number of days shown, which is smaller than the figure programmed in parameter “Maintenance Warning (days in advance)”.

The notice can be acknowledged and deactivated by simultaneously pressing the P and ↵ keys. The question “Acknowledge Maintenance Warning?” will be displayed with the option “No” as standard. In order to confirm deactivation of notice, select option “yes” and press the enter key.



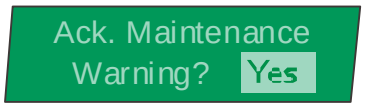
Regardless of the above acknowledgement sequence being performed, when the number of operations to maintenance is reached a new notice will be issued, “Perform OLTC Maintenance”, as described below.

OLTC Maintenance Notice in xxx Days due to Sum of Ipu²



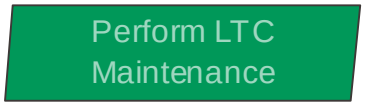
Informs that, based on the daily average of the increase in Sum of Current Switched Squared, the sum of switched current for maintenance will be reached in the number of days shown, which is smaller than the figure programmed in parameter “Maintenance Warning (days in advance)”.

The notice can be acknowledged and deactivated by simultaneously pressing the P and ↵ keys. The question “Acknowledge Maintenance Warning?” will be displayed with the option “No” as standard. In order to confirm deactivation of notice, select option “yes” and press the enter key.



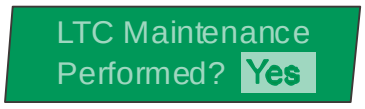
Regardless of the above acknowledgement sequence being performed, when the number of operations to maintenance is reached a new notice will be issued, “Perform OLTC Maintenance”, as described below.

Perform OLTC Maintenance



Informs that, for at least one of the criteria, the threshold was reached for maintenance of the OLTC, by number of operations or sum of current switched squared.

After performing the required maintenance on the OLTC, this must be informed to the AVR by simultaneously pressing the P and ↵ key. The question “OLTC Maintenance performed?” will be displayed with the option



"No" as standard. In order to confirm that maintenance was effectively performed and deactivate the notice, select "Yes" and press the enter key.

ATTENTION: This operation must not be carried out unless the maintenance has been effectively performed, since all counters for "Operations since Last Maintenance" and "Sum of I^2 after Last Maintenance" will automatically be reset to zero.

Alerts in Parallelism by Circulating Current Function

The alert screens shown below will be displayed only if the Parallelism by Circulating Current Function (optional item no. 6) is available.

High Circulating Current

Informs the occurrence of Circulating Current above the threshold value programmed for alarm. When this notice is displayed, users must check if OLTCs in transformers in parallel are in very discrepant tap positions. If so, causes for the event must be investigated, such as incorrect setting for Correction Gain or a defective OLTC.

The notice is automatically removed after the circulating current is restored to normal; there is no need for user acknowledgement.

Regulation Parameter Setting Error

Informs that the transformers selected for operation in parallel (in the same parallelism group) have at least one of the following regulation parameters adjusted with different values:

- Reference Voltage multiplied by the PT Ratio (Reference Voltage referred to PT high voltage side), with maximum difference of 0.1%.
- Timer type
- Type of Line Drop Compensation
- Voltage Drop Ur
- Voltage Drop Ux
- Z Compensation
- Compensation Limit
- Deviations (timer steps 1, 2 and 3)
- Raise Time Delays (timer steps 1, 2 and 3)
- Lower Time Delays (timer steps 1, 2 and 3)

Note that comparison between the parameters above in the different relays is carried out considering the Regulation Set (from 1 to 6) currently active.

The Notice is automatically withdrawn after correction of voltage regulation parameters.

3.5 Command of On Load Tap Changer (Optional items No. 3 & 6)

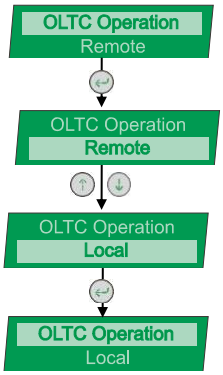
The AVR can be equipped with optional resources for Tap Position Reading and control of OLTC (optional item no. 3) and control of Transformer Parallelism by Circulating Current (optional item no. 6).

The optional feature Tap Position Reading allows the OLTC to be commanded in the automatic mode, according to the regulation parameters programmed; or manually, using the keys located in the device's front panel.

The optional feature of Parallelism by Circulating Current allows transformers in parallel to be programmed, split into up to 3 independent groups.

With one of the optional items enabled, momentarily pressing the key will access the OLTC operation command menu. Press the or keys to navigate between the command parameters *OOLTC Operation*, *Parallelism*, *Operation Mode*, *Reset Minimum Tap and Reset Maximum Tap*.

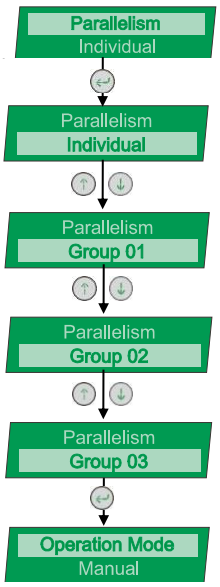
Operation of OLTC (optional items 3 or 6)



Allows the AVR operating mode to be selected between *Remote* or *Local* command modes.

- Remote: AVR will be enabled to receive raise / lower tap commands and Automatic/Manual and Parallelism Group commands using the RS485 serial communication network or external contacts. In this condition, the AVR does not accept commands given through the keyboard.
- Local: the AVR will be enabled to receive raise / lower tap commands and Automatic/Manual and Parallelism Group commands using the keyboard, ignoring commands arriving via RS485 serial communication or external contacts.

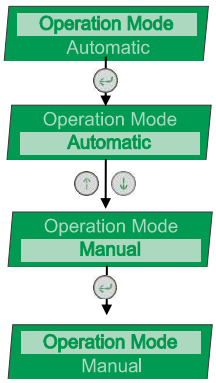
Parallelism (optional item no. 6)



Allows selection of the parallel operation mode for the transformer, as well as the parallelism group of which it is part:

- Individual: transformer is not in parallel with any other.
- Group 01: transformer is in parallel with the other transformers comprising group 1.
- Group 02: transformer is in parallel with the other transformers comprising group 2.
- Group 03: transformer is in parallel with the other transformers comprising group 3.

Mode of Operation (optional item no. 3)

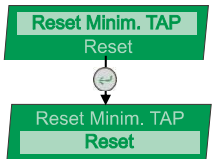


Allows selection of OLTC command mode between *Automatic* and *Manual*.

- Automatic: commands are issued automatically based on regulation parameter values set.
- Manual: user can issue raise or lower tap commands, using the device panel keyboard or serial communication. In this case automatic command is locked out.

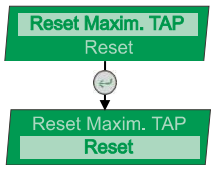
Observation: When the AVR is selected for operating within any of the Parallelism by Circulating Current groups, it is not possible to select the Manual Operation Mode. Selection of the Operation Mode is automatically defined to Automatic.

Reset Minimum Tap (optional item no. 3)



Resets register for minimum tap position reached.

Reset Maximum Tap (optional item no. 3)



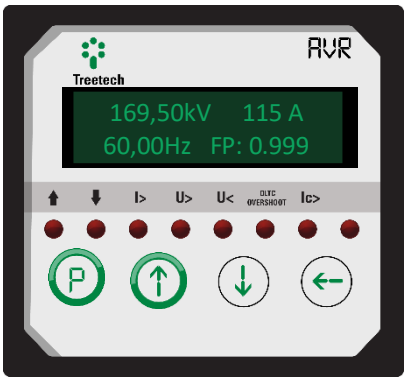
Resets register for maximum tap position reached.

Command Raise/ lower Tap Position

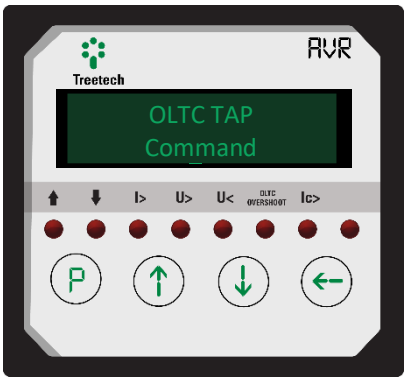
By selecting the Manual command mode, users can issue commands to raise or lower tap position, using the keyboard on the AVR front panel. In order to prevent accidental commands, each command requires pressing a set key sequence, to enable the command.

Manual commands will not be executed if the AVR operation mode selected is Automatic. The AVR will not issue the raise or lower tap command if the changer is already at the programmed maximum or minimum allowed tap position, respectively.

If AVR operation mode selected is Remote, a notice screen will be displayed with the message “OLTC Operation on Remote” when an attempt is made to access the manual command screen. Following which, the Local/Remote selection screen will be automatically displayed.

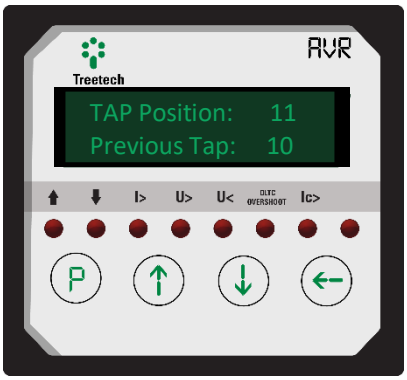


Press and hold the key P while pressing the key ↑



The manual command screen is shown. Press key ↑ to raise TAP or key ↓ to lower TAP.

Repeat this procedure to perform additional commands to raise/lower tap position



AVR will perform the command and show the present tap position.

ATTENTION: The "Manual" command refers to raising or lowering tap position. The correspondence between raise/lower tap position and raise/lower voltage must be checked

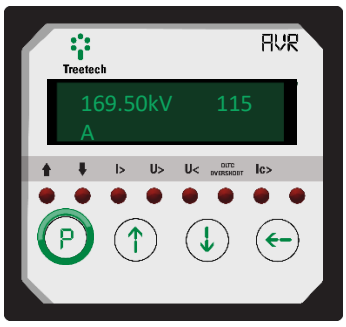
Figure 22 – Procedure for manual Raise/Lower tap position command

3.6 Parameter Definition Menus

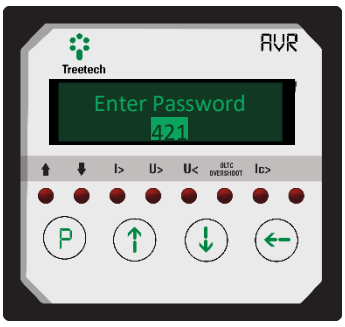
In order to ensure the correct operation of the system, ideal operation of the OLTC and its protection, the different parameters of the AVR must be adjusted to supply the equipment with the necessary operating information. Adjustments may be performed by way of the front keyboard, using the display, or by deploying parameter programming software, using the RS232 or RS485 serial communication ports, available for the user on the device's rear panel.

The programmable parameters are organized in different submenus, inserted into a main password-protected programming menu. Within each submenu, users will have access to a set of programmable parameters that must be adjusted in accordance with each application's needs and the transformer/regulator's characteristics.

Follow the procedure outlined below for access to the parameter definition menu of the AVR:

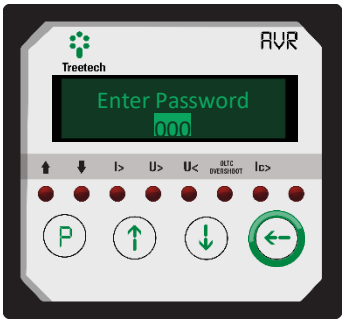


1 – In any measurement Reading screen, press and hold P for 5 seconds.

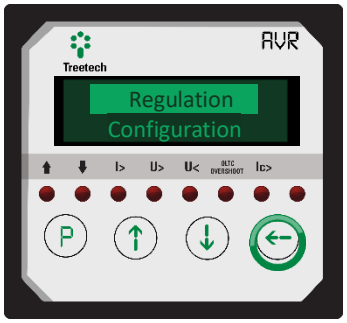


2 – The password screen is shown.

3 – Using the ↑ and ↓ keys, set the access password for the main menu. Factory set default value is 0 and the password can then be changed by user (Configuration Menu).



4 – After setting password, press ↵ to confirm and access programming menus.



5 – Available submenus are displayed, two at a time. Use ↑ and ↓ keys to move among them. Press ↵ to access a submenu.

Figure 23 – Access to parameter definition submenus

There are eight standard submenus and two optional ones, which will only be displayed when the feature is available:

- Regulation,
- Configuration,
- Set Clock,
- Transformer,
- Circulating Current (optional),
- Alarms,
- Relays,
- OLTC (optional),
- Factory Only,
- Download.

The Factory Only submenu is used only by technical assistance services and access is blocked by exclusive manufacturer password. The Download submenu is used for up-dating the AVR's firmware, and is also protected by access password to avoid accidental access. Consult Treetech in case of need to update your AVR's firmware.

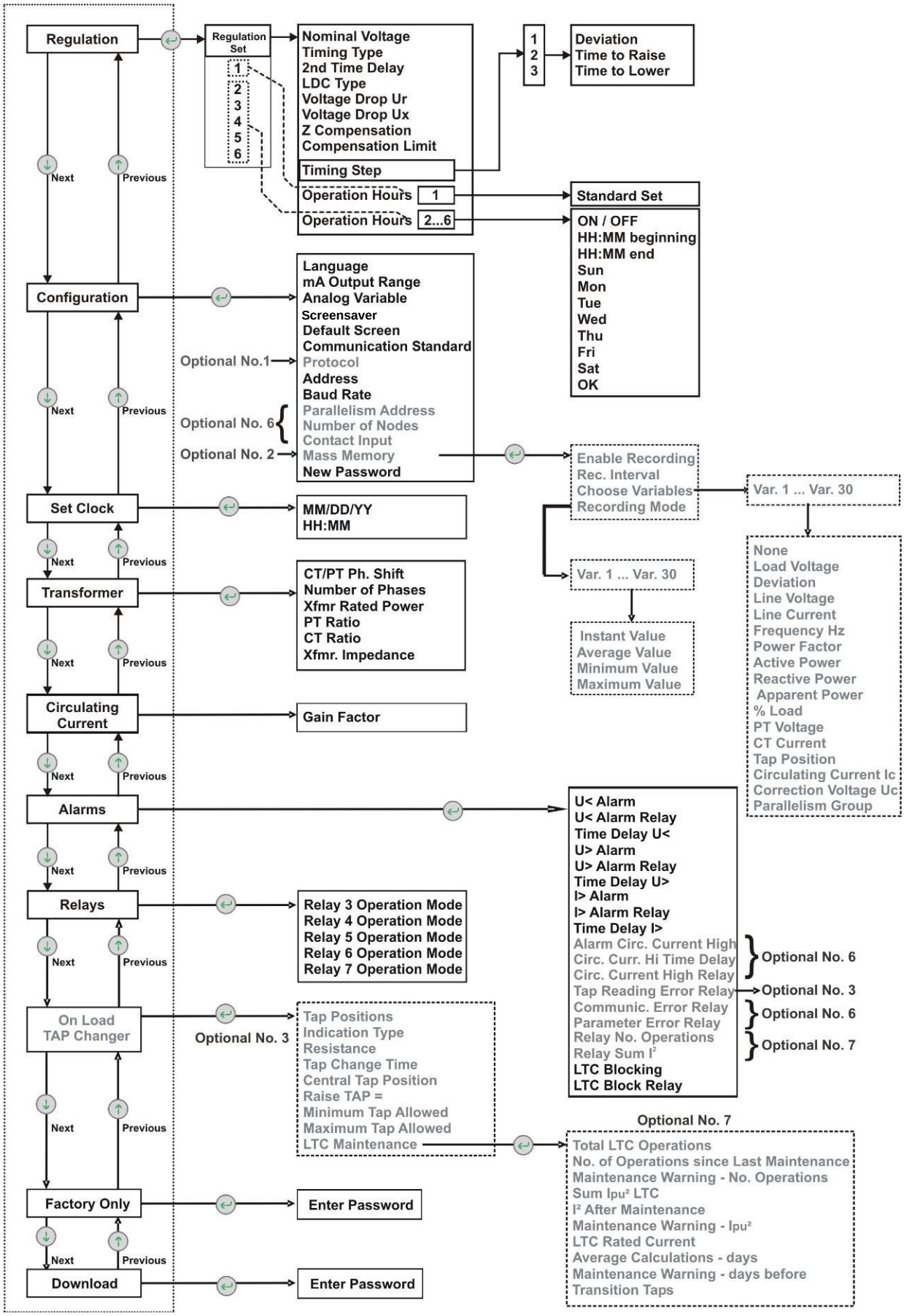


Figure 24 – Submenu Access framework.

- To Access a Submenu or Parameter

- Within the main menu, use the and/or keys to navigate among the submenus available;
- Use the key to access a submenu;
- To return to the previous menu level use the key;

Optional menus are only displayed when the respective function is enabled.

- After accessing the desired submenu:

- Within a submenu, use the and key to navigate among its parameters;
- Press to select the parameter desired for adjustment;
- Use the **or** keys to set the value desired for the parameter;
- Press save any changes made to the parameter;
- Use to exit parameter and return to the menu, without saving any changes made to the parameter.

Regulation Submenu

Allows access to all parameters related to voltage regulation.

Regulation

With the display showing ***Regulation*** menu in highlight, press .

The ***Regulation Set*** submenu will be displayed.

Select the desired set using the or keys and press the key. After selected, the Regulation Set number (1, 2, 3, 4, 5 or 6) will remain fixed at the beginning of display's second line in every parameter of this Submenu.

The AVR offers 6 sets of parameter for voltage regulation. The sets are numbered from 1 to 6.

This allows pre-programming the AVR's regulation parameters to meet the different conditions of the power system. Thus, different levels of regulation can be programmed for load peak and low load periods, for example.

The parameters in Regulation Set 1 must be programmed, since this set is used as default by the AVR whenever no other set is selected to operate. Programming the other Regulation Set s (2 to 6) is optional, and if they have not been programmed, program "***OFF"*** in the ***"Operating Hours"*** parameter.

Regulation Sets 2 to 6 can be activated by programming the hour range for each set, informing day of the week, hour and minute for beginning and end of operation of each Set (see parameter Operating Hours) These sets can also be activated by way of the external dry contacts. Selection made by dry contacts will always have priority over programmed Operating Hours activation. When Regulation Sets 2 to 6 are not active, by dry contact or programming, the device will use Set 1 as default.

Adjusting the Parameters required in each Regulation Set.

Reference Voltage

This is the theoretical voltage that we wish to maintain on the load, referred to the secondary of the measurement PT, that is:

$$\textbf{\textit{Reference Voltage}} = \frac{\textbf{\textit{Desired Voltage on the Load}}}{\textbf{\textit{PT Ratio}}}$$

Example:

- Desired voltage on load = 13200 V
- PT ratio = 13800V / 115V = 120
- Reference voltage = 13200V / 120 = 110V

Adjustment range: 50 to 140 Vac, in 0.1 V increments.

Timing Type

The timer resource is used to avoid unnecessary tap changes during momentary voltage fluctuations, such as for example during the start up of a large motor.

This parameter allows us to choose between two types of timers:

- Defined: where the time to begin an OLTC operation (after the detection of voltage deviation higher than insensitivity) are always equal to the values adjusted in the parameter “Timing Steps” obeying the deviation ranges selected;

- Inverse: where the time to begin an OLTC operation varies in inverse proportion to the measured voltage deviation compared to the reference voltage (the higher the difference between measured voltage and the programmed Reference voltage, the shorter the time for the command to operate the OLTC). Usually used for quick voltage regulation for the event of major deviations.

The timer effectively applied by the AVR in Inverse mode after detection of a voltage deviation larger than insensitivity will be given by:

$$\textit{Effective Time} = \textit{Programmed Time} \cdot \frac{\textit{Programmed Bandwidth}}{\textit{Measured Deviation}}$$

Where,

"Programmed Time" will be the value programmed for the parameter "Time to Raise", if the deviation measured is negative, or the adjustment set on "Time to Lower", if the deviation measured is positive, both in Timer Step 1;

"Programmed Bandwidth" is the value programmed in the parameter "Deviation" of Timer Step 1.

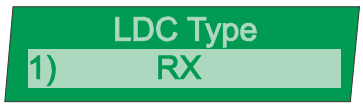
Second Time Delay

The time for the first operation of the OLTC will be adjusted in the parameter ***"Timing Step"***. If a single tap change is not enough for measured voltage to return to the adjusted bandwidth, the AVR will use the value adjusted at "Second Time Delay" as the time interval for the ensuing commands to the OLTC.

Adjustment Range: 2 to 180 seconds, in 01 second increments.

Line Drop Compensation Type

Line drop compensation is a resource in the AVR that allows load voltage (and not voltage at transformer output) to be maintained within the limits set, taking into account line voltage drops between transformer and load given the resistance and reactance of the respective line. The AVR calculates load voltage using readings taken at the output of the transformer and the load current, in addition to the line parameters programmed. The AVR offers two, user-programmable line voltage drop compensation methods:



- **RX**, usually used in systems where line drop voltage is more significant, therefore requiring more accurate compensation. For this type of compensation, the line parameters must be known: Resistance (R) and Reactance (X). When the RX method is selected, the parameters "Ur" and "Ux" must be programmed (see ahead). The "Z Compensation" parameter will have no influence in regulating the voltage;

- Z: this is a simplified method, where an overall percentage of line drop voltage is programmed, instead of the individual parameters Ur and Ux. It does not offer the same accuracy as the RX method because of not taking into account variations in the load power factor, which cause alterations in the percentage of line drop. However, for applications where the power factor does not undergo significant variation, or if the voltage drop is low, this method can have satisfactory results, with the advantage of the simplified adjustment needs. When method Z is selected, the parameter "Z compensation" must be programmed (see ahead). Parameters "Ur" and "Ux" will have no effect on regulating voltage.

Voltage Drop Ur

This parameter will only be used in regulating voltage if the "LDC Type" parameter has been set to "RX". This is the resistive component of the line voltage drop, in Volts, referred to the secondary of the PT and adjusted for the rated current of the AVR (5A).

$$Ur = 5 \,.\, R \,.\, \frac{CT\ Ratio}{PT\ Ratio}$$

Where,

"R" is the resistance of the line between the transformer and the load in ohms;

Adjustment Range: -25 to + 25V, in 0.1V increments.

Voltage Drop Ux

This parameter will only be used in regulating voltage if the "LDC Type" parameter has been set to "RX". This is the reactive component of the line voltage drop as a function of line reactance, referred to the secondary of the PT and adjusted for the rated current of the AVR (5A).

$$Ux = 5 \,.\, X \,.\, \frac{CT\ Ratio}{PT\ Ratio}$$

Where,

"X" is the reactance of the line between the transformer and the load in ohms.

Adjustment Range: -25 to + 25V, in 0.1V increments

Z Compensation

This parameter will only be used in regulating voltage if the "LDC Type" parameter has been set to "Z Compensation". This is the line drop voltage as a percentage of the transformer output voltage, adjusted for the rated current of the AVR (5A). The adjustment of Compensation Z can be obtained experimentally, by measuring simultaneously the transformer output voltage, the voltage at the load and the load current, and using this data in the formula below:

$$Z\ Comp = 100. \frac{Voltage\ at\ Transformer - Voltage\ at\ Load}{Voltage\ at\ Transformer} \,.\, \frac{5 \,.\, CT\ Ratio}{Load\ Current}$$

Adjustment Range: 0 to 15%, in 0.1% increments

Compensation Limit

When performing line drop compensation, the AVR will cause transformer output voltage to rise, for the purpose of keeping load voltage within the bandwidth limits. This rise in voltage will be proportional to the load current, so that very high load currents might lead to high rises of transformer output voltage, which could be harmful for those loads close to the transformer. To keep this from happening, the parameter "Compensation Limit" is programmed establishing an upper limit for the voltage rise expressed as a percentage of the Reference Voltage.

Adjustment Range: 0 to 25%, in 0.1% increments

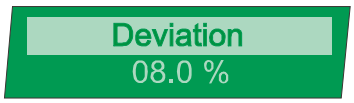
Timing Steps

This submenu adjusts the deviation (or **Bandwidth**) permitted for voltage regulation, that is, the deviation of voltage at the load, given as a percentage of Reference Voltage, which when breached triggers count down for the first operation of the OLTC (time delay to raise or time delay to lower voltage).

The AVR offers up to three different Deviation Steps, each one with its own adjustments for the Time to Raise and Time to Lower voltage.

On accessing the Timing Step submenu, the **Select Step** screen will be displayed, where users choose out of step options 1, 2 or 3. Step programming must start by programming Step 1. Each of the steps has the following parameters:

- Deviation: percent deviation between Reference Voltage (programmed) and measured Load Voltage, which when exceeded starts countdown of the times to raise or time to lower voltage, programmed below.



Adjustment Range: 0 to 10%, in 0.1% increments

- Time to Raise: Time delay set for the first raise voltage command to the OLTC (see also parameter Timing Type).

Adjustment Range: 0 to 180 seconds, in 1 second increments.

- Time to lower: Time delay set for the first lower voltage command to the OLTC (see also parameter Timing Type).

Adjustment Range: 0 a 180 seconds, in steps of 1 sec.

The adjustment for Deviation in step 1 must not be smaller than half of the voltage step (voltage difference between two consecutive taps) of the load tap changer, in order to avoid OLTC instability:

$$\textit{Deviation 1} > 50\% \cdot \frac{\textit{Voltage Step}}{\textit{Reference Voltage} \cdot \textit{PT Ratio}}$$

Example:

- OLTC Voltage Step: 172.5 V
- PT Ratio = 13800V/115V = 120
- Reference Voltage = 13200V/120 = 110V
- Deviation 1 > 50% . 172,5V/ (110V . 120)
- Deviation 1 > 0.65%

The adjustment of the Deviation for each one of the Timing Steps 1,2 and 3 interacts with the others as follows:

In setting the deviation allowed for the first step, this defines the lower limit for the adjustment range of the Second Step, which in its turn will define the beginning of the adjustment range for the third Step. For instance:

Initially Deviation Step 1 is set, with an adjustment range of 0-10%. Let's suppose the adjustment has been set at 3%;

Then Deviation Step 2 will be set, with its adjustment range beginning in 3%, and going to 10%. Let's suppose this was set at 5%

Finally, Deviation Step 3 is adjusted, whose range will begin at 5% and go to 10%. This time the adjustment was set at 8%.

Once the 3 Steps have been adjusted as shown above, let's suppose we need to go back and change the value of the Deviation for Step 2, initially set at 5%. Since the Deviations for Steps 1 and 3 are set to 3% and 8%, respectively, this time the adjustment range for Step 2 is 3% to 8%. If a value lower than 3% needs to be set, for example 2%, then we must first go to Step 1 and adjust its step deviation value to a value lower than 2%.

This way different Time Bands are created to activate the OLTC, as a function of the voltage deviation amplitude. Please remember that the three timer steps will only be effective if Timer Type is selected for Defined Timing. Otherwise, if Inverse Timing is selected as the Timing Type option, then only

the adjustment set for Timer Step 1 will be effectively used in operating the AVR.

Operation Hours

Actuation of Regulation Sets 2 to 6 can be done by programming a time band for each set, with **hour and minute of beginning** (adjustments to the left of the display), hour and minute of end (adjustments to the right of the display) and days of the week in which the time band should be actuated for each set.

- ON: For the regulation parameter set to be used at the scheduled times, "ON" must be selected in the center of the display and times (00:00-23:59) for beginning and end of operation filled in.

- OFF: If the regulation parameter set is not being used, this same parameter should be set to "OFF".

To select or deselect the days of the week, use the enter key to take the cursor to the day chosen and then press the UP or DOWN key. The selection will be confirmed when a horizontal arrow is displayed. Repeat the operation for the other desired days of the week.

Sets 2 to 6 can also be activated using the external dry contacts, and in this case, selection made by way of the dry contacts will have priority over programmed times. When Sets 2 to 6 are not activated by way of the dry contacts or programming, then Set 1 will be used by default.

Submenu Configuration

Allows access to all parameters related to the AVR's general operating configurations.

With the display highlighting the Configuration submenu, press ↵.

Setting Parameters

Language

Selection of the language used by the device to display information:

- Portuguese,
- English,
- Spanish.

mA Output Range

The analog current loop output can be programmed using this parameter in the following ranges.

Adjustment Range:

1) 0...1 mA	4) - 5...+5 mA	7) 0...20mA
2) - 1...+1 mA	5) 0...10mA	8) - 20...+20 mA
3) 0...5 mA	6) - 10...+10 mA	9) 4...20 mA

Analog Variable

The current loop output (configuration defined above) can be configured for remote display of the following readings taken by the device:

- Voltage (0...150 Vac): Voltage measured on the secondary of the PT
- Amperes (0...10 A): current measured on the secondary of the CT
- Tap Position: OLTC tap position.

Screensaver

It allows the user to parameterize the amount of time for the AVR enter power-saving mode (minimum contrast) if no key is pressed. Pressing any key, the device returns to the programmed screen contrast mode.

Adjustment Range: 1 to 15, in increments of 1 minute

Default Screen

Selects screen to be displayed automatically by the AVR equipment is on Screensaver mode. The options in this case are:

- ULoad/Deviation
- Line Voltage/Line Current
- Powers
- PT/CT
- Clock
- Current/Previous Tap position
- Min/Max Taps reached
- Parallelism Group
- OLTC Maintenance

Communication Standard

The AVR has two serial communication ports (RS232 and RS485) available for users for parameter definition and remote data capture. The two channels are not active simultaneously and the communication port that will be used is selected using parameter “Communication Standard”, with the options being:

- RS-232 = use serial RS232 (rear connector DB9)
- RS-485 = use serial RS485 (terminals 20 e 21).

Communication Protocol – Optional No. 1

If the optional DNP3.0 communication protocol is available, allows selection of the protocol used for communication with the data acquisition or parameter definition systems (otherwise Modbus RTU is the standard protocol):

- MODBUS RTU
- DNP 3.0

Communication Address

Defines the address of the AVR in RS232 or RS485 communication ports, used in communication with data acquisition and parameter definition systems.

Adjustment Range: 1 to 247, in increments of 1

Baud Rate

Selects transmission speed (baud rate) for serial communication ports RS232 and RS485, among the options:

- 9600 bps
- 19200 bps
- 38400 bps

Parallelism Address – Optional No. 6

Defines the address of the AVR at the RS485 serial communication port used to link the several different AVRs deployed in the Parallelism by Circulating Current function (optional no. 6).

Each AVR in the communication network must have a unique and sequential address, starting by 3 and rising in increments of 3. For example, in a 3-transformer parallelism, AVRs will have addresses 3, 6 and 9.

Adjustment Range: 3 to 18, in increments of 3

Number of Nodes – Optional item No. 6

Programmed only in the AVR whose address is 3 in parameter “Parallelism Address”. Defines total number of AVRs on the RS485 communication net connecting the different AVRs for the Parallelism by Circulating Current function (optional no. 6).

Adjustment Range: 2 to 6, in increments of 1

Contact Input – Optional Item No. 6

Defines the functions of external dry contact inputs (terminals 24 to 27, see Chapter 3.3.1). Programming options:

- Regulation – Selection of active set of voltage regulation parameters
- Parallelism – Selection of Parallelism by Circulating Current group to which the AVR belongs.

Mass Memory – Optional Item No. 2

This item is optional and will only be displayed if available. It records the readings taken, at user-defined interval, for user-defined variables (up to 30 variables), and the recording mode for each variable.

AVRs have 15,429 registers available for storage of the variables selected by the user. The number of registers used in each recording will be the number of variables the user wishes to store in the event LOG plus 8:

No. of registers = n+8

Where,

n is the number of variables selected by user.

For example:

If the number of variables selected for recording on the event log is 20, we will have:

No. of registers = 20+8 = 28

In this example, the AVR storage capacity will be:

$$\textit{Storage Capacity} = \frac{\textit{Total Registers Available}}{\textit{No. of Registers}} = \frac{15429}{28} = 551 \textit{ records}$$

The interval between recordings on the event LOG is user defined. To calculate the approximate number of recording days before the memory is full, just divide the storage capacity by the number of daily recordings. Continuing with the example given above, and presuming 24 recordings a day (recording interval 1 hour):

$$\textit{Recording Days} = \frac{\textit{Storage Capacity}}{\textit{Record per Day}} = \frac{551}{24} \approx 23 \textit{ days}$$

The number of records per day may vary due to additional records triggered by events such as alarms or tap changes. When the maximum number of registers is reached, the older registers begin to be discarded.

The options available to configure the operation of this optional item are:

- Enable Recording: users can determine whether or not data will be recorded on the data base.

- Recording Interval: variables selected will be stored in time intervals stipulated by the user, which can range between 1 and 120 minutes.

- Choose Variable s: the AVR allows storage of up to 30 variables in the data base. For each variable, one of the 14 magnitudes measured can be attributed. The same magnitude can be attributed to more than one variable, thus allowing different values for the same magnitude to be recorded, according to the recording mode selected (see next item). The following magnitudes can be attributed to each variable:

1)	*None*	*7)*	*Power Factor*	*13)*	*CT Current*
2)	*Load Voltage*	*8)*	*Active Power*	*14)*	*Tap Position*
3)	*Voltage Deviation*	*9)*	*Reactive Power*	*15)*	*Circulating Current*
4)	*Line Voltage*	*10)*	*Apparent Power*	*16)*	*Correction Voltage*
5)	*Line current*	*11)*	*% load*	*17)*	*Parallelism Group*
6)	*Frequency Hz*	*12)*	*PT Voltage*		

- Recording Mode: user can select for each variable the type of measurement to be recorded don the data base, which can be:
  - *Instant Value,*
  - *Average Value,*
  - *Minimum Value*
  - *Maximum Value*

- Reset Log: allows user to erase all data in AVR's mass memory. The operation must be confirmed by selecting YES and pressing the enter key.

New Password

The AVR leaves the factory with the standard menu access password "000". This parameter is used to define the new menu access password.

Note: The initial number shown in the access to programming menus can be used to recover the password, when it is lost (see item 0-Parameter Definition). Inform this number to our Technical Assistance Dept., for decoding your password.

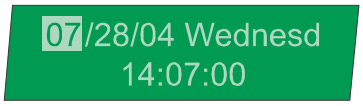
Submenu Clock Set

Sets the AVR's internal time and date.

With the display showing Clock Set in highlight, press 

Set Clock

Use the keys  and  to adjust the value for the field highlighted, then press  to navigate between the fields day, month, year, hour and minute. Once the adjustments are finished, press  to return to the main menu, at which point the clock will restart with seconds set on 00.



The date format is defined as a function of the language setting selected in the Submenu Configuration:

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

The AVR automatically calculates the day of the week.

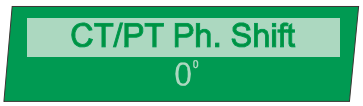
Submenu Transformer

Allows access to all parameters related to the characteristics of the transformer and PT and CT circuits used in performing measurements.

With the display showing the Transformer menu in highlight, press ↵.

The parameters listed below are available for configuration:

CT/PT Phase Shift



There are several possible connection combinations between PT and CT to AVR, and each combination generates an angular shift between the voltage and current signals. This parameter adjusts the phase angle shift between the voltage measured by the PT and the current measured by the CT. This value is used in calculating the power factor. Consult chapter 3.3.1, items 5) and 6) T measurement inputs for information and examples of the possible connection combinations.

Adjustment Range: 0° to 330° in 30° steps

Number of Phases

For the purpose of calculating the active, reactive and apparent powers, the type of transformer to which the AVR is connected must be informed:

- Single-phase
- Three-phase.

In case of a 3-single phase transformer bank, the option three-phase should be selected so that the AVR will inform the powers for the bank and not just one of its phases.

Transformer Rated Power

In order to calculate the transformer's percentage load, the AVR requires the transformer's rated power (or the rated power of the transformer bank).

Adjustment Range: 0 to 999.9 MVA, in 0.1 MVA steps.

PT Ratio

Adjustment of the PT's transformation ratio obtained by dividing the voltage on the primary winding of the PT by the voltage on its secondary winding.

Example:

Considering the voltage of the primary winding 138kV and the voltage of the secondary winding 115V, we obtain the PT's transformation ratio:

$$\textbf{PT Ratio} = \frac{\textbf{13800V}}{\textbf{115V}} = \textbf{120}$$

Adjustment Range: 0 to 9999, in increments of 1.

CT Ratio

Adjustment of the CT's transformation ratio, obtained by dividing the current on the primary by the current on the secondary winding of the CT.

Example:

Considering the current on the primary winding of the CT 2500A and the current on its secondary 5A, we obtain the CT's transformation ratio:

$$CT\ Ratio = \frac{250A}{5A} = 50$$

Adjustment Range: 0 to 9999, in increments of 1.

Transformer Impedance – Optional Item No. 6

Adjustment of transformer impedance for optional item Parallelism by Circulating Current.

The impedance must be programmed considering the same base voltage and power in the AVRs of all transformers in parallel. To do this, in necessary, base changes must be calculated, using the formula:

$$Z_{NEW\ BASE} = Z_{OLD\ BASE} \cdot \frac{V_{OLD\ BASE}^{2}}{P_{OLD\ BASE}} \cdot \frac{P_{NEW\ BASE}}{V_{NEW\ BASE}^{2}}$$

Adjustment Range: 0.1 to 99.9%, in 0.1% increments.

Submenu Circulating Current– Optional item no. 6

Allows adjusting operating parameters for Parallelism by Circulating Current.

With the display highlighting submenu *Circulating Current*, press ↵ .

The parameters used in the configuration menu *Circulating Current a*re listed below:

Gain

Define the Gain to be used in calculating correction voltage, proportional to the Circulating Current of transformers in parallel, which is added to the voltage measured to achieve reduction of circulating current, in a process of negative feedback.

As the gain is adjusted, the correction voltage for the existing situation is up-dated in the lower line of the display.

The ideal value for the Gain can be determined experimentally, using the following procedure:

1) Select manual command mode in the OLTC control cabinet and take them to tap positions with equivalent voltages (null Circulating Current between transformers) and for which the load voltage is within the bandwidth (raise/lower voltage LEDs on AVR are off);

2) Select in the front panel of AVRs the same parallelism group for all transformers in parallel;

3) Increase or reduce tap position in one of the tap changers, causing the appearance of a circulating current;

4) Gradually increase the value of the gain on the AVR for this OLTC, starting at 0%, until the LED for raise or lower voltage starts flashing. If in the previous item, the tap change was in the direction of raising voltage, the lower voltage LED should flash, and vice-versa;

5) Multiply by 1.1 the value of the gain obtained in the previous item and use the result to adjust the parameter Gain;

6) Carry out 2 tap changes in the OLTC, in the opposite direction to what was done in item 3, in order to invert the direction of the current circulation. Check if raise/lower voltage LEDs inverts (if lower LED was previously flashing, now the raise LED should be flashing, and vice-versa). If no LED flashes, increment the Gain value until this happens. Multiply by 1.1 the value of the gain obtained and use the result to readjust the parameter Gain;

7) Normalize the tap changer's position (null Circulating Current between transformers) and repeat procedure above for all other transformers in parallel.

Adjustment Range: 10 to 99% of Rated Voltage, in 1% increments.

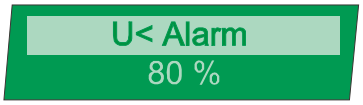
Submenu Alarms

Adjusts alarm trigger values and defines signaling relay operation modes.

With the display showing the menu Alarms in highlight, press  .

The parameters used in configuration of the *Alarms* menu are listed below:

U< Alarm



The under-voltage alarm signals an excessive voltage drop measured on the PT. This drop can be caused, for example, by a short-circuit.

This alarm is issued when the voltage measured on the secondary of the PT presents a value lower or equal to the value set in the parameter Alarm U<, expressed as a percentage of the adjusted Reference Voltage.

To avoid false alarms during de-energizing of the transformer, the U< alarm will not be triggered if voltage drops below 10% of Reference Voltage.

In order to prevent the AVR from operating the OLTC to try to increase the voltage in a short circuit, the U< alarm can be used to block the OLTC in parameter *OLTC Blocking*.

Adjustment Range: 10 to 99% of Reference Voltage, in 1% increments.

U< Relay Alarm

The under-voltage alarm can be signaled remotely using one or more of the AVR's output contacts, among the options relay 3, 4, 5, 6 or 7.

In order to change the program set for a relay, use the enter key to take the cursor to the desired relay and press the Up Key to select it or the Down key to cancel the selection. Horizontal arrows indicate the relays selected.

The same relay selected for the alarm U< can also be used to signal other alarm conditions, for example, Alarm I>.

U< Alarm Time Delay

Allows to set a time delay for the Under-Voltage Alarm, which will only be triggered if the voltage is kept below the value set for the parameter *Alarm U<* for a time longer than the adjusted.

This avoids unnecessary actuation of the alarm due to short duration events like transients in the power system, for example. Timing is not applied to blockage of the OLTC for under-voltage, if selected, since this is instantaneous.

Adjustment Range: 0 to 200 seconds, in 1s increments.

U> Alarm

The over-voltage alarm signals an excessively high voltage measured on the PT.

This alarm is issued when the voltage measured on the secondary of the PT presents a value higher or equal to the value set in the parameter Alarm U>, expressed as a percentage of the adjusted Reference Voltage. This condition can be harmful to loads connected to the transformer.

In the event of over-voltage, the AVR can operate immediately the OLTC in an attempt to lower the voltage, ignoring the timer settings. If ignoring this fast operation is desired, users can select the U> alarm as a condition for blockage of the tap changer in parameter *OLTC Blocking*.

Adjustment Range: 101 to 199% of Reference Voltage, in 1% increments.

U> Alarm Relay

The over-voltage alarm can be signaled remotely using one or more of the AVR's output contacts, among the options relay 3, 4, 5, 6 or 7.

In order to change the program set for a relay, use the enter key to take the cursor to the desired relay and press the Up Key to select it or the Down key to cancel the selection. Horizontal arrows indicate the relays selected.

The same relay selected for the alarm U> can also be used to signal other alarm conditions, for example, I> Alarm.

U> Alarm Time Delay

Allows to set a time delay for the Over-Voltage Alarm, which will only be actuated if the voltage is kept above the value set for the parameter *Alarm U>* for a time longer than the time defined.

This avoids unnecessary actuation of the alarm due to short duration events like transients in the power system, for example. Timing is not applied to blockage of the OLTC for over-voltage, nor for fast voltage reduction, if selected, since these are instantaneous.

Adjustment Range: 0 to 200 seconds, in 1s increments.

I> Alarm

The over-current alarm is issued when, due to a short-circuit or overload, the current measured in the secondary of the CT presents a value higher or equal to the one set in the parameter for I> Alarm, expressed as a percentage of the Rated Current for the AVR (5A).

Operating the OLTC under high currents can be harmful to the device's contacts. In order to prevent the AVR from actuating the tap changer to try to raise or lower the voltage during a short-circuit, users can select the I> Alarm as condition for blockage of the OLTC in parameter *OLTC Blocking*.

Adjustment Range: 10 to 200% of AVR's rated current (5A), in 1% increments.

I> Relay Alarm

The over-current alarm can be signaled remotely using one or more of the AVR's output contacts, among the options relay 3, 4, 5, 6 or 7.

In order to change the program set for a relay, use the enter key to take the cursor to the desired relay and press the Up Key to select it or the Down key to cancel the selection. Horizontal arrows indicate the relays selected.

The same relay selected for the I> Alarm can also be used to signal other alarm conditions, for example, U< Alarm.

I> Alarm Time Delay

Allows setting a time delay for the Over-Current Alarm, which will only be actuated if the current measured is above the value set for the parameter *I> Alarm* for a time longer than the time defined.

This avoids unnecessary actuation of the alarm due to short duration events. Timing is not applied to blockage of the OLTC for over-current, if selected, since this is instantaneous.

Adjustment Range: 0 to 200 seconds, in 1s increments.

High Circulating Current Alarm – Optional Item No. 6

Defines the value set for the High Circulating Current alarm between the transformers in parallel, caused by excessive divergence between the taps of the transformers.

Adjustment Range: 1 to 1000A, in 1A increments.

High Circulating Current Alarm Time Delay – Optional Item No. 6

Allows setting a timer for actuation of the High Circulating Current Alarm, which will only be actuated if the circulating current measured is above the value set for the parameter *Alarm High Circulating Current* for time longer than the time defined.

This avoids unnecessary actuation of the alarm due to short duration events. Timing is not applied to blockage of the OLTC for High Circulating Current, if selected, since this is instantaneous

Adjustment Range: 0 to 180 seconds, in 1s increments.

High Circulating Current Relay – Optional item No. 6

The High Circulating Current Alarm can be signaled remotely by way of one or more AVR outputs contacts, among the options relay 3, 4, 5, 6 or 7.

In order to change the program set for a relay, use the enter key to take the cursor to the desired relay and press the Up Key to select it or the Down key to cancel the selection. Horizontal arrows indicate the relays selected.

The same relay selected for the High Circulating Current alarm can also be used to signal other alarm conditions.

Tap Reading Error Relay – Optional Item No. 3

The alarm caused by tap reading error can be signaled remotely by way of one or more outputs contacts of the AVR. The parameter "Tap Error Relay" selects the output relays that will be used for this purpose: 3, 4, 5, 6 or 7.

In order to change the program set for a relay, use the enter key to take the cursor to the desired relay and press the Up Key to select it or the Down key to cancel the selection. Horizontal arrows indicate the relays selected.

The same relay selected for the Tap Reading Error alarm can also be used to signal other alarm conditions.

Communication Error Relay – Optional Item No. 6

Failure in communication between AVRs on transformers in parallel can be signaled remotely by way of one more outputs contacts of the AVR.

In order to change the program set for a relay, use the enter key to take the cursor to the desired relay and press the Up Key to select it or the Down key to cancel the selection. Horizontal arrows indicate the relays selected.

The same relay selected for the Communication Error alarm can also be used to signal other alarm conditions.

Parameter Definition Error Relay – Optional Item No. 6

The alarm Parameter Definition Error between AVRs of transformers in parallel, caused by programming different regulation parameters on the devices, can be signaled remotely by way of one or more AVR output contacts.

In order to change the program set for a relay, use the enter key to take the cursor to the desired relay and press the Up Key to select it or the Down key to cancel the selection. Horizontal arrows indicate the relays selected.

The same relay selected for the Parameter Definition Error alarm can also be used to signal other alarm conditions such as, for example, Communication Error Alarm or others.

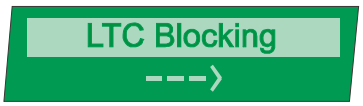
No. of Operations Relay – Optional Item No. 7

The notice issued by the AVR when the number of tap change operations reaches the value where there is a need to perform maintenance on the tap changer can be signaled remotely by way of one or more AVR output contacts. Parameter “Relay No. of Operations” is used to select the output relays that will be used for this purpose: 3, 4, 5, 6 or 7. The same relay selected for this notice can also be used to signal other alarm conditions.

Sum of Ipu^2 Relay – Optional Item No. 7

The notice issued by the AVR when the sum of current switched squared (Ipu^2) reaches the value where there is a need to perform maintenance on the tap changer can be signaled remotely by way of one or more AVR outputs contacts. Parameter “Relay Sum of I^2” is used to select the output relays that will be used for this purpose: 3, 4, 5, 6 or 7. The same relay selected for this notice can also be used to signal other alarm conditions.

OLTC Blockage



Allows selecting the conditions that should cause blockage of the on load tap changer among the following options:

- I> – Blockage for Over-Current
- U> – Blockage for Over- Voltage
- U< – Blockage for Under-Voltage
- OLTC – Blockage for Tap Changer Overshoot (OLTC performing tap changes not initiated by the AVR)
- Icirc – Blockage for High Circulating Current

When one or more of the conditions programmed in this parameter occur, the AVR will not issue any command to the OLTC, blocking the action of increasing or reducing voltage. The OLTC blockage function can be associated to an output contact, which can be used to interrupt the control or even motor power supply to the tap changer, aborting operations already

started in the driving mechanism before the operation of the main contacts.
This contact is configured in parameter *OLTC Blocking Relay*.

OLTC Blockage Relay

Allows one or more output relays to be selected to carry out the electric blocking of the on load tap changer when one or more of the conditions selected in parameter *OLTC Blockage* happen. The relays available for this parameter are: RL3, RL4, RL5, RL6 or RL7.

Submenu Relays

Selects the work mode for the AVR's output relays.

With the display showing Relays in highlight, press .

The parameters used in the configuring menu *Relays* are listed below:

Operation Mode - Relay 3 to Relay 7

Output relays 3, 4, 5, 6 and 7 of the AVR have their operating mode programmed among the options:

- Normally Open: relay will remain open, closing only on the occurrence of the condition for which it has been programmed (for example, an under-voltage alarm or OLTC blockage)
- Normally Closed: relay remains closed when AVR is energized, opening only on the occurrence of the condition for which it has been programmed or in case of power failure.

Submenu Load Tap Changer – (Optional Items Nos. 3 and 7)

This menu will only be displayed if the optional items 3 or 7 are available.

Allows parameters related to tap position measurement and OLTC command.

With the display highlighting menu *Load Tap Changer*, press .

The parameters used in configuring this menu are listed below:

Number of Tap Positions

Sets the OLTC number of taps.

Adjustment Range: 1 to 50 taps

Type of Tap Position Indication

This is the type of display for the tap reading adopted by the AVR, and generally follows the type of reading shown in the On Load Tap Changer.

Type of reading display:

- Simple Numeric
- Inverse Alphanumeric
- Alphanumeric
- Bi-lateral Inverse
- Bilateral

Step Resistance of Potentiometric Sensor

This is the resistance per step of the OLTC potentiometric tap position sensor.

Adjustment Range: 4.7 to 20 Ohms

Tap Changing Time

This is the time the OLTC takes to perform a full tap change. In the case of transformers with intermediate taps, the best part of the change will take place in tap changes requiring passage through the intermediate positions.

Adjustment Range: 1 to 100 seconds

Central Tap Position

Adjusts the central tap of the OLTC, which is the position, counted from the beginning of the measuring range, corresponding to the neutral tap. It only requires adjusting when the parameter *Indication Type* has been programmed for *Numeric bi-lateral* or *Alphanumeric*, since it enables the tap position in OLTCs with asymmetric voltage increase and reduction ranges to be read. The following table gives an example of the effect caused by this parameter in the reading of a tap position for a OLTC with a total of 33 positions and readings of the type Numeric bi-lateral and Alpha-numeric inverse.

Central Tap Parameter	Example Numeric Bi-lateral	Example Alpha Numeric Inverse
15	-14...0...+18	-14R...N...+18L
16	-15...0...+17	-15R...N...+17L
17	-16...0...+16	-16R...N...+16L
18	-17...0...+15	-17R...N...+15L

Adjustment Range: 2 to 50 Taps

Raise TAP =

This parameter indicates, for tap changer used, the raise tap command means raising voltage and the lower command tap means reducing voltage or if the raise tap command means reducing voltage and the command lower tap means increase voltage.

Beware of the fact that AVR output contacts 1-2 and 3-4 always have the function of increasing or reducing voltage respectively.

Minimum Tap permissible

This parameter limits minimum tap that the OLTC must reach, for example, to prevent the voltage from reducing and reaching values that might damage consumers farther away from the transformer.

Maximum Tap permissible

This parameter limits maximum tap that the OLTC must reach, for example, to prevent the voltage from rising and reaching values that might damage consumers closer to the transformer.

OLTC Maintenance – Optional Item No.7

This item is optional and will only be displayed if available.

The On Load tap Changer (OLTC) is one of the main sources of power transformer failures, in particular due to the existence of moving parts that carry or interrupt high voltages and currents. For this reason, the normal wear of the OLTC must be monitored, which is done by way of preventive inspections and maintenance actions based on the number of changes and use conditions, as well as in accordance with the manufacturer's recommendations.

The Tap Changer Maintenance function affords users a Maintenance Wizard for the OLTC, a tool that carries out on-line, automatic control of different parameters, such as:

• Total number of tap changer operations, from onset of operation, and number of operations after last maintenance;

• Sum of current switched (in pu – per unit) squared (Ipu^2), since the beginning of the tap changer operation and since last maintenance, affording a contact wear index;

• Daily average of tap changes and current switched squared;

• Time forecasts until the number of tap changes or sum of current switched squared for maintenance is reached, based on the daily evolution averages for these variables;

• Notice, with programmable advance, for tap changer inspection or maintenance due to reaching the number of tap changes or sum of current switched squared for maintenance.

Options available to configure operation of this optional item are:

Total OLTC Operations

Defines total number of tap changer operations since onset of operation.

Allows adjusting current number of tap changer operations, so that the count of the AVR coincides with the mechanical counter found in most OLTCs.

The OLTC operation counter is incremented each time the reading for tap position is changed.

Adjustment Range: 0 to 999,999 operations.

No. of Operations since Last Maintenance

Defines the partial number of tap changer operations, since last maintenance or inspection action carried out on it.

Allows adjusting the number of operations since tap changer maintenance on equipment already in operation when the AVR was installed.

The OLTC operation counter is incremented each time the reading for tap position is changed.

Adjustment Range: 0 to 999,999 operations.

Maintenance Notice – No. of Operations

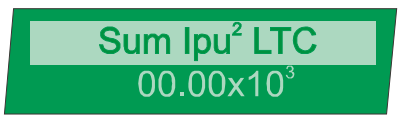
Defines the number of tap changer operations before maintenance of the OLTC is required, according to the manufacturer's indication. When the counter for "No. of Operations since Last Maintenance reaches the value configured, the AVR issues a notice indicating the need for maintenance on the tap changer.

The notice can be signaled on a programmable output relay.

The maintenance required notice remains active on the AVR, and the notice issuance contacts programmed will remain actuated, until user performs manual notice acknowledgement sequence. This procedure informs the AVR that the required maintenance has been carried out. After the acknowledgement, counter for "No. of Operations since Last Maintenance" is zeroed and the maintenance notices are deactivated.

Adjustment Range: 0 to 999 mil operations.

Sum of Ipu^2 since onset of OLTC operation



Tracks sum of current switched squared by the OLTC (Ipu^2) since the beginning of operation.

Allows adjusting the current value of this variable for tap changers on equipment already in operation when the AVR was installed.

The sum is incremented by the value of the load current measured, converted to p.u. (per unit) and squared, in the instant there is a change in OLTC tap position.

Adjustment Range: 0 to 2000 x 10^3 pu^2 in 0.01 steps (to 99.99), 0.1 (to 999.9) and 1 (starting in 1000).

Sum of Ipu^2 since Last Maintenance of OLTC

Defines the sum of current switched squared by OLTC (Ipu^2) since the last maintenance action on the tap changer.

Allows adjusting the current value of this variable for tap changers on equipment already in operation when the AVR was installed.

The sum is incremented by the value of the load current measured, converted to p.u. (per unit) and squared, in the instant there is a change in OLTC tap position.

Adjustment Range: 0 to 2000 x 10^3 pu^2 in 0.01 steps (to 99.99), 0.1 (to 999.9) and 1 (starting in 1000).

Maintenance Notice - Ipu^2

Defines the sum of current switched squared by OLTC (Ipu^2) for maintenance of the OLTC, according to the indication given by its manufacturer. When counter "I^2 Since Maintenance" reaches the value configured, the AVR issues a notice indicating the need for maintenance on the tap changer.

The maintenance required notice remains active on the AVR, and the notice issuance contacts programmed will remain actuated, until user performs manual notice acknowledgement sequence. This procedure informs the AVR that the required maintenance has been carried out. After the acknowledgement, counter for "I^2 since Maintenance" is zeroed and the maintenance notices are deactivated

Adjustment Range: 0 to 2000 x 10^3 pu^2 in increments of 1.

OLTC Rated Current

Defines the tap changer's rated current referred to the secondary of the measurement CT. The setting is used as basis for conversion of the load current measured during the tap changes from amperes to p.u. (per unit).

Adjustment Range: 0.10 to 10A, in 0.01A increments.

Calculation of the Averages

Defines the number of days to be used in calculating average daily tap changes and daily average current switched squared - Ipu^2.

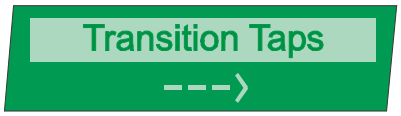
Adjustment Range: 10 to 365 days, in 01 day steps.

Maintenance Notice – Time in advance for issuance

Defines the number of days in advance that the tap changer maintenance required notice will be first issued.

Adjustment Range: 0 to 365 days, in 1 day steps.

Transition Tap Positions



Defines the transition tap changer positions, when they exist. Users can create up to 4 rules, as follows:

Enable the rule by way of option ON / OFF;

Choose the initial tap position (the final position is automatically selected, being the next position);

Inform the number of tap change operations performed by the OLTC between the initial and the final tap positions, as well as the number of times in which the current is interrupted in this process.

Submenu Factory Only

With the display highlighting the *Factory Only* menu, press ↵. The factory password will be requested.

This menu is for exclusive use by Treetech technical support service, and is not available for the user of the equipment.

Submenu Download

Access to the firmware update feature (resident program in the device's micro-controllers) using the serial communication ports RS232. Update is carried out using purpose-specific software from Treetech.

With the display showing ***Download*** in highlight, press ↵

When this submenu is selected, the access password is requested again, which is the same password used to access the main menu. This password confirmation is for the purpose of avoiding accidental access to this menu.

Once the password has been confirmed, the microcontroller (uC) that will receive the new firmware must be selected:

- Main uC
- Secondary uC

After selecting the micro-controller, the AVR will paralyze the execution of its regular program and will wait for the transmission of the new firmware by the PC connected to the serial communication port RS232 of the AVR.

If the option selected is "Main uC", the message "Ready to receive firmware" will be displayed. If "Secondary uC" is selected, the message will be "Uploading to uC2".

In order to quit this process before beginning transmission of the firmware, the AVR must be reinitialized (turned off and then on).

4 Start Up Procedure

Once the equipment has been installed as shown in

Design and Installa part of this manual, the following basic steps must be followed for start-up:

- Check that electrical wiring has been correctly done (for instance, by way of continuity testing);
- Before energizing the transformer, or before removing the short circuit of the CT secondary, make sure that the current transformer secondary circuit is correctly connected to the input of the AVR, making sure the CT secondary is not open;
- Disable the commands for OLTC (for example: detach the lower connector of the AVR – terminals 1 to 16 – or select OLTC for Local command in its control cabinet) before energizing the AVR;
- If dielectric strength tests are carried out on the wiring (applied voltage), disconnect the leads connected to the ground terminal of the AVR in order to avoid destroying the protections against over-voltages inside the device. These protections are connected internally between the input/output and ground terminals, limiting the voltage at around 300V. Applying high voltages for long periods of time (for example, 2kV for 1 minute) would destroy these protections.
- Reconnect the ground leads to the terminals of the AVR, in case they were disconnected for applied voltage testing.
- Energize the AVR with any voltage in the 38 to 265Vdc/Vac 50/60Hz range.

Carry out parameter definition of AVR, in accordance with the instructions of Chapter 0 –

- Parameter Definition , using the front panel keyboard on the device or the parameter programming software via serial ports. Values used in defining parameters can be written down in the form supplied in Appendix A;

- Remove the short circuit jumper from the secondary of the CT, if this was done previously;

- Check that voltage, current and power factor readings of the AVR are correct;

- Check that the current loop output features the correct value in relation to the variable associated (voltage, current or tap position);

- Test actuation of dry contact inputs for selection of Voltage Regulation Parameter sets or selection for the group of Parallelism by Circulating Current;

- Normalize commands for OLTC (reinsert lower connector of the AVR or select OLTC for Remote command);

- If possible use variable AC voltage and current sources in order to vary these magnitudes at the AVR's input. Check activation of raise and lower voltage contacts, the operation of the different alarms (U<, U>, I>) and blockage of the OLTC.

The user has the possibility to unlock the OLTC with the active power flow reversal alarm. However, Treetech does not recommend using this function. Its use and the consequences it generates when regulating the voltage are the sole responsibility of the user. Unlocking is done via communication protocol (see "AVR communication protocol").

5 Troubleshooting

5.1 Self-diagnostic Messages – Probable Causes and Possible Solutions

The software of the Voltage Regulator Relay AVR constantly checks the integrity of its functions by way of its self-diagnostic circuits and algorithms. Any abnormal condition observed, is signaled by the failure contact and the messages shown on the display of the AVR, helping in the failure diagnosis process.

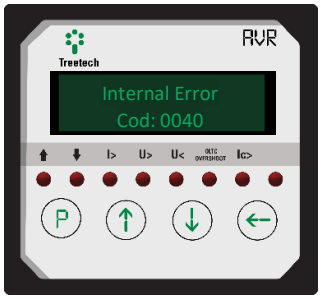


Figure 25 - Display showing self-diagnostic message

The self-diagnostic codes shown on the display of the AVR are comprised of four digits. The meaning for each digit is shown on the following tables. Inform the error code to the Treetech technical assistance service.

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Digit 1

Code Shown	Description	Probable Cause	Recommended Actions
0	*No failure*	-	-
1	*Micro-controller communication failure*	*Internal failure*	*Replace the defective equipment. Contact Treetech technical service.*
2	*Not used*	-	-
3	*Simultaneous occurrence of errors 1 and 2 above*	*See codes 1 and 2 above*	*Proceed as indicated for codes 1 and 2 above.*
4	*Internal EEPROM memory failure*	*Internal failure*	*Replace the defective equipment. Contact Treetech technical service.*
5	*Simultaneous occurrence of errors 1 and 4 above*	*See codes 1 and 4 above*	*Proceed as indicated for codes 1 and 4 above*
6	*Simultaneous occurrence of errors 2 and 4 above*	*See codes 2 and 4 above*	*Proceed as indicated for codes 2 and 4 above.*
7	*Simultaneous occurrence of errors 1, 2 and 4 above*	*See codes 1, 2 and 4 above*	*Proceed as indicated for codes 1, 2 and 4 above.*
8	*External EEPROM memory failure*	*Internal failure*	*Replace the defective equipment. Contact Treetech technical service.*

0040

Digit 2

Code Shown	Description	Probable Cause	Recommended actions
0	*No failure*	-	-
1	*Failure in measuring CT current*	*Internal failure*	*Replace the defective equipment. Contact Treetech technical service.*
2	*Failure in measuring PT*	*Internal failure*	*Replace the defective equipment. Contact Treetech technical service.*
3	*Simultaneous occurrence of errors 1 and 2 above.*	*Simultaneous occurrence of errors 1 and 2 above.*	*Proceed as indicated for codes 1 and 2 above.*
4	*Failure in reading external contact inputs*	*Internal failure*	*Replace the defective equipment. Contact Treetech technical service.*
5	*Simultaneous occurrence of errors 1 and 4*	*Simultaneous occurrence of errors 1 and 4*	*Proceed as indicated for codes 1 and 4 above.*
6	*Simultaneous occurrence of errors 2 and 4*	*Simultaneous occurrence of errors 2 and 4*	*Proceed as indicated for codes 2 and 4 above.*
7	*Simultaneous occurrence of errors 1, 2 and 4*	*Simultaneous occurrence of errors 1, 2 and 4*	*Proceed as indicated for codes 1, 2 and 4 above.*
8	*Failure in reading the position of the Tap Changer*	*Cables used in wiring for potentiometric sensor to AVR are not the shielded type.*	*Replace cables used in wiring for potentiometric sensor to AVR by shielded cables, according to the instructions of Chapter 3.3.1, item 8) Tap position reading (Optional items no. 3, 7).*
		Shielding of leads used in linking potentiometric sensor to AVR grounded in more than one point, not grounded or shielding without continuity along its length	*Ground shielding of leads for linking potentiometric sensor to AVR in just one point and preserve shielding continuity, according to instructions in Item 8) Tap position reading (Optional items no. 3, 7).*
		Bad contact in cursor of potentiometric position sensor or in connection cables linking to the AVR.	*Eliminate bad contact in leads or on cursor of potentiometric position sensor.*
		Cables connecting potentiometric sensor to AVR with resistance higher than 8 ohms per wire – gauge too small for distance covered	*Replace cables currently connecting potentiometric sensor to AVR with cables of suitable gauge, according to the instructions of Item 8) Tap position reading (Optional items no. 3, 7).*

0040

Digit 2

Code shown	Description	Probable Cause	Recommended actions
8	*Failure in reading Tap Changer Position*	*Cables connecting potentiometric sensor to AVR with different gauges and/or lengths for each wire*	*Replace cables connecting potentiometric sensor to AVR with shielded cables with identical gauges and lengths in all 3 wires, according to the instructions in Item 8) Tap position reading (Optional items no. 3, 7).*
		Error in setting parameters "Number of Tap Positions" and/or "Step Resistance" in AVR	*Correct parameter settings "Number of Tap Positions" and "Step Resistance" according to instructions of Item 0.*
		Potentiometric sensor has step resistors installed in the transition (intermediate) positions of the tap changer.	*Remove resistors from intermediate tap changer positions, replacing them with wire jumpers, according to instructions in Chapter 3.3.1, Item Requirements for tap position sensor.*
		The potentiometric sensor's step resistors have tolerance above 1% of their rated value.	*Replace potentiometric sensor's step resistors by others with accuracy better than or equal to 1%.*

0040

Digit 3

Code Shown	Description	Probable Cause	Recommended actions
0	*No failure*	-	-
1	*Communication Error between AVRs*	*Incorrect connection of communication cable*	*Check for proper connection of communication cables (polarity, eventual short-circuits, open cable, shielding grounding) between AVRs (see Chapter 3.3.1).*
		Incorrect setting of communication parameters between AVRs.	*Check for correct setting of the following parameters: "Parallelism Address" and "Number of Nodes" (see Chapter 4.6.2).*
		Distance between ends of the communication network cable longer than 1300 meters.	*If circuit length is in excess of 1300 meters, repeater modules or optic fiber cabling (with appropriate media converters) must be used.*
		Lack of grounding for the shield of communication network cables, interruption in cable shields continuity, or shield grounded at both ends.	*Lack of or incorrect shield grounding may allow induced noise or transients to corrupt data transmitted. Carry out checking of cable shields connections and grounding (see Chapter 3.3.1).*

2	*OLTC Checking Alarm*	*AVR algorithms identified that the OLTC failed to regulate the voltage levels corresponding to the sensitivity programmed in AVR.*	*Check the operation of the OLTC command by the AVR (the switch motor drive contactors, command and power voltage, command wiring between the AVR and the drive panel, local / remote and automatic / manual OLTC switches, external locks and other intermediate points that may prevent OLTC from working).*

5.2 Other Problems - Probable Causes and Possible Solutions

If there are any difficulties or problems in operating the AVR, we suggest consulting the table of simple possible causes and their solutions given below. If this information is not enough to settle the difficulty, please contact Treetech Technical assistance or your local authorized representative.

AVR shows the message “Reverse flow” / “OLTC Blocking”

Probable Causes	Possible Solutions
Incorrect value set for PT/CT Phase Shift.	*Check correct setting for parameter PT/CT Phase Shift (consult Chapter 0 Submenu Transformer, parameter PT/CT Phase Shift).*
Incorrect connection of PT/CT cables to AVR	*Connect the PT/CT cables to AVR according to the instructions of this manual.*

AVR does not measure line voltage correctly

Probable Causes	Possible Solutions
Wrong value programmed for PT transformation ratio.	*Check if the correct value was programmed for the PT ratio (consult Chapter 0 Submenu Transformer, parameter PT Ratio).*
Incorrect connection of secondary of PT to AVR	*Check if secondary of PT is correctly connected to AVR by measuring the input voltage in terminals 33 and 34.*

AVR does not measure load current correctly

Probable Causes	Possible Solutions
Short-circuit in the CT secondary circuit.	*Check if the CT’s short-circuit jumper was removed. **ATTENTION – RISK OF SEVERE ACCIDENTS**: before removing the short circuit jumper of the CT, take all the necessary precautions to avoid leaving the secondary of the CT open, checking including if the secondary of the CT is correctly connected to the input of the AVR.*
Wrong value programmed for CT transformation ratio.	*Check if the correct value was programmed for the CT Ratio. (see chapter 0 Submenu Transformer, parameter CT Ratio).*
CT burden exceeded.	*Even though the AVR offers a very small load for the current transformer, when other measuring equipment is used in series or if losses from connection cables are high (small cable gauge/long distance) the total load of the circuit may exceed CT burden. Use higher gauge cables or higher burden CT.*
Incorrect connection of CT secondary to AVR	*Check if CT secondary is correctly connected to the AVR by measuring with a clamp-on ampmeter the current reaching terminals 35 and 36. **ATTENTION – RISK OF***

	***SEVERE ACCIDENTS**: do not disconnect cables connected to terminals 35 and 36 of AVR without before making sure the secondary of the CT is duly short-circuited and grounded.*

AVR does not measure load Power Factor correctly

Probable Causes	Possible Solutions
Incorrect value set for PT/CT Phase Shift.	*Check correct setting for parameter PT/CT Phase Shift (consult Chapter 0 Submenu Transformer, parameter PT/CT Phase Shift).*

AVR does not measure correctly or displays error message in measuring Tap Position

Probable Causes	Possible Solutions
Connection cables between potentiometric sensor and AVR are not shielded.	*Replace connection cables between potentiometric sensor and AVR by shielded cables, according to instructions found in Chapter 3.3.1, item 8) Tap position reading (Optional items no. 3, 7).*
Shielding of connection cables between potentiometric sensor and AVR grounded in more than one point, not shielded or without shielding continuity along the length of the cable	*Ground shielding of connection cables between potentiometric sensor and AVR in just one point and maintain continuity of shielding, according to instructions on Item 8) Tap position reading (Optional items no. 3, 7).*
Bad contact on cursor of potentiometric position sensor or on cables connecting it to the AVR	*Eliminate bad contact on cables cursor of potentiometric position sensor.*
Connection cables between potentiometric sensor and AVR with resistance higher than 8 ohms per wire – gauge too small for the distance covered	*Replace connection cables between potentiometric sensor and AVR by cables with suitable gauge, according to instructions on Item 8) Tap position reading (Optional items no. 3, 7).*
Connection cables between potentiometric sensor and AVR with different lengths or gauges in each wire	*Replace connection cables between potentiometric sensor and AVR by shielded cables with equal gauges on all three wires, according to instructions on Item 8) Tap position reading (Optional items no. 3, 7).*
Error in setting parameters "Number of Tap Positions" and/or "Step Resistance" at the AVR	*Correct settings of parameters "Number of Tap Positions" and/or "Step Resistance" at the AVR according to instructions of Item 0.*
Potentiometric sensor has step resistors installed in transition (intermediate) tap changer positions.	*Remove resistors from transition tap changer positions, replacing them with jumpers, according to instructions of Chapter 3.3.1, Item Requirements for tap.*
Potentiometric sensor's step resistors have tolerance above 1% of their rated value.	*Replace potentiometric sensor's step resistors by others with accuracy better than or equal to 1%.*

AVR does not communicate with the data acquisition system

Probable Causes	Possible Solutions
Communication cable connected incorrectly	*Check correct connection of communication cables (polarity, eventual short-circuits, open links, shielding grounding) between the AVR and the data acquisition system (see Chapter 3.3.1).*

Incorrect programming of serial communication parameters.	*Check for correct programming of the following parameters: "Communication Standard", "Protocol", "Address" and "Baud Rate" (see Chapter 4.6.2).*
Distance between ends of the communication network cable higher than 1300 meters.	*Where the communication cable exceeds the distance of 1300 meters, auxiliary repeater modules or optic fiber cables (with appropriate media converters) must be used.*
Lack of grounding for the shield of communication network cables, interruption in cable shields continuity, or shield grounded at both ends.	*Lack of or incorrect shield grounding may allow induced noise or transients to corrupt data transmitted. Carry out checking of cable shields connections and grounding (see Chapter 3.3.1).*

Incorrect current loop (mA) reading

Probable Causes	Possible Solutions
Maximum load for output current exceeded.	*Check maximum permissible load for each output standard selected.*
Incorrect parameter setting for current output.	*Check settings of parameters "mA Output Range" and "Analog Variable" (consult Chapter 0 - Submenu Configuration).*
Incorrect mA output cable connection	*Check for correct connection of cables (polarity, eventual short-circuits, open links) between the AVR and the mA output measurement system.*
Lack of grounding, interrupted grounding or grounding at both ends of the circuit.	*Ground failures may allow noises and induced transient regimes may make it impossible to measure the current loop. Proceed with checking of cable, connections (passage terminals) and grounding.*

5.3 Firmware Version and Self-diagnostic Memory queries

Every self-diagnostic message identified by the AVR is stored and can be queried by user at the device front panel.

In order to visualize the self-diagnostic memory just press simultaneously  and  . Figure 26 shows the screen that will be displayed showing the self-diagnostic codes emitted. The same screen also displays the device's firmware version.

Figure 26 – Self-diagnostic Memory and Firmware Version Screen

To reset values stored in the self-diagnostic memory press  and  .

6 Appendix

Appendix A – Parameter Definition Tables

Remark: Tables valid for equipment starting in Firmware version 2.00. Some submenus and parameters will only be displayed if the respective optional functions are available.

Table 8 - Auxiliary parameter definition table – Regulation Menu

Parameter		Regulation Set					
		1	*2*	*3*	*4*	*5*	*6*
Reference Voltage							
Timing Type							
2nd Time Delay							
Line Drop Compensation Type							
Ur Voltage Drop							
Ux Voltage Drop							
Z Compensation							
Compensation Limit							
Timing Steps							
Step 1	Deviation (%)						
	Time to Raise (s)						
	Time to Lower (s)						
Step 2	Deviation (%)						
	Time to Raise (s)						
	Time to Lower(s)						
Step 3	Deviation (%)						
	Time to Raise (s)						
	Time to Lower(s)						
Operation Hours							
Active? (ON/OFF)		☐Yes ☐No	☐Yes ☐No	☐Yes ☐No	☐Yes ☐No	☐Yes ☐No	☐Yes ☐No
Start time (HH:MM)							
End time (HH:MM)							
Days of the Week		☐Sun ☐Mon ☐Tue ☐Wed ☐Thu ☐Fri ☐Sat	☐Sun ☐Mon ☐Tue ☐Wed ☐Thu ☐Fri ☐Sat	☐Sun ☐Mon ☐Tue ☐Wed ☐Thu ☐Fri ☐Sat	☐Sun ☐Mon ☐Tue ☐Wed ☐Thu ☐Fri ☐Sat	☐Sun ☐Mon ☐Tue ☐Wed ☐Thu ☐Fri ☐Sat	☐Sun ☐Mon ☐Tue ☐Wed ☐Thu ☐Fri ☐Sat

Table 9 - Auxiliary parameter definition Table – Configuration Menu

Configuration			
Parameter	Value Set	Parameter	Value Set
Language		Address	
mA Output Range		Baud Rate	
Analog Variable		Parallelism address (op. 6)	
Screensaver		Number of Nodes (op. 6-Address 3)	
Default Screen		Contact Input (op. 6)	
Communication Standard		New Password	
Protocol			

Mass Memory (Optional item 2)		
Parameter	Value Set	
Enable recording	☐ Yes ☐ No	
Recording Interval		
Memory Position	Choice of variable to record	Recording mode
Variable 1*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 2 *	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 3 *	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 4 *	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 5 *	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 6 *	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 7 *	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 8 *	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 9 *	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 10*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 11*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 12*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 13*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 14*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 15*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 16*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 17*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 18*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 19*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 20*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 21*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 22*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value

Memory Position	Choice of variable to record	Recording mode
Variable 23*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 24*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 25*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 26*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 27*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 28*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 29*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value
Variable 30*	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐13 ☐14 ☐15 ☐16 ☐17	☐Instant Value ☐Average Value ☐Minimum Value ☐Maximum Value

List of Variables for Recording:

1) *None*
2) *Load Voltage*
3) *Voltage Deviation*
4) *Line Voltage*
5) *Line Current*
6) *Frequency Hz*
7) *Power Factor*
8) *Active Power*
9) *Reactive Power*
10) *Apparent Power*
11) *% load*
12) *PT Voltage*
13) *CT Current*
14) *Tap Position*
15) *Circulating Current*
16) *Correction Voltage*
17) *Parallelism Group*

Table 10 - Auxiliary parameter definition table – Alarms and Relay Menu

Alarms		Relays	
Parameter	Value set	Parameter	Value set
U< Alarm		Operation relay3	☐NO ☐NC
U< Alarm relay	☐RL3 ☐RL4 ☐RL5 ☐RL6 ☐RL7	Operation relay4	☐NO ☐NC
Time Delay U<		Operation relay5	☐NO ☐NC
U> Alarm		Operation relay6	☐NO ☐NC
U> Alarm relay	☐RL3 ☐RL4 ☐RL5 ☐RL6 ☐RL7	Operation relay7	☐NO ☐NC
Time Delay U>			
I> Alarm			
I> Alarm relay	☐RL3 ☐RL4 ☐RL5 ☐RL6 ☐RL7		
Time Delay I>			
Alarm High Icirc (op. 6)			
Time Delay High Icirc (op. 6)			
Relay High Icirc. (op. 6)	☐RL3 ☐RL4 ☐RL5 ☐RL6 ☐RL7		
Relay Error Tap Read (op. 3)	☐RL3 ☐RL4 ☐RL5 ☐RL6 ☐RL7		
Relay Comm. Error (op. 6)	☐RL3 ☐RL4 ☐RL5 ☐RL6 ☐RL7		
Relay Parameter Error (op.6)	☐RL3 ☐RL4 ☐RL5 ☐RL6 ☐RL7		
Relay No. Operations (op. 7)	☐RL3 ☐RL4 ☐RL5 ☐RL6 ☐RL7		
Relay Sum I^2 (op. 7)	☐RL3 ☐RL4 ☐RL5 ☐RL6 ☐RL7		
OLTC Blocking	☐I> ☐U> ☐U< ☐OLTC ☐Icirc		
OLTC Blocking Relay	☐RL3 ☐RL4 ☐RL5 ☐RL6 ☐RL7		

Table 11 - Auxiliary parameter setting table – Menu optional item On Load Tap Changer

On Load Tap Changer (Optional item 3)							
Parameter	Setting						
Number of Tap Positions							
Indication Type							
Step Resistance							
Tap Change Time							
Central Tap Position							
Raise TAP =	☐Raise Voltage ☐Lower Voltage						
Minimum Allowed Tap							
Maximum Allowed Tap							
OLTC Maintenance (Optional item 7)							
Total OLTC Operations							
Number of Operations since last Maintenance							
Maintenance Notice – Number of Operations							k Operations
Sum Ipu^2 OLTC							$x10^3$
Ipu^2 since Maintenance							$x10^3$
Maintenance Notice – Ipu^2							$x10^3$ Ipu^2
OLTC Rated Current							A
Average Calculation							days
Maintenance Notice							days before
Transition Tap No. 1	☐On ☐Off	Initial tap:		Operations:		Sum I^2:	x
Transition Tap No. 2	☐On ☐Off	Initial tap:		Operations:		Sum I^2:	x
Transition Tap No. 3	☐On ☐Off	Initial tap:		Operations:		Sum I^2:	x
Transition Tap No. 4	☐On ☐Off	Initial tap:		Operations:		Sum I^2:	x

Table 12 - Auxiliary parameter setting table – Menus Transformer and Circulating Current

Transformer			
Parameter	Value Set	Parameter	Value Set
CT/PT Phase Shift		PT Ratio	
Number of Phases		CT Ratio	
Xfmr. Rated Power		Xfmr Impedance	

Circulating Current (Optional item 6)	
Parameter	Value set
Gain factor	

Appendix B – Technical Data

Power Input:	38 to 265 Vdc/Vac 50/60Hz
Maximum Consumption:	8W
Operating Temperature:	-40 to +85 °C
Protection degree:	IP 20
Connections – except PT and CT inputs:	0.3 to 2.5mm², 22 to 12 AWG
Connections - PT and CT inputs:	one or two 1.5 to 2.5mm2, 16 to 12 AWG - using appropriate ring type terminals
Fixation:	Fixed on panel
Measuring Range	
Voltage:	0...160V[1]
Current:	0...10A
Maximum Errors	
Voltage:	0.5% of measurement in 0...160V range
Current:	1% of full scale
Dry contact inputs:	3
Output to relays:	7 NO + 1 NC (self-diagnosis)
Maximum switching power:	70 W(dc) / 220 VA(ac) – resistive load
Maximum switching voltage:	250 Vdc / 250 Vac
Maximum conduction current:	5A
Analog output:	1 in current loop
Variable:	Programmable
Output range:	Programmable 0...1, -1...1, 0...5, -5...5, 0...10, -10...10, 0...20, -20...20, 4...20mA
Maximum Error:	0.5% of end of scale
Maximum Load	10V
Serial communication ports:	1 RS485/RS232 (for supervisory/laptop)
Setting Ranges (main parameters):	
Rated Voltage (Un):	50 to 140V, 0.1V steps
Bandwidth:	0 to 10%, 0.1% steps
Time delay for raise/lower operations:	0 to 180s, 1s steps
Line Drop Compensation R-X:	-25V to 25V, 0.1V steps
Line Drop Compensation Z:	0 to 15%, 0.1% steps
U< Alarm:	10 to 99% of Un, 1% steps
U> Alarm:	101 to 199% of Un, 1% steps
I> Alarm:	10 to 200% of In, 1% steps
Display languages:	Portuguese, English, Spanish
Optional items:	
Tap position reading input:	Potentiometric, 3 wires, resistors class 1% or better
Number of Taps on OLTC:	2 to 50
Total resistance of potentiometric sensor:	9.4 to 1000 Ω
Step Resistance of potentiometric sensor:	4.7 to 20 Ω accuracy 1% or better
Serial Communication Port:	1 RS485 (for linking AVRs in optional parallelism Functions)
Mass Memory (optional):	Non-volatile type FIFO (First In First Out)
Recording interval:	1 to 120 minutes
Capacity:	406 to 1928 records (dependent on no. of variables selected for recording by the user, from 30 to 0 variables respectively)

[1] The entrance of the TP can be damaged if the voltage values are exceeded

Appendix C – Order Specifications

The Voltage Regulator Relay AVR is universal, with the operating characteristics being selected by way of program menus. These adjustments can be made directly on its front panel or by way of specific configuration software, using the RS232 or RS485 serial communication ports. Power input is universal (38 to 265 Vdc/Vac 50/60Hz).

Therefore, in ordering the device all that needs to be specified is:

- Voltage Regulator Relay AVR.
- Number of devices;
- Optional functions desired. More than one optional item can be specified for the same device, taking into account the possible combination of optional items shown on table 13 below.

Table 13 - Possible optional item combinations

OPTIONAL ITEM	SET 1	SET 2
1) DNP3.0 Protocol		
2) Mass Memory		
3) Position Reading		
4) OLTC Checking		
6) Circulating Current Parallelism		
7) OLTC Maintenance		

SUBTITLE
Allowed
Not Allowed

Appendix D – Tests performed

Surge Immunity (IEC 61000-4-5):	
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):	
1st cycle peak value	2,5 kV
frequency:	1,1 MHz
repeat time and rate:	2 seconds, 400 surges/sec.
decay to 50%:	5 cycles
Voltage Impulse (IEC 60255-5):	
wave shape:	1.2 / 50 microseconds
amplitude and energy:	5 kV
number of pulses:	3 negative and 3 positive, 5s intervals
Insulation Voltage (IEC 60255-5):	
Voltage tolerable at industrial frequency	2 kV 60Hz 1 min. to ground
Immunity against Irradiated Electromagnetic Fields (IEC 61000-4-3):	
Frequency:	26 to 1000 MHz
Field Intensity:	10 V/m
Immunity to Conduced Electromagnetic Disturbances (IEC 61000-4-6):	
Frequency:	0.15 to 80 MHz
Field Intensity:	10 V/m
Electrostatic Discharges (IEC 60255-22-2):	
Air mode:	8 kV, ten discharges per polarity
Contact mode:	6 kV, ten discharges per polarity
Immunity to Fast Electrical Transients (IEC61000-4-4):	
Test in power feed, inputs and outputs:	4 kV
Test in serial communication:	2 kV
Climate Range test: (IEC 60068-2-14):	
Temperature range:	-40 to +85ºC
Total test time:	96 hours
Response to vibration: (IEC 60255-21-1):	
Test Mode:	3 axes (X, Y and Z), sinusoidal
Amplitude:	0.075mm from 10 to 58 Hz
	1G from 58 to 150 Hz
Duration:	8 min/axis
Resistance to vibration: (IEC 60255-21-1):	
Test Mode:	3 axis (X, Y e Z), sinusoidal
Frequency:	10 at 150 Hz
Intensity:	2G
Duration:	160 min/axis

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