USER MANUAL

Treetech

SPS

Synchronous Parallelism Supervisor

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1 Preface

1.1 Legal Information

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

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1.1.1 Disclaimer

Treetech Tecnologia reserves the right to make changes without prior notice to all products, circuits, and functionalities described herein in order to improve their reliability, function, or design. Treetech Tecnologia assumes no liability arising from the application or use of any product or circuit described herein, nor does it convey any license or patent rights of its own or of third parties.

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1.2 Presentation

This manual presents all recommendations and instructions for the installation, operation, and maintenance of the Synchronous Parallelism Supervisor - SPS/SPS-I.

1.3 Typographic Conventions

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

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

Italics: Foreign-language terms, alternatives, or terms used outside of a formal context are italicized.

Underline: References to external documents.

1.4 General and Safety Information

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

1.4.1 Safety symbols

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

Caution:
This symbol is used to alert the user to a potentially hazardous operating or maintenance procedure that requires extra care during execution. Minor or moderate injuries may occur, as well as damage to the equipment.

Warning:
This symbol is used to alert the user to a potentially dangerous operating or maintenance procedure requiring extreme caution. Serious injury or death may occur. Potential equipment damage will be irreparable.

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

1.4.2 General symbols

This manual uses the following general-purpose symbols:

Important
This symbol is used to highlight information.

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

1.4.3 Minimum recommended profile for the SPS operator and maintainer

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

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

To handle the SPS, the professional must:

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

1.4.4 Environmental and voltage conditions required for installation and operation

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

Table 1 - Operating conditions

Condition	Range/description
Application	Equipment for sheltered use in substations, industrial environments, and similar settings
Indoor/outdoor use	Indoor use
Protection rating (IEC 60529)	IP20
Altitude* (IEC EN 61010-1)	Up to 2000 m
Temperatura (IEC EN 61010-1)	
Operation	-40...+85 °C
Storage	-50...+95 °C
Umidade relativa (IEC EN 61010-1)	
Operation	5...95 % - Non-condensing
Storage	3...98 % - Non-condensing
Supply voltage fluctuation (IEC EN 61010-1)	Up to ±10% of nominal voltage
Overvoltage (IEC EN 61010-1)	Category II
Pollution rating (IEC EN 61010-1)	Degree 2
Atmospheric pressure** (IEC EN 61010-1)	80...110 kPa

* Altitudes above 2,000 m already have successful applications.
** Pressures below 80 kPa already have successful applications.

1.4.5 Instructions for testing and installation

This manual must be available to those responsible for the installation and maintenance of the Synchronous Parallelism Supervisor - SPS.

To ensure user safety, equipment protection, and correct operation, the following minimum precautions must be observed during the installation and maintenance of the SPS.

1. Read this manual carefully before installing, operating, or maintaining the SPS. Errors in the installation, maintenance, or configuration of the SPS can lead to false alarms or self-diagnosis alerts, or result in a failure to trigger relevant alarms or alerts, thereby causing a misunderstanding of the transformer's actual health and operating condition.

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

3. Special attention must be paid to the installation of the SPS, including the cable type and gauge, installation location, and commissioning, including the correct parameterization of the equipment.



The SPS must be installed in a sheltered environment (a panel without doors in a control room or an enclosed panel for outdoor installations) that does not exceed the temperature and humidity limits specified for the equipment.



Do not install the SPS near heat sources such as heating resistors, incandescent lamps, high-power devices, or components with heat sinks. Installation near ventilation openings or areas subject to forced airflow, such as cooling fan intakes or exhausts, or forced-air ducts, is also not recommended.



If the panel where the SPS is installed has a window, use G20-grade or higher tint film to prevent direct sunlight (ultraviolet rays) from striking the equipment. If the window glass is dark, this measure is not necessary.

1.4.6 Instructions for cleaning and decontamination

Exercise caution when cleaning the SPS. Use **only** a cloth dampened with soap or detergent diluted in water to clean the enclosure, front panel, or any other part of the equipment. Do not use abrasive materials, polishes, or harsh chemical solvents (such as alcohol or acetone) on any of its surfaces.

1.4.7 Instructions for inspection and maintenance

For SPS inspection and maintenance, the following points must be observed:



Do not open the equipment. It contains no user-serviceable parts. Servicing must be performed by Treetech technical support or by technicians accredited by the company. This equipment is completely maintenance-free; however, the user may perform visual and operational inspections, whether periodic or otherwise. These inspections are not mandatory.



Opening the SPS at any time will void the product warranty. In cases of unauthorized opening, Treetech cannot guarantee proper operation, regardless of whether the warranty period has expired.



All parts for this equipment must be supplied by Treetech, or by one of its authorized suppliers, in accordance with its specifications. Should the user wish to acquire them from another source, they must strictly adhere to Treetech's specifications to ensure that the performance and safety of both the user and the equipment are not compromised. Failure to follow these specifications may expose the user and the equipment to unforeseen risks.

1.5 Customer Service

Are you already familiar with our online customer service platform?

CS

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

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

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

1.6 Warranty Statement

Treetech warrants the Synchronous Parallelism Supervisor - SPS/SPS-I for a period of two (2) years from the date of purchase, exclusively against manufacturing defects or quality flaws that render it unfit for regular use.

The warranty does not cover damage to the product resulting from accidents, abuse, improper handling, incorrect installation or application, inadequate testing, or the breaking of the warranty seal.

Any need for technical assistance must be reported to Treetech or its authorized representative, and the equipment must be presented along with the corresponding proof of purchase.

No warranty, express or implied, other than those cited above, is provided by Treetech. Treetech provides no warranty regarding the suitability of the SPS for a particular application.

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

Under no circumstances shall the Seller be held liable for damages incurred, including, but not limited to: loss of profits or revenue; inability to use the SPS or any associated equipment; cost of capital; cost of purchased energy; cost of substitute equipment, facilities, or services; downtime costs; or claims by the Buyer’s customers or employees; regardless of whether such damages, claims, or losses are based on contract, warranty, negligence, tort, or any other legal theory. Under no circumstances shall the Seller be held liable for any personal injury of any kind.

2 Introduction

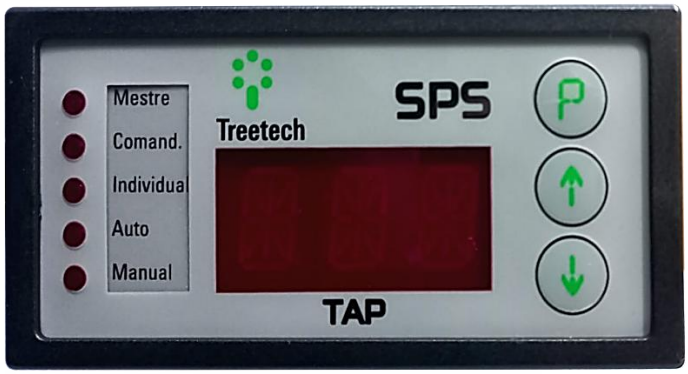


Figure 1 - Synchronous Parallelism Supervisor SPS

The Synchronous Parallelism Supervisor - SPS is a device developed by Treetech for the control and supervision of the parallel operation of power transformers equipped with on-load tap changers.

Based on microcontrollers, the SPS incorporates the functions of various devices previously used for transformer paralleling control, such as Master/Follower/Individual, Manual/Automatic, and Local/Remote selector switches, tap position indicators, and auxiliary relays for electromechanical logic, among others. Consequently, control wiring and the number of components are drastically reduced, significantly enhancing overall reliability and cutting installation and testing labor times, while also greatly simplifying maintenance.

The SPS is also equipped with output contacts for signaling, a current loop output for tap position indication, dry contact inputs for remote control, and an RS-485 serial port, enabling comprehensive data acquisition and full remote control of the paralleling system via the COMM04 Communication Module, an integral part of the SPS paralleling system.

The equipment was fully designed and tested for operation under the adverse conditions found in electrical substations, such as surges, impulses, and electromagnetic interference.

2.1 Features and Functions

Transformer paralleling

Control and supervision of the parallel operation of single-phase and/or three-phase power transformers equipped with tap changers.

Tap indication

Indication of the tap position on the equipment's front panel and via communication protocol.

Tap changer control

The user selects the OLTC control mode between Local/Remote and Manual/Automatic.

LED display

High-brightness, 3-digit LED displays for easy viewing under any lighting conditions.

Communication

RS-485 serial communication port with Modbus® RTU protocol.

Compact and versatile

The SPS features compact dimensions, resulting in space and installation cost savings.

Robust hardware

The SPS design exceeds EMC (Electromagnetic Compatibility) standards to withstand the harsh electromagnetic conditions of substations and an operating temperature range of -40 to 85°C.

Modular system

System expandable according to application requirements, with a capacity of up to 6 three-phase units, either three-phase transformers or single-phase banks.

Self-diagnosis

Detection of internal faults and integration failures with peripheral equipment, indicated by self-diagnostic relays.

2.1.1 Inputs

- ✓ Inputs for programming or external digital commands;
- ✓ Input for potentiometric tap measurement (SPS version);
- ✓ Input for tap measurement via current circuit (SPS-I version).

2.1.2 Outputs

- ✓ Analog output for remote position indication. User-selectable output range: 0...1, -1...1, 0...5, -5...5, 0...10, -10...10, 0...20, -20...20, or 4...20 mA;
- ✓ 4 output relays for self-diagnosis and status indications;
- ✓ Raise/lower tap output contacts.

2.1.3 Communication

- ✓ 1 RS-485 serial communication port.

2.2 Basic Operating Philosophy

Various reasons may lead to the decision to operate power transformers in parallel, such as the need to increase load capacity and the desire to enhance the reliability of the electric power supply, among others.

To enable parallel operation, a primary concern is preventing the flow of circulating currents between the parallel windings, a phenomenon that occurs, for instance, if they have different voltages. In transformers with a fixed transformation ratio, this concern is limited to the project design phase; once properly executed, this ensures the equipment operates flawlessly.

This is not the case for transformers equipped with on-load tap changers, as they can freely adjust their transformation ratio during operation. Consequently, the design phase must ensure that the transformer taps correspond; furthermore, care must be taken during operation to ensure that the tap changers of parallel-connected transformers are set to equivalent positions, thereby keeping the circulating current close to zero.

As a general rule, transformers operated in parallel have the same number of tap positions, with a direct correspondence between the various tap changers; that is, the tap changers must operate at numerically equal positions to minimize circulating current.

In these cases, the parallel control philosophy typically employed is the “Master-Follower” scheme, in which one transformer is designated as the Master and the others as Followers. Consequently, all tap-change commands issued by the Master must be replicated by the Followers to ensure tap synchronization. If any of the tap changers fails to execute the command, the entire system must remain locked—preventing further tap changes—and a self-diagnosis signal or alarm must be issued to indicate the occurrence.

If necessary, any of the transformers can be removed from parallel operation by selecting the “Individual” mode. In this case, its tap changer will neither maintain position synchronization with the Master nor trigger a lockout or self-diagnosis alert due to a position mismatch.

Any of the transformers can be freely selected as Master, Follower, or Individual, provided that there is no more than one Master and no Followers exist without the presence of a Master. The arrangement shown in Figure 2 is an example of one possible distribution of Master, Follower, or Individual selections. These selections can be changed at any time during parallel operation.

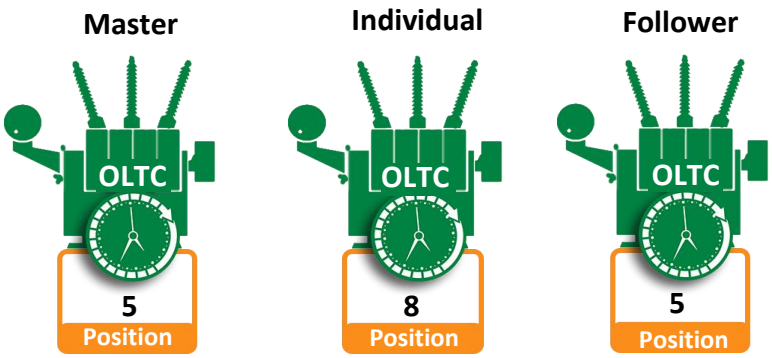


Figure 2 - Parallel operation of three-phase transformers

2.2.1 Parallel operation of single-phase transformer banks

The parallel operation of three-phase banks composed of independent single-phase units is a specific case of transformer paralleling; although it follows the same basic philosophy mentioned above for three-phase transformers, it presents certain peculiarities.

Each single-phase unit making up the three-phase bank is equipped with its own tap changer, requiring two conditions to be met for the correct operation of the system:

a) That all phases of a given bank be on the same tap position, so that there is no voltage imbalance in the three-phase system;

b) That the tap changer positions of the different banks be aligned, so that there is no circulating current between banks.

For the purposes of this manual, the three single-phase units of a three-phase bank are treated, wherever applicable, as if they were a single three-phase transformer; consequently, Master, Follower, and Individual selections are applied with reference to the state of the bank as a whole, never to the state of a single-phase unit in isolation.

In fact, under normal operating conditions, the three single-phase units of a bank will behave as if they were a single three-phase transformer.

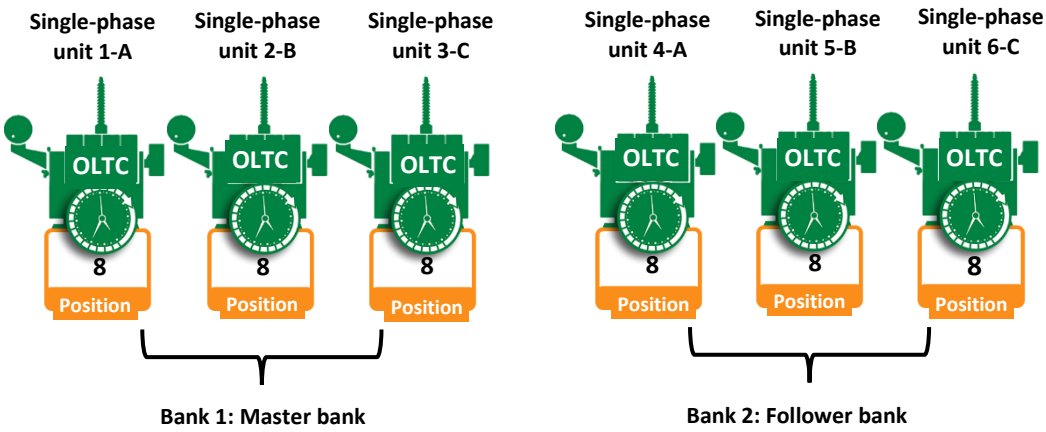


Figure 3 - Parallel operation of three-phase banks composed of single-phase units

Within a single bank, the three phases are identified as “Main,” “Secondary 1,” and “Secondary 2.” If the bank is selected for Individual mode, there are two possible operating conditions:

a) Operation as a “Bank”—that is, as if it were a single three-phase transformer—while maintaining position synchronism among the bank’s phases. This is the most common mode of operation; in this case, the “Secondary 1” and “Secondary 2” phases use the tap changer position of the “Main” phase as a reference to verify synchronism among the bank’s phases;

b) Operation in "Individual Phase" mode is typically used only for maintenance and testing purposes. In this mode, a specific phase of the bank can be operated individually in manual mode. This mode of operation is only possible if the bank is not connected in parallel with any other bank and is not in Automatic control mode.

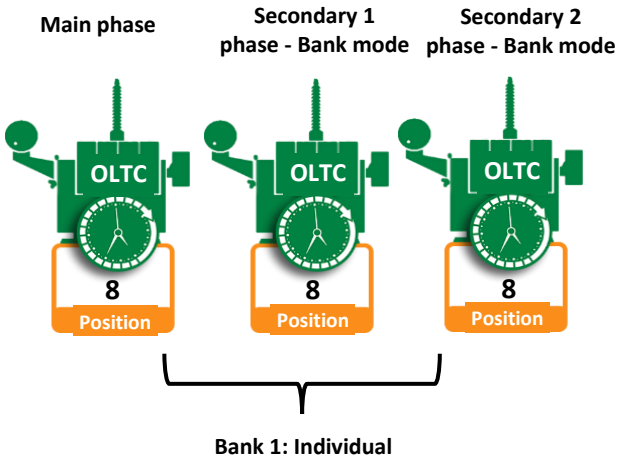


Figure 4 - Operation of Individual bank in “Bank” mode

2.2.2 Local/Remote operating modes

It is possible to make SPS configuration selections regarding the network (Master/Follower or Individual) and control mode (Automatic/Manual), as well as send Tap Raise/Lower commands, in three different ways:

a) Local operation, via the SPS front-panel keys;
b) Remote operation, via external dry contacts connected to the SPS;
c) Remote operation, via RS-485 serial communication.

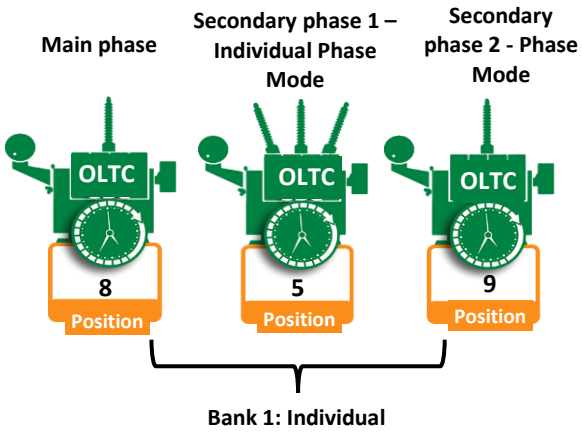


Figure 5 - Operation of Individual bank in “Individual Phase” mode

If the Local command is selected, both remote command options are disabled (in the case of serial communication, only data acquisition is possible). If the Remote command is selected, system operation via the front keypad is disabled, enabling both remote command modes. Generally, only one of the two remote command options is used, as one eliminates the need for the other; however, it is possible to have both options operating simultaneously.

As with the Master, Follower, and Individual selections, for transformer banks, the Manual/Automatic selections always apply to the state of the bank as a whole, never to the state of an individual single-phase unit in isolation.

2.2.3 Automatic/Manual command modes

The SPS features two control modes for raising/lowering the tap changer positions:

Manual Control: tap changes occur only when requested by the operator. Manual commands can be issued locally via front-panel keys, or remotely via external contacts (using digital control inputs) or protocol-based commands.

Automatic Control: tap raise/lower commands issued by external equipment, such as an Automatic Voltage Regulator relay (Relay 90), via digital control inputs are enabled.

The selection of Automatic or Manual control mode only has a practical effect on transformers (or banks) operating in Master or Individual modes. In Follower mode, the Manual/Automatic selection is irrelevant, as the Follower unit simply keeps its tap changer synchronized with the Master and does not have its own control logic. Digital inputs as per Table 2 - .

As with the Master, Follower, and Individual selections, for transformer banks, the Manual/Automatic selections always apply to the state of the bank as a whole, **never to the state of an individual single-phase unit in isolation**.

2.3 Intended Use

It is recommended to use networked SPS units (1 to 18 SPS units in parallel for single-phase banks, or 6 SPS units for three-phase transformer paralleling) based on a "Master-Follower" operating philosophy, in which one transformer is designated as the Master while the others are designated as Followers. In this configuration, all tap position changes made by the Master must be replicated by the Followers to maintain tap synchronization. If any of the tap changers fail to execute the command, the entire system must lock out, preventing further position changes, and a self-diagnosis message or alarm must be issued to signal the occurrence of the problem.

The SPS output contacts for the tap-raise and tap-lower commands are connected directly to the control circuit of the corresponding on-load tap changer. Furthermore, all commands intended to change the tap position, whether initiated locally via the SPS front panel or remotely via dry contacts or serial communication, are routed to the on-load tap changer using the Tap Raise/Lower output contacts, ensuring the proper transmission of instructions.

3 Design and Installation

This chapter presents the specific topological features of the SPS for use with three-phase transformers and three-phase banks composed of single-phase units, always bearing in mind the need to connect the COMM04 to the network alongside the SPS units.

3.1 Topology for Three-phase Transformers

The application of SPSs for three-phase transformers, as well as the basic interconnections between the various pieces of equipment, can be observed in the following figure.

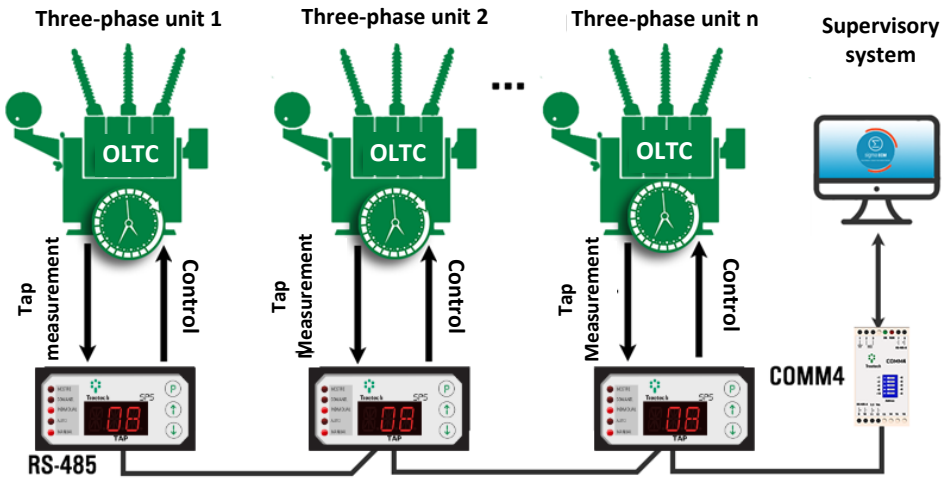


Figure 6 - SPS application topology with three-phase transformers

3.1.1 Topology for single-phase transformer banks

Figure 7 shows the application of SPSs to three-phase banks composed of single-phase transformers, as well as the basic interconnections between the various pieces of equipment.

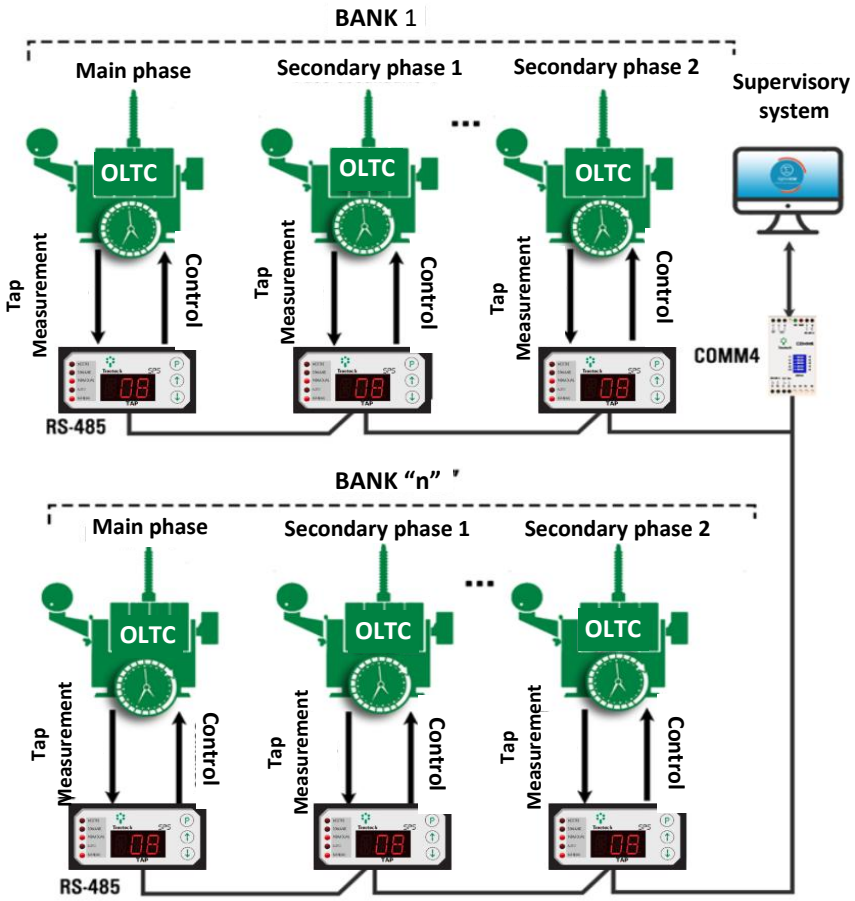


Figure 7 - SPS application topology with three-phase banks

3.2 Electrical Installation

The SPS is a versatile piece of equipment capable of handling a wide variety of applications.

Thus, its installation requires a higher level of study and care than equipment dedicated exclusively to a single application or task.

The SPS offers various electrical installation configurations. These configurations are determined by whether the application in question utilizes the available features and options.

Study and understand the application in which you intend to use the SPS, and familiarize yourself with its functional, electrical, and configuration characteristics. This way, you will be able to make the most of the equipment and minimize safety risks.

This equipment operates at dangerous supply voltage levels, which may result in death or serious injury to the operator or maintenance personnel.

Certain special precautions must be followed for the design and installation of the SPS, as described below.

A circuit breaker must be installed immediately upstream of the power input (universal power supply – 38 to 265 VAC/VDC, <8 W, 50/60 Hz), corresponding to pins 16 and 17 of the SPS.

The circuit breaker must have a number of poles matching the number of phases used in the power supply; the poles must interrupt only the phase conductors—never the neutral or ground—and must provide thermal and electrical protection for the conductors supplying the equipment. Additionally, the breaker must be located near the equipment and be easily accessible to the operator.

It must also bear an indelible label identifying it as the electrical disconnection device for the SPS.

The following circuit breaker specification is recommended when used exclusively for the SPS:
• AC/DC supply, Phase-Neutral: Single-pole circuit breaker, 1 A ≤ In ≤ 2 A, curve B or C, standards NBR/IEC 60947-2, NBR/IEC 60898, or IEEE 1015-2006;
• AC/DC supply, Phase-Phase: Two-pole circuit breaker, 1 A ≤ In ≤ 2 A, curve B or C, standards NBR/IEC 60947-2, NBR/IEC 60898, or IEEE 1015-2006.

The standard schematic diagram of the SPS connections shows all the connection possibilities they provide, identifying them as shown in the following figure:

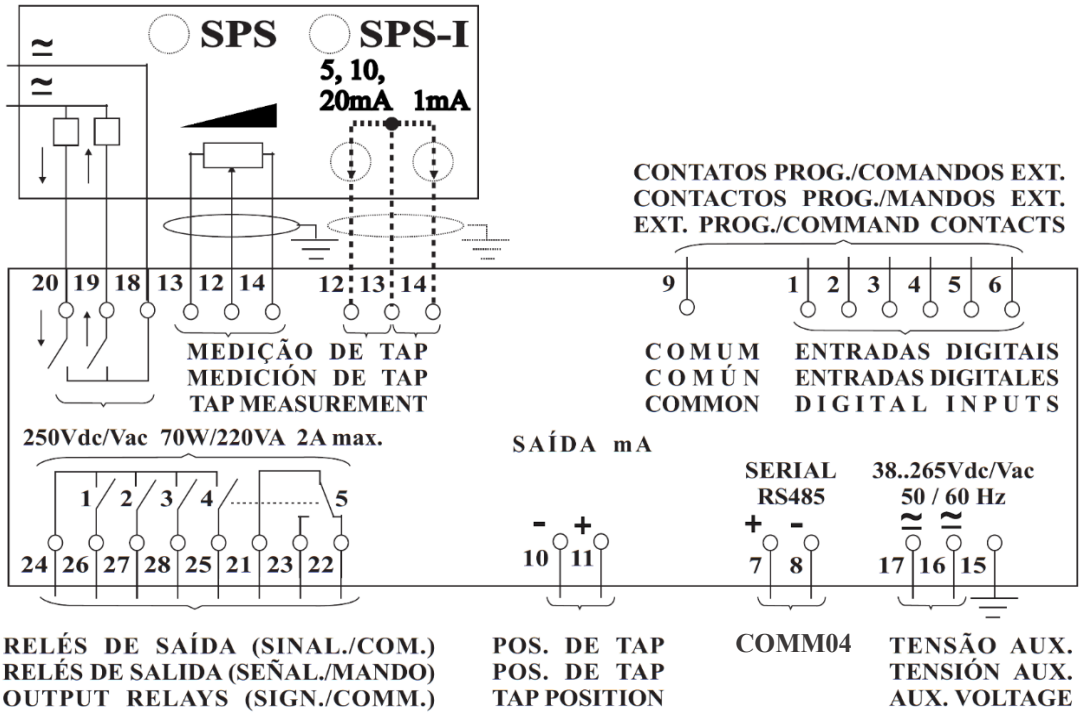


Figure 8 - SPS wiring diagram

3.3 Input and Output Terminals

The inputs and outputs described below are available on the SPS/SPS-I. The contents of the table will be detailed further in other subsections.

Table 2 - SPS/SPS-I input and output terminals

Description	Terminal
Auxiliary power supply and ground Input terminals for universal power supply (85 to 265 VAC/VDC, 50/60 Hz, ≤ 6 W).	15 – ground 16 – DC/AC 17 – DC/AC
Master mode/Single phase Terminal for remote programming of the SPS/SPS-I in master mode or, for secondary phases of single-phase transformer banks, for programming it as a single phase.	1
Follower mode/ Bank Terminal for remote programming of the SPS/SPS-I in commanded mode or, in the case of secondary phases of single-phase transformer banks, for programming them in bank mode.	2
Individual mode Terminal for remote programming of the SPS/SPS-I in individual mode. Works with three-phase transformers and the main phases of single-phase banks.	3
Manual mode/Automatic (Pulse) Terminal for remote programming of the SPS/SPS-I in manual or automatic mode. The SPS/SPS-I will change state with each pulse received at the contact.	4
Local mode/Remote Terminals for remote programming of the SPS/SPS-I in local/remote mode. Operation is triggered by simultaneous pulses on the three terminals.	1, 2, and 3 simultaneously
Raise command Terminal for the SPS/SPS-I remote tap-raise command. A pulse at this terminal will issue the “raise tap” command.	5
Lower command Terminal for the SPS/SPS-I remote tap-lower command. A pulse at this terminal will issue the "lower tap" command.	6
Common point Terminal common to terminals 1 through 6.	9 – common
Serial communication Terminals for connecting the RS-485 serial cable.	7 – (+) 8 – (-)
Analog output	10 (-)

Terminals for current loop output.	11 (+)
Tap-changer position measurement (Model SPS) Terminals for connecting the potentiometer ring for tap measurement.	12 (cursor) 13 (minimum tap) 14 (maximum tap)
Tap-changer position measurement (Model SPS-I) Terminals for connecting the analog current input for tap measurement.	12 (+) 13 (-)
Tap raise/lower output contacts Output terminals for tap changer commands.	18 – common 19 – tap up 20 – tap down
Automatic/Manual auxiliary contacts SPS/SPS-I auxiliary terminals that change state according to the programmed control mode.	21 – common 22 – automatic 23 – manual
Signaling relays Terminals for the SPS/SPS-I output relays. Relays 1, 2, and 3 are programmable. Relay 4 is fixed and indicates whether the SPS/SPS-I is in manual or automatic mode.	24 – common 25 – relay 4 26 – relay 1 27 – relay 2 28 – relay 3

3.3.1 Auxiliary power supply and ground

The SPS is capable of operating with auxiliary supply voltages in the range of 38 to 265 V (DC or AC, 50 or 60 Hz) with a power consumption of less than 6 W. The ground terminal must be connected.

3.3.2 Contact inputs for programming/remote commands

The six dry contact inputs on each SPS allow both network configuration and paralleling system commands to be executed remotely by closing the contact between the common point (terminal 9) and another terminal (1 through 6).

The function of each SPS input varies depending on the type of transformer operating in parallel, either a three-phase unit or a bank of single-phase transformers. In the latter case, the function of each input also depends on the SPS's position within the bank (Master or Follower).

To ensure a transmitted command is recognized by the SPS, the contacts must remain closed for a minimum duration of 0.2 seconds.



The contacts connected to these inputs must be free of any external potential and are energized by an internal potential from the SPS, via a common point shared by all the contacts.

These inputs allow for the remote selection of the configuration mode within the SPS network. Both pulse and continuous commands can be used. The available configurations depend on the SPS's position within the paralleling system. For:

- **Three-phase transformers and main phases of single-phase banks:** Master/Follower mode or Individual mode.
- **Secondary phases of single-phase banks:** Bank mode or Individual phase mode.

If an invalid configuration is attempted (for example, trying to select a transformer as Master when another Master already exists), the pulse command is ignored, and the SPS remains in its previous state. If the invalid command persists, it is not executed, the SPS remains in its previous state, and a programming error self-diagnosis (E04) is issued after the programmed diagnostic time delay has elapsed. A programming error self-diagnosis is also issued if two of these contacts remain closed simultaneously for a duration exceeding this time delay.

3.3.2.1 Master Mode / Individual Phase programming

Terminal 1 is used for remote programming of the SPS in Master mode (provided there is no other Master on the same network) or as an Individual phase, in cases involving secondary phases of single-phase transformer banks that will not be included in the paralleling system. Use terminal 9 as the common.

3.3.2.2 Slave Mode / Bank programming

Terminal 2 is used for remote programming of the SPS in Follower mode (if a Master is present on the same network) or as a bank connection in cases involving secondary phases of transformer banks. Use terminal 9 as the common terminal.

3.3.2.3 Individual Mode programming

Terminal 3 is used for remote programming of the SPS in Individual mode, that is, to set the three-phase transformer(s) or the main phase(s) of single-phase banks to operate outside the paralleling system. Use terminal 9 as the common.

3.3.2.4 Manual / Automatic programming

This input (terminal 4) allows for the remote selection of the Manual/Automatic control mode. Pulse control must be used. The control mode toggles (from Manual to Automatic or vice versa) whenever the contact connected to the Manual/Automatic programming input is momentarily closed. If the contact closes and remains closed, the Manual/Automatic control mode will toggle only once. Further toggling is only possible if the contact opens and closes again. Use terminal 9 as the common connection.

It is also possible to perform the Manual/Automatic selection using two independent contacts instead of a single contact, one assigned the Manual function and the other the Automatic function. For this purpose, the Manual/Automatic auxiliary changeover contact (terminals 21 and 22) must be used. In the case of single-phase transformer banks, this contact is located in the bank's "Main" SPS.

Comparing Figure 9a, which shows the single control contact option, with Figure 9b, showing the independent contacts option, it can be seen that in both cases the programming input receives pulses to toggle the state; however, in the second case, the pulse only reaches this input if the contact corresponding to the condition opposite to the SPS' current programming is closed. If the contact corresponding to the condition already present in the SPS is closed, the input does not receive the toggle pulse, and the current condition is maintained.

Note that the SPS Automatic/Manual auxiliary contact shown in the figure below is used simultaneously in the circuit of the external control contacts Raise/Lower tap.

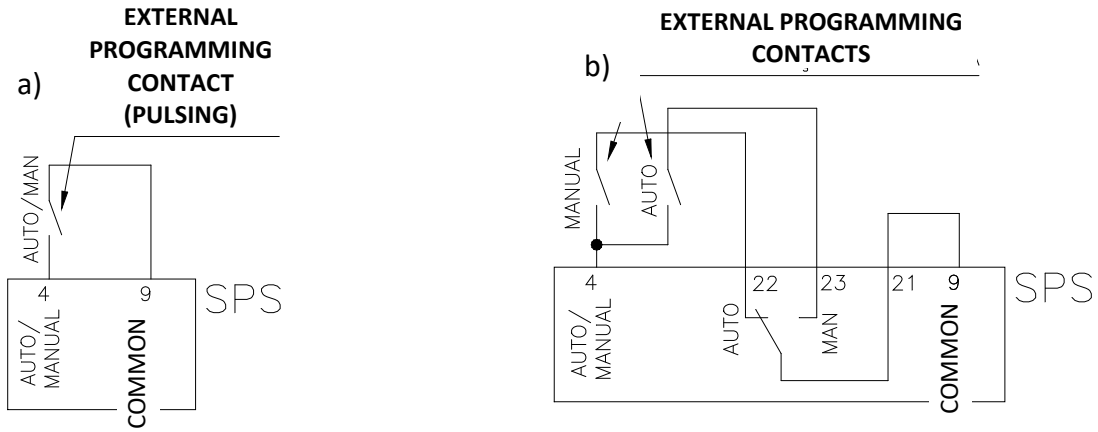


Figure 9 - Manual/Automatic remote programming. (a) Using a single programming contact; (b) Using two programming contacts

3.3.2.5 Local / Remote programming

This control mode is toggled (from Local to Remote or vice versa) whenever the contacts connected to the three programming inputs—1, 2, and 3—are closed simultaneously and momentarily. If the three contacts close and remain closed, only a single toggle of the Local/Remote control mode will occur. Further toggling is only possible if the contacts open and then close simultaneously again. Use terminal 9 as the common terminal.

3.3.2.6 Tap raise/lower command inputs

Through these inputs (5 and 6), tap raise/lower commands can be generated by devices external to the SPS. These devices fall into two categories: automatic control devices and manual control devices. Two of the most commonly used examples are the voltage regulating relay for automatic control and the RTU (Remote Terminal Unit) for remote manual control.

In the case of single-phase transformer banks, this contact is located on the bank's "Master" unit, and the "Follower" unit will respond solely to raise/lower commands originating from the main phase.

Among the four possible combinations of the SPS's Manual/Automatic and Local/Remote control modes, there is only one—the Manual and Local combination—in which commands received at the Raise/Lower tap contact inputs are not executed. Therefore, to prevent the SPS from simultaneously receiving and executing Automatic and Manual remote commands, the SPS's Manual/Automatic auxiliary contact is used for interlocking, as shown in Figure 10.

Note that the SPS Automatic/Manual auxiliary contact shown in Figure 10 can be used simultaneously in the remote Manual/Automatic selection circuit.

Special attention must be paid to the correspondence between the raise/lower tap commands and the raise/lower voltage commands. In some applications, raising the tap may mean lowering the voltage, and vice versa. The SPS Raise/Lower inputs always refer to the tap position.

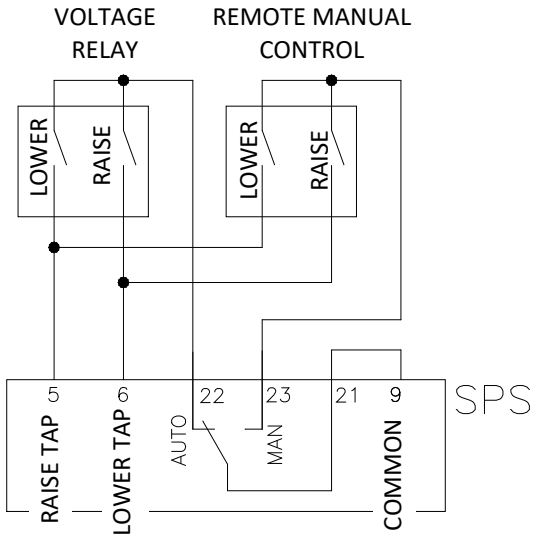


Figure 10 - Connection of external Raise/Lower control contacts for Automatic and Manual operating devices

3.3.3 Serial communication

Each SPS features an RS-485 serial communication port used to communicate with the COMM04 Communication Module. Through this communication channel, the SPS transmits and receives the information necessary to maintain synchronization between transformers operating in parallel and to monitor all operating conditions.

A single COMM04 communication module is used for all SPS units in a given communication network (up to 18 single-phase or 6 three-phase transformers in parallel). This module features a second RS-485 port available for user access. All information, settings, and commands for any SPS unit can be accessed via this port.

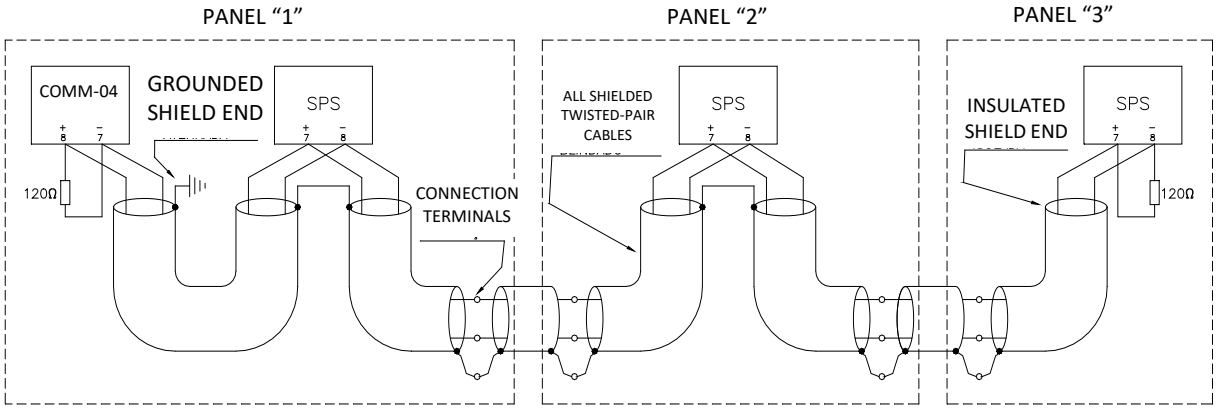


Figure 11 - Shield connection for serial communication cables

If a single shielded twisted-pair cable is not used for the entire run, for instance, due to intermediate terminal blocks, shield continuity must be ensured by connecting the shield ends of the various cables. The unshielded cable section resulting from the splice must be as short as possible.

The maximum end-to-end distance for RS-485 serial communication cables is 1,200 meters, both for the serial link connecting the PLCs to the COMM04 and for the serial link from the COMM04 to the supervisory system (if used).

3.3.3.1 RS-485 serial communication (COMM04 with 3.3 Vdc output)

The RS-485 port connection for the SPS and COMM04 is shown in Figure 12 for three-phase transformers and in Figure 13 for single-phase transformer banks.

The cable used must be of the shielded twisted-pair type, grounded at a single point.

The 3.3 VDC output of the COMM04 module is used to bias (pull-up/pull-down) the serial communication network, making it less susceptible to interference. Its use is recommended provided there is no other biasing device at the same electrical level of the network, that is, on the same physical RS-485 bus. A 120 Ω termination resistor is recommended at each end of the communication network.

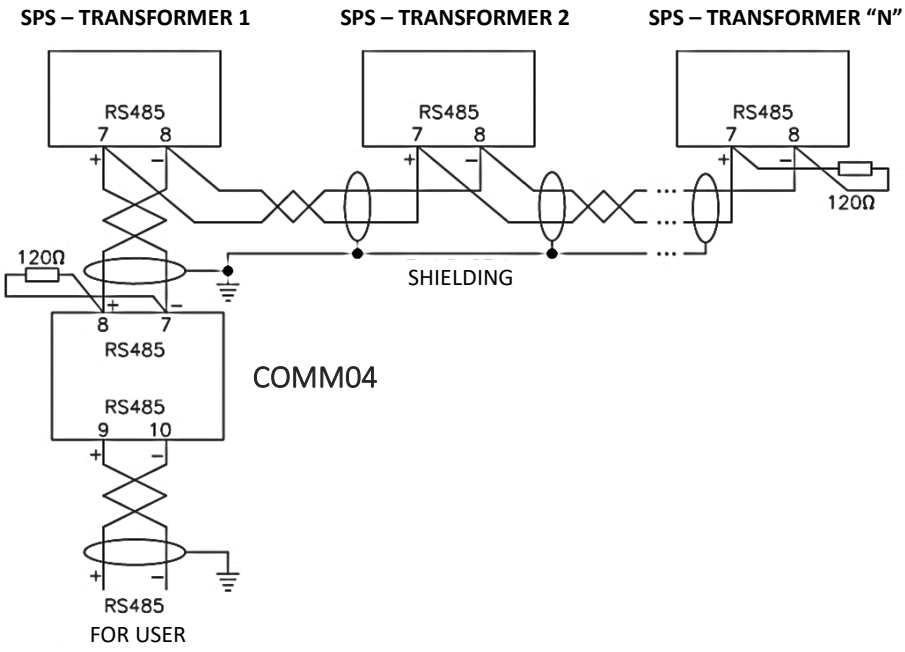


Figure 12 - RS-485 port connection between SPS and COMM04 for three-phase transformers

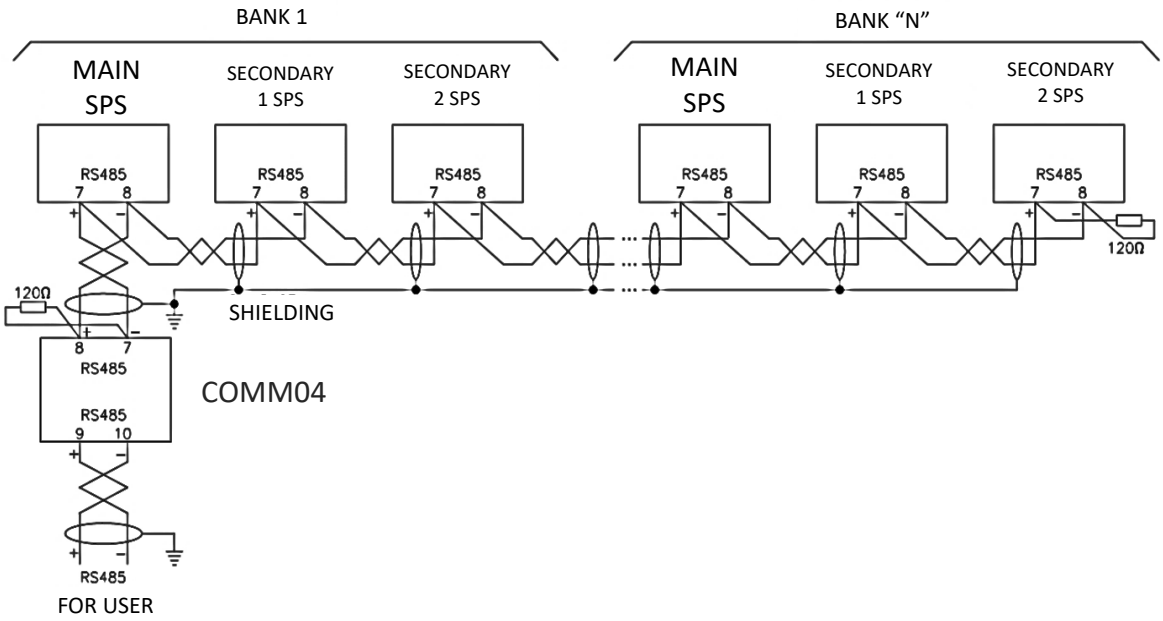


Figure 13 - RS-485 port connection between SPS and COMM04 for single-phase transformer banks

3.3.4 Tap changer position analog output

The SPS features a current-loop analog output for remote indication of the on-load tap changer position. The current output range can be selected via the SPS front panel from the options listed below. The maximum output voltage is 12 V, allowing for the connection of the maximum loads indicated next to each option:

Table 3 - Maximum load per output option

Output option	Maximum load
-1...+1 mA	12000 Ω
0...1 mA	12000 Ω
-5...+5 mA	2400 Ω
0...5 mA	2400 Ω
-10...+10 mA	1200 Ω
0...10 mA	1200 Ω
-20...+20 mA	600 Ω
0...20 mA	600 Ω
4...20 mA	600 Ω

The current output will vary linearly within the selected range, in proportion to the ongoin tap position. Thus, the output value for a given tap position can be calculated using the following simple formula:

$$mA\ Output = \frac{End\ of\ Scale[mA] - Start\ of\ Scale[mA]}{Final\ Tap\ -\ Initial\ Tap} \times (Ongoing\ Tap - Initial\ Tap + Start\ of\ Scale[mA])$$

In the event of a Tap Read Error (E08), the current output will continue to indicate the last tap position read prior to the error.

3.3.5 Tap changer position measurement

The SPS/SPS-I measures the tap position of the on-load tap changer. This measurement is performed via an SPS/SPS-I input specifically designed for connecting a potentiometric position transmitter from the on-load tap changer, or via a current loop input (mA).

Two versions are available: the standard SPS version with a potentiometric measurement input, and the SPS-I version with a current loop measurement input.

3.3.5.1 Potentiometric measurement input - Model SPS

The connection of the on-load tap changer's potentiometric position transmitter to the SPS is made via three wires: the cursor, the start, and the end of the potentiometer.

The SPS automatically compensates for the resistance of the potentiometer transmitter's connecting cables. Therefore, the three wires must have the same length and gauge, with a maximum permissible resistance of 8 Ω for each wire.

Based on this maximum resistance and the gauge of the cables used, the maximum permissible length for these cables can be determined. Considering cables with typical resistances of 13.3 Ω/km, 7.98 Ω/km, and 4.95 Ω/km for gauges of 1.5 mm², 2.5 mm², and 4 mm², respectively (untinned cables with stranding class 4), the maximum lengths are as shown in the following table.

Table 4 - Maximum cable length

Cable 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

3.3.5.1.1 Requirements for the tap position transmitter

The tap changer position transmitter shall be of the potentiometric type, with its resistance varying from zero to the maximum value for the initial and final positions of the tap changer, respectively.

For tap changers with “intermediate” positions, that is, transition positions sharing the same voltage as adjacent positions, as illustrated in the following table, the potentiometer ring resistors corresponding to these positions must be removed and/or short-circuited, as shown in the example below. All intermediate positions (6A, 6, and 6B in the example) will be designated as tap “6,” since they share the same voltage.

Table 5 - Potentiometric transmitter configuration

Tap position	Voltage (V)	Current (A)	Resistance between cursor and initial position (example using 10 Ω/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

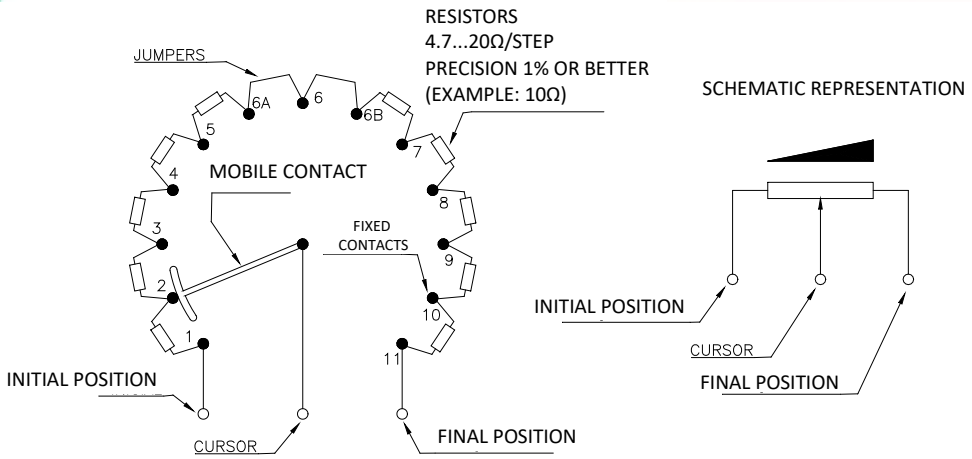


Figure 14 - Configuration of the potentiometric transmitter resistors at the intermediate positions of the on-load tap changer

The SPS accepts a potentiometer transmitter step resistance (i.e., the value of each individual resistor shown in Figure 14) in the range of 4.7 to 20 Ω, and a total transmitter resistance of 9.4 to 1000 Ω. The moving contact (cursor) of the potentiometer transmitter may be either the “make-before-break” or “break-before-make” type. The potentiometer transmitter resistors must be precision resistors, that is, with error tolerances of no more than 1%.

In this case, the SPS parameterization regarding the tap changer must be performed taking into account: the resistance value per step, the total number of tap positions, the center tap, and the tap changer's synchronization time. For further details regarding parameterization, refer to Chapter **Erro! Fonte de referência não encontrada.**.

The ongoing tap position of the associated on-load tap changer can be reported in the following formats: simple numeric (1...17), bilateral numeric (-8...0...+8), or alphanumeric (8L...N...8R).

If the number of taps is 10, for example, and the representation is not a simple numeric format, it is necessary to additionally specify the center tap, which is the tap considered as 0 in the bilateral classification or N in the alphanumeric scale. Based on this value, the SPS corrects the tap indication according to the adjusted center tap value.

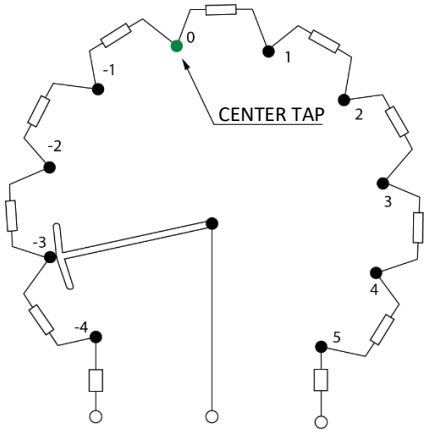


Figure 15 - Center tap indication

3.3.5.2 Analog current measurement input - Model SPS-I

Tap measurement is performed via two SPS-I inputs designed for connecting an on-load tap changer position transmitter using a current loop. One input is dedicated to 0–1 mA signals, while the other is dedicated to 0–5 mA, 0–10 mA, 0–20 mA, or 4–20 mA signals.

The current loop signal must vary from its minimum value to its maximum value for the initial and final positions of the OLTC, respectively.

For tap changers with “intermediate” positions, that is, transition positions sharing the same voltage as adjacent positions, the current loop signal corresponding to these positions must remain constant. All intermediate positions (e.g., 6A, 6, and 6B) shall be designated as tap “6,” given that they have the same voltage.

The current loop tap measurement input can be done in two ways (see Figure 16):

- **0...1 mA current loop**: terminals 13 (-) and 14 (+);
- **0...5, 0...10, 0...20, 4...20 mA current loop**: terminals 13 (-) and 12 (+).

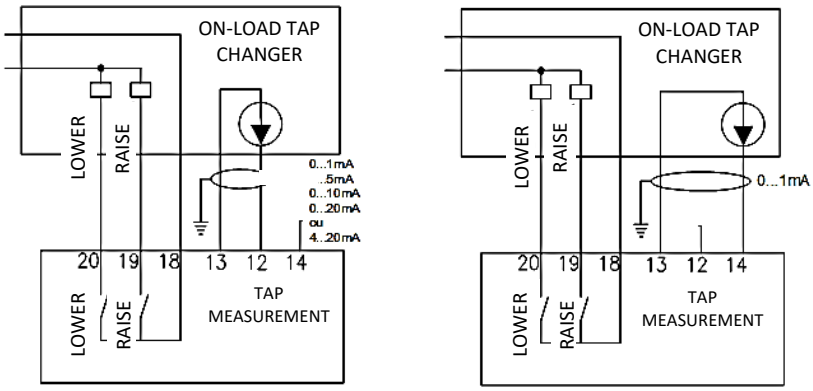


Figure 16 - Connection diagram for current loop tap measurement

3.3.6 Tap raise/lower output contacts

The output contacts for the SPS tap-raise and tap-lower commands are connected directly to the control circuit of the corresponding on-load tap changer; they typically operate by energizing the coils of the Raise/Lower contactors, which in turn energize the drive motor.

All tap-change commands, whether initiated locally via the SPS front panel or remotely via dry contacts or serial communication, are relayed to the on-load tap changer through the Raise/Lower Tap output contacts.

These contacts operate momentarily; thus, for each tap-change command issued by the SPS, they close once for a duration of approximately 0.5 seconds. For this reason, on-load tap changers equipped with intermediate positions, that is, transition positions sharing the same voltage as adjacent positions, must feature automatic transition through these intermediate positions.

Still considering this example, if the tap changer is in position 5 and the SPS issues a single "Raise Tap" command, the on-load tap changer must automatically move from position 5 to 6A and then from 6A to 6.

The tap changer output contacts can switch loads of up to 250 Vdc or 250 Vac, with maximum power ratings of 70 W or 220 VA, respectively. Their current-carrying capacity (thermal current) is 2 A continuous.

3.3.7 Output relays

The SPS provides output contacts for signaling operating conditions and/or self-diagnosis states within the paralleling system.

3.3.7.1 Signaling contact arrangement – Three-phase transformers

For the parallel operation of three-phase transformers, an SPS is used for each transformer, with the signaling contact arrangement shown in Figure 17. One of the contacts has a fixed signaling function (Manual control mode), operating as normally open (NO). The others have a programmable function.

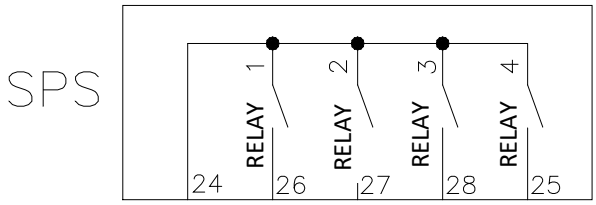


Figure 17 - SPS signaling contacts with three-phase transformer

3.3.7.2 Signaling contact arrangement – Single-phase transformers

For the parallel operation of single-phase transformer banks, one SPS unit is used for each phase of the bank, totaling three SPS units per bank. The distribution of signaling contacts among the SPS units of a bank is shown in Figure 18. One of the contacts on the bank's Main SPS has a fixed signaling function (Manual control mode), operating as normally open (NO). The other contacts have programmable functions; note that on Secondary SPS 1 and Secondary SPS 2, relays 4 and 5 operate simultaneously, meaning the function selected for relay 4 is replicated on relay 5.

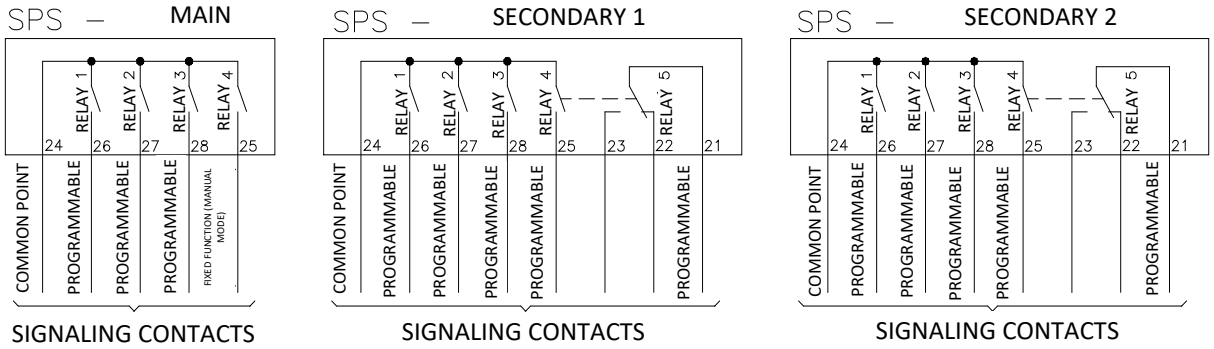


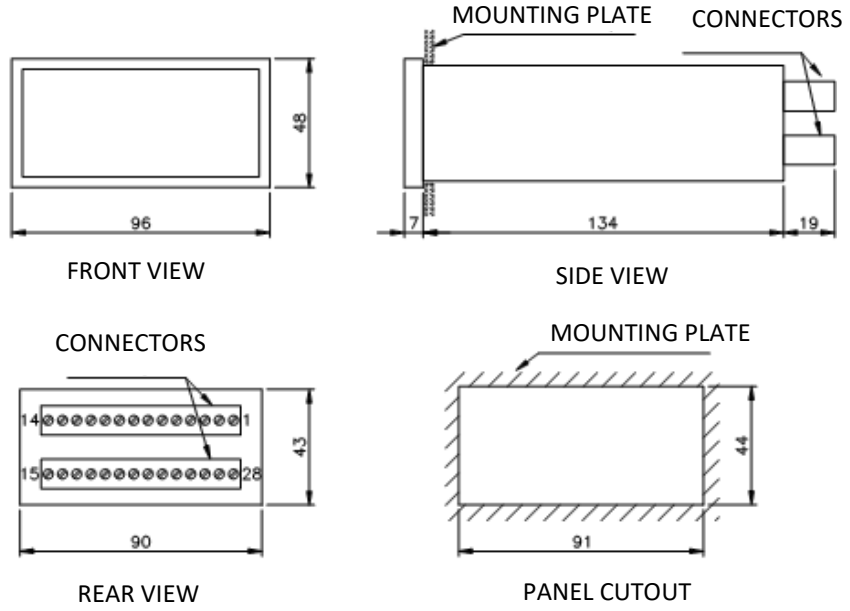
Figure 18 - SPS signaling contacts with single-phase banks

3.4 Mechanical Installation

The SPS paralleling system equipment must be installed protected from the elements, either inside panels or housed within buildings. In either case, an anti-condensation system must be provided.

The SPS is suitable for flush mounting and can be secured, for example, to panel doors or faceplates. Mounting clips are supplied with the SPS. The figure below shows the equipment's main dimensions, as well as the dimensions of the panel cutout required for installation. Particular attention should be paid to the thickness of the paint layers on the panel where the cutout is made; in some cases, if a thick paint coating is used, the reduction in the cutout's clear opening may even prevent the equipment from being inserted.

The connection terminals are located on two removable connectors at the rear of the SPS to facilitate wiring. Cables ranging from 0.5 to 2.5 mm² can be used, either bare or fitted with pin-type (or needle-type) ferrules.



ALL DIMENSIONS IN mm

Figure 19 - Main external dimensions of the SPS

4 Operation

Local operation of the Synchronous Parallelism Supervisor - SPS can be performed using the keys on its front panel. The ongoing tap position, self-diagnostic events, and other screens are shown on the display. The SPS configuration can be checked via the LEDs.

4.1 Key Functions

The keys have the following functions:

Table 6 - Function of the programming keys

Key	Function
	**Programming key**: Allows access to the SPS configuration screens within the SPS network and to the password entry for the programming menu. Saves the configuration and the selected parameter value. Confirming a selection advances to the next configuration screen or parameter.
	**Up arrow key**: Increases the programmed value while editing a parameter. Issues a "raise tap" command while viewing the ongoing tap changer position.
	**Down arrow key:** Decreases the programmed value while editing a parameter. Issues a "lower tap" command while viewing the ongoing tap changer position.

4.2 LED Operation

The SPS LEDs indicate its configuration within the SPS network, and this indication will vary according to the parameters entered into the equipment.

Use the language labels supplied with the equipment to correctly identify the LEDs.

4.3 Display Indications

During autonomous system operation, without operator intervention via the front-panel keys, the SPS display may show one of the following indications:

4.3.1 Ongoing tap-changer position

The display continuously indicates the ongoing tap of the tap changer.

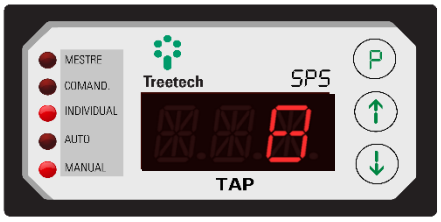


Figure 20 - Indication of the tap changer's ongoing tap position

4.3.2 Tap change in progress

The display intermittently indicates the current tap position of the tap changer and the symbols ^^^ or vvv, if a tap change is in progress to raise or lower the tap, respectively.

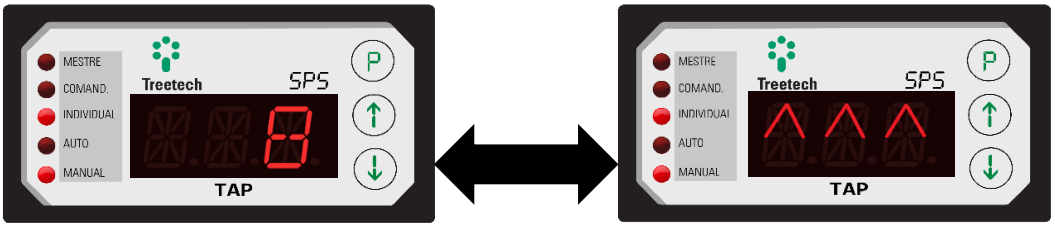


Figure 21 - Indication during a tap position change in progress (tap raise)

4.4 Selections: Local/Remote, Master/Follower/Individual, and Manual/Automatic

The Local/Remote, Master/Follower/Individual, and Manual/Automatic selections can be made locally via the SPS front keypad, as described below.

In the case of single-phase transformer banks, these selections are made via the front panel of the “Main” SPS; however, it must be noted that these selections apply to the bank as a whole, not just to the “Main” phase.

On the home screen, press the P key, one of the following screens will appear, depending on the previously selected option. Use the arrow keys to switch between options and the P key to select one and proceed to the next screen.

For indication of local or remote mode operation; see subsection **Erro! Fonte de referência não encontrada.**.

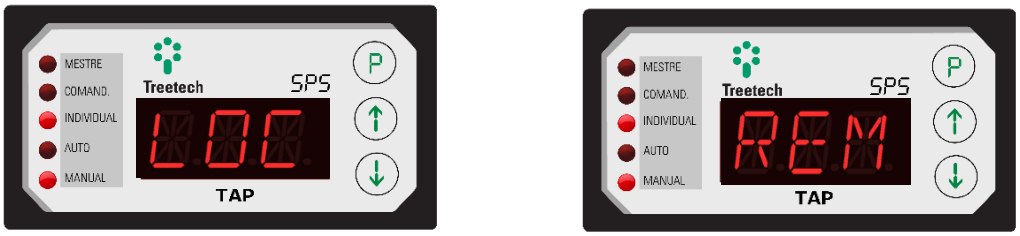


Figure 22 - Display indicating operation in Local (LOC) or Remote (REM) mode

Indication of operation in Individual, Follower, or Master mode.



Figure 23 - Display indicating operation in Individual (INd), Follower (COM), or Master (MAS) mode

Indication of Manual or Automatic mode operation.



Figure 24 - Display indicating operation in Manual (MAN) or Automatic (AUT) mode

4.5 Selection of Bank/Individual Phase

The Bank/Individual Phase selection applies only to the “Secondary 1” and “Secondary 2” phases of three-phase banks composed of single-phase units. This item is not applicable to three-phase transformers.

This selection can be performed locally using the SPS front keypad, as described below.

For indication of operation in bank or individual phase mode; see subsection **Erro! Fonte de referência não encontrada.**.

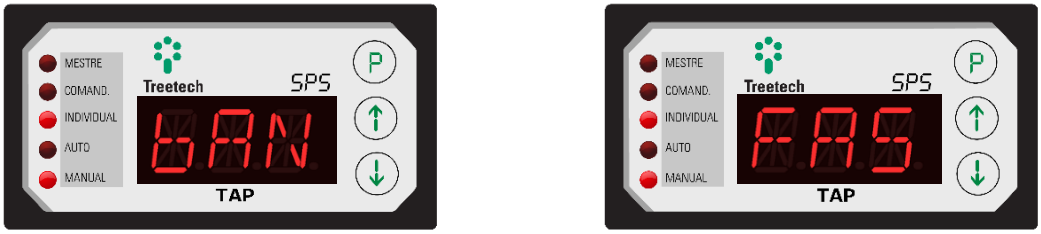


Figure 25 - Display indicating operation in Bank mode (BAN) or Individual phase mode (FAS)

If the corresponding “Main” phase is in Individual and Manual modes, the selection switches from Bank to Individual Phase or vice versa.

If the corresponding “Main” phase is **not** in Individual and Manual modes, the selection remains in Bank mode, and the Individual Phase selection is not accepted.

4.6 Manual Tap Raise/Lower Commands

Manual commands to raise or lower the tap position of the on-load tap changer can be performed locally using the ↑ and ↓ keys on the SPS front panel, as described below.

These commands will only be executed if the Local and Manual command modes have been previously selected and the transformer (or bank) is **not** in Follower mode.

For a three-phase bank composed of single-phase units, a manual command to raise or lower the tap on the "Secondary 1" or "Secondary 2" phases will only be executed if the corresponding SPS has been previously selected in Individual Phase mode. If the selection is set to Bank mode, the "Secondary 1" and "Secondary 2" phases will respond to raise/lower commands originating from the bank's "Main" phase.

If the transformer (or bank) is in Remote mode, the message shown in the figure below will appear on the display for 1 second, indicating that the command will not be executed because the transformer (or bank) is set to this mode.

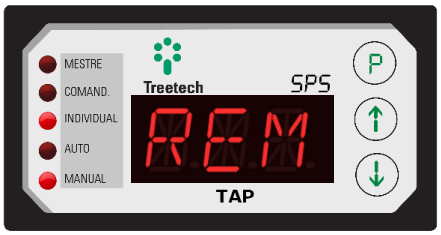


Figure 26 - Display indicating Remote mode operation

If Local **and** Manual control modes are selected, **and** the transformer (or bank) is **not** in Follower mode, the corresponding command is issued to the tap changer, and the display indicates that the tap-changing operation is in progress via the symbols ∧∧∧ or ∨∨∨, which flash on the display.

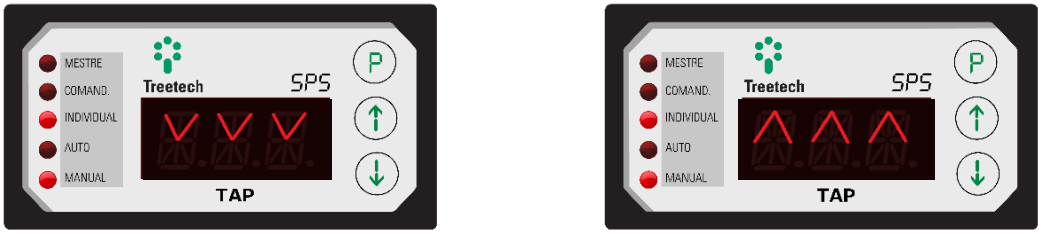


Figure 27 - Display indicating tap raising or lowering

If the symbols ∧∧∧ or ∨∨∨, are still flashing on the display, a new command to raise or lower the tap will not be accepted, as the previous switching operation may still be in progress.

4.7 Examples of Tap Raise/Lower Commands

Examples of tap raise/lower commands for various situations and parallel system configurations are presented below.

4.7.1 Three-phase transformers

One Master transformer, two Follower units, one Individual unit. "Raise" command executed on the Master SPS.

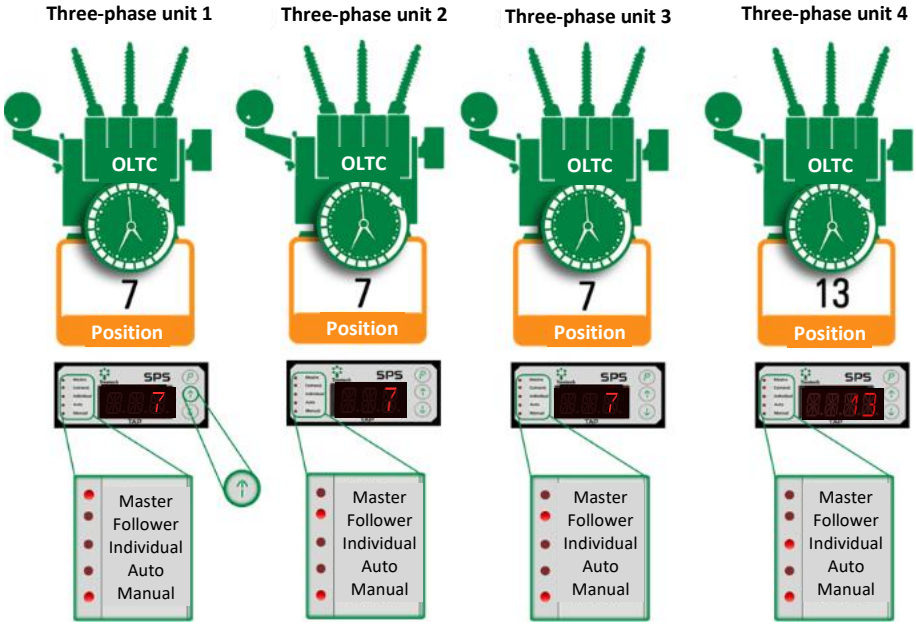


Figure 28 - Example of the raise tap command – Initial state (before the command)

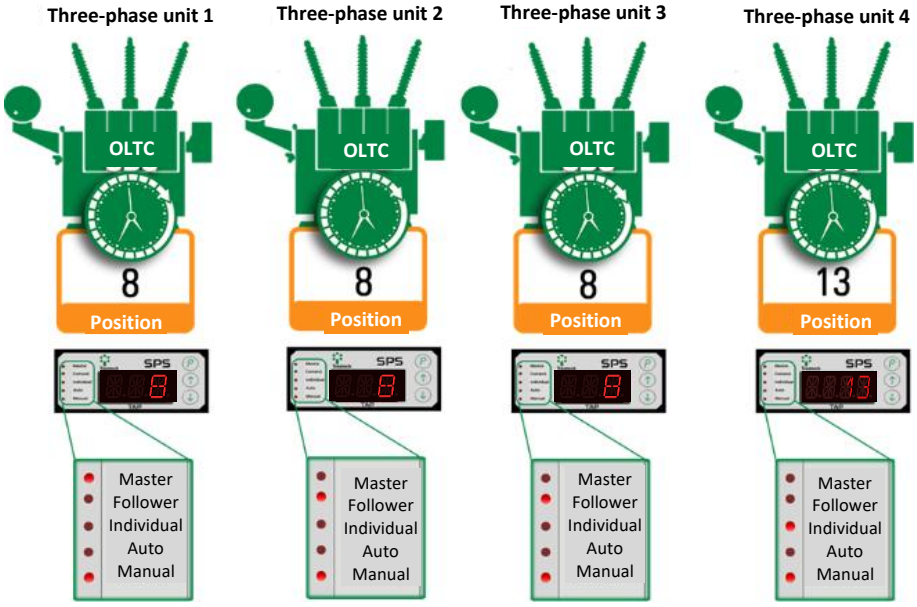


Figure 29 - Example of the raise tap command – Final state (after the command)

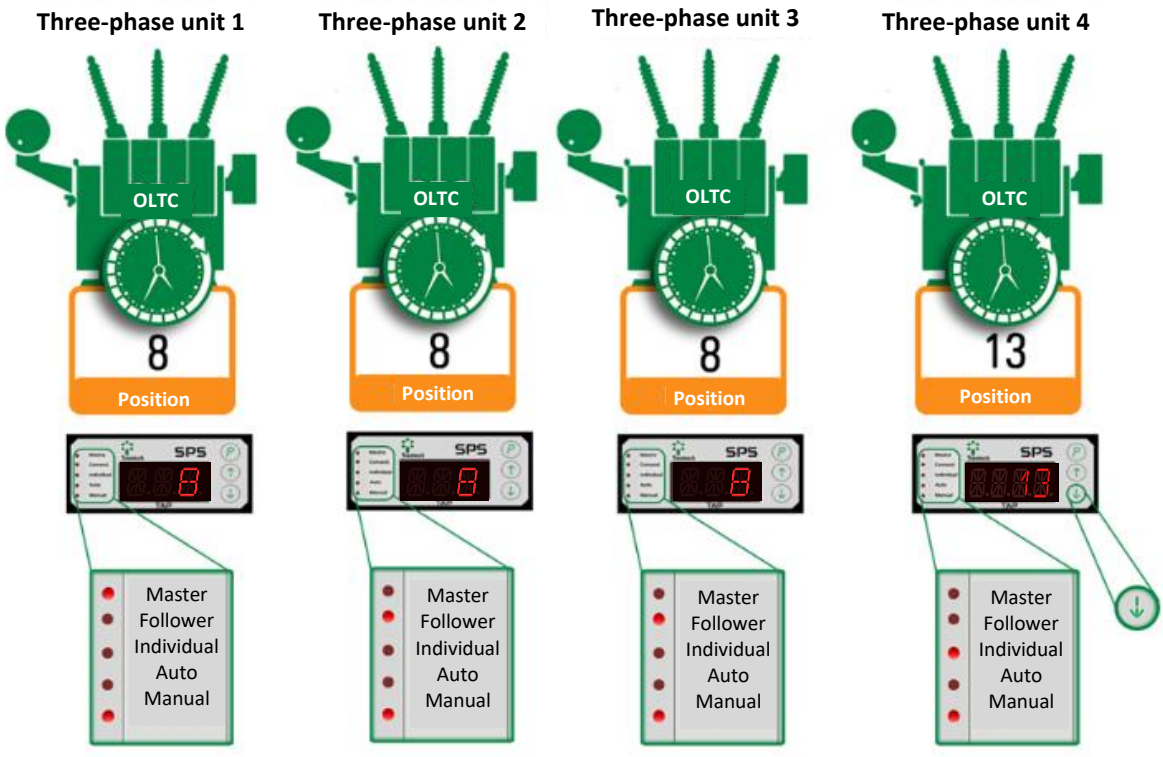


Figure 30 - Example of the lower tap command – Initial state (before the command)

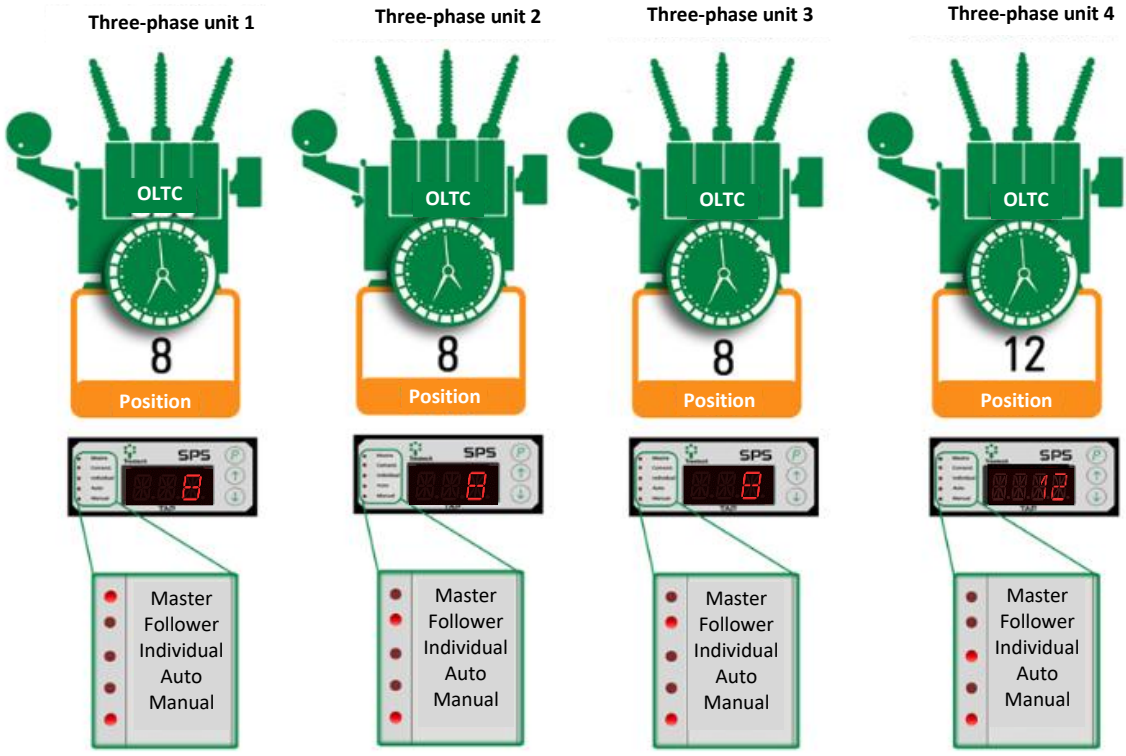


Figure 31 - Example of the lower tap command – Final state (after the command)

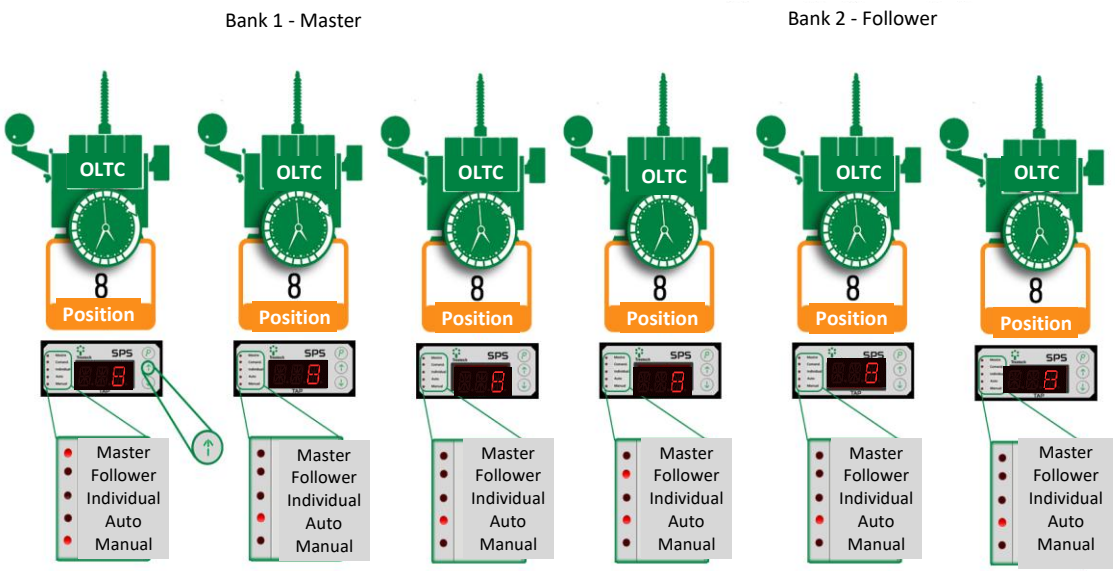


Figure 32 - Example of the raise tap command – Initial state (before the command)

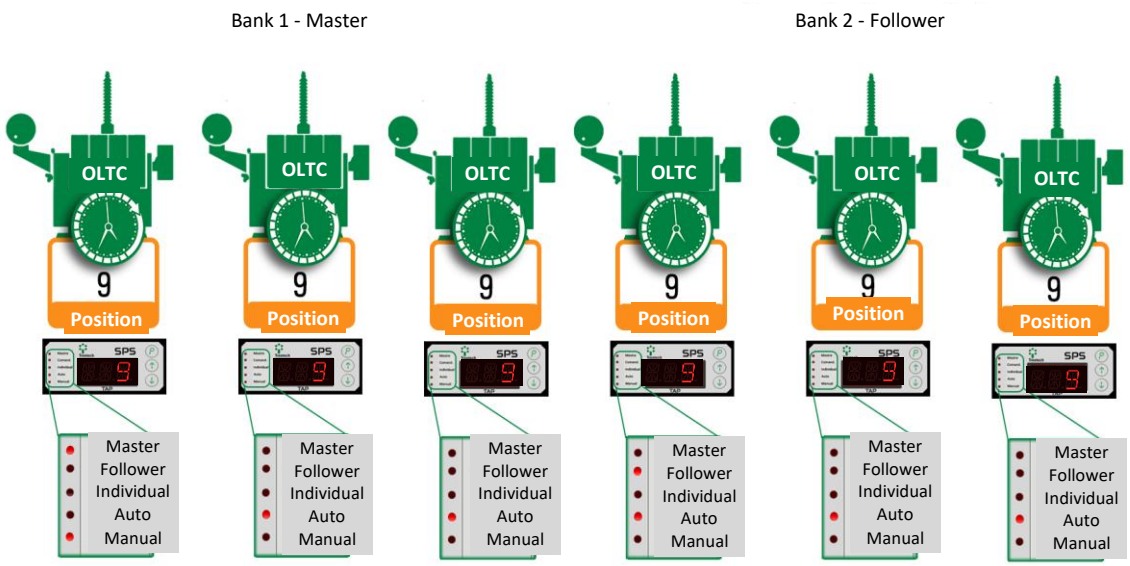


Figure 33 - Example of the raise tap command – Final state (after the command)

5 Parameterization

To ensure the correct operation of the paralleling system, various parameters must be adjusted in the SPS; these provide the equipment with the information necessary for its operation. Adjustments can be made via the front keypad, using the display for guidance, or through the user-accessible serial communication port on the COMM04 communication module.

5.1 Parameterization of the Synchronous Parallelism Supervisor - SPS

The procedure for accessing the various SPS adjustment parameters is presented below. Note that, to access the parameter settings, it is first necessary to enter the programming menu.



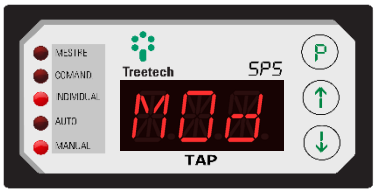
On any of the primary display screens, press and hold the key.



You will be prompted for the access password for the parameterization menus. By factory default, the number 165 will appear on the screen, and the password will be 0.

All SPS units are supplied with the default access password 0 (zero). After the initial login, the user can customize the password in the equipment's configuration menu.

If the newly set password is lost or forgotten, Treetech's Customer Service can assist with recovery if the number displayed on the screen when the SPS requests the password is provided.



After entering the password, use the key to move to the next parameter and the arrow keys to change the value of the parameter displayed on the screen.

Attention!
Once you move past a parameter, you cannot go back; you will need to cycle through all the parameters and repeat the access process described above to reach the desired parameter.

Below, you will find a description of each parameter, as well as recommendations for their selection.

5.1.1 MOD – Operating mode



Allows you to select the SPS parallelism mode.

Adjustment range: 0 (no paralleling); 1 (paralleling of single-phase bank), 2 (paralleling of three-phase transformers).
Default value: 0.

Option 0 allows the SPS to operate in isolation, without exchanging information with the Communication Module or other SPS units. In this case, the Master/Follower/Individual selection remains disabled, as the transformer will always operate in Indivisual mode.

Under this condition, the use of the COMM04 communication module is optional, unless the chosen communication protocol is DNP3.

5.1.2 ADR - Address



This is the SPS' address for serial communication with the COMM04 communication module. As a general rule, each SPS connected to the same communication network must have a unique address—no duplicates are allowed.

The addresses accepted by the SPS during parameterization will vary according to the previously selected operating mode (**MOD**) and whether the system is three-phase or single-phase, as detailed below.

Adjustment range: 0 to 18, in steps of 1.
Default value: 0.

5.1.2.1 ADR programming for single-phase operating mode

If the single-phase operating mode (MOD=1) is selected, the SPS allows any value within the range of 1 to 18 to be programmed for the **ADR** parameter, enabling a total of up to 6 transformer banks to operate in parallel.

In this operating mode, the value programmed for the address determines which bank the SPS belongs to, as well as the function it assumes within the single-phase bank ("Main," "Secondary 1," or "Secondary 2") as shown in the table below.

Address numbering must necessarily start at bank 1 and proceed to the addresses of subsequent banks, if present. For example, if there are 3 banks, addresses 1 through 9 must be programmed; addresses 4 through 12, for instance, must not be programmed.

Incorrect address programming will trigger a Communication Error (E02) self-diagnosis.

Table 7 - Adjustment of the ADR parameter for single-phase operation mode

ADR parameter	Bank to which the SPS belongs	SPS function within the bank
1	Bank 1	Secondary 2
2		Secondary 1
3		Main
4	Bank 2	Secondary 2
5		Secondary 1
6		Main
7	Bank 3	Secondary 2
8		Secondary 1
9		Main
10	Bank 4	Secondary 2
11		Secondary 1
12		Main
13	Bank 5	Secondary 2
14		Secondary 1
15		Main
16	Bank 6	Secondary 2
17		Secondary 1
18		Main

5.1.2.2 ADR programming for three-phase operating mode

If the three-phase operating mode (MOD=2) is selected, the SPS only allows the **ADR** parameter to be programmed with multiples of 3 within the range of 3 to 18, enabling up to six three-phase transformers to operate in parallel. Following a philosophy similar to that described above for the single-phase operating mode, other values (1, 2, 4, 5, ..., 16, 17) are not accepted by the SPS, given that a single three-phase transformer comprises three single-phase units.

Address numbering must necessarily begin with transformer 1, proceeding to the addresses of subsequent transformers, if any. For example, if there are three three-phase transformers, addresses 3, 6, and 9 must be programmed; addresses such as 6, 9, and 12, for instance, must not be programmed.

Incorrect address programming will trigger a Communication Error (E02) self-diagnosis.

Table 8 - Adjustment of the ADR parameter for three-phase operation mode

ADR parameter	Three-phase transformer to which the SPS belongs
3	Transformer 1
6	Transformer 2
9	Transformer 3
12	Transformer 4
15	Transformer 5
18	Transformer 6

5.1.2.3 ADR programming for the joint operation of three-phase transformers and single-phase banks

The philosophy applied to the allocation of SPS addresses for three-phase and single-phase operating modes allows for the parallel operation of three-phase transformers and single-phase banks.

The following table presents an example of address programming for the operation of one single-phase bank and two three-phase transformers. This example is not exhaustive; any combination of three-phase transformers and single-phase banks may be used.

Table 9 - Adjustment of the ADR parameter for combinations of three-phase transformers and single-phase banks

ADR parameter	Three-phase transformer to which the SPS belongs
3	Three-phase transformer 1
6	Three-phase transformer 2
7	Single-phase bank 3
8	
9	

5.1.3 NOD - Number of three-phase sets



Selection of the total number of three-phase sets operating in parallel, with the SPSs connected to the same serial communication network.
For example, if there is a single-phase bank and two three-phase transformers operating in parallel, the NOD parameter will be programmed as 3.

The **NOD** parameter is programmed only on the SPS unit whose address (**ADR** parameter) has been set to 3. For the other SPS units, the **NOD** parameter will not be requested.

Adjustment range: 1 to 6, in steps of 1.
Default value: 01.

5.1.4 TAP - Total number of tap positions



Selection of the total number of tap-changer positions.
The TAP parameter value must not include intermediate positions—that is, transition positions that have the same voltage as other adjacent positions.

Adjustment range: 2 to 50, in steps of 1.
Default value: 17.

5.1.5 IDC – Type of indication



This is the type of tap indication adopted for display on the SPS, which generally follows the indication type used on the on-load tap-changer itself.

There are five indication options, shown in the table below.
Adjustment range: 0 to 4.

Default value: 4.

Table 10 - Adjustment of the IDC parameter

IDC parameter	Description	Example 1	Example 2
0	Two-way numeric	-8 ... 0 ... +8	-12 ... 0 ... +20
1	Reverse two-way numeric	+8 ... 0 ... -8	+12 ... 0 ... -20
2	Alphanumeric	8L ... N ... 8R	12L ... N ... 20R
3	Reverse alphanumeric	8R ... N ... 8L	12R ... N ... 20L
4	Simple numeric	1 ... 17	1 ... 33

5.1.6 CNT – Center tap



This is the position, measured from the start of the measurement range, where the "neutral" tap of the on-load tap changer is located. This parameter is adjusted only when the "Two-way numeric" or "Alphanumeric" indication type is selected, as it allows for the indication of tap positions for tap changers with asymmetrical voltage-raising and voltage-lowering ranges.

Adjustment range: 2 to 50.

The table below illustrates the effect of this parameter on the tap indication for a tap changer with a total of 33 positions, featuring Two-way numeric and Reverse alphanumeric indications.

Table 11 - Adjustment of the CNT parameter

CNT parameter	Two-way numerical example	Reverse alphanumeric example
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
19	-18 ... 0 ... +14	18R ... N ... 14L

5.1.7 FSR - Analog output range



Selection of the current loop standard to be measured by the SPS-I.

Adjustment range:

1 - 0...1 mA;
2 - 0...5 mA;
3 - 0...10 mA;
4 - 0...20 mA;

5 - 4...20 mA.

This parameter is available only on the model with a current loop measurement input (model SPS-I). This parameter is not programmable on the SPS version designed for a potentiometer transmitter input.

5.1.8 RES - Resistance per step



It is the resistance per step of the on-load tap changer's potentiometer transmitter.

Adjustment range: 4.7 to 20Ω.
Default value: 10.0.

This parameter is available only in the version with a potentiometer transmitter measurement input (model SPS). This parameter is not programmed in the SPS-I version, which uses a current loop input.

5.1.9 SNC - Synchronization time



The SNC parameter (synchronization time) is associated with the time the on-load tap changer takes to complete a full tap change.

Adjustment range: 1 to 100 seconds, in 1-second steps.
Default value: 94.

The adjusted value for this parameter is used by the SPS for the following functions:

- Timing for self-diagnosis of synchronization error (E01) – For example, in the event of a discrepancy between the tap of a Follower transformer and the Master unit, the SPS will only issue a synchronization error self-diagnosis after the time set in **SNC** has elapsed;
- Wait time for successive tap changes – If multiple successive tap changes are required, the Master SPS will only accept a new change command after the **SNC** time has elapsed for all parallel tap changers. This prevents a new tap change from being initiated before all tap changers have completed the previous one, which could cause a synchronization error. During the **SNC** timing period following the issuance of a tap change command, the SPS indicates on its display that the switching operation is in progress using the symbols ^^^ or ᵛᵛᵛ (indicating the tap changer is raising or lowering the tap, respectively).

Given these functions performed by the SPS based on the **SNC** parameter, the parameter's setting must exceed the tap changer's longest tap-changing time by a margin of at least 2 seconds. For transformers with intermediate taps, the longest switching time occurs during

the operation that requires passing through intermediate positions. Consider the following example, where the time required to perform a single tap change is 5 seconds:

Table 12- Tap-changing time - SNC parameter

OLTC Position	1	2	3	4	5	6A	6	6B	7	8	9	10	11
Tap-changing time (s)		5	5	5	5	10		10		5	5	5	5

As can be seen, moving from position 5 to 6 and from 6 to 7 requires passing through the intermediate positions 6A and 6B, respectively. Thus, the actual tap-changing time is 10 seconds, rather than the initially expected 5 seconds. Consequently, the **SNC** parameter setting should be the maximum tap-changing time (10 s) plus the minimum margin (2 s), resulting in an ideal setting of 12 seconds.

5.1.10 PRG - Self-diagnosis delay due to invalid programming (E04)



The PRG parameter is a time delay for triggering the self-diagnosis of invalid programming (E04), intended to prevent unnecessary self-diagnosis alerts caused by only temporary invalid conditions.

Adjustment range: 2 to 25 seconds.
Default value: 25.

5.1.11 RL'x' - Relays



This parameter contains the settings for relays 1 through 4. These settings are repeated for the various relays. However, output relay 4 does not have a programmable signaling function in all cases.

In three-phase operating mode and when acting as the Master for a single-phase bank, relay 4 performs the fixed signaling function: "Manual Command" (normally open). In these cases, the SPS will not prompt for the programming of parameter RL4. The "x" indicates the relay number.

Example: RL1, RL2, RL3 and RL4.

Default value:

RL1 – 17.
RL2 – 19.
RL3 – 21.

Table 13 - Adjustment of the RL1 parameter

Parameter RL1, RL2, RL3, or RL4	Operating mode	Signaling condition	Location of the condition
01	NO[1]	Synchronization error between three-phase transformers or between banks (E01)	At the bank or transformer itself
02	NC[2]		
03	NO	Phase synchronization error in the bank (E01) – For single-phase transformer banks only	At the bank itself
04	NC		
05	NO	Communication error between SPS and COMM04 (E02)	At any point in the system
06	NC		
07	NO	Communication error between SPS and COMM04 (E02)	At the SPS itself
08	NC		
09	NO	Programming error (E04)	At any point in the system
10	NC		
11	NO	Tap position reading error (E08)	At any point in the system
12	NC		
13	NO	Tap position reading error (E08)	At the bank or transformer itself
14	NC		
15	NO	Correct timing and programming	At the bank or transformer itself
16	NC		
17	NO	Three-phase transformer or bank in Master mode	At the bank or transformer itself
18	NC		
19	NO	Three-phase transformer or bank in Follower mode	At the bank or transformer itself
20	NC		
21	NO	Three-phase transformer or bank in Individual mode	At the bank or transformer itself
22	NC		
23	NO	Three-phase transformer or bank in Automatic mode	At the bank or transformer itself
24	NC		
25	NO	Both “Secondary” phases in Bank mode – For single-phase transformer banks only	At the bank itself
26	NC		
27	NO	Three-phase transformer or bank in Remote mode	At the bank or transformer itself
28	NC		
29	NO	Three-phase transformer or bank in Local mode	At the bank or transformer itself
30	NC		
31	NO	Both “Secondary” phases in Individual Phase mode – For single-phase transformer banks only	At the bank itself
32	NC		

33	NO	SPS Secondary 1 or Secondary 2 in Individual Phase mode – For single-phase transformer banks only	At the SPS itself
34	NC		

1 - NO = Normally Open
2 - NC = Normally Closed

5.1.12 PSS - New password



Sets a new password for accessing the programming menus.
The default password is 0 (zero).

Adjustment range: 0 to 999, in steps of 1.
Default value: 00.

5.1.13 OCS – Indication of tap position via analog output



This involves selecting the output range for the SPS current-loop analog output, used for remote indication of the on-load tap changer's tap position. Subsection 3.2.4 details the operation of the current output.

Adjustment range: 0 to 9, in steps of 1.
Default value: 00.

The adjustment options for this parameter are shown in the table below:

Table 14 - Adjustment of the OCS parameter

OCS parameter	Output range
1	0...1mA
2	-1...+1mA
3	0...5mA
4	-5...+5mA
5	0...10mA
6	-10...+10mA
7	0...20mA
8	-20...+20mA
9	4...20mA

5.1.14 LNG - Language



It is the selection of the interface language for operating the SPS.

Adjustment range:
1 – *Português*;
2 – English;
3 – *Español*.
Default value: 1.

6 Commissioning for Entry into Service

Once the equipment has been installed, commissioning must follow the basic steps below:

- ✓ Disable the tap changer controls (e.g., turn off motor circuit breakers or set the control switch to "Local") before energizing the SPS units. During this period, any tap-changing operations that may be required must be performed at the tap changer cabinet itself;
- ✓ Check the correctness of electrical connections (e.g., via continuity tests);
- ✓ Energize the SPS and COMM04 units with a supply voltage of 38 to 265 VDC/VAC;
- ✓ Perform all SPS parameterization;
- ✓ Set all SPS units to Local, Individual, and Manual control modes;
- ✓ For single-phase transformer banks, select Secondary 1 and Secondary 2 phases of the bank in Individual Phase mode;
- ✓ If there are no error indications, enable remote control of the tap changers, allowing operation via the SPS units;
- ✓ Manually operate each tap changer using its corresponding SPS unit, cycling through all tap positions; verify that the "raise tap" and "lower tap" signals are not reversed, that the tap indication is correct at all positions, and that no tap reading errors (E08) occur;
- ✓ Manually adjust all tap changers, placing them in the same tap position;
- ✓ Select one of the transformers or banks as Master and select the remaining transformers or banks, one by one, as Follower;
- ✓ Manually operate the Master, raising or lowering the position via the front keypad, and verify that all Followers track the Master;
- ✓ Simulate, to the extent possible, the various error conditions, verifying the error indications on the display as well as the operation of the programmed self-diagnosis contacts;
- ✓ Simulate, to the extent possible, the various operating conditions (e.g., Master, Follower, Manual, Automatic, etc.), verifying the operation of the programmed signaling contacts;
- ✓ Select the desired final operating configuration, specifically, which transformers or banks are to be Master, Follower, or Individual, and the desired control mode (Manual or Automatic, and Local or Remote).

6.1 Parameterization Spreadsheet

Below is a link, along with a QR code, leading to our Wiki. It contains a spreadsheet (which can be printed) listing all SPS parameters, designed to assist with the equipment's parameterization process.

Parameterization

7 Troubleshooting

Upon detecting a problem, the SPS will activate its self-diagnosis contact, and the display will flash the tap changer's current tap position and an error code.

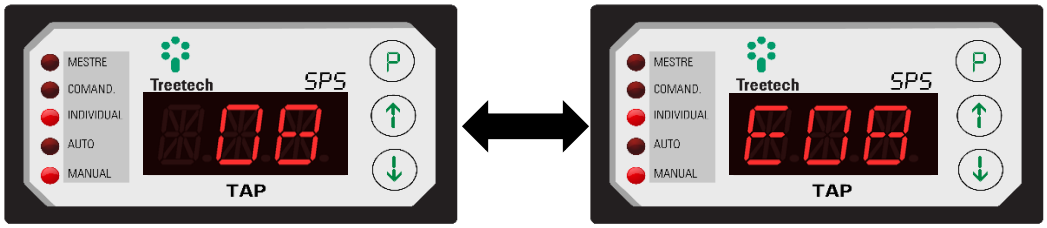


Figure 34 - Indication during an error condition

In the event of a self-diagnosis and possible errors generated by the SPS, follow the instructions by clicking the link below or scanning the QR code to be redirected to Treetech Customer Support.

Self-diagnosis

8 Technical Data and Type Tests

8.1 Technical Data

Table 15 - SPS Technical data

Information	Range/Description
Supply voltage:	38…265 V DC/AC 50/60 Hz
Power consumption:	< 5 W
Operating temperature:	-10…+70 °C
Protection rating:	IP 40
Mounting:	Panel-mounted
Tap measurement input:	Potentiometric, 3-wire
Number of tap changer positions:	2 to 50
Total resistance of the potentiometer transmitter (SPS):	9.4...1000 Ω
Resistance per step of the potentiometer transmitter (SPS):	4.7 to 20 Ω, 1% class or better
Tap measurement input (SPS-I):	Current loop, 2-wire
Current loop input standards (SPS-I):	0 ... 1 mA 0 ... 5 mA 0 ... 10 mA 0 ... 20 mA 4 ... 20 mA
Input impedance for current loop:	1mA = 4.7 k Ω 5, 10, 20mA = 238 Ω
Analog output options and maximum load:	0 ... 1 mA - 12000 Ω 0 ... 5 mA - 2400 Ω 0 ... 10 mA - 1200 Ω 0 ... 20 mA - 600 Ω 4 ... 20 mA - 600 Ω
Maximum error of analog output:	0.5% end-of-scale
Output contacts:	Potential-free
Maximum switching power:	70 W / 250 VA
Maximum switching voltage:	250 VDC/VAC (Non-inductive)
Maximum continuous current:	2.0 A
Serial communication port:	01 (one) RS-485 for connection to the COMM04
Communication protocol with COMM04:	Modbus RTU (*slave*)
Banks or three-phase transformers in parallel:	Maximum of 6 (six)

8.2 Type Tests

Table 16 - Type tests

Type tests	
Surges and transients (IEC 60255-6)	
1st cycle peak value: Frequency: Duration: Repetition rate: Decay to 50%:	2.5 kV 1.1 MHz 2 s 400 (surges/s) 5 cycles
Impulse (IEC 60255-5)	
Waveform: Amplitude: Number of pulses: Energy:	1.2/50 µs 5 kV 3 negative and 3 positive with a 5-second interval between pulses 0.5J
Applied voltage (IEC 60255-5)	
Rated power-frequency withstand voltage:	2.0 kVrms, 60 Hz, for 1 minute between circuits and mounting panel
Electromagnetic susceptibility (IEC 61000-4-3)	
Severity level: Frequency: Field strength:	3 20 to 2000MHz 10 V/m
Electrostatic discharge (IEC 61000-4-2)	
Air mode: Contact mode:	10 discharges at level 3 (8 kV) 10 discharges at level 3 (8 kV)
Fast electrical transients (IEC 61000-4-4)	
Severity level: Power input test: Input/output test:	4 4kV 2kV
Climatic test (IEC 60068-2-14)	
Temperature range: Test duration:	-10...+70 °C 6 hours

9 Order Specification

The SPS was designed for universal application, with most of its features selectable via its programming menus. These adjustments can be made directly on the front panel or via the RS-485 serial communication port.

The power input is universal (85 to 265 Vac/Vdc, 50/60 Hz).

To order the purchase of the device, you only need to inform:

1. Product model

- **SPS** (input for potentiometric tap position measurement);
- **SPS-I** (input for current loop tap position measurement).

2. Quantity

- Number of units;

3. Serial communication module

- Number of units;
- Communication protocol to be used.

BRASIL
Treetech Tecnologia Ltda
Rua José Alvim, 112, Centro
CEP 12.940-750 - Atibaia/SP
+ 55 11 2410-1190
www.treetech.com.br