



SuperTAPP SG

Voltage Control & Monitoring Relay User Documentation

Part 1 Installation, Operation and Maintenance Guide



About this manual

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This document is one part (highlighted in bold below) of the complete user documentation set, which comprises three parts in total:

- ▲ **Part 1 Installation, Operation and Maintenance Guide**
- ▲ Part 2 Technical Reference
- ▲ Part 3 SCADA Communication Guide

Manufacturer and Publisher

SuperTAPP SG is manufactured by, and this manual is published by:

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Document Reference FP1034-U-5 v4.4

Scope

This document is applicable to all SuperTAPP SG relay types.

Version Information

Document Issue

Issue	Issue Date	Description of Main Changes	Applicable relay version
1.0	April 2016	First issue	h/w 00, s/w v4.x
2.0	September 2016	Substantial changes to section 15. Subsections renumbered and subsections 15.6, 15.8 and 15.9 added to support new features. Improved description in most other subsections with function diagrams added. Minor updates throughout.	h/w 01 s/w v5.x
2.1 2.2	January 2017 March 2017	4.1 Table 1-2 Message descriptions clarified 4.6.1 Table 1-4 Overloaded AC input alarm 5 Figures updated throughout	h/w 01,02 s/w v5.x
2.3	September 2017	1.3 Figure 1-1 and Table 1-1 warning label for SFP removal 11.1 Warning to remove SFPs before withdrawing relay from case	h/w 03,04 s/w v6.0, v6.1
3.0	May 2018	6.1 Added coverage of the setting password 7.8.2.3 Fast tap delay is now settable	h/w 04,05 s/w v6.6 – v6.8, v7.3, v7.4
3.1	July 2019	4.4 Added section for alarm timers screen 4.6 Updated list of instruments screens 4.7.1 Updated list of alarm messages 7.3 Updated list of transformer nameplate settings	h/w 04,05 s/w v8.1-8.2
3.2	November 2019	3.8 Added section for additional resistor chain resistors	h/w 04,05 s/w v8.1-8.3.1
3.3	November 2020	3.7 Added wiring details for inter-relay connection Updated “Figure 1-7 Inter-relay connections” to reflect correct high and low terminals 7.2 Updated screenshot in General Installation Checks - “Figure 1-16 Relay Software version”	h/w 04,05 s/w v8.1-8.5
4.0	February 2021	4.4 Thermal Management Screen 7.7 Thermal Management correction test	h/w 05 s/w v9.1
4.1	June 2021	3.8.1 Tap customisation	h/w 05 s/w v9.2
4.2	November 2021	1.4 General Operating Conditions – updated temperature range 5.4 Updating Software	h/w 05 s/w v9.3

		5.6 Settings File Info 13 Locations	
4.3	May 2022	Terms and conditions 4.1 In Main Data Screen removed the used of IED name 13 Locations	h/w 05 s/w v9.4
4.4	Mar 2023	Updating the SW version table to latest V10.0.2	h/w 05 s/w v10.0.2

Hardware Version

Version	Release Date	Description of Main Changes
00	April 2016	First release
01	September 2016	Module type P Tap position input connections changed Module type S Orientation of Ethernet ports changed Serial communication terminating resistor moved
02	January 2017	Module type D Frequency measurement response time reduced
03	May 2017	Module type G Ability to reject AC signals added (selectable in software)
04	June 2017	Case height marginally reduced to meet 4u cutout standard SFP removal warning added
05	June 2018	Real time clock lithium backup battery replaced with capacitor Module type A Voltage range of tapchanger interface extended

Note. The hardware version of the relay may be determined from the label in the bottom left-hand corner of the front panel. The relay type is printed in the form 'FP1034-XXXXXXXXXX-**HH**', and the digits in the position 'HH' represent the hardware version.

Software Version

Version	Release Date	Description of Main Changes
v4.0	April 2016	First release
v5.0	December 2016	New features added: ▲ General voltage offset group B ▲ Load response ▲ Frequency response ▲ Tap stagger ▲ Frequency tripping
v6.0	March 2017	Some features (load response, frequency response, frequency tripping) moved to correct feature level (Ultimate)
v6.1	May 2017	New features added: ▲ 3-phase and 2-wattmeter power measurements ▲ Tap change impact calculations

Version	Release Date	Description of Main Changes
v6.6	September 2017	New features added: <ul style="list-style-type: none"> ▲ Input/output timers ▲ CT Trim added Adjustments to behaviour of some features in non-availability or activation fail conditions (load response, frequency response, tap stagger, frequency tripping)
v6.7	October 2017	Fixes to the following issues: <ul style="list-style-type: none"> ▲ handling of transfer taps in step-by-step mode ▲ handling of Auto command from SCADA ▲ possibility of relay reboot when current is zero.
V6.8	November 2017	New features added: <ul style="list-style-type: none"> ▲ Configurable deadbands for reporting of analogues over SCADA communications Fixes to the following issues: <ul style="list-style-type: none"> ▲ Internal driver error which causes loss of event and command handling
v7.3	February 2018	New features added: <ul style="list-style-type: none"> ▲ Addition of master-follower functionality ▲ Ability to upgrade SCADA communications software via Ethernet
v7.4	April 2018	Fixes to the following issues: <ul style="list-style-type: none"> ▲ A driver error which can cause lock up of the SD card which records measurement and event data, and also prevent comms event reporting
v 7.5	June 2018	New features added: <ul style="list-style-type: none"> ▲ “Automatic” option for inter-tap time delay setting ▲ Adjustable bandwidth hysteresis Fixes for the following issues: <ul style="list-style-type: none"> ▲ Possible incorrect tap position displayed during tap changer lockout
v 7.7	October 2018	New features added: <ul style="list-style-type: none"> ▲ Alarms information screen
v8.1	April 2019	New features added: <ul style="list-style-type: none"> ▲ Automatic busbar topology detection ▲ Measurement and control of voltages on either side of the transformer ▲ Pseudo-VT ▲ Real time clock monitoring ▲ Block SCADA control input ▲ Reset lockout by SCADA command
v8.2	July 2019	New features added: <ul style="list-style-type: none"> ▲ Support for IEC 60870-5-103 SCADA communications
v8.3.1	September 2019	New features added: <ul style="list-style-type: none"> ▲ Nominal transformer voltage settings default to be the same as nominal system voltages ▲ Inter tap time delay and tap pulse time settings now default to ‘automatic’ Fixes for the following issues: <ul style="list-style-type: none"> ▲ Feeder measurements are assigned to the wrong bus section when busbar grouping is controlled by CB statuses or is automatic
v9.1	February 2021	New features added: <ul style="list-style-type: none"> ▲ Transformer thermal monitoring and display ▲ Transformer thermal management

Version	Release Date	Description of Main Changes
V9.2	June 2021	New features added: ▲ Tap customisation
V9.3	November 2021	New feature added: ▲ Network circulating current factor setting can be set to “disabled”. Fixes for the following issues: ▲ Issue accessing settings over USB on v9.2 Basic relays.
V9.4	May 2022	Updates to IEC 61850 implementation
V10.0.2	January 2023	New Features added: ▲ Extended voltage range ▲ Compatibility for additional module type D

Note. The software version of the relay may be determined from within the menu structure in ‘Instruments/Diagnostics/Relay Information’ (see section 4.7 for further guidance). The software version is the displayed on the first line of the display.

Terms and Conditions

The warranties given at the time of supply shall not apply to the extent that the warranty claim arises from any element of the SuperTAPP SG:

- a) being used outside its normal environmental or operational parameters as set out in this documentation; or
- b) being subject to accidental damage; or
- c) being modified other than by Fundamentals or under Fundamentals’ explicit written instructions; or
- d) being integrated with third party software or hardware without Fundamentals’ prior written consent.

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Conventions and Definitions

Text Conventions

Important information in the text may be in the form of either Warnings or Notes:



A Warning contains information about situations that could result in personal injury to yourself or other persons, or risk damaging the relay or associated equipment.

NOTE: A note gives significant additional information about the use of the product.

Glossary

Primary	(VT, CT related) refers to the winding of a VT or CT which receives the voltage or current to be measured
Pseudo-VT	Feature which calculates the voltage and current on the opposite side of the transformer from that on which it is measured.
Secondary	(VT, CT related) refers to the winding of a VT or CT which produces the transformed voltage or current

Abbreviations

AVC	Automatic Voltage Control
AT	Ampere-turns
CT	Current Transformer
DSS	Directional Sequence Switch – signals whenever a raise or lower operation occurs at the tap changer
ESD	Electrostatic Discharge
HV	High Voltage (see Voltage Conventions)
LSS	Local Selector Switch – controls whether the tap changer is operated locally (at the mechanism itself) by an operator, or remotely by the AVC system
RFI	Radiofrequency Interference
SFP	Small Form-factor Pluggable – refers to a communication transceiver standard for pluggable Ethernet communications modules
VT	Voltage Transformer

1 Safety Information

1.1 Overview

This section contains details of the safety precautions for the SuperTAPP SG voltage control relay. These precautions must be followed by anyone who installs, commissions, operates or maintains the relay.

Before performing any of the operations described in this manual, read and understand all of the safety instructions and procedures. Before proceeding contact Fundamentals if anything is unclear.

1.2 General Precautions

- ▲ Read the relevant sections of this manual before installing, commissioning, operating or maintaining the SuperTAPP SG relay.
- ▲ Disconnect all electrical power to the relay before making any adjustments to the connections on the rear panel.
- ▲ Before removing the SuperTAPP SG from the panel, ensure that all electrical power has been disconnected.





1.3 Warning Markings

The warning markings on the SuperTAPP SG relay are shown in Figure 1-1 and described in Table 1-1.

Figure 1-1 Location of warning markings



Table 1-1 Warning symbols on SuperTAPP SG relay

Symbol	Location	Precautions
	Side cheeks on front panel (not h/w ver. 03)	Do not remove the relay from its case unless any SFP modules have been removed first.
	Rear panel	Do not disconnect when the relay is in service as this will affect the automatic voltage control system. Refer to section 3.6 for connection details.
	Rear panel	Electrical hazard – only qualified personnel should work on these connections.
	Rear panel	Earthing terminal – do not disconnect while the relay is switched on.

1.4 General Operating Conditions

The SuperTAPP SG relay has been designed and tested in accordance with the safety requirements of BS EN 60255:27 (Product Safety Requirements for Measuring Relays and Protection Equipment).

Only store and use the SuperTAPP SG under the environmental conditions described below.

▲ Storage temperature range:

Dry conditions -20–70 °C (-4–158 °F)

▲ Operating temperature range:

Dry conditions 0–55 °C (32–131 °F)

Damp conditions maximum 55 °C (131 °F) at 95% relative humidity

1.5 Electrical Safety

1.5.1 Power supply

The SuperTAPP SG relay supports two types of power supply:

- Type A power supply requires an input voltage in the nominal range of 110 V DC or 110–250 V AC, at a frequency of 50–60 Hz.
- Type B power supply requires an input voltage in the nominal range of 24–48 V DC.

1.5.2 Installation information

The SuperTAPP SG is a Class I insulated appliance which must be connected to earth. Refer to section 3.5.

When mounted in the panel in the normal position of use, the appliance has a protection rating of IP54.

The appliance is suitable for use in an environment of pollution degree 2. Normally, only non-conductive pollution occurs; occasionally, however, a temporary conductivity caused by condensation must be expected.

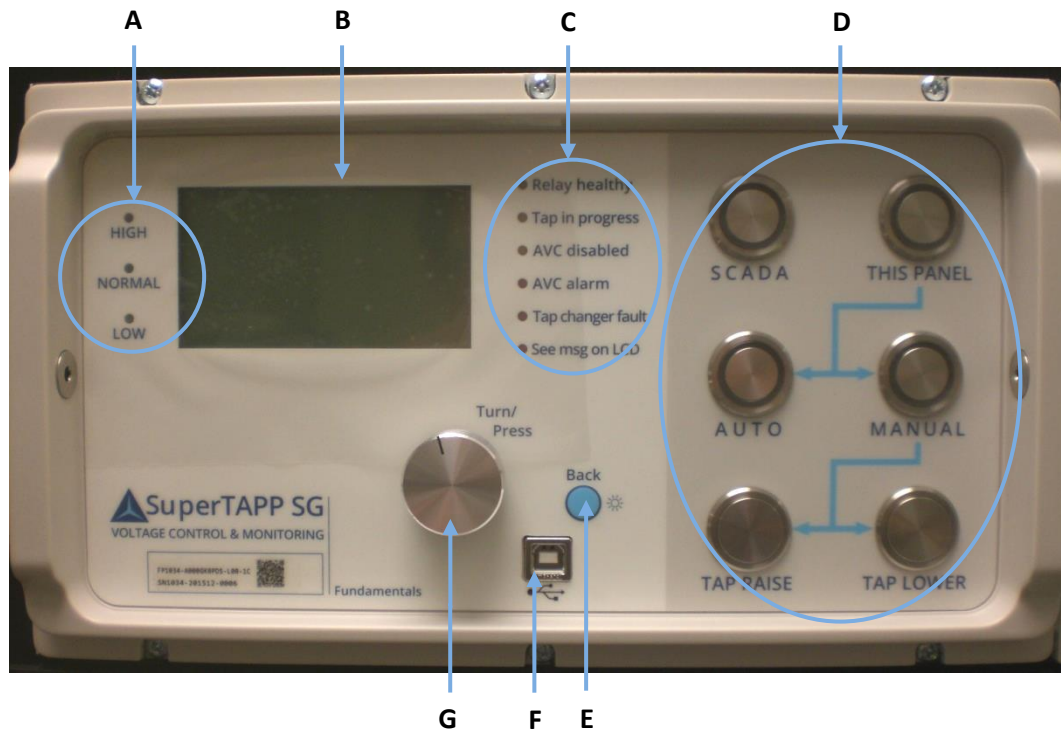
1.5.3 Further information

Refer to section 18 (Specifications) in Part 2 (Technical Reference) for further details of the relay's safety testing and performance.

2 Front Panel Description

The SuperTAPP SG has been designed with the user in mind, and features a simple front display and clear status indications. Control modes are selected using a simple set of buttons, and a single rotary control allows navigation through the menu system and application of settings. The relay front panel is shown in Figure 1-2.

Figure 1-2 Relay front panel



- A. Voltage status indication LEDs
- B. LCD for display of measurement and status information
- C. Relay status indication LEDs
- D. Control panel for relay mode and tap changer operation
- E. Back button
- F. USB port for upload or retrieval of data
- G. Rotary control for menu system navigation and settings changes

2.1 Display Screen

A 40 × 13 character LCD with backlighting allows a variety of information to be displayed, as well as interaction with the various software menus. The backlighting is activated by a push of the control knob and deactivated after 5 minutes of inactivity.

2.2 Control Panel

The SuperTAPP SG front panel contains a set of buttons that allow selection of the control mode and, in certain circumstances as indicated by the blue arrows on the front panel, direct operation of the tap changer. The various modes are explained in more detail in sections 7.7 and 7.9.

2.3 Indication LEDs

2.3.1 Voltage Status LEDs

These LEDs indicate whether the measured voltage is within the range defined in the relay settings (Normal, green), below the lower limit (Low, yellow) or above the upper limit (High, yellow). During normal operation, the voltage value in relation to the upper and lower limits is shown on a scale at the bottom of the display screen (section 4.1). In cases where the voltage falls more than 2% above or below the limits, the status will change to Very High or Very Low, and the appropriate yellow LED will flash.

2.3.2 Relay Status LEDs

A series of LEDs indicate the operating status of the SuperTAPP SG relay and the AVC system, as follows:

- ▲ Relay healthy (green) – lit during normal operation.
- ▲ Tap in progress (amber) – lit while the tap changer motor is running.
- ▲ AVC disabled (amber) – indicates that control is at the tap changer, not the relay.
- ▲ AVC alarm (red) – indicates an abnormal voltage that the AVC system cannot correct.
- ▲ Tap changer fault (red) – indicates a problem with the tap changer.
- ▲ See msg on LCD (red) – indicates an alarm condition; refer to the display screen for details.

2.4 Rotary Control

The rotary control on the relay front panel allows navigation through the software menus, selection of settings, and viewing of the data screens. This is explained in detail in the appropriate sections of this manual, but the following general operations are available:

- ▲ Press control once – activates the display screen backlight after a period of inactivity.
- ▲ Press control once when screen backlit – displays the main menu.
- ▲ Rotate right – scrolls down the menu options (indicated by highlighting).
- ▲ Rotate left – scrolls up the menu options (scrolling down continually does not result in the cursor returning to the top of the menu).
- ▲ Press control once – selects a highlighted option.
- ▲ Press and hold control – moves sequentially back up the levels of the menu structure to the top screen.

To move up one level in the menu structure, press the **Back** button.

3 SuperTAPP SG Installation

3.1 Unpacking and Storage

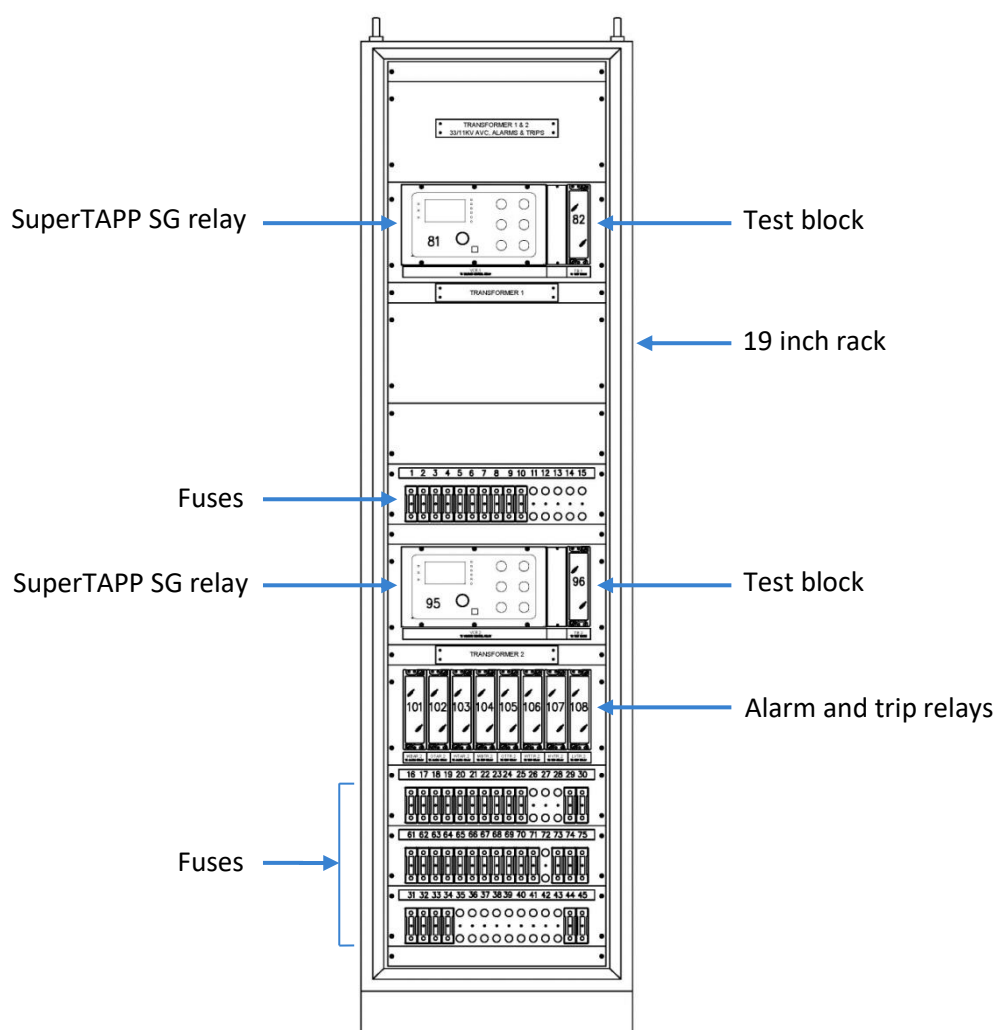
On receipt, unpack the relay and inspect for any obvious damage. It is not normally necessary to remove the relay from its wrapping unless some damage is suspected or if it is required for immediate use. If damage has been sustained, a claim should immediately be made against the carrier. The damage should also be reported to Fundamentals.

When not immediately required, return the relay to its carton and store in a clean, dry place which meets the requirements for storage (section 1.4).

3.2 Recommended Mounting

The SuperTAPP SG relay is normally mounted in a 19" panel. The mounting of two systems in a cubicle allows an economic use of space for a two-transformer application as shown in Figure 1-3.

Figure 1-3 Dual-relay panel



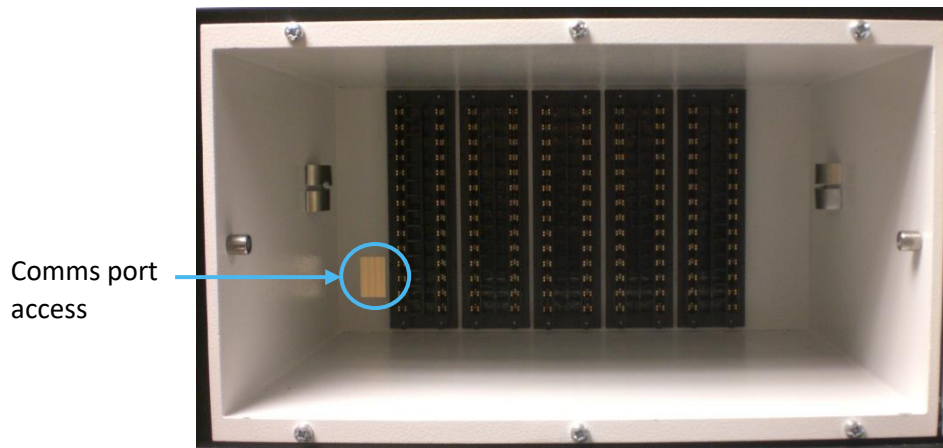


WARNING

Equipment should be isolated from auxiliary supplies prior to commencing any work on an installation.

The SuperTAPP SG relay is located inside a case that is secured into the panel, and to which the required electrical connections are made. Ensure that the case is fitted with the communications port access hole on the bottom left when viewed from the front (Figure 1-4), and secure the case in place with six M4 screws. Refer to section 18 (Specifications) in Part 2 (Technical Reference) for details of case size, fixing dimensions and connections.

Figure 1-4 Relay case fitted into panel



3.3 Wiring Connections

All connections are made using the supplied M4 x 8mm pan head screws. Each connector point allows a maximum crimp terminal width of 7.5 mm. Maintain a space of 50 mm behind the panel to accommodate the bend radius for connecting wires.

For details of the connections needed to control the tap changer, refer to the supplied drawings for your system and section 3.6.

3.4 Installing the Relay

To install the relay into the case:

1. Slide the relay carefully into the case until it reaches a hard stop.
2. Insert two 4 mm hexagonal keys into the bolts on either side of the front panel as shown in Figure 1-5, and firmly push both upwards simultaneously until a loud click is heard from each side.

The relay will slide the remaining distance into the case and be locked in position.

3. Remove the hexagonal keys.

Figure 1-5 Installing the relay



3.5 Earthing

Connect the earth terminal on the PSU card to the case earthing stud. Refer to the drawings supplied with your relay and Figure 1-6.

Figure 1-6 Location of earth terminal



3.6 Integration with Tap Changer

The SuperTAPP SG relay always contains, as a minimum, the following modules located in the slots at the rear of the relay:

- ▲ Power Supply Unit (PSU) card – slot A, at the extreme left of the rear panel
- ▲ Tap Position Indicator (TPI) card – slot H
- ▲ AC card – slot I, for measuring the voltage and current of the network
- ▲ Communications (Comms) card – slot J, at the extreme right of the rear panel

To integrate the SuperTAPP SG relay with a tap changer, the following connections need to be made to the appropriate terminals on the rear of the case, as shown in the drawings supplied with your relay:

1. Connect the power supply cables for the relay to the PSU card.

It is recommended that the relay is powered from the DC supply or battery in the substation, and not from the 110 VAC supply used by the tap changer. This allows the relay to continue reporting the transformer output in the event of a loss of power to the tap changer.

2. Connect the Control Remote signal from the Local Selector Switch (LSS) on the tap changer to the PSU card.

This allows the tap changer to be controlled from the relay when the LSS is set to Remote. The tap change operation can be initiated either using the control panel of the relay or automatically by software commands. If the LSS is set to Local, then the tap changer can only be controlled from the mechanism itself.

3. Connect the Control Circuit Common terminal on the PSU card to the tap changer power supply.

This provides a current return path for the sensing and control functions.

4. Connect the Raise and Lower outputs from the relay PSU card to the tap changer contactors.

These send signals to the tap changer mechanism to raise or lower the tap position (when the LSS is set to Remote).

5. Connect the Tap Change in Progress signal from the tap changer to the PSU card.

This signal is usually provided by the Directional Sequence Switch (DSS) at the tap changer. The relay will use this signal to prevent a further tap change being initiated while one is in progress, together with controlling other tap changer monitoring functions.

6. Connect the Tap Lockout signals from the PSU card to the LSS and the shunt trip on the tap changer.

This sends a signal to trip the driving motor if the tap changer behaves abnormally during a tap change, or to prevent tap changer runaway.

7. Connect the signals from the tap position indicator to the TPI card.

These are required for the relay to be aware of the number of tap changes that are available. The relay can accept inputs from various types of tap position indicators, including resistor chain, BCD or milliamp sender units. For resistor chain TPI sender units there are normally three connections at the relay: the top, bottom and current tap positions (the last of which is connected to the moving wiper).

8. Connect the voltage and current outputs from the network (the corresponding VTs and CTs) to the AC card.

These connections are the minimum required to perform commissioning of the relay (described in section 7). Some voltage control schemes may require other connections to the PSU card, for example the Local Raise and Lower Command sensing signals which can prevent lockout. If in doubt, contact your Fundamentals representative for further information.

3.7 Inter-relay Communications

If you are controlling a group of transformers working in parallel, connect the inter-relay communication signals to the Comms card in slot J as shown in Figure 1-7. This allows the measurements from each transformer to be shared with the other relays in the group, and permits the determination of summed measurements and calculation of values which are important for AVC functions. The cable used should be twisted-pair with a characteristic impedance of 120Ω and individually-screened pairs with drain wire.

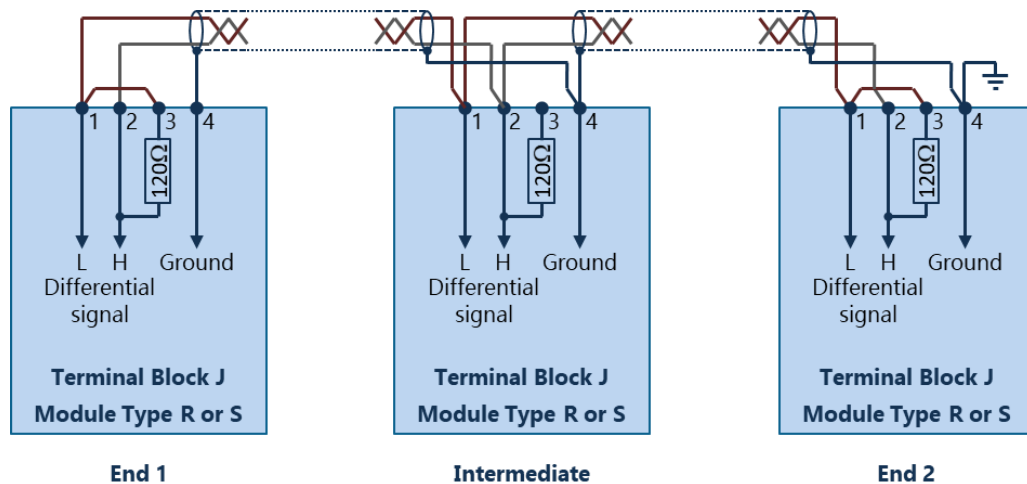
If there are more than two SuperTAPPs they should be daisy-chained together directly on to the SuperTAPP SG terminals (i.e. no stub tee).

NOTE: Keep stub length to a minimum by joining connections at the rear panel of the relay instead of using external terminal blocks. No more than two connections should be made to a terminal block. Ensure that the inter-relay communication link is terminated at the first and last relays using termination links as shown in Figure 1-7.

The relevant terminals on the Comms card are:

- ▲ J1 Low
- ▲ J2 High
- ▲ J3 Termination
- ▲ J4 Ground

Figure 1-7 Connecting inter-relay communication links (for groups of 2 and 3 relays)



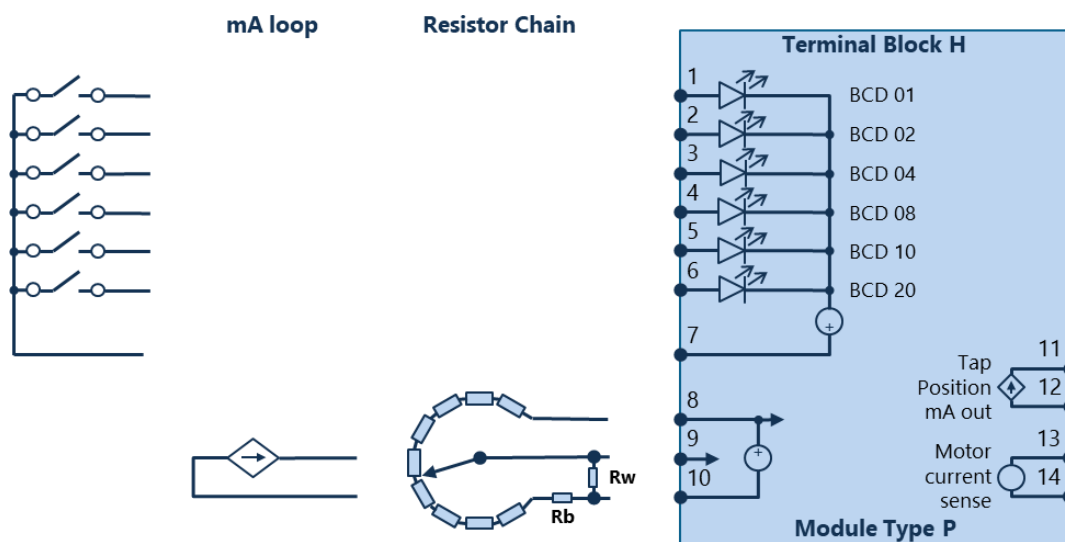
3.8 Tap Position Indicator

For tap position indication and monitoring using resistor chain senders, three connections into the TPI card are required. In hardware versions 00-05 additional external resistors are required as shown in Figure 1-8.

As outlined above the additional external resistors are required in order for the relay to provide monitoring of the resistor chain, allowing the relay to detect error conditions in the connection

between the relay and the resistor chain sender. The most common cause of error condition being poor contact on the resistor chain wiper contact leading to an open circuit wiper.

Figure 1-8 Connecting a resistor chain sender to the TPI card



A 1M Ω ¼ Watt pull-down resistor, labelled **Rw**, is required between terminals 9 & 10 of the TPI card. This should be as close to the TPI card terminals as possible, both physically and electrically.

The resistor labelled **Rb** is required if there is no additional bottom resistor on the resistor chain sender. It should be of the same type and value as the individual resistors on the resistor chain and to be located as physically and electrically close to the resistor chain sender as possible. If **Rb** is installed where no additional top and/or bottom resistors are present a setting is required in **Settings > Tap changer > Extra bottom rstor equiv to** which should be set to **1.00**.

NOTE: Additional external TPI resistor **Rw** is not needed and **Rb** is optional on new hardware 05 relays with a fixed TPI card (v7). They are needed on all other hardware 05 relays. TPI version can be viewed in measurement screen under "Fitted hardware submenu".

3.8.1 Tap customisation

Some tap changers have transfer taps so that a smaller proportion of winding can be used to give a wider range in ratios. These tap changers have discrete positions which give no change in the transformer ratio and are proceeded through in normal tapping operation. TPI senders can report these discrete positions as different TPI values (non-shorter sender) or as the same value (shorter sender) which in the shorter sender is usually signified by positions A, B and C. This produces complications for when additional tap operations are allowed and errors when calculating anything that uses the transformer ratio. Tap customisation gives the ability to resolve these complications.

Table 1-2 Transformer non-shorter sender example

Indicated Position	HV		LV	
	Voltage(V)	Current (A)	Voltage(V)	Current (A)
1	36776	358.9	11000	1200
2	36304	363.6		
3	35832	368.4		
4	35360	373.3		
5	34888	378.4		
6	34416	383.5		
7	33944	388.9		
8	33472	394.4		
9	33000	400		
10	33000	400		
11	33000	400		
12	32528	405.8		
13	32056	411.8		
14	31584	417.9		
15	31112	424.3		
16	30640	430.8		
17	30168	437.5		
18	29696	444.5		
19	29224	451.7		

Table 1-2 Transformer non-shorter sender example shows an example of a non-shorter sender or a sender which indicates different values for the discrete positions. In these circumstances the TPI customisation should be configured so that indicated positions 9, 10 and 11 have the same ratio. The display setting found in “Tap changer” submenu “Tap position indication” will be set to “Indicated TPI tap pos” to signify that we are displaying the same as TPI sender. Example settings for this scenario as seen in Table 1-3

Table 1-3 Transformer with non-shorted sender example settings

Setting Menu >Tapchanger	Setting Name (Parameter)	Value
Tap position indicator submenu		
	Number of tap positions	19
	Minimum tap position	1
	Maximum tap position	19
	Number of consecutive transfer taps	1
	Display	Indicated TPI tap position
TPI customisation submenu		
	Tpi tap 1 : wdg ratio tap	1
	Tpi tap 2 : wdg ratio tap	2
	Tpi tap 3 : wdg ratio tap	3
	Tpi tap 4 : wdg ratio tap	4
	Tpi tap 5 : wdg ratio tap	5
	Tpi tap 6 : wdg ratio tap	6
	Tpi tap 7 : wdg ratio tap	7
	Tpi tap 8 : wdg ratio tap	8
	Tpi tap 9 : wdg ratio tap	9
	Tpi tap 10 : wdg ratio tap	9
	Tpi tap 11 : wdg ratio tap	9
	Tpi tap 12 : wdg ratio tap	10
	Tpi tap 13 : wdg ratio tap	11
	Tpi tap 14 : wdg ratio tap	12
	Tpi tap 15 : wdg ratio tap	13
	Tpi tap 16 : wdg ratio tap	14
	Tpi tap 17 : wdg ratio tap	15
	Tpi tap 18 : wdg ratio tap	16
	Tpi tap 19 : wdg ratio tap	17

Another common form of transition tap indication is when the sender gives the same value for the discrete positions as its rest position (shorted sender). This can be achieved by varying means which are dependent on the transformer manufacturer but generally means additional links have been applied to the sender. This can be seen in the example Table 1-4 and is signified by the A, B and C positions.

Table 1-4 Transformer shorted sender example

Indicated Position	HV		LV	
	Voltage(V)	Current (A)	Voltage(V)	Current (A)
1	36776	358.9	11000	1200
2	36304	363.6		
3	35832	368.4		
4	35360	373.3		
5	34888	378.4		
6	34416	383.5		
7	33944	388.9		
8	33472	394.4		
9 a	33000	400		
9 b	33000	400		
9 c	33000	400		
10	32528	405.8		
11	32056	411.8		
12	31584	417.9		
13	31112	424.3		
14	30640	430.8		
15	30168	437.5		
16	29696	444.5		
17	29224	451.7		

The use of the setting “Xfer pos” in the TPI customisation submenu is needed in this instance. “Xfer pos” means that extra taps are expected entering and leaving the specified position and that the sender value will not change with these additional taps. The numbers of additional taps allowed are defined by the “Number of consecutive transfer taps” located in the tap position indication sub menu. Any spurious taps completed after this number has elapsed will be considered a tap change runaway situation. The “number of consecutive transfer taps” setting is relevant for all forms of TPI input (BCD, Grey code, Resistor, Binary, mA). Example settings for example Table 1-4 can be found below in Table 1-5

Table 1-5 Transformer with shorted sender example settings

Setting Menu >Tapchanger	Setting Name (Parameter)	Value
Tap position indicator submenu		
	Number of tap positions	17
	Minimum tap position	1
	Maximum tap position	17
	Number of consecutive transfer taps	1
	Display	Winding ratio tap pos
TPI customisation submenu		
	Tpi tap 1 : wdg ratio tap	1
	Tpi tap 2 : wdg ratio tap	2
	Tpi tap 3 : wdg ratio tap	3
	Tpi tap 4 : wdg ratio tap	4
	Tpi tap 5 : wdg ratio tap	5
	Tpi tap 6 : wdg ratio tap	6
	Tpi tap 7 : wdg ratio tap	7
	Tpi tap 8 : wdg ratio tap	8
	Tpi tap 9 : wdg ratio tap	9 Xfer pos
	Tpi tap 10 : wdg ratio tap	10
	Tpi tap 11 : wdg ratio tap	11
	Tpi tap 12 : wdg ratio tap	12
	Tpi tap 13 : wdg ratio tap	13
	Tpi tap 14 : wdg ratio tap	14
	Tpi tap 15 : wdg ratio tap	15
	Tpi tap 16 : wdg ratio tap	16
	Tpi tap 17 : wdg ratio tap	17

The relay will detect if the transfer and tap customisation has been entered incorrectly. An error message will be displayed on the relay LCD screen indicating “TPI Settings error”. This should be observed through commissioning or setting changes and does not have any application to comms.

3.9 Additional Installation Requirements

Additional data handling capabilities can be provided by using digital input/output (I/O) cards for digital data, and milliamp (mA) cards for analogue data. These extra cards may be ordered for the SuperTAPP SG relay and should be connected as shown in the drawings supplied. Further information on setting up these data handling functions is provided in section 7.4 and section 7.5.

4 Basic Operation

When the power to the SuperTAPP SG relay is switched on, the relay will display an initialisation screen while it checks functions and tests the front panel LEDs. The main data screen is then displayed. This, together with the LEDs, contains the essential information needed to understand the relay's operation. Further details can be found in the screens showing voltage history (section 4.2) and load vectors (section 4.3), and the Instruments menu (section 4.7).

4.1 Main Data Screen

The main data screen is displayed after the relay is switched on and has initialised. The top line contains the Relay name (configurable in the Relay configuration settings) and associated transformer number. The rest of the screen summarises the essential information about the AVC scheme, including the measured and target voltages, group load and circulating current. These terms are described in more detail in section 15 (Description of Functions) in Part 2 (Technical Reference). The screen also displays the settings group number (explained in section 6.2).

The bottom line displays a scale representing the voltage bandwidth that is permitted before the relay initiates a tap changer operation, with the current voltage shown as a black square. This scale is replaced by status messages that the relay displays during operation. A full list of messages that may be displayed on the main data screen is given in Table 1-6.

Figure 1-9 Main data screen

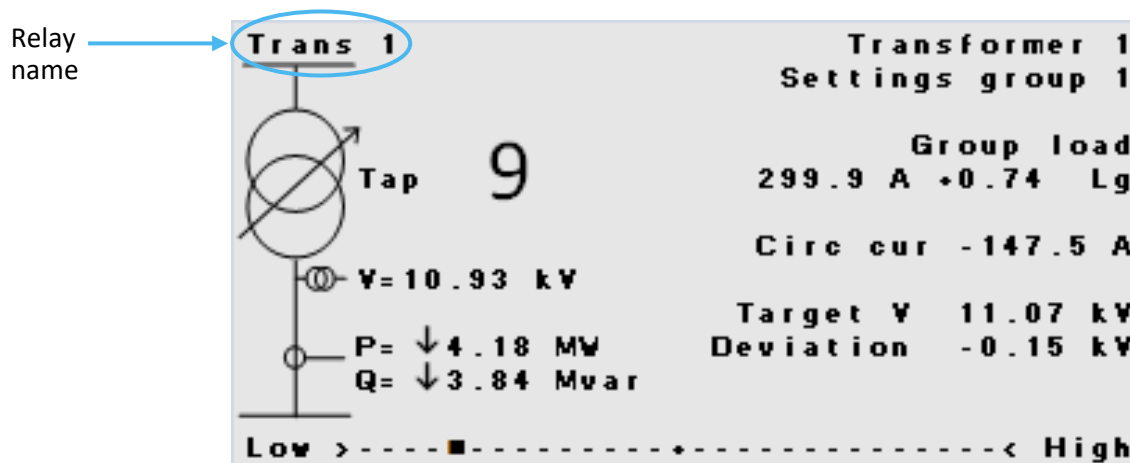


Table 1-6 Status messages (displayed at bottom of screen)

Status Message	Description
High voltage	The measured transformer voltage is outside the set bandwidth and automatic control has been disabled.
Very high voltage	The measured transformer voltage is outside the set bandwidth and automatic control has been disabled.
Zero voltage	The measured transformer voltage is less than 25% of target, therefore automatic control is inhibited.

Status Message	Description
Low voltage	The measured transformer voltage is outside the set bandwidth and automatic control has been disabled.
Under-voltage	The measured transformer voltage is less than 80% of target, therefore automatic control is inhibited.
Very low voltage	The measured transformer voltage is outside the set bandwidth and automatic control has been disabled.
Tapping blocked	The tap changer has reached its limit and further tap changes are not possible.
Time to tap	The relay is timing down to a tap change.
Raising tap	The relay is issuing a 'tap up' command.
Lowering tap	The relay is issuing a 'tap down' command.

4.2 Voltage History Screen

The voltage history screen can be viewed from the main data screen by turning the rotary control one setting to the right.

The screen plots the measured voltage against time for the previous 1 hour. It also shows the upper and lower voltage limits as dotted lines.

4.3 Load Vectors Screen

The load vectors screen can be viewed from the voltage history screen by turning the rotary control one setting to the right.

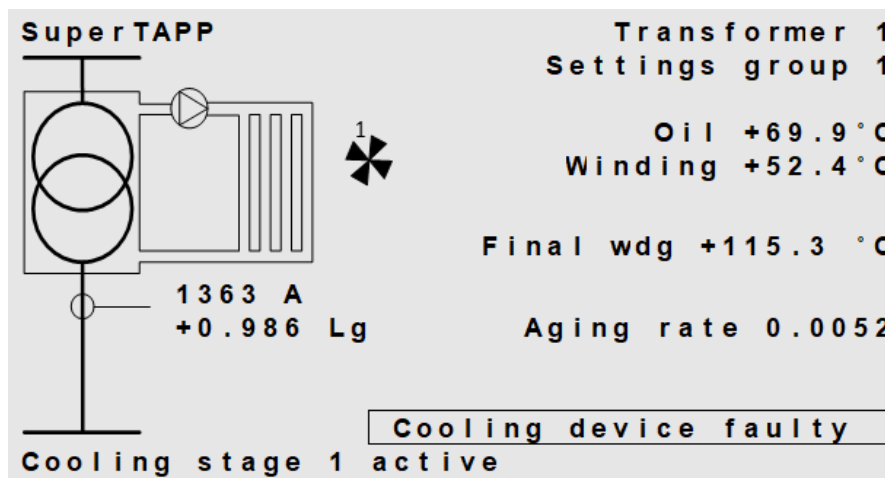
The screen plots the voltage vector (designated as V) and the transformer current vector (designated as I_t). When there is a parallel transformer the group current vector (I_l) is also shown and when there is measured generation the generator current vector (I_g) is shown too.

4.4 Thermal Management Screen

The Thermal Management screen can be viewed from the load vectors screen by turning the rotary control one setting to the right.

In this screen as illustrated in Figure 1-10, the main temperature measurements and status of pumps and fans are displayed alongside with the load current and power factor calculated values. The animated pumps and fans symbols display the status of the outputs and the number next to each symbol indicates how many output signals are energized.

Figure 1-10 Thermal management screen



There are also estimated values displayed on this screen such as Final wdg (Final winding temperature). This is the temperature of the transformer winding after the set time, with the current cooling conditions, and the Aging rate of the transformer based on the existing conditions. Refer to Table 1-7 for description of items.

In the right bottom corner of the screen, there is a message in a box that describes the alarm condition.

Table 1-7 Main thermal management screen items

Item	Description
Oil	Measured oil temperature
Winding	Measured winding temperature
Final winding temperature	Temperature of the transformer winding after the set time if with the current cooling conditions
Aging rate	The aging rate of the transformer with the current temperatures

4.5 Alarm Timers Screen

The alarm timers screen can be viewed from the load vectors screen by turning the rotary control one setting to the right.

The screen shows the timers for the messages and alarms which are active on the main data screen. Conditions for which the alarm timer has expired are highlighted with reversed colours.

Turning the rotary control one setting to the right returns the display to the main data screen.

4.6 Description of a Tap Change Operation

1. When the measured transformer voltage is within the set voltage bandwidth, a scale is displayed along the bottom of the main data screen, with a black rectangle denoting the position of the voltage measurement within the bandwidth range.

2. If the voltage goes above or below this range, the appropriate voltage control LED will be lit. The relay now initiates a tap change operation. A countdown begins, shown in place of the voltage scale alongside the message **Time to tap**. For normal voltage deviations, this is typically 60 seconds, to allow time for the system to recover itself and prevent unnecessary tap changes. However, if the voltage discrepancy is more than $\pm 2\%$ of the target voltage, the LED will flash and the countdown will be much shorter (5 seconds).
3. Once the countdown is completed, the tap operation begins as shown by another countdown and the lighting of the 'tap in progress' LED. The tap number on the screen changes.
4. If this tap change results in the voltage returning to the set bandwidth, then the scale is displayed again. If not, then the relay initiates a further tap change operation, but with a shorter countdown on this occasion.
5. This process continues until either the measured voltage returns to the set bandwidth, or until the tap number limit of the transformer is reached, at which point an alarm is raised.

4.7 Instruments Menu

The Instruments menu contains the data currently being measured and calculated by the relay. This may be useful in assessing the current performance of the relay, as well as in diagnosing problems (section 8).

To view the Instruments menu:

1. Press the rotary control to display the main menu.
2. Rotate the control to select **Instruments**.
3. Press the control to display the top screen of the menu.

The Instruments menu comprises a series of read-only screens that list various measured and calculated values. The screens are grouped within the following sub-menus:

- ▲ Measurements
- ▲ Calculations
- ▲ Monitoring
- ▲ Diagnostics

4. Select the sub-menu you require by rotating and pressing the rotary control.
5. Rotate the control to scroll through the screens in the sub-menu.

The exact number and content of the screens in each of these sections will depend on the voltage control scheme being used. Refer to Table 1-8 for general descriptions of the information available.

Table 1-8 Instruments menu

Sub-menu	Name	Description
Measurements	AC card secondaries	Voltage and current values on secondary windings as measured by the AC card.

Sub-menu	Name	Description
	AC card primaries	Voltage and current values on primary windings as measured by the AC card.
	VT X	Secondary voltages and angles for each VT.
		Primary voltages and angles for each VT.
		Percentages of nominal voltage for each VT.
	Winding X	Primary loads for each winding.
	Fitted hardware	List of installed cards and their locations in slots A-J of the relay.
	PSU card	Lists inputs and outputs on PSU card, with shaded boxes for active signals.
	Digital I/O card X	Lists inputs and outputs on each I/O card and required terminal connections. Shaded boxes indicate when I/O is energised.
	Milliamp card X	Lists values of measured inputs and outputs (only shown when card installed).
	TPI card	Displays current tap position and other data from tap changer.
Calculations	Transformer winding X	Load, site circulating current, tap stagger current, impedance (based on the rating), busbar group, CB status, predicted CB trip voltage step.
	Winding X voltage biases	Biases for LDC, generator, site and network circulating current, tap stagger, with effective target voltage and deviation from measured voltage.
	Busbar X	Data for transformers operated as a group: voltage, group load, generator load, summed transformer load, network circulating current, summed transformer and generator ratings and the parallel impedance of the transformers, based on the sum of the transformer ratings.
	Thermal management	Information related to measured, calculated, forecasted and final temperatures, the transformer life loss, Load current and the state of thermal alarms.
Monitoring	Tap changer monitoring	Tap changer status, direction of tapping, tap position, number of taps completed and operation timer.
	Voltage monitoring	Reasons for blocking tapping.
Diagnostics	Commissioning data	Real and reactive power, power factor, circulating currents, tap changer position and status.
	Tap timing	Initial tap delay timer, inter-tap timer, tap pulse timer, operation timer.
	Busbar group X (advanced relays only)	Other data for each busbar group: load not measured by feeder CTs, estimate load and generation on generator feeders, circulating current on interconnectors and K_P and K_Q .
	Busbar groups	The bus group for each bus section,

Sub-menu	Name	Description
	AC measurements quality	Crest factors, form factors, frequency and period of AC measurements.
	Calibration	This shows calibration data for the AC measurement cards.
	Restarts	Information on most recent relay restart and build date of installed firmware.
	Clock	Current date and time, date and time of last switch off, current temperature.
	Data logging	Information about the internal data storage medium.
	Inter-relay CAN	Status of communication between up to eight interconnected relays (relays seen, off and missing, messages missing and bad data).
	TPI card	Measurement data from tap position indicator card.
	Voltage control functions status	Relay function level information.
	Tap stagger status (ultimate relays only)	Tap stagger information.
	Frequency trip status (ultimate relays only)	Frequency tripping information.
	Predicted temps per cooling stage	Active cooling stage, Forecast oil temperature, Final oil temperature, Forecast winding temperature, Final winding temperature.

4.8 Failure States

4.8.1 Alarms

The relay is self-monitoring and can detect various failure states which may render it non-functional and requiring attention. These states are displayed at the bottom of the main data screen in a text box. Corresponding alarm outputs are available if the relay is equipped with an I/O card and these are discussed in section 7.4.

The response of the relay to a failure state depends on whether the faulty hardware is critical for voltage control functions. Critical hardware failures will result in the loss of automatic voltage control.

Non-critical hardware failures will not result in the loss of automatic voltage control, but operation may be impaired.

The relay's voltage and tapchanger monitoring function can also produce alarm messages when the controlled system is in an abnormal state. All alarms for which the alarm timer has expired will illuminate the 'AVC alarm' LED, 'Tap changer fault LED' or 'See msg on LCD' LED. Other status messages are also displayed which will not cause an LED to be illuminated. When more than one message is applicable, the one with the highest priority is displayed. Other messages may be viewed on the Alarm Timers Screen. The lowest number is the highest priority.

A full list of messages that may be displayed on the main data screen is given in Table 1-9.

Table 1-9 Display messages

Message	Description	Problem with	Priority
Uncalibrated AC input	An AC measurement input is uncalibrated	SuperTAPP SG	1
AC measurement error	The relay is unable to properly measure the applied AC signals	SuperTAPP SG	2
CAN error	Communication failure between relays using inter-relay communications	SuperTAPP SG / Installation	8
Comms card failure	There is a problem with the SCADA communications card	SuperTAPP SG	26
CAN data missing	Communication failure between relays using inter-relay communications	SuperTAPP SG / Installation	28
Data logging error	There is a problem writing analogue and event data to the internal storage	SuperTAPP SG	36
Battery is dead	The internal battery for the real time clock needs replacing	SuperTAPP SG	38
VT fuse failure	When a 3-phase VT is used excessive difference between phase measurements are present	Installation	3
Overloaded AC input	An AC measurement input has a signal which is above its design limit	Installation	9
No phase reference	No voltage is available to provide a phase reference.	Installation	17
Auto busbar group warning	The automatic busbar grouping function has failed to determine whether another transformer is in parallel	Installation	18
Time not set	The real time clock has not been set so the relay is running with the default date and time	Installation	35
Alarm time disabled	The 'Alarm time' setting has been set to 'Disabled'	Installation	39
Tap changer runaway	Signals from the tap changer indicate the tapchanger executes multiple tapping actions for a single command	Tapchanger	5
Tap change incomplete	Signals from the tap changer indicate the tapchanger never completed the tapping action	Tapchanger	6
Tap changer motor overload	Tapchanger motor MCB tripped indicating suspected overload to tapchanger motor	Tapchanger	7
Tap position out of step	The tap position is different to that of a parallel transformer in master-follower mode.	Tapchanger	14
Tap position indicator failure	The relay has failed to determine the current tap position	Tapchanger	37
Transformer overloaded	The transformer load is above the tap changer overcurrent limit	Transformer	10
Reverse current limit exceeded	The transformer load is above the tap changer overcurrent limit in the reverse direction (separate limit)	Transformer	11
Invalid CB status signal	Circuit breaker contacts are inconsistent (when multiple contacts used)	Circuit breaker	12

Message	Description	Problem with	Priority
Voltage above limit	The measured voltage is above the voltage high limit	Power system	15
Voltage below limit	The measured voltage is below the voltage low limit	Power system	16
Voltage out of band	The voltage deviation has been outside the bandwidth for the alarm time	Power system	24
Tap not achievable	A lower is requested when on bottom tap, or a raise when on top tap.	Tapchanger / Power system	25
Freq trip CB tripped	The frequency tripping function has tripped the transformer circuit breaker		4
Freq trip volt ctrl inhibited	Tapping is inhibited because the frequency tripping function has tripped the circuit breaker of a parallel transformer		13
Tap block command	Tapping is being blocked because a 'tap block' command has been received		23
Ready for switch out	Prepare for switchout function has completed		29
Preparing for switch out	Prepare for switchout function is active		30
SCADA control blocked	SCADA control is blocked because a 'Block SCADA ctrl' command has been received		34
USB Connected	Event/analogue logging is inhibited while the USB is connected.		33
Cooling equipment faulty	Cooling device activation signal was sent but no feedback received	Transformer	22
Thermal H1 alarm	The measured/calculated temperature is above the H1 alarm trigger limit	Transformer	21
Thermal H2 alarm	The measured/calculated temperature is above the H2 alarm trigger limit	Transformer	20
mA or Pt100 input fault	A m/A inputs outside the range given in the mA settings or Pt100 input has invalid measurement.	Installation	19
mA output overloaded	The burden on a milliamp output is too great or disconnected.	Installation	32
Communications link lost	The SCADA communications link has been lost.	Installation	27
TPI settings error	This indicates that a setting in the Tap changer submenus is incorrect	SuperTAPP SG settings	31

4.8.2 Lockouts

If a lockout has occurred then a **Tap changer lockout** option will be displayed at the top of the main menu.

To clear the lockout:

1. Press the rotary control to display the main menu.
2. Press the control to select **Tap changer lockout**.
Information about the lockout will be displayed.
3. Press the control again to clear the lockout and return the relay to normal operation.

The 'tap changer fault' LED should go out, and the screen displays the status of the tap changer.

4. Press the **Back** button twice to return to the main data screen.

If necessary, manually reset the tap changer shunt motor.

5 PC Interface Software

The SuperTAPP SG software application for PCs supplied by Fundamentals offers a number of features that are particularly useful when commissioning a new relay installation. This section provides a brief overview of the software but is not comprehensive and may not be fully up to date. A separate user manual for the PC software is available.

5.1 Connecting to the Relay

1. Double-click on the Fundamentals icon on your PC desktop to launch the software.
2. Connect the PC to the relay via the USB connection on the front panel (F in Figure 1-2).

When connection is established with the relay, the top right-hand corner will display the message: **Application Mode Connected**

If a connection cannot be established with the relay, then it will display: **Not Connected**

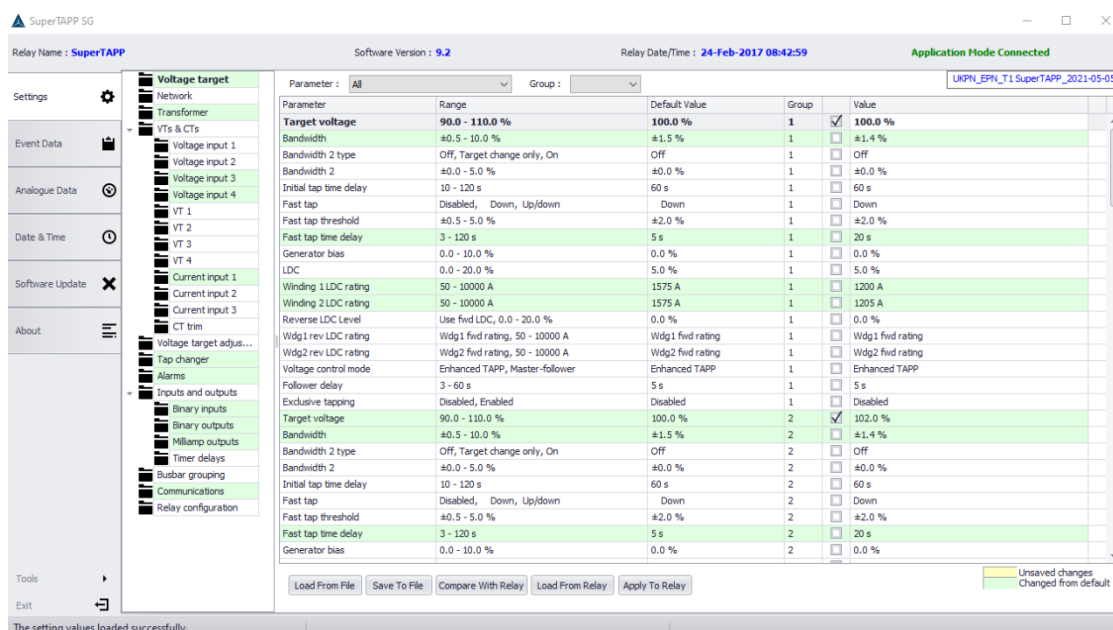
Check that the USB lead is properly connected, and that the relay is switched on and operating normally.

5.2 Reviewing and Updating Settings

To download the current settings on the relay:

1. Establish a connection to the relay (section 5.1).
2. Click **Settings** on the left side of the screen.
3. Click **Download Settings** to display a list of the current settings on the relay.

Figure 1-11 Settings shown in PC Application



The screenshot shows the SuperTAPP SG software interface. On the left is a sidebar with a tree view containing categories like Settings, Event Data, Analogue Data, Date & Time, Software Update, and About. The 'Settings' category is expanded, showing a list of parameters such as Voltage target, Network, Transformer, VTs & CTs, Voltage input 1, Voltage input 2, Voltage input 3, Voltage input 4, YT 1, YT 2, YT 3, YT 4, Current input 1, Current input 2, Current input 3, CT trim, Voltage target adjust..., Tap changer, Alarms, Inputs and outputs, Binary inputs, Binary outputs, Millamp outputs, Timer delays, Busbar grouping, Communications, and Relay configuration. The main window displays a table of settings for 'Relay Name: SuperTAPP'. The table has columns for Parameter, Range, Default Value, Group, and Value. The 'Value' column includes checkboxes and input fields for each parameter. At the bottom of the table are buttons: Load From File, Save To File, Compare With Relay, Load From Relay, and Apply To Relay. A status bar at the bottom indicates 'The setting values loaded successfully.'

Parameter	Range	Default Value	Group	Value
Target voltage	90.0 - 110.0 %	100.0 %	1	<input checked="" type="checkbox"/> 100.0 %
Bandwidth	±0.5 - 10.0 %	±1.5 %	1	<input type="checkbox"/> ±1.4 %
Bandwidth 2 type	Off, Target change only, On	Off	1	<input type="checkbox"/> Off
Bandwidth 2	±0.0 - 5.0 %	±0.0 %	1	<input type="checkbox"/> ±0.0 %
Initial tap time delay	10 - 120 s	60 s	1	<input type="checkbox"/> 60 s
Fast tap	Disabled, Down, Up/down	Down	1	<input type="checkbox"/> Down
Fast tap threshold	±0.5 - 5.0 %	±2.0 %	1	<input type="checkbox"/> ±2.0 %
Fast tap time delay	3 - 120 s	5 s	1	<input type="checkbox"/> 20 s
Generator bias	0.0 - 10.0 %	0.0 %	1	<input type="checkbox"/> 0.0 %
LDC	0.0 - 20.0 %	5.0 %	1	<input type="checkbox"/> 5.0 %
Winding 1 LDC rating	50 - 10000 A	1575 A	1	<input type="checkbox"/> 1200 A
Winding 2 LDC rating	50 - 10000 A	1575 A	1	<input type="checkbox"/> 1205 A
Reverse LDC Level	Use fnd LDC, 0.0 - 20.0 %	0.0 %	1	<input type="checkbox"/> 0.0 %
Wdg1 rev LDC rating	Wdg1 fnd rating, 50 - 10000 A	Wdg1 fnd rating	1	<input type="checkbox"/> Wdg1 fnd rating
Wdg2 rev LDC rating	Wdg2 fnd rating, 50 - 10000 A	Wdg2 fnd rating	1	<input type="checkbox"/> Wdg2 fnd rating
Voltage control mode	Enhanced TAPP, Master-follower	Enhanced TAPP	1	<input type="checkbox"/> Enhanced TAPP
Follower delay	3 - 60 s	5 s	1	<input type="checkbox"/> 5 s
Exclusive tapping	Disabled, Enabled	Disabled	1	<input type="checkbox"/> Disabled
Target voltage	90.0 - 110.0 %	100.0 %	2	<input checked="" type="checkbox"/> 102.0 %
Bandwidth	±0.5 - 10.0 %	±1.5 %	2	<input type="checkbox"/> ±1.4 %
Bandwidth 2 type	Off, Target change only, On	Off	2	<input type="checkbox"/> Off
Bandwidth 2	±0.0 - 5.0 %	±0.0 %	2	<input type="checkbox"/> ±0.0 %
Initial tap time delay	10 - 120 s	60 s	2	<input type="checkbox"/> 60 s
Fast tap	Disabled, Down, Up/down	Down	2	<input type="checkbox"/> Down
Fast tap threshold	±0.5 - 5.0 %	±2.0 %	2	<input type="checkbox"/> ±2.0 %
Fast tap time delay	3 - 120 s	5 s	2	<input type="checkbox"/> 20 s
Generator bias	0.0 - 10.0 %	0.0 %	2	<input type="checkbox"/> 0.0 %

The table of settings has the same structure as the Settings menu on the relay (section 17 (Settings List) in Part 2 (Technical Reference)).

NOTE: You can amend the settings in the PC software by double-clicking in the Value column and selecting a new value or option.

Settings can be configured using the software application when disconnected from a relay and saved for subsequent editing and uploading to a relay.

- ▲ Click **Save Settings** to save a file.
- ▲ Click **Load Settings** to open a previously saved file.
- ▲ Click **Check Differences** to highlight any recently modified settings in an open file.

To update the settings on the relay after configuring the values:

1. Establish a connection to the relay (section 5.1).
2. Click **Upload Settings** to begin updating the settings on the relay.

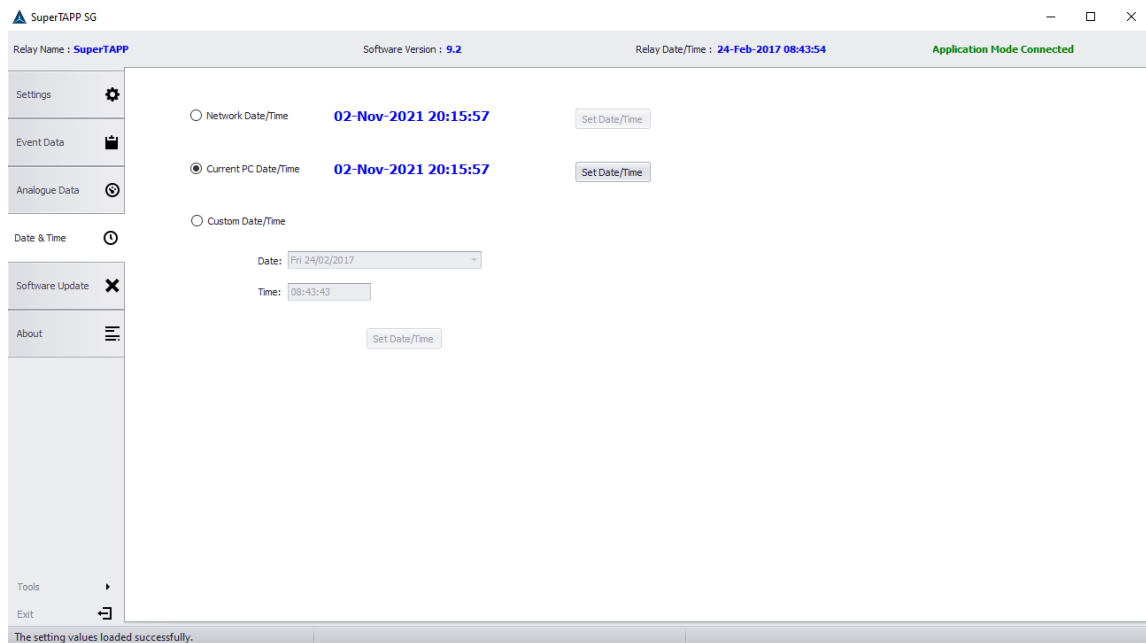
The software will indicate when the uploading is completed.

5.3 Changing the Relay Date and Time

1. Establish a connection to the relay (section 5.1).
2. Click **Date & Time** on the left side of the screen.

The following screen will be displayed:

Figure 1-12 Changing Date and Time through PC Application



3. The current relay date and time is shown in the top bar as **Board Date/Time**.
4. To set a new date and/or time, select the appropriate time to use, either from the network, the PC time or a custom time, then click the **Set Date/Time** button.

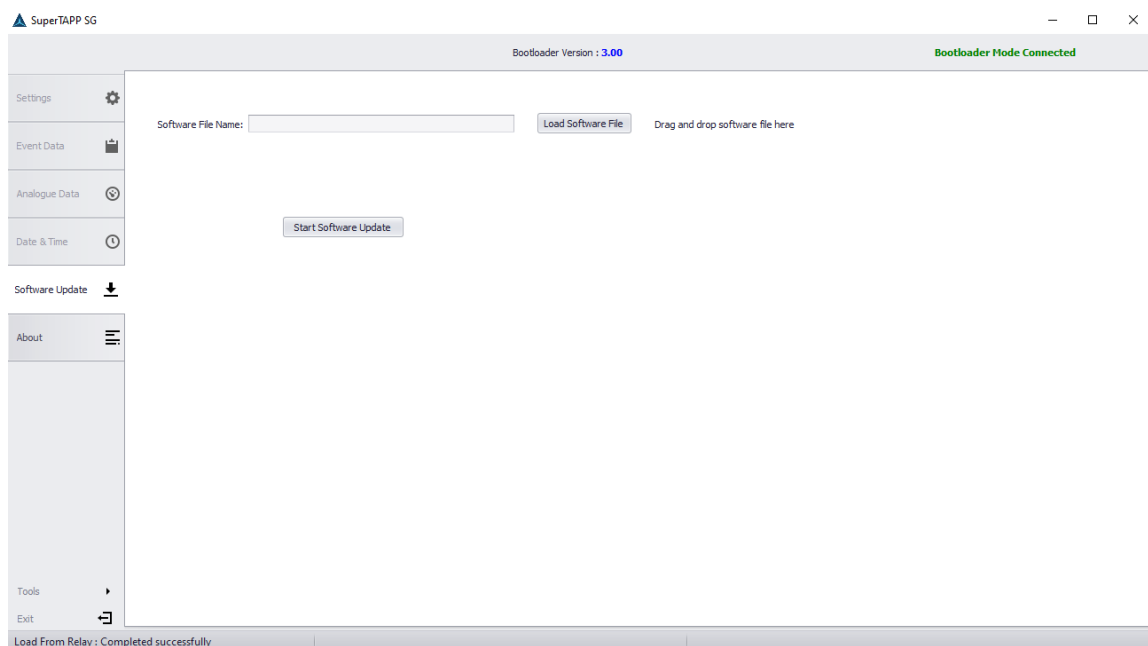
5.4 Updating Software

From time to time, Fundamentals may supply updated software in the form of a .hex file. This can be uploaded to the relay as follows:

1. Establish a connection to the relay (section 5.1).
2. On the relay navigate to the **Relay Configuration** menu and select **Upgrade software, Yes**.
3. Click **Software Update** on the left side of the screen.

The relay will indicate it is in Bootloader Mode and the PC Application in the top right-hand corner will display: **Bootloader Mode Connected**.

Figure 1-13 PC Application in Bootloader Mode



4. Click **Load Software File**, and browse to and select the updated software .hex file supplied by Fundamentals.
5. Click **Send Software to Relay**.

The new software will be uploaded. Once the upload is completed, the relay will automatically return to normal operating mode.

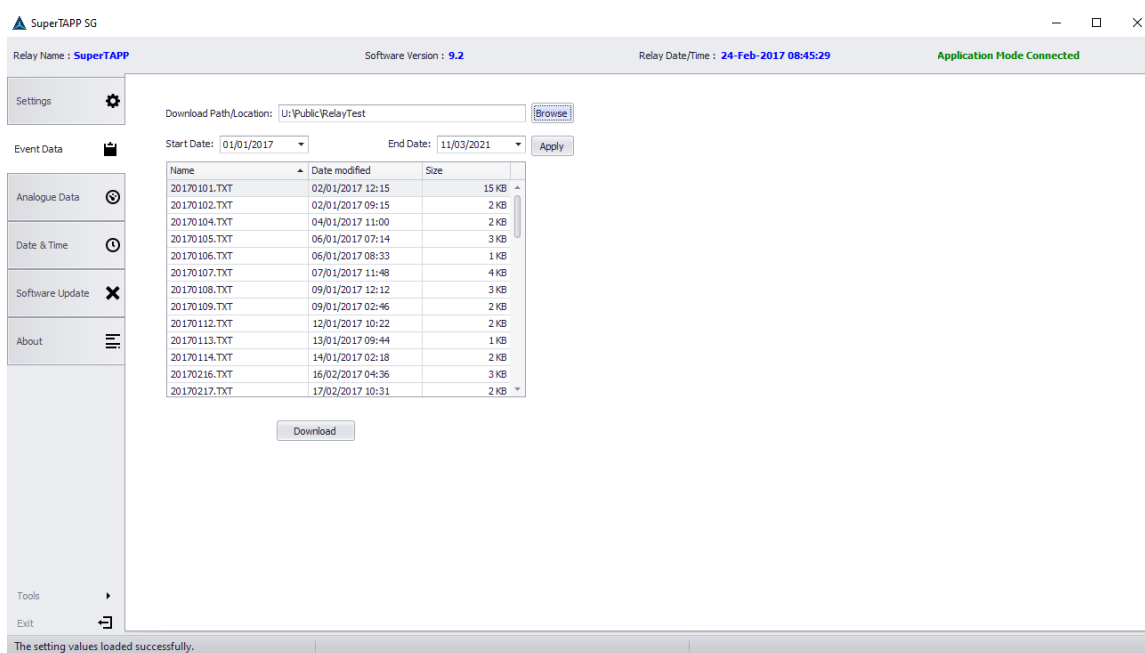
5.5 Reviewing Data

The SuperTAPP SG relay stores event data and analogue input and output data on an SD card located within it, which is not physically accessible during normal use. However, the data on the card can be read and saved using the **Event Data** and **Analogue Data** options in the PC software application.

The event and analogue data are stored in text and .CSV files respectively, one file for each day's data. To download the event data:

1. Click **Event Data** on the left side of the screen.
The following screen will be displayed:

Figure 1-14 PC Application showing Event Data



2. Select a location on your PC for the files to be saved.
3. Highlight the files that you want to download from the list.
To search for files between specific dates, click the **Start Date** and **End Date** drop-down boxes, select the dates from the calendar, and click **Apply**.
4. Click **Save**.
The selected files will be downloaded. The application will indicate when the download is complete.

A very similar procedure using the **Analogue Data** screen can be used to download .CSV files containing analogue input and output data from the relay.

5.6 Settings File Info

The feature to capture Relay information when saving its settings to a file is introduced with PC application version 3.3.0.

The Settings File Info view consists of the following parts, referring to Figure 1-15:

1. Settings File Info tab [dynamic]

The Settings File Info tab will appear automatically when a setting file created with PC Application version 3.3.0 or newer is loaded onto the application using the “Load From File” button in the Settings tab view.

2. Setting file

The setting file’s name and full path location.

3. PC Application version info

This is a note which indicates the version of the PC application used to save the loaded setting file.

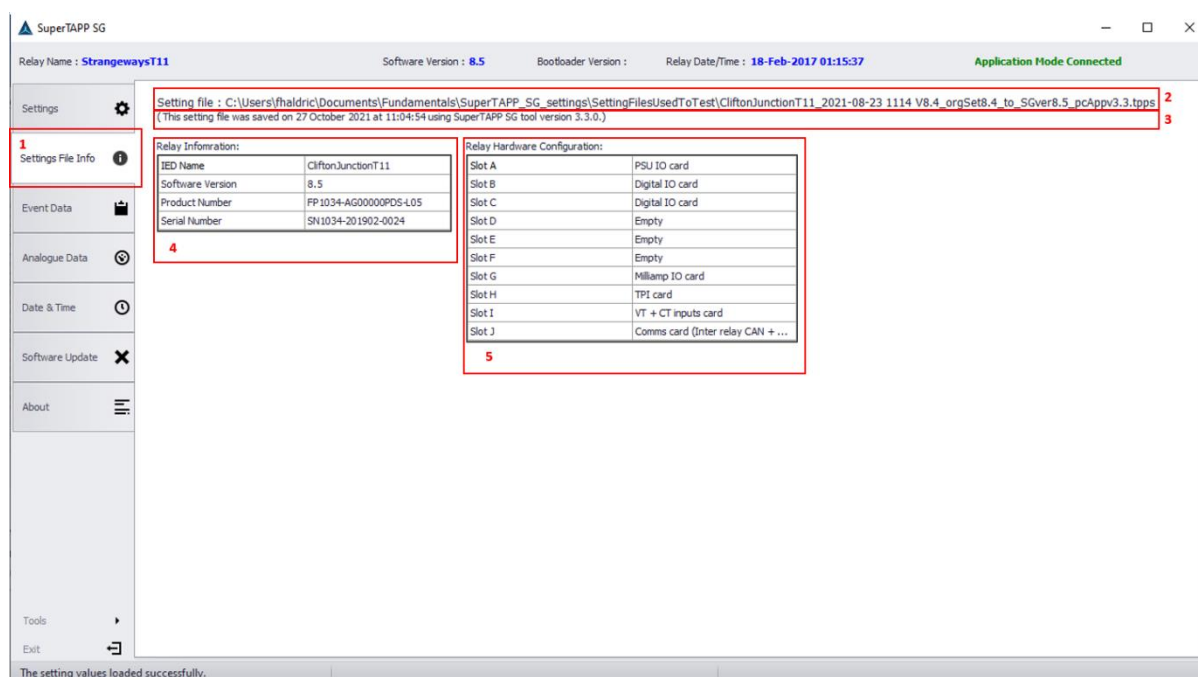
4. Relay Information

This section contains basic information related to the Relay which the settings were saved from. The information captured is the Relay’s name, software version, product and serial numbers.

5. Relay Hardware Configuration

This section shows the cards configured in each of the Relay’s slot at the time the settings were saved.

Figure 1-15 Settings File Info view



5.7 Closing the PC Software

1. Click **Exit** to close the software application.
2. Remove the USB cable from the port in the front panel of the relay.

6 Configuration of Relay Settings

The relay settings must be configured to represent the particular application. Some settings are always used and must be configured in the relay to render it operational.

The Settings menu allows the user to view and amend the relay settings. The full Settings menu is shown in section 17 (Settings List) in Part 2 (Technical Reference) with ranges and default values.

6.1 Editing Settings

Settings can be edited as follows:

1. Press the rotary control until the main menu is displayed.
2. Rotate the control until **Settings** is selected, and press the control to enter the menu.
3. Repeat step 2 to select the sub-menu you want to access.
4. Rotate the control until the required setting is highlighted.
5. Press the control to enter Edit mode.
6. Rotate the control until the desired value or option is seen, and press the control to save the new setting.
7. For text settings, bitfield settings (for input and output configuration) and other multi-field settings each push of the rotary control will move to the next field. If you wish to save the setting without stepping through each field press and hold the control.

NOTE Any of the following conditions will prevent editing of settings.

- Relay is in SCADA
- Relay is in AUTO
- A settings password is applied and user is logged out

If you try to edit a setting while in one of the above conditions a flashing message will be displayed indicating why this is prevented. Address the problem as follows:

Reason editing is prevented	Indication	How to address
Relay is in SCADA	White LED on SCADA pushbutton is illuminated If editing is attempted a flashing message appears "Editing is allowed only in THIS PAN/MANUAL"	Press the THIS PANEL pushbutton (Amber LED on pushbutton should illuminate)
Relay is in Auto	White LED on AUTO pushbutton is illuminated If editing is attempted a flashing message appears "Editing is allowed only in THIS PAN/MANUAL"	Press the MANUAL pushbutton (Amber LED on pushbutton should illuminate)
Password is set and user logged out	If editing is attempted a flashing message appears "Enter password in Relay config menu"	Follow the instructions in 0 below

If the control supply is removed from the relay none of the pushbutton LEDs will be illuminated and, if the relay supply is present, the AVC disabled LED will be illuminated. In this circumstance editing of the settings will not be prevented the SCADA or Auto modes.

6.1.1 Settings Password

If a settings password has been set, navigate to the Settings→Relay configuration menu. The first entry will show *Enter password* and the second entry will show *Reset password* code. Select *Enter password* and enter the correct password as per step 7 above.

When the correct password is entered the first entry will change to display *Edit password* and the second entry will show *Log out*. You will now be able to edit settings in all setting menus and will remain logged in until either you select *Log out* in the Settings→Relay configuration menu, or the display automatically switches off (10 minutes after the last user interaction).

If the password is entered incorrectly the first menu entry will continue to show *Enter password*. If a password is not known Fundamentals are able to provide a special reset code, however we will undertake a number of checks first to ascertain that the request is properly authorised. The code we provide should be entered in the *Reset password code* setting.

Once a password has been set it can be removed by setting it to all spaces (once you have correctly logged in).

6.2 Settings Groups

The SuperTAPP SG relay allows up to eight groups of settings to be saved so that a relay can be rapidly configured for a new application. Certain settings can be customised for a particular group. Screens in the menu that display customisable settings contain an **Edit group** option; all settings on that screen are used in the settings group number displayed. When settings are changed, you are able to choose whether the setting should be classed as 'common' (used in all settings groups) or 'group' (only used in the selected settings group). A hyphen (—) signals a common setting, and an asterisk (*) denotes a group setting. After entering the setting value, choose from these two options in the same way using the rotary control. Refer to Figure 1-15 and Figure 1-16.

Settings on screens without an **Edit group** option will be applied to all groups (in the same way as the 'common' settings described above).

Figure 1-15 Selecting a common or group setting

Voltage target settings		
Edit group		1
Target voltage	110.0	%
Bandwidth	±1.5	%
Initial tap time delay	60	s
Fast tap	Down	
LDC	5.0	%
Winding 1 LDC rating	1600	A
Generator bias	0.0	%
Load ratio	0	%
- => common, * => group		

If you choose a setting to be a group setting, then the asterisk remains displayed on the screen next to the value of the setting (Figure 1-16).

Figure 1-16 Group setting display

Voltage target settings	
Edit group	1
Target voltage	110.0 %
Bandwidth	±1.5 %
Initial tap time delay	60 s *
Fast tap	Down
LDC	5.0 %
Winding 1 LDC rating	1600 A
Generator bias	0.0 %
Load ratio	0 %
* Settings are only for this group	

7 Commissioning

7.1 Introduction

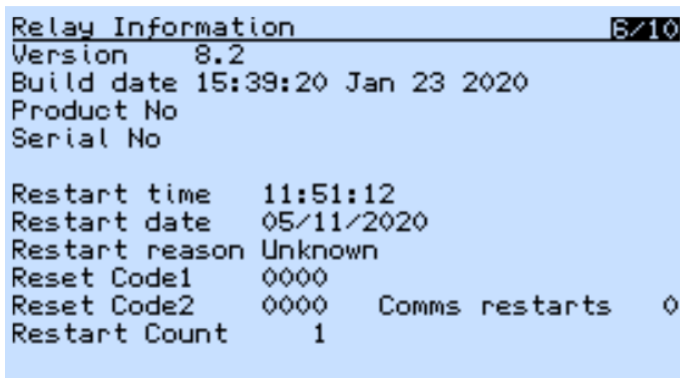
Extensive accuracy, functional, and endurance testing is carried out at the factory prior to despatch. On-site confirmation of the settings ranges and accuracy levels are not necessary. However, in order to confirm correct operation of the overall voltage control scheme, there are a number of tests which should be carried out after installation. These tests have been grouped as follows:

- ▲ General installation
- ▲ Relay settings
- ▲ Relay connections:
 - Voltage and current inputs
 - Outputs
 - Inter-relay communications
- ▲ Tap changer control modes:
 - This Panel
 - SCADA
- ▲ Tap changer operation modes:
 - Manual
 - Auto

7.2 General Installation Checks

1. Ensure that all connections to the rear of the case are tight and in accordance with the relay wiring diagrams.
2. Check that the relay is fully inserted into the case (section 3.4).
3. Note down the site name, transformer ID and relay serial number which are shown on the front panel. The software build version should also be recorded and can be found in the **Relay Information** screen in the Diagnostics sub-menu of the Instruments menu (Figure 1-17).

Figure 1-17 Relay software version



```
Relay Information 16/10
Version      8.2
Build date 15:39:20 Jan 23 2020
Product No
Serial No

Restart time 11:51:12
Restart date 05/11/2020
Restart reason Unknown
Reset Code1 0000
Reset Code2 0000 Comms restarts 0
Restart Count 1
```

7.3 Selecting the Correct Settings Values

Every setting has a default which represents the most commonly used value. Many settings should be programmed according to the parameters of the transformer which the relay is controlling. An example transformer nameplate is shown in Figure 1-18 with key parameters highlighted.

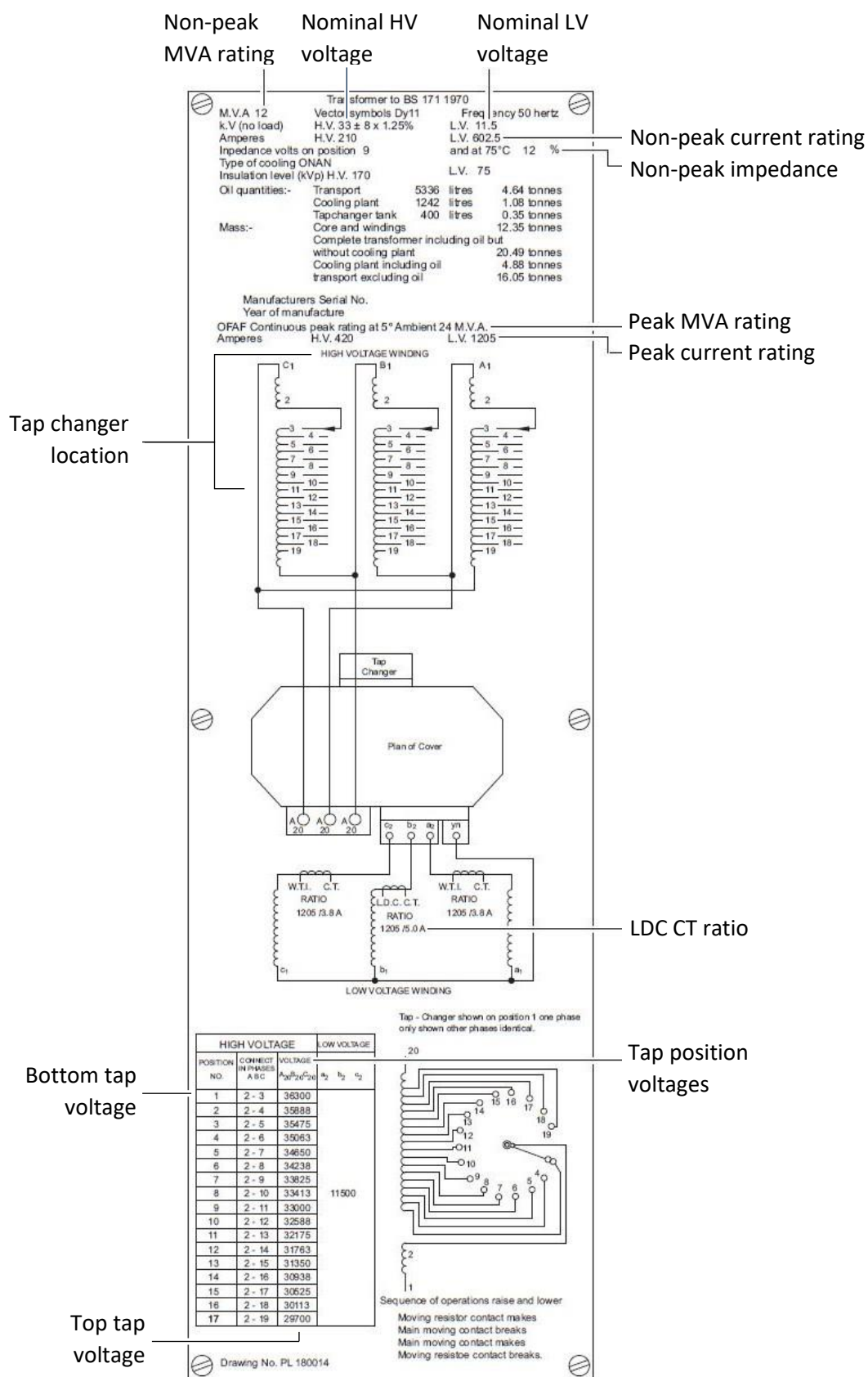
Table 1-10 shows how some of the key parameters shown on the transformer nameplate can be correlated with relay settings in the SuperTAPP SG software.

Table 1-10 Correlation of relay settings with transformer nameplate data

Nameplate Parameter	SuperTAPP SG Setting	Comments
Peak current rating - I_{peak} (Amps)	Winding 1 rating (MVA)	This should be calculated using the nominal voltage from the same side of the transformer. Calculation = $I_{peak} \times \sqrt{3} \times V_{nom}$
Nominal LV voltage - V_{nom} (kV)	Tx nominal LV voltage (kV)	Sometimes the nominal secondary voltage of the transformer does not match the nominal network voltage
Nominal HV voltage - V_{nom} (kV)	Tx nominal HV voltage (kV)	Sometimes the nominal primary voltage of the transformer does not match the nominal network voltage
Peak MVA rating - S_{peak} (MVA)	Winding 1 rating (MVA)	
LDC CT ratio (x:y)	Winding 1 rating (MVA)	Normally the primary rating (x) will represent the transformer LV peak current rating (Amps). Calculation = $x \times \sqrt{3} \times V_{nom}$
LDC CT ratio (x:y)	Current input ratio (number)	The CT ratio is calculated as (x/y).
Non-peak impedance (%)	Winding 1 impedance (%)	The transformer impedance setting in the relay should correspond to the nominal impedance for the transformer peak MVA rating. This is not always listed on the nameplate, but can be calculated from the non-peak value using the ratio of the peak rating to the non-peak rating, which would make a 24% setting for the transformer shown in Figure 1-18.
Tap position voltages (V)	Bandwidth (%)	The tap position voltages shown on the transformer nameplate allow a calculation of the tap step (%) which should in turn define the bandwidth setting (see section 16.3 (Determination of Settings) in Part 2 (Technical Reference)).
Bottom tap voltage (V)	Bottom tap voltage (V)	
Top tap voltage (V)	Top tap voltage (V)	
Tap changer location	Tap changer location	Is the tap changer connected to the high or low voltage windings.

Further information on the configuration of settings for specific AVC schemes can be found in Part 2 of this manual.

Figure 1-18 Transformer nameplate



7.3.1 Downloading Settings via USB

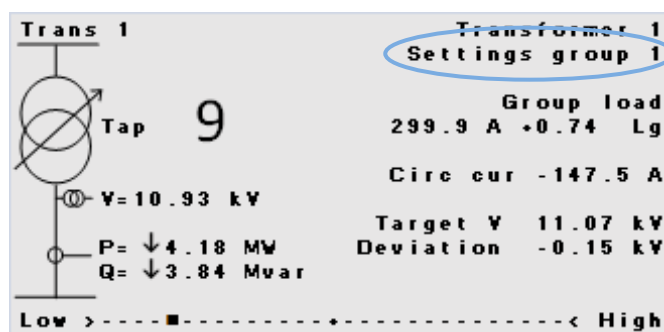
Settings for a relay can either be configured using the control panel (section 6.1), or prepared using the SuperTAPP SG software application for PCs and downloaded to the relay through the USB port on the front panel. This is described in more detail in section 5.2.

7.3.2 Applying Settings

Check that the settings group shown on the main data screen (Figure 1-19) is correct and that it can be changed in the following ways as appropriate:

- ▲ Send an analogue command via SCADA if the relay is set to SCADA mode (section 7.7).
OR
- ▲ Use one of the designated **Alt settings group** digital inputs to apply the settings group values if the relay is equipped with an I/O card (section 7.4).

Figure 1-19 Settings group used to apply alternative settings



7.4 Configuring Digital Inputs and Outputs

The SuperTAPP SG relay may contain one or more digital input/output (I/O) cards, each of which contains a series of input and output terminals. More than one input can be connected to each of these terminals. These connections should be made during the installation stage (refer to section 3.3).

During commissioning, digital inputs and outputs must be configured using the Settings menu, as follows:

1. Navigate to **Settings > Inputs and outputs**.
2. To configure digital inputs, select **Config dig input terminals**.

A table is displayed showing all the input options available.

Digital inputs settings					
Functions	1	2	3	4	5
Invert input					
SCADA auto control					
SCADA manual control					
SCADA raise tap					
SCADA lower tap					
Tap R/L block					
CB status					
Blocking					
Prepare for switchout					

- Highlight the input option to be configured by rotating the rotary control left or right to scroll up and down, and press the control to edit the input.
- Select the I/O card number (shown on the right side of the table) to which the input has been connected during installation by rotating the control.

If there is more than one I/O card installed, their numbering goes from left to right, looking at the rear of the relay from the back of the panel.

- Press the control to select the input, as shown by a cross.
- Press and hold the control to enter this setting.

Digital inputs settings					
Functions	1	2	3	4	5
Invert input					
SCADA auto control					
SCADA manual control					
SCADA raise tap					
SCADA lower tap					
Tap R/L block					
CB status					
Blocking					
Prepare for switchout					

The relay is now aware that this input is one of those connected to the I/O card.

- Repeat as necessary to enter the other input options.

NOTE: The signal from a single physical input connection can be applied to control multiple input settings on the I/O card. Conversely, the signals from multiple input connections can be mapped to a single input setting, giving a series of OR conditions that can switch the setting. The same options are available for digital outputs.

- To configure the digital outputs, return to the Inputs & Outputs menu and select **Config dig output terminals** before repeating the steps above for the options listed in the output table.

NOTE: To remove an input or output setting, proceed through the same steps and press the rotary control to remove the cross from the table.

9. To check that the digital I/O card has been set up correctly, go to **Instruments > Measurements > Digital I/O card X**.

The active inputs and outputs will be shown with a box shaded in black. The screen also displays the connections that are needed for this input or output on the rear panel of the relay case, allowing the relay connections to also be checked.

Digital I/O card 1			
Slot	B		Terminals
Input	1	<input type="checkbox"/>	1 . 5
Input	2	<input type="checkbox"/>	2 . 5
Input	3	<input checked="" type="checkbox"/>	3 . 5
Input	4	<input type="checkbox"/>	4 . 5
Input	5	<input type="checkbox"/>	6 . 7
Output	1	<input type="checkbox"/>	8 . 9 . 12
Output	2	<input type="checkbox"/>	10 . 12
Output	3	<input type="checkbox"/>	11 . 12
Output	4	<input type="checkbox"/>	13 . 14

The complete list of inputs and outputs available for an I/O card is given in section 17 (Settings List) in Part 2 (Technical Reference).

7.5 Configuring Analogue Inputs and Outputs

The SuperTAPP SG relay can be equipped with one or more milliamp (mA) cards for handling analogue inputs and outputs, as well as temperature measurements using Pt100 sensors. The connections to the terminals on these cards should be made during the installation stage (refer to section 3.3). During commissioning, these inputs and outputs must be configured using the Settings menu.

To configure the analogue outputs, use the following procedure:

1. Navigate to **Settings > Inputs and outputs**.
2. To configure the analogue outputs, select **Set mA outputs terminals**.
3. For each output, select the required parameter from the options available by turning the rotary control.
4. Press **Back** to return to the previous screen, and then select **Config mA output function**.
5. For each output (identified by its function, for example, 'Target voltage output'), enter the maximum and minimum values of the parameter being measured.
6. Press **Back** to return to the previous screen, and then select **Config mA outputs range**.
7. For each output, select the current values (in mA) corresponding to the maximum and minimum parameter values previously selected.

The procedure for configuring the analogue inputs is similar:

1. Navigate to **Settings > Inputs and outputs > Set mA inputs terminals**.
A series of input parameters are listed on the screen.
2. Select a different input on the milliamp card for each parameter you want to set as an input.

3. Press **Back** to return to the previous screen, and then select **Config mA inputs range**.
4. For each input, select the current values (in mA) corresponding to the maximum and minimum parameter values.

The values of each of the analogue inputs and outputs are shown on the **Milliamp card** screen in the Measurements sub-menu of the Instruments menu.

7.6 Relay Connection Tests

To commission the relay for automatic voltage control, the various connections to the system need to be tested.

NOTE: These tests should ideally be performed with the relay in Manual control mode. Any relay which has not been completely commissioned should not be switched to Auto mode except when specified in this manual.



WARNING

Disconnect the raise and lower signal wiring connections (section 3.6) to stop actual tap changer operations until required in later commissioning tests.

7.6.1 VT Input Settings

Configure the VT input settings used for voltage measurements as appropriate for the application. VT inputs which are used for voltage control should have 'Connected to' set to 'Transformer winding *n*' (usually VT1 only, but both VT1 and VT2 in double-winding applications for voltage averaging – see section 15.7 in Part 2 (Technical Reference)). For applications where a 'backup' voltage reference is required (see VT switching in section 16.4 (Feeder Current Measurements) in Part 2 (Technical Reference)), VT2 can be used with the 'Connected to' set to 'Busbar *n*'.

7.6.1.1 Secondary voltage measurements

Check that the voltage measurement on each VT input is correct. Navigate to **Instruments > Measurements** and to the **AC card X secondaries** screen (shown in Figure 1-20). Compare the voltage displayed for each VT input with that measured by a voltmeter.

Figure 1-20 Secondary voltages

AC card 1 secondaries			
Y1	109.6	V	0.0°
Y2	0.0	V	
Y3	0.0	V	
Y4	0.0	V	
C1	300.0	mA	-132.6°
C2	0.0	mA	
C3	0.0	mA	

7.6.1.2 Primary voltage measurements

The relay converts secondary values into primary values using VT ratio and VT phase settings.

Calculate the VT ratio by dividing the primary rating of the VT by the secondary rating of the VT (e.g. for a VT with rating 11,000:110 V, the ratio is 100).

Navigate to **Instruments > Measurements > AC card X primaries** screen (shown in Figure 1-21). Check the value by comparing the primary voltage measurement in the relay with the known system primary voltage (as indicated elsewhere in the substation).

Figure 1-21 Primary voltage and current measurements

AC card 1 primaries			
Y1	10.95	kV	
C1	300.1	A	+0.73 Lg

7.6.1.3 VT phase

Set the VT phase according to the system VT connections as shown in the scheme drawings. It is more difficult to check, but is possible with reference to current measurements which are also in use.

7.6.2 Current Input Settings

Configure the Current inputs used for current measurements as appropriate for the application. Current inputs used for transformer current measurement (normally the case) should have the 'function' set to 'Transformer winding X' (usually one of the three available Current inputs only, but two for double-winding applications for load summation – see section 15.7 (AVC for 3-Winding Transformers) in Part 2 (Technical Reference). Other functions are available as described in section 16.4 (Feeder Current Measurements) in Part 2 (Technical Reference).

7.6.2.1 Secondary current measurements

Check that the secondary current measurement magnitude on each CT is correct. Navigate to **Instruments > Measurements > AC card X secondaries** screen (shown in Figure 1-22). Compare the current displayed with that measured by a clamp CT on the secondary wiring of the main CT.

Figure 1-22 Secondary currents

AC card 1 secondaries				
V1	109.6	V		0.0 °
V2	0.0	V		
V3	0.0	V		
V4	0.0	V		
C1	300.0	mA	-132.6	°
C2	0.0	mA		
C3	0.0	mA		

7.6.2.2 Primary current measurements

The relay converts the secondary values into primary values using the CT ratio and CT turns settings.

Calculate the CT ratio by dividing the primary rating of the CT by the secondary rating of the CT (for example, for a CT with rating 600:5, the ratio is 120).

The number of interposer turns is usually set in order to achieve 5 'Amp turns' at full CT rating. Normally this results in 1 turn for a 5 Amp CT secondary and 5 turns for a 1 Amp CT secondary (other values are sometimes required to give more accuracy if the system is lightly loaded).

Check the CT ratio and number of interposer turns settings by comparing the magnitude of the primary current measurements in the relay (Figure 1-21) with the known system values (as indicated elsewhere in the substation).

7.6.2.3 CT phase

Navigate to **Settings > VTs & CTs > CTx** and set the phase according to the system CT connections as shown on the scheme drawings.

7.6.2.4 Forward and reversed connections

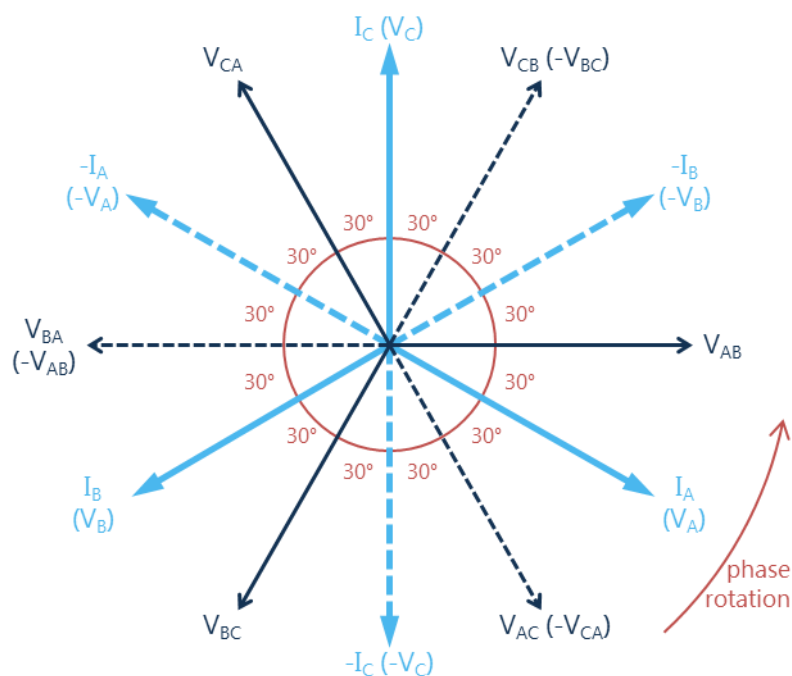
Navigate to **Settings > VTs & CTs > Current input X settings** and check if the **Reversed connection** setting for the CT should be set to **Yes**. This is used to correct a CT which may be connected with an incorrect polarity. Forward sense is usual for a transformer LDC CT, reverse for a feeder protection CT used to measure transformer current.

7.6.2.5 Calculating the power factor

The relay shows the absolute measured angle between the VTs and CTs in use (see Figure 1-22), which is then used to calculate the resulting system power factor according to the phase settings. It is useful to know what the real system power factor of the individual current measurements should be (by reference to other instruments in the substation) to check the primary values as shown in the relay.

Figure 1-23 shows the possible VT and CT phase relationships and can be used to identify correct phase settings.

Figure 1-23 VT / CT relationships



7.6.3 PSU Card Inputs and Outputs

Test the inputs and outputs on the PSU card to confirm that the AVC scheme is functioning correctly. These can be observed in the **PSU card** screen in the Measurements sub-menu of the Instruments menu (as shown in Figure 1-24), and can be checked using a hand-held meter connected to the appropriate connections on the rear panel (refer to the PSU card drawing supplied with your system).

Figure 1-24 Status of inputs and outputs to the PSU card

PSU card			
INPUTS		OUTPUTS	
This panel button	<input type="checkbox"/>	Raise tap	<input type="checkbox"/>
SCADA button	<input type="checkbox"/>	Lower tap	<input type="checkbox"/>
Auto button	<input type="checkbox"/>	Block raise	<input type="checkbox"/>
Manual button	<input type="checkbox"/>	Block lower	<input type="checkbox"/>
Raise cmnd sense	<input type="checkbox"/>	Tapchanger lockout	<input type="checkbox"/>
Lower cmnd sense	<input type="checkbox"/>	Auto control	<input type="checkbox"/>
Relay enable	<input checked="" type="checkbox"/>	SCADA control	<input type="checkbox"/>
Tap in progress	<input type="checkbox"/>		

7.6.3.1 Relay healthy signal

Check that the 'Relay healthy' LED is lit on the front panel when the relay is switched on and operating normally.

7.6.3.2 Tap changer LSS setting

Check that switching the LSS between Local and Remote causes the Control Circuit Supply (Remote) input to go low and high accordingly.

7.6.3.3 Raise and lower outputs

Test the Raise and Lower outputs as follows:

1. Set the relay to This Panel control mode using the control panel buttons.
2. Set the relay to Auto mode using the control panel buttons.
3. Adjust the basic target setting of the relay (in **Settings > Voltage target**) to promote a corresponding raise/lower operation (that is, by making the measured voltage out-of-band).
4. Check that the expected operation occurs.

For example, if the measured voltage is 100% (of nominal voltage) and the bandwidth setting is $\pm 2\%$, a raise operation can be initiated by adjusting the basic target setting to a value below 98%, and a lower operation can be initiated by adjusting the setting to a value above 102%.

NOTE: Although the common convention is for a raise operation to produce an increase in LV voltage (i.e., a decrease in transformer ratio), some tap changers operate in the opposite sense. This should be checked for each application. The convention used for the SuperTAPP SG relay is that a low voltage condition will result in a Raise operation and a high voltage condition will result in a Lower operation. The Raise and Lower outputs should be connected appropriately.

7.6.3.4 Raise and lower command sense inputs

With the LSS switched to Local, check that raise and lower operations initiated at the tap changer are signalled correctly by the **Raise** and **Lower** sense inputs on the PSU card.

7.6.3.5 Blocking outputs

When the tap changer has reached its upper or lower limit, the relay should block any further operations from being initiated. This can be tested as follows:

1. Set the relay mode to This Panel-Manual using the buttons on the control panel.
2. Use the Tap Raise button to perform repeated raise operations until the upper tap limit is reached.
3. When pressing the Tap Raise button, use the **PSU card** screen in the Measurements sub-menu of the Instruments menu to confirm that the **Block raise** output of the PSU card is high and that the **Raise tap** output does not respond. Also check the Raise Command Signal output on the rear panel is not activated.
4. Repeat steps 2 and 3 for the **Block lower** and **Lower tap** outputs.

7.6.3.6 AVC alarm

This alarm is activated by various operational conditions indicating that there is a voltage control problem.

1. Disconnect the VT input(s) to the relay (on the AC card).
This will cause a 'zero voltage' state.
2. Check that the alarm is activated and the 'AVC alarm' LED is lit on the front panel.

NOTE: The alarm will not be activated until the alarm time has passed (the system default setting is 15 minutes).

7.6.4 Lockout

To protect against potentially damaging events such as tap changer runaway, the relay can trip the drive motor on the tap changer and prevent any further operations being initiated, a condition known as 'lockout'. This operation can be tested as follows:

1. Set the relay mode to This Panel-Manual using the buttons on the control panel.
2. Press and hold the Tap Raise or Tap Lower button until the 'tap changer fault' LED is lit.
The relay is now in lockout. Confirm that no further tap change operations can be initiated from the relay or locally at the tap changer.

To clear the lockout condition:

1. Press the rotary control to display the main menu.
2. Press the control to select **Tap changer lockout**.
Information about the lockout will be displayed.
3. Press the control again to clear the lockout and return the relay to normal operation.
The 'tap changer fault' LED should go out, and the screen displays the status of the tap changer.
4. Press the **Back** button twice to return to the main data screen.
5. If necessary, manually reset the tap changer shunt motor.

7.6.5 Inter-relay Communications

Test the relay communications by referring to the **Inter relay CAN** screen in the Diagnostics sub-menu of the Instruments menu (see Figure 1-25), and also messages displayed on the main data screen when there are problems.

Configure each relay to have a unique transformer ID, normally to match the transformer to which it is connected (**Settings > Transformer settings**). Relays controlling transformers connected in parallel should be configured to operate in the same busbar group.

Check the group load displayed on the main data screen is the same for all relays controlling transformers which are on load and are configured to operate in the same group.

Further information on inter-relay communications can be found in section 15.11 (Communications and Data Storage) in Part 2 (Technical Reference).

Figure 1-25 Inter relay communications status

Inter relay CAN								
Relays	1	2	3	4	5	6	7	8
Relays seen								
Relays missing								
Messages missing								
Bad data								

7.6.6 Digital Inputs and Outputs

Test the digital inputs and outputs to ensure that the responses of the relay are correct. Check that the relay registers the appropriate signal for a given operation using the **Digital I/O card** screen in the Measurements sub-menu of the Instruments menu (see Figure 1-26). There may be multiple signals connected to each terminal. Perform the appropriate operation to generate each input or output and check that the corresponding box on the Digital I/O card screen is shaded when it is active.

Figure 1-26 Status of digital inputs and outputs

Digital I/O card 1			
Slot	B		Terminals
Input	1		1 . 5
Input	2		2 . 5
Input	3		3 . 5
Input	4		4 . 5
Input	5		6 . 7
Output	1		8 . 9 . 12
Output	2		10 . 12
Output	3		11 . 12
Output	4		13 . 14

Information on configuring digital inputs and outputs can be found in section 7.4.

7.6.7 Analogue Inputs and Outputs

Where applicable, test that the responses of the analogue inputs and outputs are correct. The values measured can be observed using the **Milliamp card** screen in the Measurements sub-menu of the Instruments menu. Convert these to the parameter values using the mA scaling settings (section 7.5) and check that they correspond with the values displayed in the main data screen or the other Measurements sub-menu screens.

7.7 Thermal Management correction test

To commission the relay for temperature management, the relevant connections to the transformer need to be tested.

7.7.1 Temperature measurement and calculations

See section 15.10.2 of the Technical Reference document for more information and schematics.

Depending on the selected analogue setting follow the procedure below:

1. Have the relay displaying the thermal management measurement screen.
2. Use a signal generator to inject to either the mA, or Pt100 inputs of the relay.
3. Observe the changes in measurements in proportion with the injection.
4. Approve the correct temperature to milliamp scaling for mA inputs.

7.7.2 Operation of fans and pumps

Ensure the thermal characteristic settings of the relay are correct for the transformer thermal specification and cooling type (ONAN, ONAF, OF). Also, configure the digital and analogue inputs and outputs as appropriate for the application. See section 7.4 for information about the configuration of digital input and outputs.

When the mA or Pt100 signals for the thermal measurements pass the set threshold, the selected output(s) must be energised. Also, the corresponding cooling device icon on the main thermal management screen will start to animate and the cooling stage activation message will be displayed.

Follow the steps below to test the operation of thermal management output signals:

1. Go to any of the 'Cooling stage settings' in the thermal management settings menu.
2. Select the number of pumps and fans that are desired for that cooling stage.
3. Adjust the oil and winding temperature thresholds. (This means at what temperature the assigned output will be energised)
4. Increase the input signal to a value more than the set thresholds.
5. Verify the correct operation of the digital outputs for relevant pumps and fans. Section 7.4 explains the steps to check the state of the energised digital outputs.

If oil and winding temperature measurements are not available, activation of cooling devices can also be triggered using the calculated temperatures. However, this will take longer. The relay does this by considering the amount of load on the transformer and the ambient temperature. To test the operation of pumps and fans using these calculated temperatures, you must do the following:

1. Inject a large current via an interposing CT (for example transformer full load) to the current input of the relay.
2. Verify the correct operation of the digital outputs for relevant pumps and fans. Section 7.4 explains the steps to check the state of the energised digital outputs.

7.7.3 Thermal management alarms

Adjust the oil/tap changer and the winding temperature hysteresis values in general alarms settings. The relay uses these values to determine the history of the temperatures and to prevent unwanted cycling of alarms.

Assign outputs for alarms in “Digital outputs settings”. Adjust the temperature thresholds and timer delay times for H1 and H2 alarm settings. These are found in the thermal management section. The relay will energise the assigned output(s) once the alarm condition has been met and an alarm message will be displayed in thermal management screen.

“Cooling device fault” alarm will be raised when the relay energises an output contact to operate a pump or fan. If the SuperTAPP SG does not receive a signal back for the operation of the cooling device, the alarm condition will be raised. This will be indicated on the thermal management screen and if the alarm is mapped the assigned digital output will be energised. Follow the steps in section 7.7.2, observe the alarm message on the screen and verify the operation of alarm output signal. See Figure 1 for the display of the alarm messages.

Disconnect the mA or the Pt100 connection to the relay and, verify the “mA/Pt100 alarm” using the same method.

7.7.4 Operation of cooling stages

SuperTAPP SG has three cooling stages that will be activated depending on the measured and forecast temperatures. To test the basic operation of cooling stages, configure the appropriate pump and fan outputs for each cooling stage. Then verify the activation of each cooling stage by changing the input signals and monitoring the thermal management screen. Figure 1-10 displays the activation of cooling stage 1.

- ▲ Forecast oil and winding temperatures are the estimated oil and winding temperatures after the short-term forecast time has elapsed. It refers to the temperature of the transformer oil and winding after a set time, if no cooling stage is activated.
- ▲ Final oil and winding temperature which is the temperature of the transformer oil and winding after the set time if no cooling stage is activated.

Once the temperature has dropped below the set limit, the cooling stage will be deactivated. The message on the bottom of the screen will disappear, and the fan/pump icon will stop animating.

7.7.5 Sequencing and periodic operation

Configure the “Max pump runtime” and the “Max fan runtime” in the “General cooling sequence settings”. The relay uses this information to swap the operating fans and pumps.

Prove the operation of this function using the two following methods:

1. Adjust these timers and observe the change of energised output(s) after the specified time.
2. Activate a different cooling stage by varying the injected signal. The relay will then alter the energised output(s).

Similarly, select the time and day of the periodic run as well as the time and number of running equipment for periodic operation. The corresponding output(s) will be energised once the time has arrived.

7.8 Control Mode Tests

There are two modes for controlling the SuperTAPP SG relay, as follows:

- ▲ This Panel – tap changer is controlled via the relay at the substation (either at the tap changer or at the tap changer control panel/relay)
- ▲ SCADA – tap changer is controlled via the relay by SCADA communications

7.8.1 Local Control (This Panel)

Test operation in local control as follows:

1. Select This Panel control mode using the button on the control panel.
2. Select Manual operation mode using the button on the control panel.
3. Confirm that the tap changer responds to pressing the Tap Raise and Tap Lower buttons.
4. Confirm that SCADA commands sent to the relay have no effect.

7.8.2 Remote Control (SCADA)

Confirm that no local operations are possible, as follows:

1. In This Panel mode, select Manual operation using the button on the control panel.
2. Select SCADA control mode using the button on the control panel.
3. Press the Tap Raise and Tap Lower buttons to operate the tap changer.

There should be no response from the tap changer.

Other tests to confirm remote control can include the following:

- ▲ Switch the relay to Manual from SCADA and issue remote raise and lower operations. Appropriate voltage changes should be observed with corresponding messages to indicate that tap changes are occurring. The PSU card screen in the Measurements sub-menu of the Instruments menu will also show if the correct inputs and outputs are active during the tap change operation.
- ▲ Switch the relay to Auto from SCADA and issue target voltage adjustments which can be viewed on the screens in the Calculations sub-menu of the Instruments menu.

7.9 Operation Mode Tests

There are two operation modes for the relay as follows:

- ▲ Manual – operator controls the tap changer
- ▲ Auto – relay controls the tap changer

These operation modes are available for both control modes (This Panel and SCADA).

7.9.1 Manual Mode

In this mode, the relay should operate normally and display all measurement data, but will not automatically operate the tap changer in response to changes in output voltage.

1. Select This Panel control mode using the button on the control panel.
2. Select Manual operation mode using the button on the control panel.
3. Generate an out-of-band voltage condition by operating the tap changer or by injection testing (applying the appropriate voltage to the VT inputs from a test set).
4. Confirm that the relay displays the correct messages in response to the change (see Table 1-6) but does not operate the tap changer to correct the problem, or generate AVC alarms.

You will need to wait until the initial tap timer duration has elapsed to confirm this behaviour.

5. Confirm that tap changer operations can be manually performed from the following locations:
 - ▲ At the relay control panel via Tap Raise/Tap Lower buttons (if the LSS is set to Remote)
 - ▲ At the tap changer via raise/lower switches (if the LSS is set to Local)
 - ▲ At the control centre via remote control (where SCADA communications are in use)

When the relay is switched from Manual to Auto control and the voltage has been out-of-band for longer than the initial tap timer duration, an immediate corrective tap changer operation should be initiated (this can be tested once Auto control has been tested – see section 7.9.2).

7.9.2 Auto Mode – Basic Operation

These tests should confirm that the relay can automatically correct system voltages according to the application requirements. Basic relay operation should be tested first before application-dependent functions such as LDC or circulating current are considered.

Perform these tests with the relay measuring voltage only (to ensure no biasing for circulating current control or LDC) and with the CAN bus disconnected or paralleled units configured into different groups (to ensure that no other units are influencing the relay response). These tests can therefore be performed with the transformer off-load or with the CT(s) shorted.

Maintain the relay in Manual control mode until directed otherwise.

7.9.2.1 Upper and lower voltage band

Check that the voltage levels at which the relay initiates tap changer operations are correct:

1. Generate an out-of-band voltage condition by operating the tap changer or preferably by injection testing (applying the appropriate voltage to the VT inputs from a test set).
2. Note the voltage value at which the high voltage LED is lit.

The value should be the target voltage setting plus the bandwidth setting, as selected in **Settings > Voltage target**.

3. Repeat for the value at which the low voltage LED is lit, which should be the target voltage setting minus the bandwidth setting.

If injection testing is not possible then the actual system voltage must be used. Modify the target voltage setting (V_{basic}) as shown below to 'force' an out-of-band condition depending on the measured system voltage (V_{meas}):

- ▲ High voltage: $V_{\text{basic}} = V_{\text{meas}} - \text{bandwidth}$
- ▲ Low voltage: $V_{\text{basic}} = V_{\text{meas}} + \text{bandwidth}$

7.9.2.2 Tap timers

Check the relay initial tap and inter-tap delay timers. The relay should be in Auto control mode for this test but the raise and lower outputs should be disconnected for safety so that no actual tap changer operations are initiated.

1. Confirm the initial tap time delay setting (in **Settings > Voltage target**) by measuring the time between an out-of-band voltage occurring (produced as in section 7.9.2.1) and initiation of the appropriate tap changer operation (indicated by the status messages 'Lowering tap' for high voltage and 'Raising tap' for low voltage).
2. Confirm the inter-tap time delay setting (in **Settings > Tap changer**) by measuring the time between initiation of the first tap changer operation and a subsequent operation.

This time delay is only used if the out-of-band condition persists after the first tap changer operation, that is, if the voltage has not been corrected. This will be the case here since the relay raise and lower outputs should not be connected to the tap changer at this stage.

NOTE: It is important that the inter-tap time delay is at least 25% longer than the operational time of the tap changer to give an adequate safety margin.

7.9.2.3 Fast tap

This is only applicable where the fast tap facility is being used (a settable shorter time delay for certain voltage conditions). This can be configured by selecting **Settings > Voltage target > Fast tap**.

1. Create the fast tap voltage condition (voltage more than 2% above or below limits).
The high or low voltage LEDs should flash.
2. Check that the time delay before a tap operation is initiated is as per the Fast tap time delay setting.

7.9.2.4 Voltage correction

Confirm basic relay operation by observing real tap changer operations which correct system voltages (both high and low). These tests can only take place with the transformer energised. The relay should be in Auto control mode and the raise and lower outputs should be connected.

There are three ways to test basic operation:

- ▲ Wait for the system voltage to drift out-of-band (not recommended).
- ▲ Modify the basic target setting to cause the out-of-band condition.

- ▲ Manually operate the tap changer to cause the out-of-band condition and then switch the relay back to Auto control mode.

The result of the tap changer operation should be a corrected system voltage to within the bandwidth, as shown by the normal voltage LED and the scale displayed at the bottom of the main data screen.

The voltage change observed will be dependent on the tap step of the tap changer (calculated from the nameplate – see Figure 1-18) and the number of paralleled transformers. For example, if the tap step of the tap changer is 1.25% and there are two transformers operating in parallel, the observed voltage deviation when one of the tap changers operates will be 0.625%.

7.9.3 Circulating Current

This section is only relevant for transformers which are being operated in parallel, using Enhanced TAPP voltage control mode.

As described in section 15.3 in Part 2 (Technical Reference), transformers can be paralleled at a site or across the network, although the former is much more common. The relay calculates circulating current (comprising both site and network components) and converts it into a corrective bias, V_{circ} . This bias promotes tap changer operations to reduce the circulating current.

The transformer LDC CT and CAN bus must be connected for this test since circulating current control depends on the summed transformer load across the group.

The test can be performed in two parts:

1. Confirmation of circulating current calculations.
2. Corrective tap changer operations.

7.9.3.1 Calculations

Confirm the circulating current calculations by reference to screens which show the calculated values of site circulating current and network circulating current. These can be found in the Calculations sub-menu of the Instruments menu (Figure 1-27).

Figure 1-27 Circulating current measurement

Winding 1 voltage biases	
Set target	100.0 %
LDC bias	0.0 %
Generator bias	0.0 %
Site circ cur bias	0.0 %
Net circ cur bias	0.0 %

Effective target	100.0 %
Measured voltage	101.5 %

Deviation	+1.5 %

In order to promote the flow of circulating current and confirm the calculations, the site transformers need to be tapped apart. This is done with the relay in Manual control mode. The relay can then be left in this mode to check the calculations.

The transformer which is on the lower ratio (normally the higher tap position) and therefore trying to output the higher voltage will export circulating current (lagging VArS). This will be displayed on the main data screen as negative circulating current. The resulting voltage bias for circulating current will also be negative and reduce the relay target voltage; this can be confirmed using the **Voltage biases** screen in the Calculations sub-menu of the Instruments menu (Figure 1-27). Eventually the system reaches an out-of-band condition (high voltage) and wants to tap down.

The transformer which is on the higher ratio (normally the lower tap position) and therefore trying to output the lower voltage will import circulating current (leading VArS). This will be displayed in the main data screen as positive circulating current. The resulting voltage bias for circulating current will also be positive and increase the relay target; this can be confirmed using the **Voltage biases** screen in the Calculations sub-menu of the Instruments menu (Figure 1-27). Eventually the system reaches an out-of-band condition (low voltage) and wants to tap up.

NOTE: If the direction of the site circulating current and corresponding bias is not correct then check the CT connection to confirm polarity (see section 7.6.2).

Network circulating current is more difficult to confirm since it is not possible to know the relative output voltages of transformers paralleled across the network. Despite this, the calculation can be checked by reference to the measured group load of the relay (shown in the **Busbar** screen(s) in the Calculations sub-menu of the Instruments menu). If the group load is more lagging than the relay target power factor setting (selected in **Network settings** in the Settings menu), the resultant network circulating current should be negative. If the group load is more leading than the relay target power factor setting, the resultant network circulating current should be positive.

7.9.3.2 Corrective operations

Complete the tests for circulating current as follows:

1. Create the situation described above where the transformer exports circulating current and wants to tap down.
2. Switch the relay to Auto control mode.
The relay should initiate tap changer operations which lower the system voltage to within the target bandwidth and minimise the circulating current.
3. Repeat the test in the opposite direction, with circulating current imported.

7.9.4 Master-follower

This section is only relevant for transformers which are being operated in parallel, using Master-follower voltage control mode.

Fundamentals do not recommend the use of master-follower mode except in situations where it is unavoidable, because it is an inferior method of keeping transformers in step and because of the constraints it imposes. Operation of master-follower is described in section 15.1.3.3 in Part 2 (Technical Reference).

Master-follower must be selected with the **Settings > Voltage target > Voltage control mode** setting. Once selected press the cancel button repeatedly until the main data screen shows.

If this is the first relay in the group to be configured in master-follower then it will automatically become the master ('A' in Figure 1-28).

If there are already other relays connected and configured to operate in the same group, and in master-follower mode, then that relay will already be showing master, and this new relay will automatically enter follower mode ('A' in Figure 1-29) and will display which transformer it is following.

The following commissioning tests can only be carried out when there are two or more relays in the same group and configured in master-follower mode.

7.9.4.1 Follower operations

On the relay to be tested carry out the following:

1. Set the relay to Manual mode and ensure the relay is in master-follower voltage control mode.
2. Manually tap down by one tap so that the tap position is different to the tap position of the master.
The relay (and the master) should show 'Tap position out of step' (as per 'B' in Figure 1-29).
3. Switch the relay to Auto control mode.
The relay should display 'Time to tap' ('C' in Figure 1-29) and count down in seconds before tapping to the same position as the master.
4. Return the relay to Manual mode.

7.9.4.2 Selection of Master

Check that each relay can be selected as master as follows:

1. Press and hold the **Auto** button until the mode changes to master
2. Check that the other relays display that they are following the new master

Figure 1-28 Master-follower main data screen – Master relay

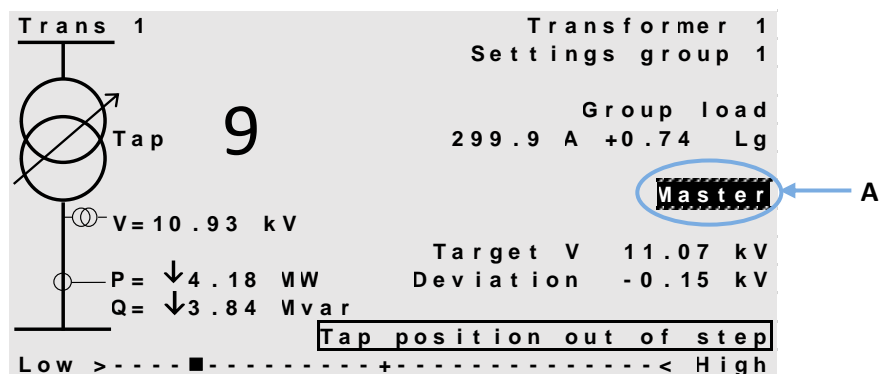
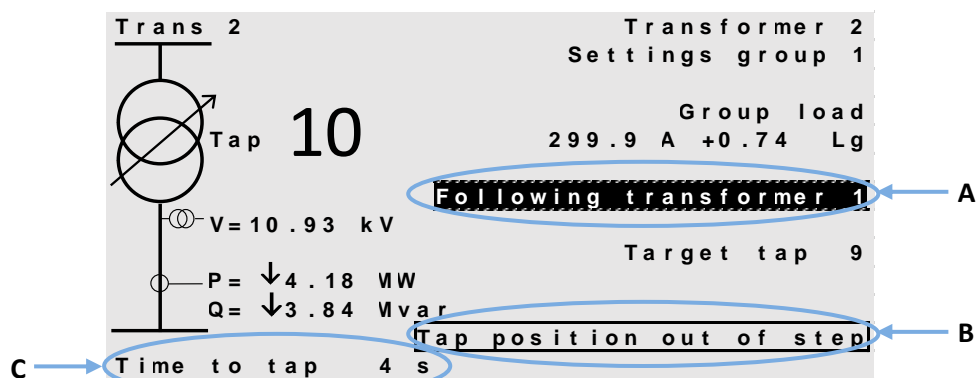


Figure 1-29 Master-follower main data screen – Follower relay



7.9.5 LDC

Load drop compensation is described in section 15.2 in Part 2 (Technical Reference). Since relay operation has already been confirmed in previous tests, the only test required for LDC is that the voltage bias is correct for the existing load conditions. The bias depends on the LDC setting, the group load, the target power factor setting and the site firm capacity as follows:

$$V_{LDC} = k \times \text{LDC setting} \times (\text{group load} / \text{firm capacity})$$

where k is a coefficient (between 0 and 1) representing the component of group load at target power factor setting and V_{LDC} is capped at the LDC setting.

The biases can be checked using the **Voltage biases** screen in the Calculations sub-menu (Figure 1-27). The relay can therefore be in Manual control mode for this test.

The normal situation is where the transformer is supplying real and reactive power to the network. The measured transformer current in this situation shows a positive lagging power factor (positive

group load in the **Busbar** screen(s) in the Calculations sub-menu of the Instruments menu). The effect of LDC should be a positive voltage bias in the **Voltage biases** screen such that the relay target voltage increases and the relay attempts to tap up (with a corresponding low voltage indication). If the direction of the bias is not correct then the current input connection should be checked to confirm polarity (see section 7.6.2).

Where the transformers are in reverse power and the group load is negative, for example where there is a high level of embedded generation on the network, the voltage bias is dependent on the relay reverse LDC setting (in **Settings > Voltage target**) as follows:

- ▲ Reverse LDC on: V_{LDC} as per above equation but capped at the reverse LDC setting
- ▲ Reverse LDC off: $V_{LDC} = \text{zero}$

Although it is difficult to test this with real reverse power on the transformer(s), the effect can be simulated and LDC response observed by reversing the 'sense' of the current inputs in use (this should reverse the group load).

If reverse LDC is on, the effect will be to reduce the target voltage and make the relay want to tap down (with a corresponding high voltage indication). If reverse LDC is off, there should be no bias applied. The LDC bias can be checked using the **Voltage biases** screen in the Calculations sub-menu (Figure 1-27).

Once this test has been performed the current input 'sense' setting should be changed back to the correct polarity.

7.9.6 Voltage Target Adjustments

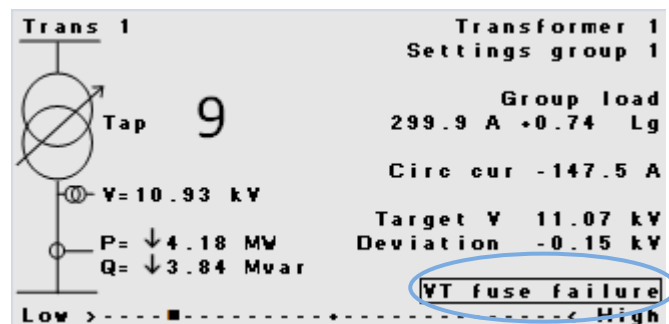
The **Voltage target adjustments** screen in the Settings menu allows voltage offsets to be configured to amend the relay set point. The response of the relay following the application of each offset (and combination of offsets) should be checked, by observing the change to the relay effective target voltage in the **Voltage biases** screen in the Calculations sub-menu of the Instruments menu (Figure 1-27).

Other types of voltage adjustments are available with Advanced and Ultimate versions of the SuperTAPP SG relay (refer to section 15.10 in Part 2 (Technical Reference)).

8 Diagnosis of Problems

The SuperTAPP SG relay indicates problems by a series of red LEDs on the front panel, and by displaying messages near the bottom of the LCD screen (Figure 1-30).

Figure 1-30 Alarm message displayed in main data screen



The alarm LEDs are:

- ▲ AVC alarm – indicates an abnormal voltage that the AVC system cannot correct.
Check that the LSS on the tap changer is set to Remote.
If the relay is set to SCADA control mode, check that SCADA commands are still being received by the relay.
If the relay is set to Manual operation mode, check that the Tap Raise and Tap Lower buttons on the control panel operate the tap changer.
- ▲ Tap changer fault – indicates a problem with the tap changer.
Inspect the tap changer mechanism and perform any maintenance required (refer to section 10 and information supplied by the tap changer manufacturer).
- ▲ See msg on LCD – indicates an alarm condition; refer to the display screen for details.
Table 1-9 gives guidance on how to respond to the messages that may be displayed.

If the guidance above does not allow you to resolve the problem, contact Fundamentals for further support.

9 Routine Maintenance of SuperTAPP SG

The SuperTAPP SG does not require any special maintenance procedures and contains no user-serviceable parts.

If the front panel becomes soiled, wipe clean with a damp cloth. Do not use detergents, solvents or excessive quantities of water.

9.1 In-Service Tests

AVC systems are in continual operation when in service, and any deviations in accuracy and control will affect the customers connected to the power system. Minimal checks may be carried out on the relay when in service to check that it is operating correctly. No specialist test equipment is required.

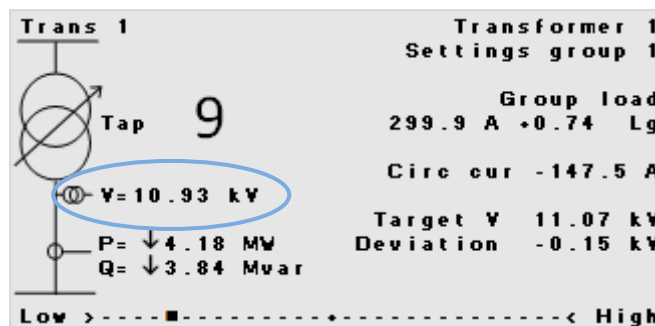


These checks should only be performed by personnel trained in relay operation who are capable of observing all the required safety precautions and regulations for both the relay and the associated primary plant.

9.1.1 Voltage Transformer Monitor Levels

1. Use a good quality RMS voltmeter to measure the incoming transformer voltage.
2. Compare the result to the value displayed on the main data screen and confirm that they agree closely.

Figure 1-31 Transformer voltage displayed in main data screen



9.1.2 Checking for Normal Operation

1. Set the relay control mode to This Panel.
2. Set the operating mode to Manual.
3. Press the Tap Raise button to initiate a tap change operation and check for correct operation at the tap changer.
4. As soon as the 'tap in progress' LED goes out, repeat the raise operation.
5. Repeat for the lower operation to return to the original tap changer position.

9.1.3 Testing Lockout

1. Simulate a runaway condition by pressing and holding the Tap Raise or Tap Lower button when in This Panel-Manual mode. Confirm that the 'tap changer fault' LED is lit and that the relay has no control of the tap changer.
2. Go to **Faults > Reset lockout** and select **Y** to return the relay to the normal operating mode.

9.2 Alarms

1. With the tap changer disabled, alter the target voltage setting in **Settings > Voltage target** so that the relay reads a low voltage.
2. Check that the alarm LED is lit, and that the Raise Command Signal output from the PSU card is high.

NOTE: On completion of the maintenance tests, return all settings to normal values.

10 Tap Changer Maintenance

In addition to testing the AVC relay as described in section 9, it is very important to carry out regular inspection and maintenance of the tap changer itself to avoid system malfunction. The majority of on-load tap changers are mechanical devices operating many times a day, and are often located outdoors where they may be subjected to a variety of weather conditions which can affect their performance. In particular, the diverter switch is subjected to considerable mechanical wear and will need regular cleaning and replacement of contacts and insulating oil.

Detailed guidance can be obtained from the manufacturer of your tap changer, but the following general advice may be helpful:

- ▲ Observe the maintenance intervals recommended by the tap changer manufacturer.
- ▲ Check the insulating oil's dielectric strength and water content at recommended intervals. When these fall outside the specified limits, replace the oil but also check the condition of gaskets and silica gel breathers on the oil reservoir.
- ▲ Strip down and clean all parts of the diverter switch at recommended intervals (normally based on the number of switching operations performed). Replace worn springs, switch contacts, etc., as required.
- ▲ Inspect the tap changer head, protective relay, motor and drive shaft regularly for signs of wear, corrosion and oil leaks, and repair accordingly.

NOTE: Remember that a problem with an AVC system may be due to a fault in the tap changer rather than a problem with the AVC relay.

11 Removal and Replacement of SuperTAPP SG

The SuperTAPP SG control relay sits inside a case mounted in the panel, and can be easily removed if repair or replacement is required without disturbing the wiring or earthing connections.



Before removing the SuperTAPP SG, ensure that the relay has been switched off.

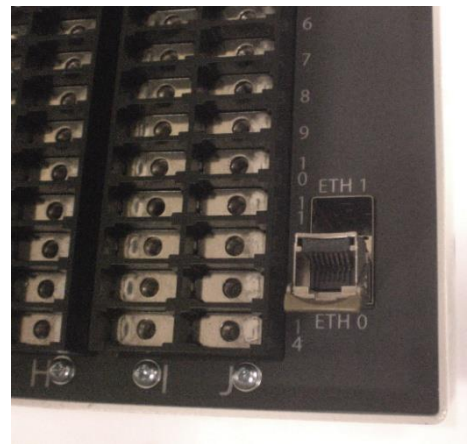
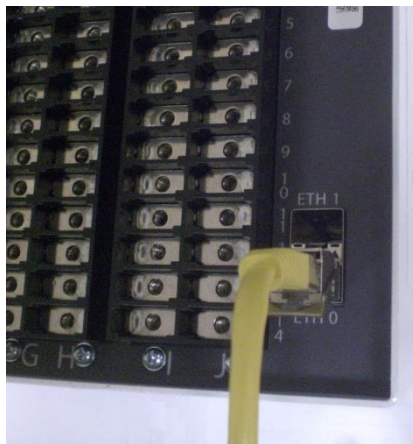
11.1 Removing the SuperTAPP SG

1. Open the rear door of the panel, and disconnect any communications cables and SFP modules from the rear panel of the relay (Figure 1-32).



You MUST remove the SFP modules before withdrawing the relay to prevent damage to the connections.

Figure 1-32 Remove communications cables (left) and SFP modules (right) BEFORE removing the relay



2. Insert two 4 mm hexagonal keys in the bolts on either side of the front panel as shown in Figure 1-33, and simultaneously push both downwards firmly.

The relay will be unlocked from the case.

Figure 1-33 Removing the relay



3. Remove the hexagonal keys and gently pull the relay out of the case.

11.2 Replacing the SuperTAPP SG

1. Slide the relay carefully into the case until a hard stop is felt.
2. Insert two 4 mm hexagonal keys into the bolts on either side of the front panel as shown in Figure 1-34, and firmly push both upwards simultaneously until a loud click is heard from each side.

The relay will slide into the case and be locked in position.

Figure 1-34 Replacing the relay



3. Remove the hexagonal keys.
4. Reconnect the SFP modules and communications cables in the rear panel (Figure 1-32).

11.3 Decommissioning and Disposal

European Union only



A label with a crossed-out wheeled bin symbol and a rectangular bar indicates that the product is covered by the Waste Electrical and Electronic Equipment (WEEE) Directive and is not to be disposed of as unsorted municipal waste. Any products marked with this symbol must be collected separately, and in accordance with the regulatory guidelines in your area.

The objectives of this program are to preserve, protect and improve the quality of the environment, protect human health, and utilise natural resources prudently and rationally. Specific treatment of WEEE is indispensable in order to avoid the dispersion of pollutants into the recycled material or waste stream. Such treatment is the most effective means of protecting the customer's environment.

The requirements for waste collection, reuse, recycling, and recovery programs are set by the regulatory authority in your location. Contact your local responsible person or authorised representative for information regarding applicable disposal regulations. If further assistance is required, contact Fundamentals.

12 Fundamentals Support Services

12.1 Remote Support

Fundamentals has a team of experienced engineers who can assist with diagnosing the cause of problems with the operation of the SuperTAPP SG relay. In many cases they are able to communicate directly with the relay to monitor its performance or reconfigure the settings. Please contact your Fundamentals representative for further details.

12.2 Fundamentals Site Services

In addition to remote support services, Fundamentals and its partner network can offer maintenance contracts for on-load tap changers and assist with upgrading transformers to extend their operational lifetime. Please contact your Fundamentals representative for further details.

13 Locations

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