FUNDAMENTALS

SuperTAPP SG

Voltage Control and Monitoring Relay

Data Sheet

SuperTAPP SG is the latest realisation of the market-leading automatic voltage control (AVC) relay for transformer and tapchanger management. SuperTAPP SG provides practical options for all voltage control applications from the straightforward to the complex and difficult to solve. Situations which it can handle include two-winding transformers, three-winding transformers, distributed or embedded generation, fluctuating load power factors, differing voltage sources, transformers and tap spacings, paralleling across networks, transfer taps and many more.

SuperTAPP SG is the fourth generation of AVC relay designed by Fundamentals, building on a rich history and heritage gained from direct experience of working with the fundamentals of power system operation. Previous relays in the line of succession include the original TAPP, SuperTAPP, MicroTAPP and SuperTAPP n+.

Key Features

- Complete voltage control package for Smart Grid
- Basic voltage control for standard applications
- Advanced solutions for distributed generation
- Accommodates reverse power flows, diverse feeder load profiles and variable power factors
- Integrated control panel with real control switches
- Comprehensive SCADA protocols including IEC 61850, DNP3 and IEC 60870 series
- PC software for management of entire SuperTAPP SG fleet, including settings, tapchanger operation, relay and tap-changer diagnostics and historical data
- Optional transformer temperature monitoring and control

Key Benefits

For network operation

- Fewer customer complaints
- Reduce losses

For connection of generation

- Maximise voltage headroom and reduce generator curtailment
- Avoid complex ANM schemes for voltage management
- Reduce connection costs for DG

For asset management and replacement

- Deliver asset health indices at lower cost
- Reduce tapchanger maintenance costs
- Reduce effects of tapchanger failure and risk of damage

For reinforcement projects

- Deliver reinforcement plan at reduced cost
- Easy to install and commission
- Supports use with all types of transformer, tapchanger and schemes

Table of Contents

1 Functional Description

1.1 AVC for 2-Winding Transformers

The basic operation of voltage control compares a measured voltage (V_{VT}) with a *target voltage* for the relay (V_{tgt}). If the difference exceeds the *bandwidth* setting, following an *initial delay* a tapchange operation is initiated to adjust the transformer voltage to a satisfactory level.

Figure 1 Simplified AVC operation

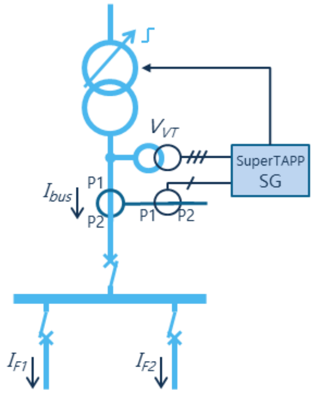
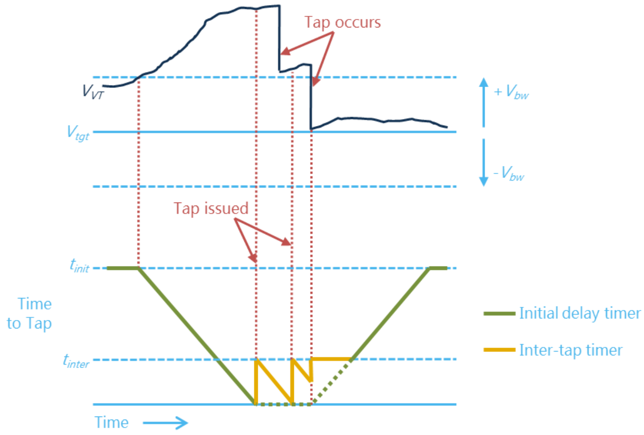


Figure 2 Tapchanger operation timing



Successive Tap Operations

Following a tapchanger operation, if further corrections are required, an *inter-tap delay* is used. A tapchange operation usually requires a number of seconds to complete, and the *inter-tap delay* allows for this before requesting further operations, Figure 2.

Fast Tap

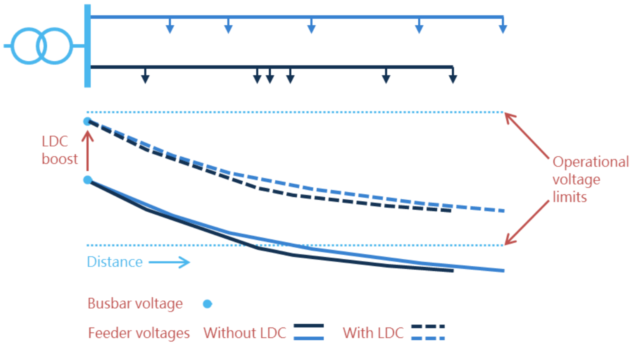
Under some circumstances the initial time delay is bypassed and a corrective tapchanger operation is initiated after a short, fixed time delay of 5 seconds. The conditions under which fast tapping can take place are 2% outside the band (user configurable), or following a change to the target voltage.

1.2 Load (or Line) Drop Compensation (LDC)

Load drop compensation (LDC) is used to offset voltage drops across a network caused by load current, as shown in Figure 3.

The voltage bias for LDC (V_{LDC}) is applied in proportion to the load current (I_{bus} in Figure 1) and is expressed as a percentage boost at full load.

Figure 3 Load drop compensation (LDC)

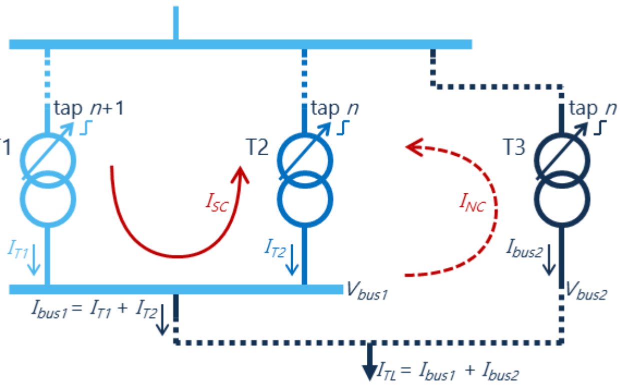


1.3 Parallel Transformers

Circulating Current Minimisation

SuperTAPP SG employs the 'enhanced TAPP' method to calculate the circulating current and convert it into a bias which promotes tapchanger operations that reduce the circulating current to a minimum. The circulating current bias is made up of two components: a bias arising from site circulating current, and a bias arising from network circulating current.

Figure 4 Parallel transformers across a network



LDC on Multi-transformer Busbars

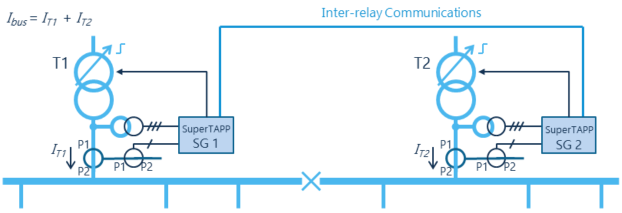
On busbars fed by multiple transformers, as bus1 in Figure 4, the total load on the busbar is the sum of the loads on all the transformers connected to the busbar. It is this summated load which is applied for the calculation of the LDC effect.

The loads of multiple transformers on a busbar are summated using inter-relay communications, which can connect together multiple SuperTAPP SG relays on a site.

Inter-relay Communications

SuperTAPP SG can accommodate parallel operation of up to eight units using the Inter-relay Communications system.

Figure 5 Inter-relay communications



The inter-relay communications system is used to exchange a number of information types, for example:

- ▲ Transformer and feeder currents for LDC and minimisation of circulating current
- ▲ Checking that voltage measurements and targets are consistent across the busbar group
- ▲ Sharing of target adjustments to ensure correct operation across the busbar group
- ▲ Cooperative functions such as prepare for switchout and tap stagger
- ▲ Identification of busbar groups and circuit breaker switch positions

1.4 Integrated Control Panel

Control Points

The SuperTAPP SG accommodates three points of control for tap-changers:

- ▲ Local, i.e. local to the tap-changer.
- ▲ This Panel, i.e. on the SuperTAPP SG integrated control panel or adjacent panel switches .
- ▲ SCADA, via the relay by SCADA communications (DNP3, IEC 61850 etc, or hardwired)

Modes of Operation

There are two modes of operation:

- ▲ Auto – controlled by the SuperTAPP SG AVC algorithm
- ▲ Manual – an operator controls the tapchanger
- ▲ In manual mode the relay maintains measurements and indications according to the operational state but does not issue tapchanger operations or operational alarms.

Figure 6 Front panel features

1.5 Tapchanger Monitoring and Runaway Prevention

If the voltage cannot be corrected (e.g. tapchanger mechanism fault or end of range), the relay will stop issuing raise/lower signals and may additionally trip the tapchanger motor MCB. Additionally after a common alarm time the associated AVC alarm will be raised. A list and description of each monitored condition is given in Table 1.

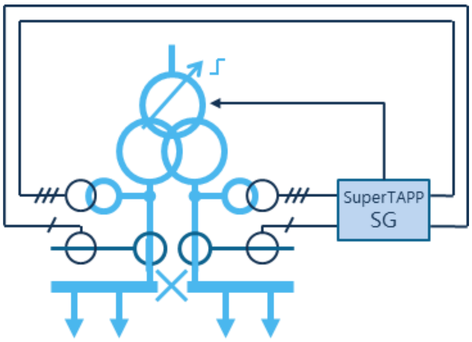
Table 1 Monitored conditions and alarms

Condition	Blocking	Alarm
VT fuse failure	Both directions	After alarm time
End of tap range	In relevant direction	Immediate
Target not achievable		Immediate
CAN bus failure		After alarm time
Overload	Both directions	After alarm time
Voltage high	Raise blocked	After alarm time
Voltage low	Lower blocked	After alarm time
Phase reference alarm	Both directions	After alarm time
Voltage out of band alarm		After alarm time
Tapchanger runaway	Tapchanger motor may be tripped	Immediate
Tap incomplete	Tapchanger motor may be tripped	Immediate

1.6 AVC for 3-Winding Transformers (Double Secondary Winding)

Regulation of transformers with two secondary windings requires the calculation of an optimum taking into account the voltage and load on each winding. Two VT inputs and two CT inputs are used for control of double-secondary winding transformers, as shown in Figure 7.

Figure 7 Double secondary winding transformer



Where the measured voltage on a VT input falls below 80% nominal voltage (for example in the event of a fuse failure), the relay will automatically revert to using the remaining VT for voltage control.

1.7 Adjustments to Target Voltage

Within SuperTAPP SG temporary adjustments can be made to the basic target voltage.

Voltage offsets

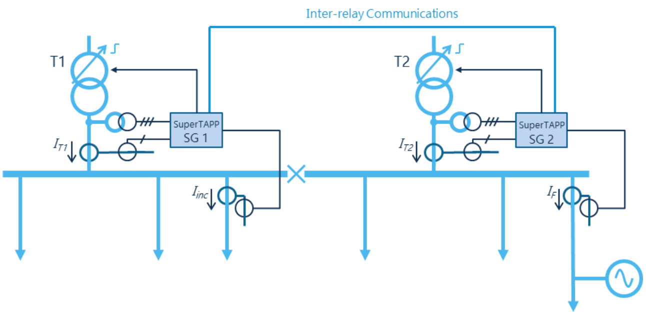
Voltage offsets can be selected through digital inputs or through SCADA communications.

On a SuperTAPP Basic or Advanced SG four fixed target adjustments are available, while on a SuperTAPP Ultimate SG six adjustments are provided.

1.8 Feeder Current Measurements

SuperTAPP SG is designed to measure feeder currents in addition to the transformer current. Normally, feeder current measurements are only possible using protection CTs. In order that the protection scheme is not compromised, low burden interposing CTs are used to interface with the relay, Figure 8.

Figure 8 Additional feeder current measurements



Advanced Voltage Control

Feeder current measurements can be used for advanced control catering for the following situations:

- ▲ Generator – connected directly to the busbar
- ▲ Generator Feeder – measurement of the net load into a feeder which has a generator embedded within it
- ▲ Excluded – the load on this feeder is excluded from circulating current consideration
- ▲ Corrected load – the load on this feeder is modified based on known “good” loads
- ▲ Monitor – the measured load on this feeder is used for instrument purposes only
- ▲ Interconnector – this feeder is a tie-line to a parallel substation

1.9 Optional Tranformer Temperature Monitoring and Control

A high proportion of transformer faults are related to the temperatures and there is not enough useful information about asset condition. The SuperTAPP SG enables users to manage transformers by measuring:

- ▲ Ambient temperature
- ▲ Transformer oil temperature
- ▲ Transformer winding temperature
- ▲ Tap changer temperature

These signals are then used to:

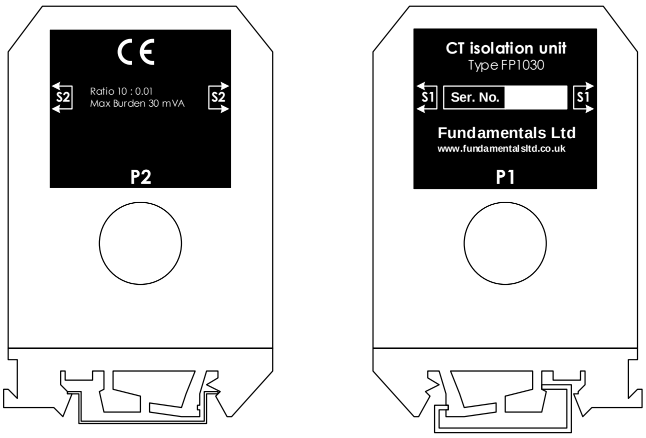
- ▲ Monitor oil pumps and fans
- ▲ Estimate Transformer Top Oil and Hotspot Temperature

2 Interposing CT

The interposing CT designed for use with the SuperTAPP SG provides a high level of electrical isolation between the source current circuitry and imposes virtually no burden upon the measurement current transformer.

Figure 9 gives an external view of the interposing unit, which can be mounted within a circuit breaker panel using a DIN rail.

Figure 9 Interposing CT



3 Physical Description

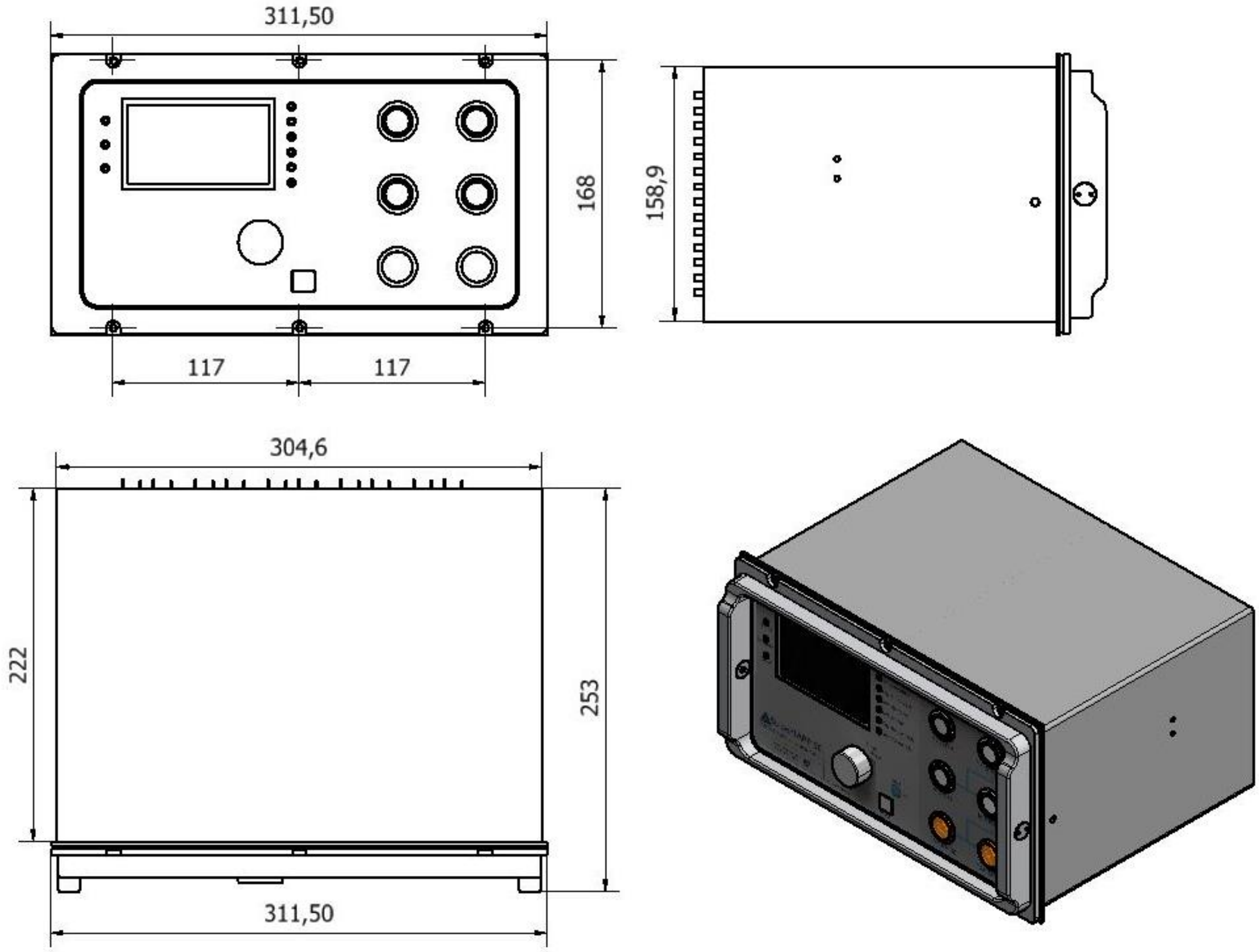
The SuperTAPP SG is designed for fitting in the front panel of a 19" rack-mounting system and occupies ¾ width of a 4U subrack, allowing a complete voltage control for one transformer and test blocks to be fitted in a single subrack.

SuperTAPP SG is a modular relay. Ordering options allow the user to select the hardware functions which are required for the particular scheme and these are easily built into the relay. Additional hardware can be added later if required.

SuperTAPP SG is a withdrawable relay. Once the relay is wired into the panel the relay chassis can be withdrawn from the case without disturbing the wiring.

Figure 10 SuperTAPP SG dimensions

(all dimensions in mm)



4 Specifications

4.1 General

Legal Requirements – European Union

Conformity	Reference
Low Voltage Directive	2014/35/EU
Electromagnetic Compatibility Directive	2014/30/EU
Batteries and Accumulators Directive	2013/56/EU
Restriction of Hazardous Substances Directive	2011/65/EU

SuperTAPP SG is CE marked.

Product Standards

Standard		Reference
Measuring relays and protection equipment	Electromagnetic compatibility requirements	BS EN 60255-26:2013 (IEC 60255-26:2013)
	Product safety requirements	BS EN 60255-27:2014 (IEC 60255-27:2013)

Reference Conditions

Specification	Levels
Ambient temperature	20 °C
Energising quantities	Nominal (unless specified)
Frequency	50 / 60 Hz

Operating Environment

Specification	Levels
Environmental level	Zone A, severe electrical environment
Overvoltage category	III
Pollution degree	2

4.2 Functional Characteristics

Functional Accuracy

Characteristic	Accuracy
Timers	±250 ms
Frequency	±0.05 Hz
Frequency response	400 ms

Communications

Characteristic	Specification
Physical layer options	RS485 over serial twisted pair, ethernet 100base-T, ethernet 100base-F
Data link layer options	RS485, TCP/IP
Application layer options	IEC 61850, DNP3, IEC 60870-5-103

4.3 Electrical Characteristics

Energising and Output Quantities

Port		Nominal‡	Operating Range	Withstand	Burden	Accuracy
Auxiliary supply	(type A)	Vx = 110/230 V ~	87.5–260 V ~ 47-63 Hz ~	300 V ≂	< 30/50 VA †	–
		Vx = 110 V ⎓	87.5–132 V ⎓		< 15/25 W †	
	(type B)	Vx = 24/48 V ⎓	18–72 V ⎓	75 V ≂	< 15/25 W †	
Tapchanger interface		110/230 V ≂	87.5–260 V ≂ 45-63 Hz ~	300 V ≂	–	–
Voltage inputs		Vn = 63.5/110 V ~	0–145 V ~ 45-65 Hz ~	264 V ~ cont. 300 V ~ 1 s	< 1 VA (across op. range)	±0.5% (80%-120% Vn)
Current inputs		5 mA ~	0–10 mA ~ 45-65 Hz ~	10 mA ~	≤ 30 mVA (across op. range)	±1% (20%-120% nom.)
with external CT type FP1030		In = 0.5/1/5 A ~	0–10 A ~ 45-65 Hz ~	40 A cont. 1000 A 1 s (1 turn)	≤ 30 mVA (across op. range)	±1% (20%-120% In)
Digital inputs		24/48/110/220 V ⎓ 110/230 V ~	19.2–260 V ⎓ 87.5-260 V ~ 45-63 Hz ~	300 V ≂	< 0.2 W ⎓ < 0.5 VA ~	–
mA inputs (passive)		0-10 / 0-20 / 4-20 mA ⎓	−25 - +25 mA ⎓	25 mA ⎓	100 Ω	±1% (20%-100% nom.)
RTD inputs (Pt100 Temperature sensor resistor)		IEC 60751 100 Ω platinum resistor	−80 - +327 ˚C	0 - ∞ Ω	–	±0.5 ˚C
Analogue tap position input		–	chain resistance 50 Ω - 50 kΩ min. 5 Ω per res.	0 - ∞ Ω	–	±0.2 taps on 40 position tapchanger
mA (passive)		0-10 / 0-20 / 4-20 mA ⎓	0 - +25 mA ⎓	50 mA ⎓	270 Ω	±1% (20%-100% nom.)
Digital tap position inputs		Dry / volt-free contacts	–	–	–	–
mA outputs (active)		0-10 / 0-20 / 4-20 mA ⎓	0 - 24 mA ⎓ loop res. ≤ 1 kΩ	–	–	±1% (20%-100% nom.)

† Quiescent / Maximum burden

‡ Nominal AC frequency 50/60 Hz

Output Relays

Specification	Levels
No. of cycles	>100,000
Make and carry	10 A ≂
Break	10 A ~ 300 W ⎓

Electrical Withstand

Specification	Levels
Rated insulation voltage	300 V ≂
Dielectric test voltage	2.3 kV ~ for 1 min
Impulse test voltage	5 kV

Insulation Class I. Equipment must be earthed.

4.4 Electromagnetic Characteristics

Radiated Emissions

Specification	Levels
CISPR 11 30 – 230 MHz	40/50 dB qp 10/3m
CISPR 11 230 – 1000 MHz	47/57 dB qp 10/3m
CISPR 22 1 – 3 GHz	56 dB avg / 76 dB pk 3m
CISPR 22 3 – 6 GHz	60 dB avg / 80 dB pk 3m

Conducted Emissions

Specification	Levels
CISPR 22 0.15 – 0.5 MHz	79 dB qp / 66 dB avg
CISPR 22 0.5 – 30 MHz	73 dB qp / 60 dB avg

Electromagnetic Immunity

Specification	Levels
IEC 61000-4-2 Electrostatic discharge	6 kV contact
IEC 61000-4-3 Radiated radiofrequency interference	10 V/m rms
IEC 61000-4-4 Fast transient	4 kV (2kV comms)
IEC 61000-4-5 Surge	4 kV (2kV comms)
IEC 61000-4-6 Radiofrequency interference	10 V rms sweep
	10 V rms spot 27, 68 MHz
IEC 61000-4-8 Power frequency magnetic field	30 A/m continuous
	300 A/m 1 s – 3 s

4.5 Mechanical and Atmospheric Characteristics

IP Rating

Specification	Levels
From front of panel when mounted in normal position of use	IP54

Temperature

Specification		Levels
IEC 60255-1 dry heat and cold	operational	0 – +55 °C
	storage	-20 – +70 °C
IEC 60255-1 damp heat	operational	+55 °C 95% r.h.

Mechanical

Specification	Levels
IEC 60255-21-1 vibration	Severity class 1
IEC 60255-21-2 shock	Severity class 1
IEC 60255-21-2 bump	Severity class 1
IEC 60255-21-3 seismic	Severity class 1

Weight Unpackaged

Specification	Kg
Relay with no additional cards	7 Kg
Relay with all additional cards	8 Kg

4.6 Interposing CT specification

Electrical Characteristics

Parameter	Specified value
Ratio	10A : 0.01 A
Maximum primary current	10 A
Burden	0.03 VA
Isolation	> 3 kV
Material	UV 94-V-0 polyamide 66/6

Interposing CT turns

CT Secondary Rating	Recommended Turns
5 A	1
1 A	5
0.5 A	10

5 Ordering Options

5.1 Function Levels

Three levels of relay function are available: basic, advanced and ultimate which define the voltage and current measuring and voltage control functionalities of the relay.

Table 2 Function levels

Basic SG	AVC for 2-winding transformers Load drop compensation Parallel transformers Integrated control panel Tap-changer monitoring and runaway prevention Four voltage offsets Optional transformer oil and winding temperature measurements†
Advanced SG	All Basic SG functions + AVC for 3-winding transformers Feeder current measurements with advanced voltage control Stepped target adjustments * Transformer thermal monitoring + control † Eight voltage offsets
Ultimate SG *	All Advanced SG functions + Per feeder settings with ultimate voltage control Autonomous frequency- and load-based offsetting Tap Stagger

* Availability to be confirmed
† When DC analogue card fitted

5.2 Module Options

Table 3 Module locations

Slot:	A	B	C	D	E	F	G	H	I	J
Base hardware build	A/B PSU 4DI 7DO							P TPI	D 4V 3I	R CAN
Options:										
Additional digital I/O		G 5DI 4DO	G 5DI 4DO	G 5DI 4DO	G 5DI 4DO	G 5DI 4DO	G 5DI 4DO			
Additional AC inputs							F 7I			
DC analogue (mA and RTD)						K,L †AI AO RTD				
SCADA comms.										+ SCADA

† Module type K has 2AI, 3AO and 1RTD; module L has 1AI, 1AO and 3RTD

The following modules are fitted as standard:

- A: PSU 4DI 7DO — 110/230 V power supply with 6 digital input and 5 digital output relays prewired as tapchanger control scheme
- B: PSU 4DI 7DO — alternative to A for 24/48 VDC
- D: 4V 3I — 4 AC voltage inputs and 3 AC current inputs †
- P: TPI — Tap position inputs using resistor chain, binary, BCD, gray code, mA with motor current sense and TPI mA output
- R: CAN — Inter-relay communications

The following different module types are available as options:

- F: 7I — 7 AC current inputs
- G: 5DI 4DO — Digital I/O – 5 digital input and 4 digital output relays
- K: 2AI 3AO RTD — DC analogue – 2 mA inputs, 3 mA outputs and 1 RTD input (3 wire)
- L: 1AI 1AO 3RTD — DC analogue – 1 mA input, 1 mA output and 3 RTD inputs (3 wire)
- S: CAN+SCADA — Inter-relay and SCADA communications (replaces module type R)

† Basic SG function level only gives access to 3V & 1I.

5.3 Product Codes

The product code for the relay is defined in Table 4, including the most common I/O options which may be selected.

Table 4 SuperTAPP SG product code

Product Code	FP1034	-								P	D		-		v v	-		
Power Supply																		
110/230 V AC/DC			A															
24/48 V DC			B															
Digital I/O																		
Scheme I/O only (4I & 7O)				0	0	0	0											
Scheme I/O + 5I & 4O (1 c/o)				G	0	0	0											
Scheme I/O + 10I & 8O (2 c/o)				G	G	0	0											
Scheme I/O + 15I & 12O (3 c/o)				G	G	G	0											
Scheme I/O + 20I & 16O (5 c/o)				G	G	G	G											
Analogue DC																		
None								0										
mA 2I & 3O + PT100 input								K										
mA I & 1 O + 3 PT100 input								L										
AC Input Options																		
2 x 3ph. VTs & 3CTs									0									
2 x 3ph. VTs & 10CTs									F									
SCADA Communications																		
None												R		O				
IEC 61850, IEC 60870, DNP3												S		L				
Function Level																		
Basic SG																	1	
Advanced SG																	2	
Ultimate SG																	3	
Ethernet																		
None																		0
100base-T RJ45																		A
100base-SX (850nm MM) LC																		B
100base-T RJ45 x2																		C
100base-SX (850nm MM) LC x2																		D
100base-FX (1300nm MM) LC																		E
100base-FX (1300nm MM) LC x2																		F
100base-LX (1300nm SM) LC																		G
100base-LX (1300nm SM) LC x2																		H

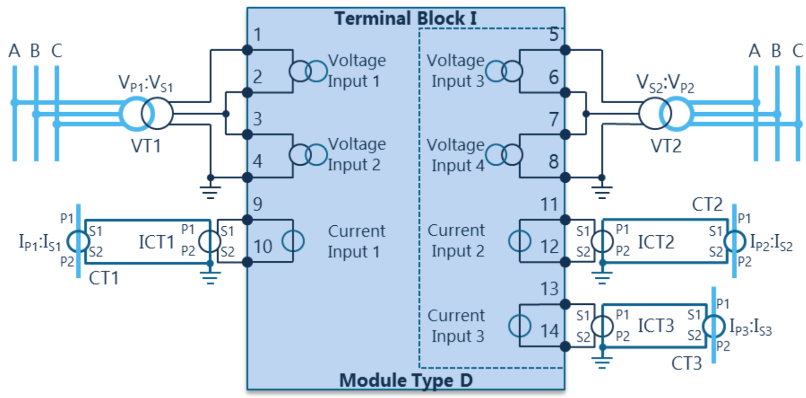
Note ‘v v’ in the product code is a 2-digit number indicating the hardware version. This data sheet is valid for hardware versions 04 and 05. Hardware version 05 has an extended voltage range on the tap changer interface and the data retention battery has been eliminated. For a full listing of differences between hardware versions please contact Fundamentals.

6 Connection Diagrams

The diagrams which follow show connection arrangements for the various modules which SuperTAPP SG can contain. All labelling and numbering is **typical**, with the exact allocation being dependent on the number, location and configuration of the modules fitted. Please refer to the connection diagram, provided on request and with each SuperTAPP SG, to determine the exact configuration and **do not rely on the numbering in these diagrams** *.

The user must refer to the relay code, printed on the front of the relay, to determine which module is in each location, and hence connected to which terminal block.

Figure 11 Typical connection diagram for AC input module (type D)



† Access to voltage input 4 and current inputs 2 & 3, only possible with Advanced or Ultimate SG function levels.

Figure 12 Typical connection diagram for power supply and scheme logic module (type A or B)

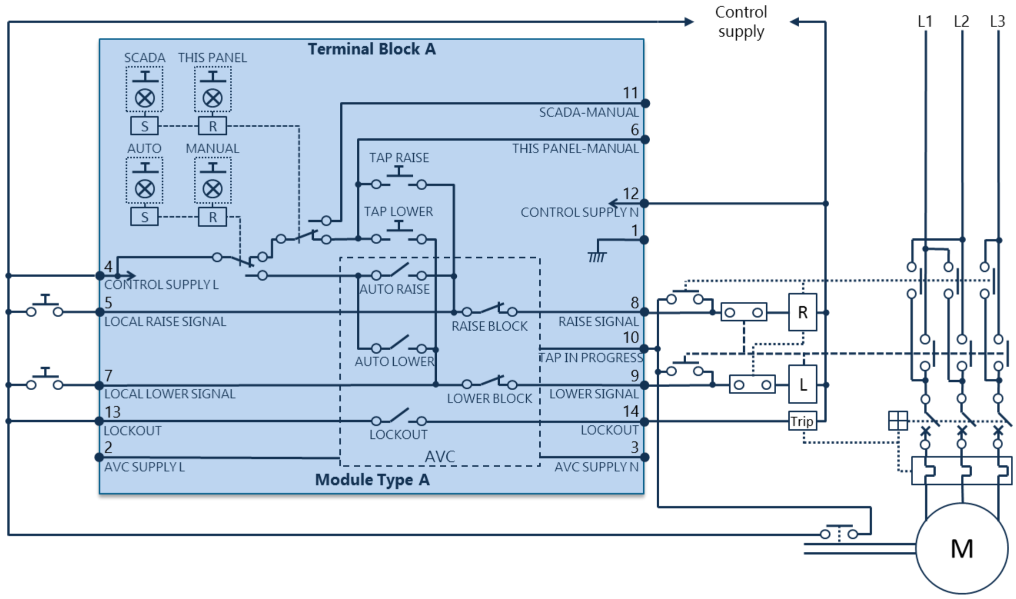


Figure 13 Typical connection diagram for inter-relay communications

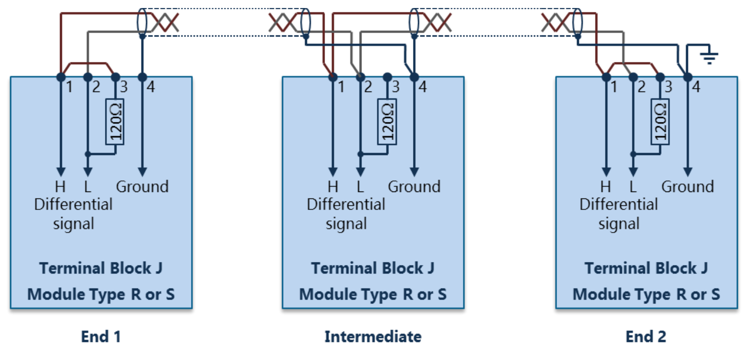


Figure 14 Typical connection diagram for tap position input module (type H)

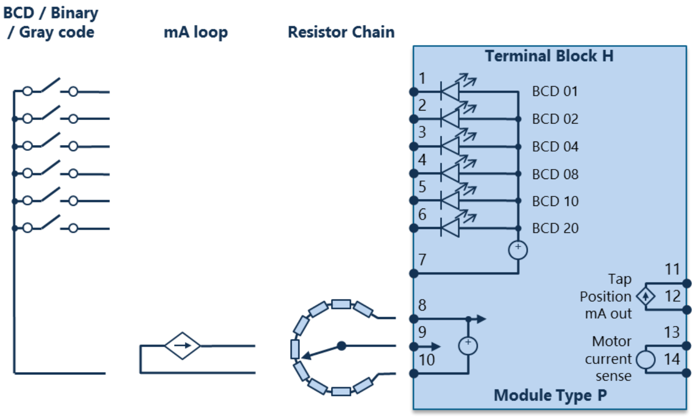


Figure 15 Terminal arrangements for additional I/O modules (type G)

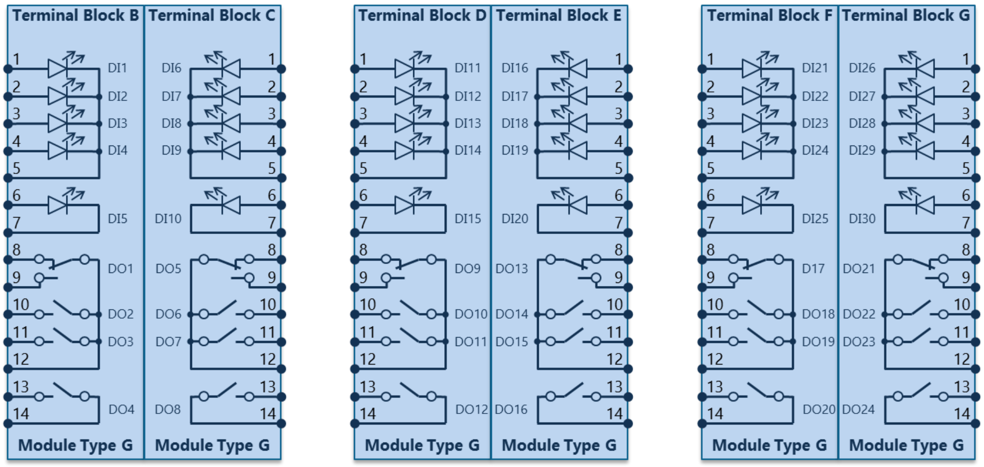


Figure 16 Terminal arrangements for DC analogue modules (type K and type L)

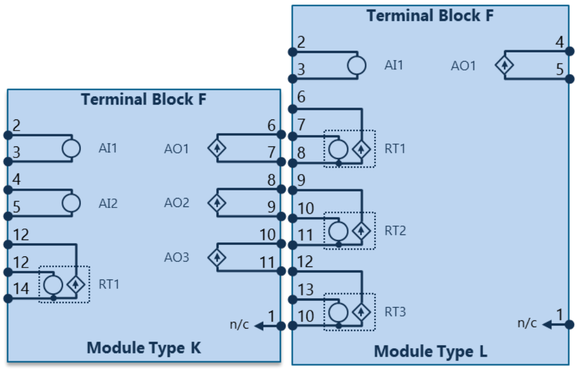
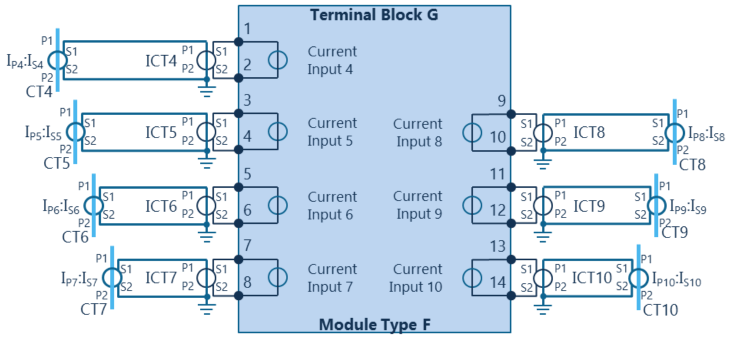


Figure 17 Terminal arrangements for AC input module (type F)



Fundamentals Services

Fundamentals Application Support

When you buy a Fundamentals product you can expect to receive expert assistance to apply your relay. Please contact your sales office or agent and we will do our best to advise you. We will gladly provide you with advice on an ad hoc basis, or if you have an extensive requirement for support, we can offer services for scheme design, panel builds, installation and commissioning.

Our global partners are carefully chosen to ensure that they have application support capabilities which are backed up by Fundamentals voltage control experts.

Other Services

Fundamentals can assist with all aspects of voltage control applications and transformer and tapchanger management:

- Design and engineering
- Panel/cubicle build
- Site surveys, installation, and commissioning
- Tapchanger health checks, maintenance, and reverse power assessments
- Transformer online dissolved gas analysis (DGA)
- Technical support and troubleshooting
- Power system analysis
- Generation connection assessment

FP1034-U-7 v2.1

United Kingdom and Europe

Fundamentals Ltd

Swindon
Unit 2, Hillmead Enterprise Park
Marshall Road, Swindon
Wiltshire, SN5 5FZ
United Kingdom
Tel: +44 (0)1793 847163
Fax: +44 (0)1793 847245
www.fundamentalsltd.co.uk
tech@fundamentalsltd.co.uk

Belfast
City East Business Centre
68-72 Newtownards Road
Belfast, BT4 1GW
United Kingdom

Australia

Fundamentals Australia Pty Ltd

Sydney
Unit 11, 25 Stoddart Road,
Prospect NSW 2148
Tel: +61 (0)2 9896 3221
www.fundamentalsltd.co.uk/australia

Value Added Resellers

Power Economy Middle East Co. LLC

U.A.E.
Industrial City of Abu Dhabi
P.O.Box 6072
Tel: +971-(0)2-5501077
sales@powereconomy.net
www.powereconomy.net

JET Engineering Solutions Sdn. Bhd.

Malaysia
(1284649-K) R-03A-22, Emporis,
Persiaran Surian, Kota Damansara,
47810 Petaling Jaya, Selangor.
info@jetengsolutions.com

FUNDAMENTALS