Contents

1. INTRODUCTION

The SuperTAPP voltage control system undergoes full calibration and functional checks during manufacture. Some on site checks are necessary to confirm correct operation of the relay and the external connections prior to operation.

Commissioning of equipment should only be carried out by skilled personnel trained in relay operation and capable of observing all the necessary safety precautions and regulations appropriate to this equipment and also the associated primary plant. Ensure that all test equipment and leads have been correctly maintained and are in good condition.

Full operational checks should be carried out with the transformer(s) on load using system voltage and currents to ensure that the VT/CT relationships, both phase angle and magnitude, are correct.

2. INSPECTION

A visual check should be made of all wiring to confirm correct connections. Pre-testing of the tap change mechanism is assumed for the purposes of this document.

3. TEST SUPPLIES

A good quality rms sensing voltmeter and a variable output transformer can be used to confirm operation of the relay.

4. TESTS

4.1. Insulation

It is an advantage to have an insulation resistance testing schedule. It is usual to measure and record the insulation resistance section by section, each section being defined by its supply sub-fuse. Insulation resistance can be measured before the supply fuses and links are inserted by testing from the load side of the fuse and link bases. These tests should be carried out with all the wiring in a section shorted together, therefore temporary connections will be needed to link-in any wiring separated by normally open contacts etc.. While tests are being carried out on one section all other sections should be earthed using temporary connections.

Where particular circuits are normally earthed, e.g. C.T. secondary circuits, one earth link at a time should be removed to permit the testing of its associated circuits. Replacement of the earthing links and the removal of all temporary connections, including temporary earth connections, should be confirmed by an entry in the insulation resistance testing schedule.

The insulation resistance values that should be considered to be acceptable depends upon the amount of wiring involved. Where a considerable amount of multi-core cabling is included, a reading of 2.5 to 3.0 megohms is reasonable, but for shorter lengths of panel wiring, higher readings should be expected. A reading 1.0 megohm or less should not be considered satisfactory and should be investigated.

5. RVM VOLTAGE CONTROL RELAYS

5.1. Secondary Current Injection

The current transformer which is used for LDC purposes will be mounted either at the transformer or the transformer LV circuit breaker. Injection testing to confirm CT quality and suitability is carried out as part of the testing regimes for these items, no CT injection tests should, therefore, be required.

It should be noted, however, that the SuperTAPP system requires a VT/CT relationship of 30° current leading and the on load commissioning test should confirm this relationship. In the case of a CT mounted within a circuit breaker the CT polarity will normally be reversed in terms of the load current flow. The description of operation section 1 of this document gives more information in respect of the choice of VT and CT.

5.2. Secondary Voltage Injection

A variable output transformer can be used to confirm the relay operation at key set-points. The tables below give examples :

Voltmeter

For testing purposes the Digital voltmeter (DVM) can be calibrated to the secondary voltage, say 110V for easier commissioning testing. When finally on load the DVM can be set to the system voltage using the VT output as a reference.

Basic level

With the VT and CT out of service and the operation of the tap changer inhibited, use a Variac connected to terminals 21 & 22 of the relay to apply 110V AC.

Vary the voltage applied to confirm the Basic and Bandwidth control settings.

Basic %	± Band %	High Ind. (V)	Low. Ind. (V)	Tolerance of nom. (%)
95	1			1
100	1			0.5
105	1			1
100	2.5			0.5

Fast tap down

Raise voltage until High + 2% LED indicates and confirm operation of tap pulse after 4 seconds. Check inhibit switch

Basic %	± Band %	High Ind. (V)	Tolerance (%)
100	1		0.5

< 80% Inhibit

With bandwidth setting at 1% reduce voltage until 80% LED indicates. Check voltage is at 80% of basic setting and that the timing sequence is inhibited.

Basic %	± Band %	Inhibit Ind. (V)	Tolerance
100	1		87-89V

Voltage Offset
With the basic level set to 100% operate the Voltage Offset to confirm the correct indication and effect.

5.3. Timers

With the Basic set to 100% and the relay balanced (green LED on), rotate the basic control until a LOW indication is shown. At the end of the test the relay should be allowed to operate until the alarm is initiated.

Initial Delay	Inter-tap Delay	Time	Tolerance (sec)
Minimum		sec.	10 ± 0.5
	Minimum	sec.	5 ± 0.5
Maximum		sec.	120 ± 2
	Maximum	sec.	60 ± 1

Alarm	min.	15min. ± 10sec

5.3.1. Inter-Tap Delay Setting.

Set the inter-tap delay setting on the voltage regulating relay to be longer than the total operating time of the tap-changer plus a 25% safety margin to allow for increased operating times in colder weather etc., and longer than the indication of 'in progress' if either the RTMU or RTPI with runaway prevention is used for protection of the tap change system before a further tap-change is initiated, otherwise continuous tapping will be assumed and a lockout initiated.

5.4. On Load checks

5.4.1. Summation Bus-wiring

The arrangement for the inter-connecting buswires is shown in figure 1. Using a 'clothes peg' CT measure the current flowing in the secondary wiring as follows:
On each unit the transformer load, in secondary terms, should be measured flowing into terminal 3.

The summated substation load should be measured flowing in bus-wires 2-5 between each relay. The CT connections used with the SuperTAPP relay allow for 0.5A, lA or 5A CT secondary outputs. The input matching transformer in the SuperTAPP changes any input to a common 0.5A value. This ratio change must be taken into account when confirmation of the correct load summation is made.

As an example, consider the following arrangements:

1. 2 x l0MVA transformers, 25% full load on each, 500/l LDC CT. If a lA CT is used the output current from each CT will be 250mA. As the lA secondary is changed to 0.5A by the input matching transformer this current will now be 125mA, and the summated load in bus-wire 2-5 will be 125mA + 125mA = 250mA.

2. 2 x l0MVA transformers, 25% full load on each, 500/5 LDC CT. If a 5A CT is used the output current from each CT will be 1250mA. As the 5A secondary is changed to 0.5A by the input matching transformer this current will now be 125mA, and the summated load in bus-wire 2-5 will be 125mA + 125mA = 250mA.

3. 3 x l0MVA transformers, 25% full load on each, 500/l LDC CT. If a lA CT is used the output current from each CT will be 250mA. As the lA secondary is changed to 0.5A by the input matching transformer this current will now be 125mA, and the summated load in bus-wire 2-5 will be 125mA + 125mA + 125mA = 375mA.

Terminal	T1	T2	T3	T4
3	mA	mA	mA	mA
2 or 5	mA	mA	mA	mA

Note: For a 2 transformer arrangement, T2 will be connected as the "last" transformer. For a 3 transformer arrangement, T3 will be connected as the "last" transformer. For a 4 transformer arrangement, T4 will be connected as the "last" transformer.

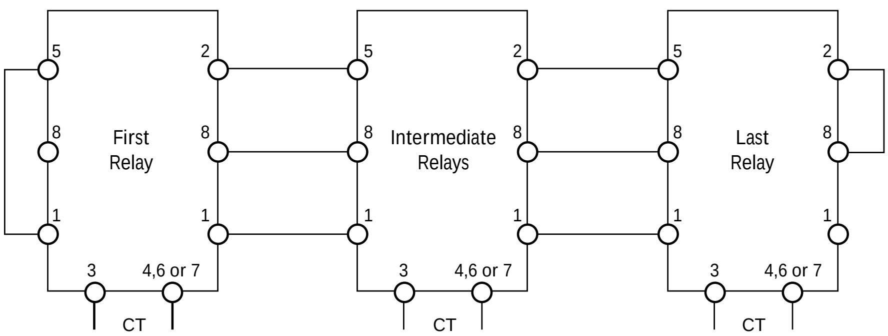


FIGURE 1 INTERCONNECTIONS BETWEEN RELAYS FOR PARALLEL TRANSFORMERS

5.4.2. CT/VT phasing check

The VT/CT connection relationship must be 30° current leading. This can be confirmed by observing the relay response as follows:

Initial Conditions:

- Circulating current should be at a minimum level and if possible the transformers should be on load
- Fast tap down on relay should be disabled (0)
- Initial and Inter tap delays set to maximum
- Band to minimum (±1 %)
- LDC to 0%
- Coupling to mid position
- Adjust Basic set-point midway between HIGH and LOW

Test as follows:
Increase each LDC until either HIGH or LOW led indicates, or to maximum. If the VT/CT relationship is correct the relay should respond by measuring an apparently lower voltage, i.e. a tendency to increase the transformer output voltage. The LDC setting at which this occurs should be equivalent to a 1% boost for the site load because the effective measuring point is moved by one half of the deadband (1%) by adjustment of the LDC control, e.g. if the site is on 1/4 full load for this test it would be expected that the LDC would be advanced to 4% to give an effective boost of 1%. Allowance must be made if the current transformer used for LDC is not rated to the transformer capacity.

If this test shows that the direction is reversed the VT connections can be reversed to correct the relay sense and the above tests repeated.

If this test shows that the expected LDC setting is exceeded greatly or that the relay does not respond, VT/CT phase relationship may be incorrect, which the next test will confirm.

Return LDC to 0%.

Rotate the Coupling control fully in both directions, the relay should not respond. If a response is noted, then the previous test for LDC effect should have indicated a sluggish response and shows that the VT/CT phase relationship is incorrect.

If the LDC and Coupling checks are correct other relays in the group can be checked in the same manner.

The table below will allow the results to be analysed for confirmation of the correct operation of the system.

	LDC	Coupling	Action
30º Lead	Low LED at 1% equivalent LDC	Minimum of No effect	None
30º Lead Reversed	High LED at 1% equivalent LDC	Minimum or No effect	Reverse VT Connections

The above table can be used where the power factor is 'normal', say from unity down to 0.94 lag. If the test is inconclusive a Power Factor meter should be used to confirm the correct relationship between the VT and CT.

The final checks vary depending upon the number of transformers that form a group at a single location and are connected with inter-unit wiring.

5.4.3. Single transformer

For this test the network supplied by the transformer should be operated in parallel with a remote substation. With transformers at each end set to non-auto the tap changers should be operated to reduce the circulating current to a minimum.

The following confirmation checks may now be carried out:

1. Set band to minimum (±1%)
2. Set LDC to 0%
3. Switch tap change to auto
4. Adjust basic setting midway between High and Low indications
5. Switch to non-auto
6. Tap down transformer by 2 taps
7. Reduce the Basic setting by the amount that the voltage has changed
8. Switch tap change to auto
9. Relay should require a raise operation (Low LED on)
10. Set basic setting to normal
11. Allow tap change operations to return voltage to normal

5.4.4. Two transformer substation

For this test the 2 transformers should be arranged such that the busbar voltage is normal and no circulating current is flowing.

The following procedure should now be carried out:

1. Set band to minimum (±1%) on each relay
2. Set LDC to 0% on each relay
3. Switch tap changers to auto
4. Adjust basic setting midway between High and Low indications on each relay, note the position
5. Switch to non-auto
6. Tap down transformer 1 by 1 tap
7. Tap up transformer 2 by 1 tap
8. Switch tap change to auto
9. Transformer 1 relay should require a raise operation (Low LED on)
10. Transformer 2 relay should require a lower operation (High LED on)
11. Allow tap change operations to return transformers to correct tap position
12. Switch tap changers to non-auto

High impedance transformers

Circulating current between transformers is essentially determined by the sum of the transformer impedance's and the difference in the terminal voltages. When the overall network impedance is high the test detailed above may not result in the transformers operating to the same tap position immediately.

A further tests can be carried out to confirm the correct operation of the SuperTAPP system in these circumstances:-

A. As the magnitude of circulating current is small the transformers can be operated 2 taps up and 2 taps down. The above procedure 5.4.4 can then be resumed from step 8.

B. If difficulty is still experienced in confirmation of the relay action, or it is not felt desirable to operate the transformers more than two taps apart, the following test can be carried out.

1. Carry out the above procedure 5.4.4 up to step 7.

2. With the transformers 2 taps apart, for the transformer on the HIGHER tap, carefully rotate the basic control knob anticlockwise until the HIGH led is ON. Note the position.

3. Rotate the Basic control knob clockwise until the LOW led is ON. Note the position.

4. Confirm that the balance point of the Basic control has moved such that the transformer on the higher tap is BIASED towards the LOWER direction.

5. With the transformers 2 taps apart, for the transformer on the LOWER tap, carefully rotate the basic control knob clockwise until the LOW led is ON. Note the position.

6. Rotate the Basic control knob anticlockwise until the HIGH led is ON. Note the position.

7. Confirm that the balance point of the Basic control has moved such that the transformer on the lower tap is BIASED towards the RAISE direction.

5.4.5. Three and four transformer substations

These tests can be carried out using the principle for a 2 transformer substation. The transformers should be arranged such that the busbar voltage is normal and no circulating current is flowing.

The following procedure should now be carried out:

1. Carry out procedure for a 2 transformer substation on T1 and T2
2. Carry out procedure for a 2 transformer substation on T2 and T3
3. Carry out procedure for a 2 transformer substation on T3 and T4

5.4.6. Final Setting up

1. Adjust all settings to the required values
2. Switch all tap change controls to auto and allow relays to achieve balance
3. Make fine adjustments to Basic, Bandwidth and LDC settings
4. Monitor voltage levels, transformer loads and operation counter over a period (say 2 weeks) to confirm correct system operation under various load conditions

5.5. Power Factor

In some circumstances low system power factors can cause a drooping voltage with increasing load. Although the design of the SuperTAPP system reduces this effect, which is common to all negative reactance type systems, some compensation may be required if the effect is noticeable.

Table 1 gives a range of LDC settings that may be applied to maintain a level characteristic for a range of low power factor loads. This adjustment is additional to any LDC applied for load.

By design, the relay coupling control settings are made to give optimum performance when set to the transformer nameplate impedance. However, a reduced setting will still be effective in the minimisation of circulating current, and in practice a minimum coupling setting of 6% applied to high impedance transformers will give satisfactory operation. If switched in at widely different tap positions transformers will not tap together as quickly as for the correct setting, but, as the impedance is high a small circulating current will flow. Following normal tapping for voltage regulation, any tap change operations will bring the transformers to the same tap positions (if identical).
e.g. If a design coupling setting of 15% is required and the power factor is 0.9, either of the following adjustments can be made :

Power Factor	6% Coupling	10% Coupling	15% Coupling
0.96	0	0	0
0.94	0	0.5%	1.0%
0.92	0.5%	1.0%	1.5%
0.90	1.0%	1.5%	2.0%

Table 1

1 Increase LDC by 2%, or
2 Reduce coupling control to 6% and increase LDC by 1%

These settings are provided as a guide only, fine tuning should be carried out after a network survey to confirm the correct operation of the voltage control system.

6. RTMU AND RTPI MONITOR RELAYS

6.1. Control Module (RTMU only)

The module may be panel mounted or rack mounted as required. A check should be made to ensure that the tap changer functions correctly for both automatic and manual operations.

6.2. Tap Position Indicator.

Three connections are required to a remote resistance type sender unit. Please note that on some older types of control circuit the 110V a.c. supply may have been connected directly across the remote sender unit and in this case it must be removed before connecting the new unit.

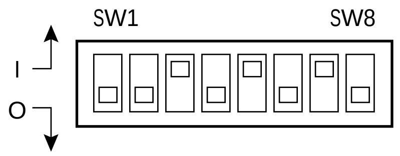
For older units it is recommended that the opportunity is taken to clean and lubricate the contacts of the remote sender unit particularly if the Runaway Prevention feature is to be used.

6.2.1. Conditioning

The site conditioning switches are located at the bottom right of the RTMU fascia plate, see Description of Operation section of this document and are arranged as shown below

Maximum Tap Position

For calculation of the actual tap position SW1 to SW4 must be set for the maximum number of taps for the particular tap changer.



Site Conditioning Switch

If the tap changer has an even number of taps with a resistor type sender unit, an extra resistor should be inserted at the top of the resistor chain and the switch selected for Max.+1.

Number of Taps	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
11	O	O	O	O				
13	I	O	O	O				
15	O	I	O	O				
17	I	I	O	O				
19	O	O	I	O				
21	I	O	I	O				
23	O	I	I	O				
25	I	I	I	O				
27	O	O	O	I				
29	I	O	O	I				
31	O	I	O	I				
33	I	I	O	I				
35	O	O	I	I				
37	I	O	I	I				
39	O	I	I	I				
41	I	I	I	I				

Type of Sender Unit

Set SW5 according to the type of sender unit, resistor or binary coded decimal (BCD).

Type of Tap change

Some tap changers have transitional tap positions where more than one operation is carried out for a single raise or lower

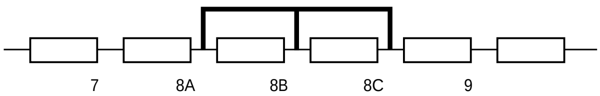
	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
Resistor					I			
BCD					O			

control signal. Furthermore, some tap changers have these transfer positions indicated as, say, 8A, 8B & 8C where positions 8B and 8C are not used for voltage change. For the same effect another tap changer may have positions 8, 9 &10 where 8 & 10 are not used for voltage change.

To clarify the types of transfer tap changers, those with suffix letters A B C etc. are termed 'suffix' type, those with discrete numbers, e.g. 8 9 10 are termed 'discrete' type.

Where the relay is used with a 'suffix' type tap changer the sender unit (resistor or BCD) should be arranged to send the same signal for each of the suffix positions and SW6 should be set to Off (normal). Resistor types should have the appropriate resistors on the sender unit shorted out, see diagram below.

Where the relay is used with a tap change having "discrete" transfer positions, this switch should be set to On (transfer). The relay is normally supplied to allow for two "discrete" transfer tap change operations per control signal.



Replacement controller IC's are available on request for non-standard schemes including BCD with an even number of taps and Discrete types with more than 2 consecutive transfer operations.

	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
Transfer						I		
Normal						O		

6.2.2. TPI Operation

- Operate the tap changer to the highest tap position and confirm correct indications. If the transformer cannot be taken out of service the top tap position can conveniently be simulated by temporarily disconnecting the wire going to terminal 26 and then shorting 26 to 27.
- After replacing any temporary connections, check the indication through the full range of the tap-changer (if possible).

In the unlikely event that satisfactory calibration cannot be obtained, the sender unit resistors should be replaced. Suitable resistors are 100ohm, 1Watt, 1% tolerance metal film resistors.

6.2.3. Checking for Normal Operation.

- Operate the tap changer in the raise direction and observe the normal correct operation of tap changer. Immediately the "in Progress" LED goes off, operate the tap change once more in the same direction and again observe correct operation.
- Repeat for the lower direction.

Induced voltages on quiescent "raise", "lower" and "In Progress" wiring can, if excessive, power the In Progress LED. The application of a 0.22µF mains suppression capacitor between the relevant input terminals and "neutral" of the RTMU or RTPI relays will attenuate these false signals

6.2.4. Checking for Lockout.

- Carry out a raise operation but this time simulate a potential runaway condition by permanently energising the "raise" contactor or, alternatively, by repeated operation of the tap change control switch. The runaway Prevention Unit should lock out soon after the first complete tap change operation, depending on the tap change operating time.

- Repeat for the lower direction.

For very fast tap change mechanisms more than one tap change operation may occur before the lockout operates. In this case great care should be exercised if the test is carried out with the transformer on load.

6.3. Voltage Monitor (RTMU only)

Determination of High and Low Alarm Settings.

The High setting is calculated using the formula:

(Basic Voltage %) + (Full Load LDC Boost%)
+ (Upper Bandwidth %) + (1/2% for safety)

Similarly the low setting formula is :

(Basic Voltage %) - (6% Load Shed) - (Lower Bandwidth %)
- (1/2% for safety)

e.g. With a 100% basic setting, a 5% LDC setting and a plus/minus 1.5% band width setting the "high" setting would be 107% and the "low" setting 92%

The raise and lower "inhibit" relays are automatically set to operate 2% before the "Alarm" settings thus preventing the tap changer from operating in a direction which would cause the voltage to go outside the alarm limits.

6.3.1. Checking for Correct Operation.

The voltage monitor can be checked using a variable test supply and an accurate voltmeter, voltage difference feature will need to be disabled. The "High" and "Low" LED's will indicate when the alarm settings are reached. During this test the proper functioning of the inhibit circuits and 15 minute alarm can also be checked

Voltage Difference

SW7 should be set for phase voltage difference detection
SW8 determines the voltage difference sensitivity
The correct operation of the voltage difference detector can be confirmed by removal of the VT fuse which does not supply the RVM relay. In this case the voltage monitor will block any raise control signals.

	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
Disable							I	
Enable							O	

	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
10%								I
5%								O

- Set basic control to force RVM relay to raise voltage
- Confirm 'raise' control signals are blocked