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This manual covers all SuperTAPP relays manufactured from September 1997. Earlier relays do not necessarily incorporate all the features described. Our policy of continuous improvement may mean that extra features and functionality have been added.

DESCRIPTION OF OPERATION
RVM Voltage Control Relays

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SUPERTAPP

Contents

1. INTRODUCTION

Large power transformers are generally provided with motorised tap changing equipment which allows the output voltage to be regulated by a voltage control relay. Over many years systems have grown in complexity to the point where it is not unusual for the voltage control system of each transformer to occupy a complete control panel. The SuperTAPP system has simplified voltage control to a point where only the voltage regulating relay and a few other components are necessary.

SuperTAPP is based on a modified Negative Reactance principle, it allows up to 4 transformers to be operated in parallel at the same site without the need for complex control circuits. System power transformers with otherwise incompatible tap change control schemes can easily be made to operate in parallel and networks can be paralleled without first inhibiting the automatic voltage control. It gives a very good line drop compensation performance over the normal range of system power factors and avoids the drooping characteristic associated with normal negative reactance schemes at normal power system power factors.

2. VOLTAGE CONTROL FUNCTIONS

2.1. Voltage Measurement

Connections from the line voltage transformer are used for separate basic voltage level measurement and voltage level indication via the integral Digital Voltmeter (DVM). Each measuring element determines the true rms value of the incoming signal by use of an rms computational IC.

2.1.1. Basic Voltage

The nominal factory setting for the measuring circuit is 110V = 100%.

This setting can be adjusted on site for nominal voltages in the range 60V to 140V achieved by use of a setting adjustment (see settings).

2.1.2. Digital Voltmeter

The DVM is adjustable on site to indicate the local primary system voltage in the range of approximately 2kV to 520kV and achieved by use of a setting adjustment (see user interface).

2.2. Current Measurement

A 30° Current leading Voltage connection for normal phase rotation is required. External relay connections are provided for current transformers with 0.5A, lA, or 5A secondary outputs.

2.3. Output Contacts

2.3.1. Alarms.

If voltage remains outside the normal bandwidth of the relay continuously for more than 15 minutes an alarm contact operates and the raise/lower control circuit is inhibited. The alarm is reset when the measured voltage is restored within the normal dead band.
The alarm is disabled if the measured voltage is less than 80% of nominal.

2.3.2. Tap change control

An output relay with make contacts is provided for each of the tap change control functions; Raise and Lower.

2.4 Input Connections

Four inputs are provided for use with SCADA systems which allow the Basic level setting of the relay to be altered as follows :

3%	Voltage reduction
6%	Voltage reduction
1.5%	Voltage increase
3%	Voltage increase

These inputs may be mixed to give the following remote voltage adjustment :

Input Used	Revised Basic Level
-3%, -6%	Basic -9%*
-3%, -6%, +1.5%	Basic -7.5%*
-6%	Basic -6%
-6%, +1.5%	Basic -4.5%
-3%	Basic -3%
-3%, +1.5%	Basic -1.5%
Normal	Basic
+1.5%	Basic +1.5%
+3%	Basic +3%
+1.5%, +3%	Basic +4.5%

* Only allowed if Voltage reduction add switch set

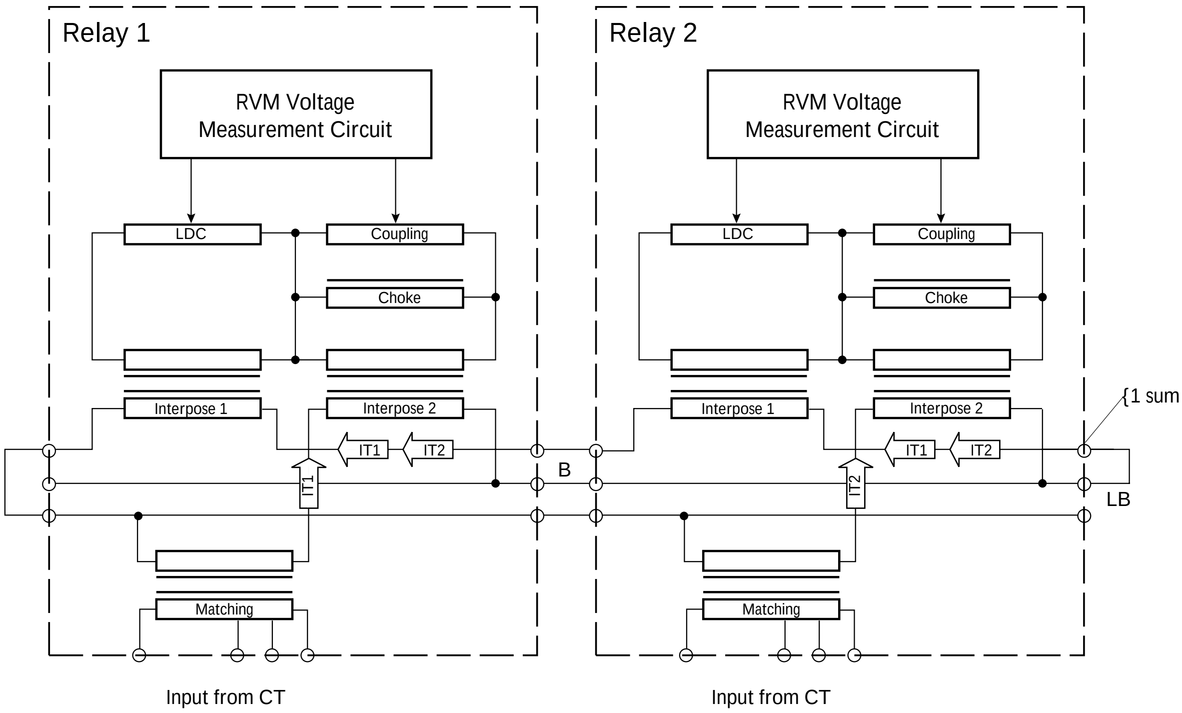

Figure 1 TAPP circuit - Current summation

3. DESIGN

3. 1. TAPP

To demonstrate the basic design of the TAPP circuit, figure 1 and 2 show the current circuit interconnections made between two SuperTAPP relays in a typical 2 transformer installation. The relay is designed to function correctly with a 30° relationship between the VT secondary voltage and the load secondary current.

Transformer load consists of two components, power system load and inter-transformer circulating current. Referring to Figure 1, current from the load sensing current transformer (CT), IT1 & IT2, on each power transformer respectively is injected into the inter relay bus wiring via the matching interpose transformer, used to convert the CT secondary output to a standard 0.5A output.

The load current from each matching transformer is passed through Interpose 2, producing a voltage across the choke. This voltage leads the current by an angle approaching 90° and by virtue of the 30° VT/CT connection arrangement and internal design, is made to be ineffective at normal system power factors.

After passing through the interpose transformer, the current from each relay is summated by use of bus wire B and link LB on the last relay in the group. The summated current, Isum (ITl+IT2), is now passed through each Interpose 1 transformer, the current from which is used to produce a voltage across the single Load Drop Compensation control (LDC). This voltage is in phase with the load current and by virtue of the 30° connection arrangement is made to be extremely effective at normal system power factors and accurate under practical network conditions. It is important to note here that Isum represents the total connected load at a site regardless of the number of transformers in service.

The summation circuitry is designed for use with up to 4 transformers operated in parallel. If more than this number are used, each relay can be configured as a single transformer (see 4.1 control of multiple transformers).

When 2 or more transformers are connected in parallel either within the same site or across a network a reactive circulating current may flow between them unless the following conditions are met:

- The transformers are identical
- The transformers have the same number of taps and tapping interval
- The transformers are always on the same tap position
- The transformers have the same impedance

- The transformers are fed from the same primary source or, more correctly, have the same voltage applied to the primary winding connections

These conditions put constraints on power system design which are eliminated by the SuperTAPP voltage control system. Any circulating current is minimised as follows.

Under the condition where circulating current flows between transformers, figure 2 shows the action of the TAPP circuitry for a typical 2 transformer arrangement where one transformer may be on a higher tap. If a circulating current is exported from the first transformer it will flow into the terminals of the second transformer. The secondary CT currents flowing as a result of circulating currents flow in the TAPP circuitry as shown. The circulating current (Icirc) flowing from the matching interpose transformer in relay 1 passes through Interpose 2 the current from which produces a voltage across the choke. This voltage leads the circulating current by an amount approaching 90°. As circulating current is highly reactive. and therefore lagging the normal load power factor by a substantial amount, the voltage produced is now highly effective in the relay measuring circuitry. By design this voltage is made to increase the measured voltage if a transformer is exporting reactive circulating current (on a higher tap) and reduce the measured voltage if a transformer is importing reactive circulating current (on a lower tap), resulting in a tendency for the transformer on the higher tap to tap down and a tendency for the transformer on the lower tap to tap up.

It can also be noted by reference to figure 2 that no component of circulating current flows along the summation bus wire and through the LDC section of the measuring circuitry thus enabling the SuperTAPP relay to respond to the total connected load at all times and not to the individual transformer loads. Also, as the inter-relay bus-wiring is only used for LDC purposes, circulating current, from the transformers into the network is detected and minimised in the same way as for transformers connected to a common busbar.

3.2. Measurement & Control

Figure 3 shows the internal functional action of the RVM voltage control relay. A voltage applied to the measuring circuit of the relay equivalent to the basic set-point level is modified by the LDC required and the bias level for any circulating current which may be flowing. The single resulting voltage is presented to a chain of comparators, the trigger level of each being dependent upon the relay settings. The trigger level of the upper and lower limits of 'normal' voltage is designed with approximately 1/4% hysteresis to ensure a definite relay response when the system voltage is fluctuating around the upper or lower deadband.

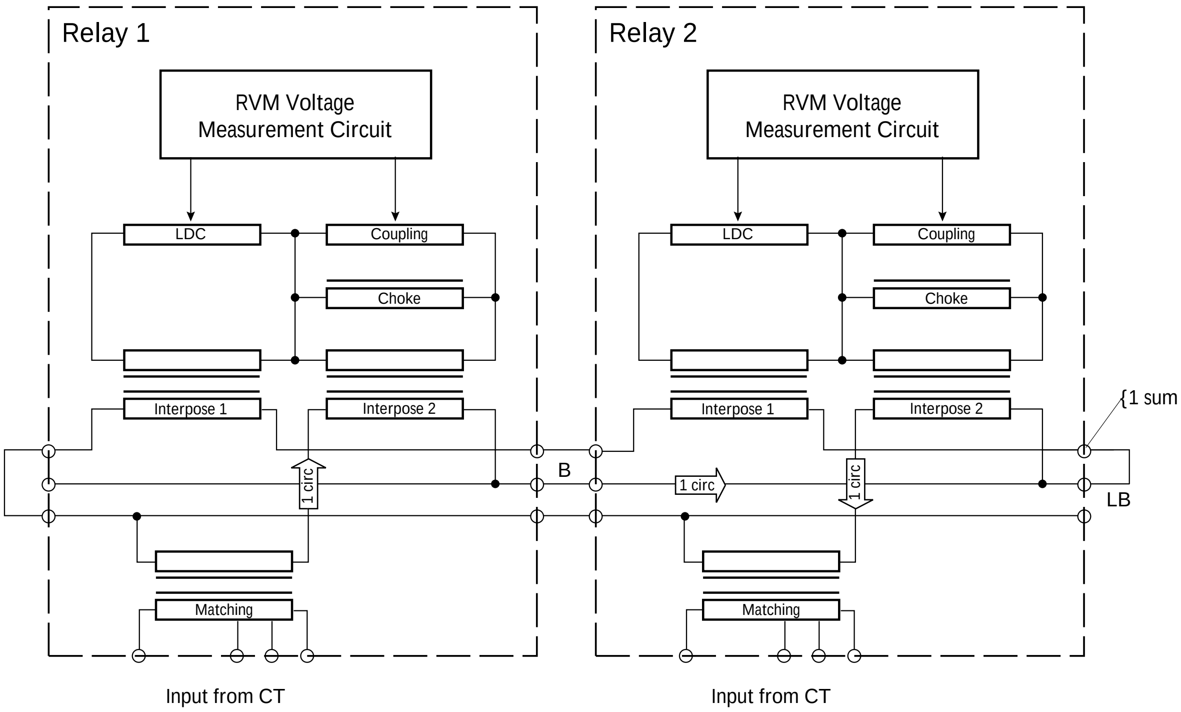

Figure 2 TAPP circuit - Circulating current summation

Following a persistent excursion of measured effective voltage outside of the deadband, the relay will output a control pulse to initiate a tap change operation unless the voltage falls below 80% of the basic setpoint in which case tap changing and alarms will be inhibited. The length of the control pulse is designed to be sufficient to ensure that the tap change maintaining mechanism takes over to complete the tap changing operation.

For security, a tap change pulse is only allowed when:

- the voltage is outside of the deadband
- a timing interval is complete
- a tap change pulse in the opposite direction is inhibited
- a voltage swing through the deadband does not occur

Given a normal phase rotation of ABC the relationship between measuring voltage and CT secondary current for a 30° connection is:

Voltage 21 - 22	Current S2 - 3, S1 - 4, 6 or 7
A - B	B
B - C	C
C - A	A

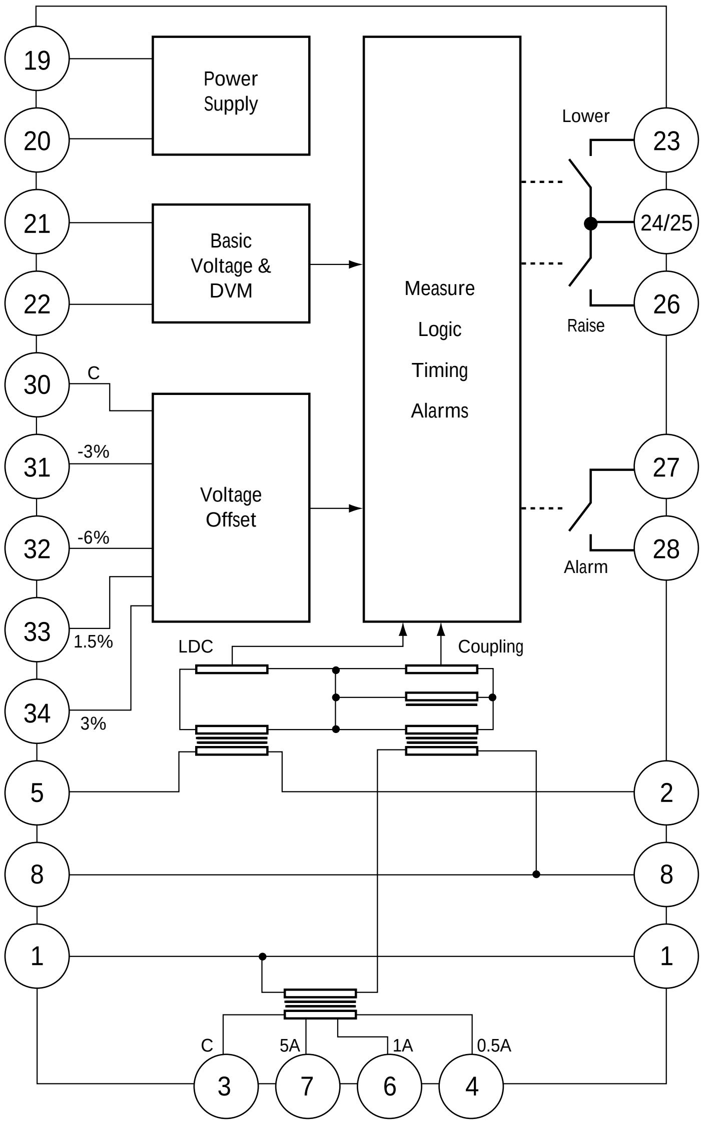

Figure 3 RVM Block Diagram

4. DESCRIPTION OF FEATURES

4.1. Control of Multiple Transformers

When SuperTAPP relays are used to control the tap changers of transformers at the same site, 3 buswires may be used to allow summation of load current for LDC purposes, as previously described. To complete the summation circuitry a loop between connections 1 & 5 on the first unit and between 2 & 8 on the last unit is necessary, Figure 4. The buswires are not used for circulating current detection.
If a relay is used with a single transformer then loops 2-8 and 1-5 are needed to complete the LDC and Coupling circuitry.

4.2. Dissimilar Transformers

Where transformers are operated in parallel, circulating currents will flow between them unless the individual tap changes are arranged to be on positions of equal voltage output. The modified negative reactance principle used in the SuperTAPP relay detects and minimises any circulating current, thereby allowing any transformers with a suitable tapping range to be paralleled.

4.3. Network Operation

Where networks are operated in parallel, either as a permanent arrangement or for short periods during network abnormalities, circulating currents will flow between transformers coupled via the network. The modified negative reactance principle used in the SuperTAPP relay detects and minimises any circulating currents flowing through networks while at the same time maintaining correct voltage levels.

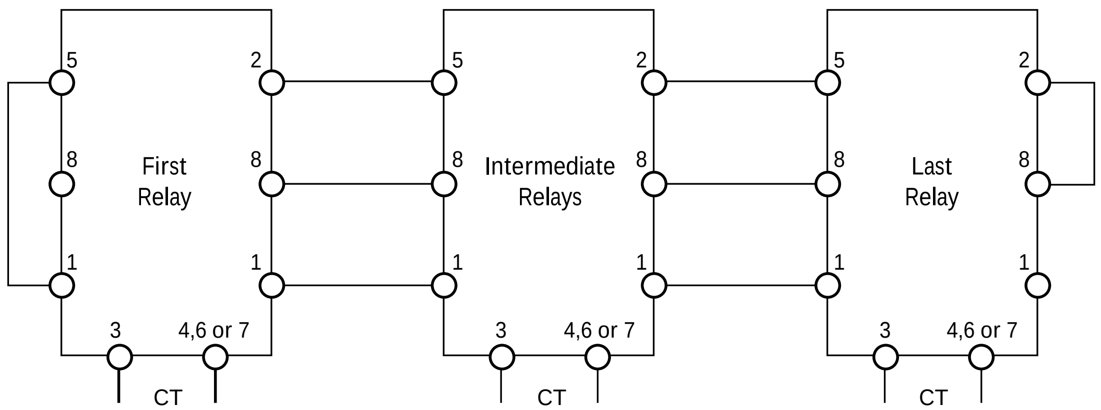

Figure 4 Interconnections between relays for load drop compensation

5 USER INTERFACE

5.1. General

The design of the relay fascia plate (RVM/5 and RVM/4) is user friendly. From the digital voltmeter, indicating the system voltage level, the control process is shown as a series of logical functions progressing to the output of a tap change control.

Figures 5 & 6 show the layout of the relay fascia plate with the site conditioning settings which are exposed with the front cover removed.

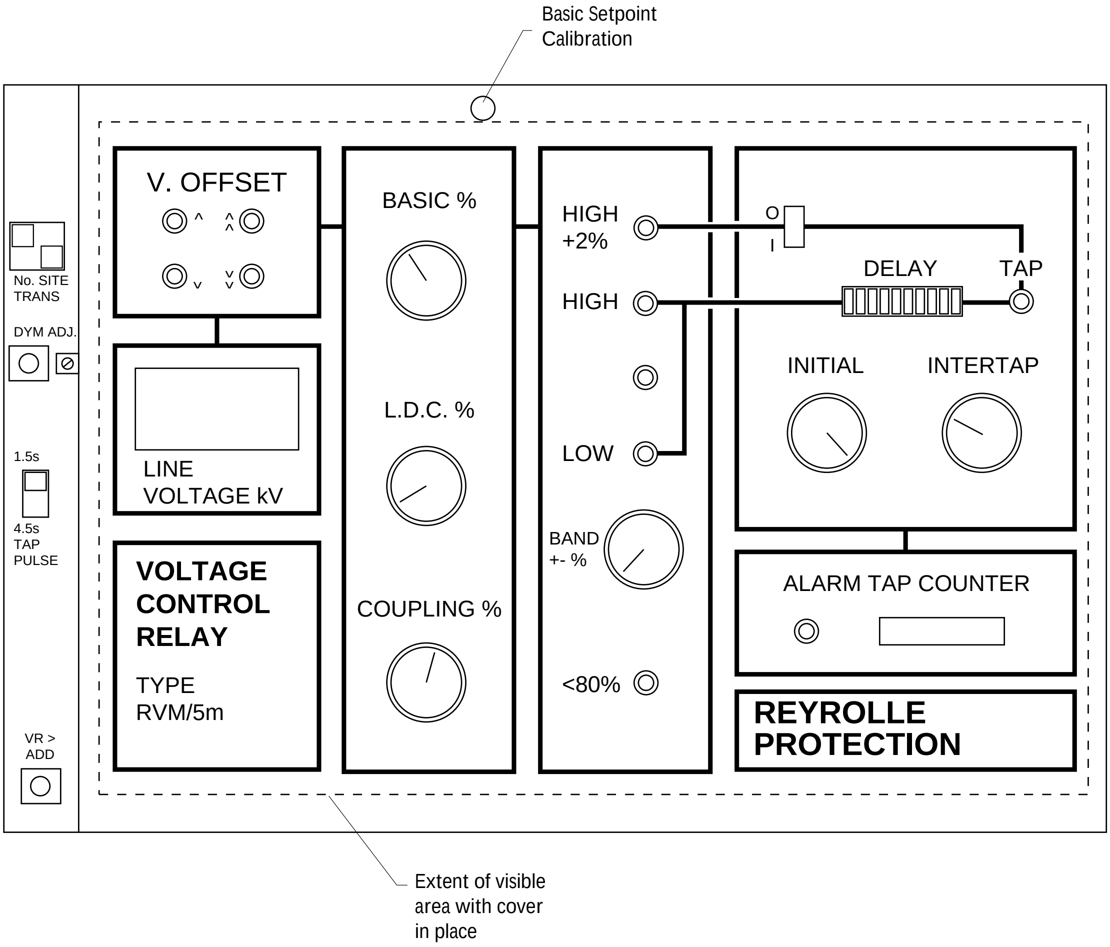

Figure 5 RVM/5m Relay Fascia Plate

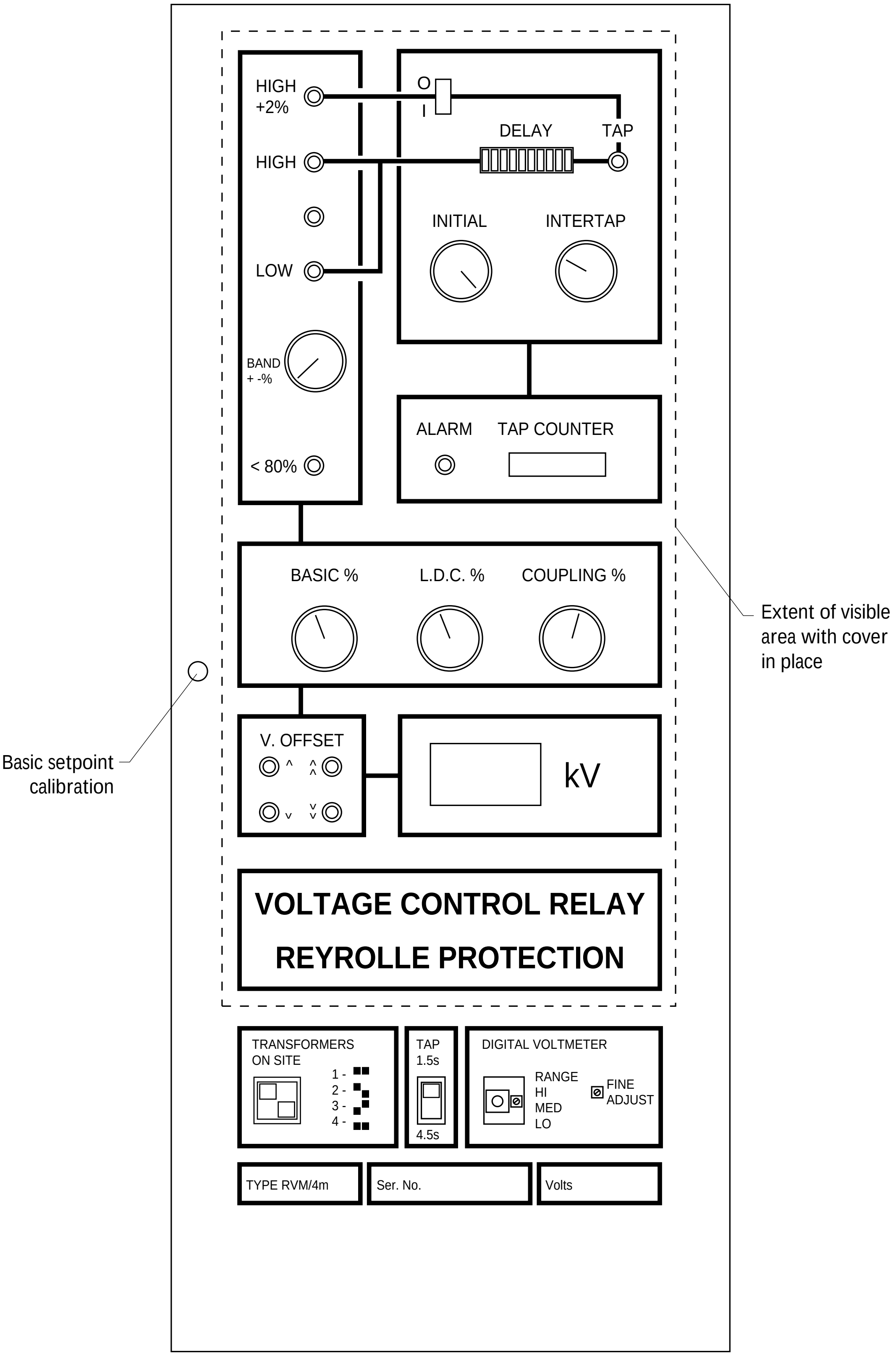

Figure 6 RVM/4m Fascia Plate

5.2. Indications

LED's are provided to indicate the following:

Function	Colour	Description
V. OFFSET ^	Amber	1.5% voltage increase is applied
V. OFFSET ^^	Amber	3% voltage increase is applied
V. OFFSET v	Red	3% voltage reduction is applied
V. OFFSET vv	Red	6% voltage reduction is applied
HIGH + 2%	Red	Measured voltage is >2% above upper band
HIGH	Red	Measured voltage is above upper band
NORMAL	Green	Measured voltage is within the deadband and normal
LOW	Red	Measured voltage is below lower band
< 80%	Red	Relay input voltage is below 80% and no control pulses or alarm will be issued
TAP	Amber	Control pulse output, either 'Raise' or 'Lower'
ALARM	Red	Relay input voltage has remained outside the bandwidth setting continuously for more than 15 minutes
DELAY	Red Bargraph	Progress of the time delay following the detection of and abnormal voltage prior to tap change operation

Other indications are :

LINE VOLTAGE	Digital Voltmeter	LCD display indicating power system voltage
TAP COUNTER	Tap change counter	Number of relay initiated tap change operations

5.3 CONTROLS

5.3.1. Basic Voltage

A basic voltage adjustment is provided which has a range of 95% to 105%, to allow operational adjustment of the relay nominal setting.

5.3.2. L.D.C. (Load Drop Compensation)

30° connection. adjustable over the range 0-10% based on the total loading of the substation with up to 4 transformers in parallel.

5.3.3. Coupling

This control is calibrated in transformer impedance and variable from 6% to 15% covering a range of transformer impedances from 6% to 30%.

5.3.4. Bandwidth

This is continuously adjustable from ±1% to ±2.5%.

5.3.5. Time Delays

5.3.5.l. Initial time delay

Following the first excursion of voltage from the normal level deadband a time delay set by the Initial control takes place prior to initiation of a tap change. This control is continuously adjustable from 10 to 120 seconds.

5.3.5.2. Inter-tap delay

The delay between all subsequent tap change commands which follow the first tap change operation, the inter-tap delay, is continuously adjustable from 5 to 60 seconds.

5.3.6. Fast tap down

For voltage excursions above the normal deadband setting a fast tap down feature can be implemented. If set a voltage of 2% above the upper deadband will initiate a 'lower' tap change operation after an initial delay of 4 seconds.

5.3.7. Remote voltage offset

The voltage offset terminals are independent and isolated from the internal electronics. Combinations of inputs allow the basic level setting to be remotely altered.

5.3.8. VR add

When remote voltage reduction is used the 3% and 6% voltage offset inputs can be made additive if this switch is set, giving a 9% setting.

6. SETTINGS

6.1. Site arrangement

6.1.1. Number of transformers

The effective LDC setting is dependent upon the site capacity, that is the maximum load that can be provided under firm load conditions (one transformer outage). For the relay to calculate the site firm capacity, two switches are used to indicate the number of transformers installed.
2 DIL switches select the number of transformers which can be connected to a busbar arrangement. If the busbar normally runs split it is suggested that the setting is still applied for the total number of transformers. This topic is discussed further in the applications section.

6.1.2. Digital Voltmeter

The DVM indicates the line voltage and is calibrated using the range switch (LO/MED/HI) and pre-set screw. For a 110V VT output the adjustable range is approximately 3kV - 52kV (LO). 16kV - 88kV (MED) and 30kV - 520kV (HI).

6.1.3. Tap initiation pulse length

The operating pulse length is selectable to 1.5 or 4.5 seconds and should be set to be compatible with the pick up time of the tap change mechanism. The 1.5 second setting is normally suitable for all modern transformers but the 4.5 second option may be required for older transformers with slower operating mechanisms.

6.1.4. Basic Nominal Set-point

Relays are factory set to 110V at 100% basic setting. If required this setting can be readjusted through the range of 60 - 130V by the potentiometer accessible through a hole located on the edge of the fascia plate. Figures 5 & 6.

7. HARDWARE

7.1. Relay Construction

The RVM/5m relay is housed in a mild steel case finished in black oven baked powder coating.

7.2. Terminal Blocks

At the rear of the relay two 12 way terminal strips allow for all connections to the relay. The Installation section details the connection arrangement.