Busbar differential protection

RADSS 3-phase

1MRK 505 008-BEN
Page 1
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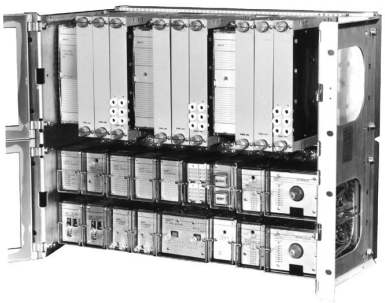
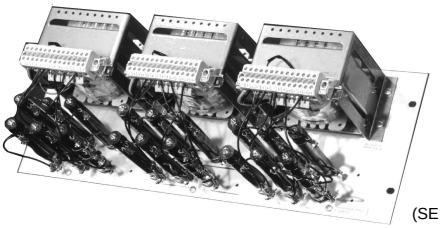


(SE 81 02 58)



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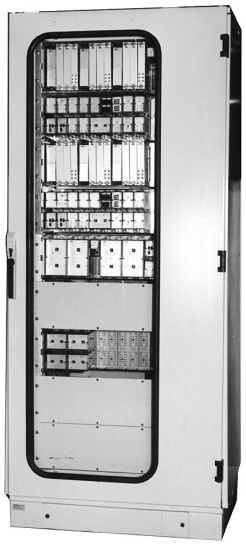


(SE 88 05 68)

Features

- Percentage restrained bus differential relay for phase and earth faults
- 1-3 ms fault detection, 8-13 ms to energise circuit breaker trip coil
- Fully stable in the event of through faults, even with infinite fault-MVA and complete line CT saturation
- Sensitivity: 20-60% of largest line CT in directly earthed networks.
  A separate sensitive E/F-relay scheme is available when the network is resistance earthed
- Adaptable to all types of bus configurations
- No practical limit to the number of lines
- Line CT's may be of standard design with poor characteristics and with different turns ratios, range 10:1, e.g. 2000/5 A and 200/5 A. Special range 20:1
- Other relays may be connected to the same CT-core as the bus differential relay
- Long CT leads acceptable
- Sensitive CT-open-circuit Alarm Relay (AR)
- Starting Relay (SR) for added security and normally set as an O/C relay

Application

RADSS three-phase differential relay
The RADSS is a high-speed, percentage restrained bus differential relay for phase and earth fault protection of buses and short lines. Internal faults are detected prior to CT saturation. Stability on external faults is guaranteed even with instantaneous line CT saturation.

The relationship between the maximum and minimum line CT ratios may as a standard be = 10:1 and in special cases 20:1.

The relay may be used as stand-alone unit in single-zone applications and in the most complex H.V. installations with a large number of zones and with switching of auxiliary CT secondary circuits.

When SF6 gas insulated buses are protected, externally mounted single-phase slip-over cable CT's may be used with great advantage. Particularly if these are made with the most suitable ratio, so as to avoid auxiliary CT's. The complete gas insulated bus may thereby be included in the bus zone.

Auxiliary CT's are used for ratio correction, and to bring down the 5 A rated current to 1 A or less.

The auxiliary CT's may be mounted close to the RADSS relay, but in some special cases they may be placed relatively close to the line CT's so as to reduce the burden of the 5 A secondary circuit.

Application (cont'd)

In some cases, a feeder connected to the bus may have its CT's a long distance away, for example in the bushings of a step-up power transformer. This is quite acceptable and if the distance of the pilot-wire is more than 3 km, isolating auxiliary CT's may be installed at both ends of the pilot-wire circuit.

When all line CT's are rated 1 A, and of the same ratio, auxiliary CT's are not required, but may be included for reasons of insulation separation. When auxiliary CT's are not included, one voltage limiting reactor (TMz) must be used per phase if the main CT saturation voltage is higher than 500 V.
The stability of the RADSS is independent of the magnitude of the through-fault current and the knee-point voltage of the line CT's. The stability is only dependent on the value of the secondary-loop resistance RX2 of the smallest line CT TMX (see Fig. 4 and Table 2).

The line CT's must have a certain knee-point voltage in order to guarantee operation in cases of internal busbar faults.

Busbar arrangements

The arrangements of power system buses vary widely depending on the magnitude of the through going load current, the number of line circuits and the need for splitting up the station in several zones subsequent to an internal bus fault.

The normal rating of a bus conductor is from 1000-3000 A and a typical number of lines to a certain bus zone is 6-12 L. For the largest installations 2, 4 and 6 relay zones may be installed.

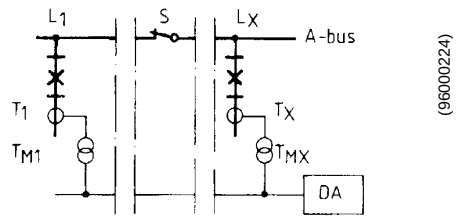


Fig. 1 Single-bus one-zone with bus section switch normally closed

Single bus one-zone

The most simple and reliable installation is the single bus one-zone arrangement (Fig. 1). In this case it can also be permitted that the bus section switch (S) is opened at certain times to split the bus in two parts.
As long as there is no internal fault the RADSS differential relay remains stable. This applies even when the two bus sections are working asynchronously, e.g. at different frequencies. However, when an internal fault occurs, both sections will be tripped simultaneously. It is then required that the fault current to one section does not pass through the other sound section.

Single bus two-zones

When the bus section switch (A12) in Fig. 2 is kept open during longer periods of time, it may be an advantage to include two differential relays. The two sections may then work independently and when a fault occurs only the affected section is tripped.

When the A12 switch is closed, all the input circuits will be connected to the DA1 relay and the DA2 relay is disconnected. The operating sensitivity is then determined only by the DA1 relay. If both relays should be kept in service at the same time the total relay operating current becomes twice as large.

The relay units shown in the drawing, A12X and DA2X, consist of RXMVB 4 change-over relay and RXMM 1 auxiliary relay. These relay units are arranged to work in a special sequence so that the CT secondary circuits never become open-circuited.

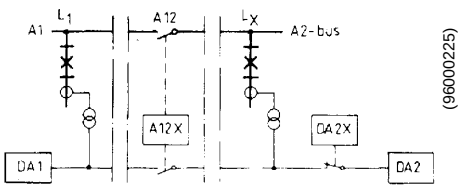


Fig. 2 Single-bus two-zones with bus section switch normally open

Double-bus with CT switching

One of the most common arrangements is the double-bus, with one bus coupler and one circuit-breaker per line (Fig. 3).

When line L1, connected to the A-bus (L1:1 closed), is to be switched to the B-bus, the following sequence is used:

1) The bus coupler circuit-breaker K:0 is closed.

2) The selector switch L1:2 is closed. Its corresponding auxiliary contact in the CT secondary is arranged to close earlier than the main (HV) contact.

3) Both selector switches (L1:1 and:2) are now closed and this situation activates a bus interconnection relay unit, which interconnects the CT circuits of the A- and B-zones and disconnects the DB-relay. The operating sensitivity then becomes controlled by only one relay, instead of two relays in parallel. Also, the two trip circuits are interconnected so that both buses are tripped for a fault on one bus.

4) The selector switch L1:1 is then opened and the bus interconnection unit brings the DB-relay back into service and separates both the CT and the trip circuit interconnection.

It should be noticed that during this switching operation, the CT secondaries are never open-circuited, so no dangerous voltages will occur. If an internal fault occurs during the switching operation, one or both buses will be tripped instantaneously.

In the case of double-buses it is recommended that the main bus coupler CT has two separate cores, one for each bus zone, so as to avoid interference from one zone to the other.

If only one core is available, two aux CT's with series connected primary windings, must be used. The knee-point voltage of the main CT should then be higher than the knee-point voltages of the two auxiliary CT primary windings put together.

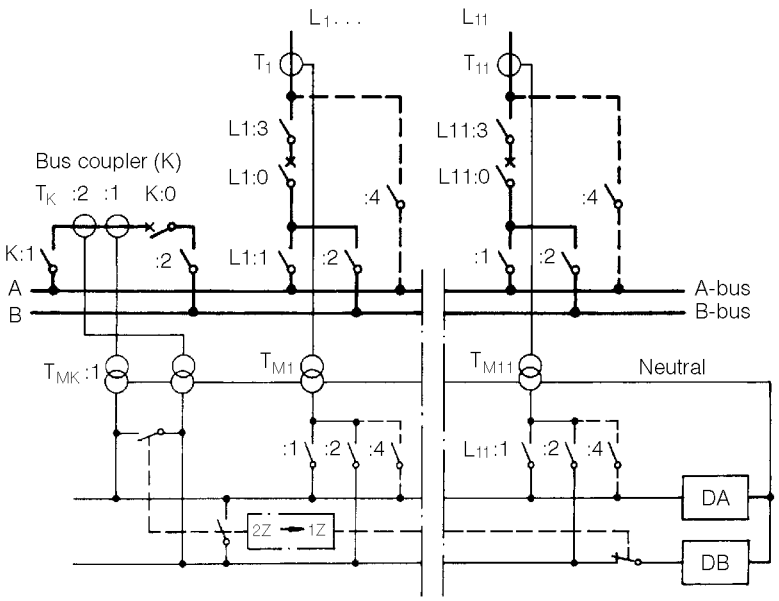


Fig. 3 Double-bus, two-zones with bypass switch and switching of CT secondary circuit.

RADSS three-phase differential relay
The RADSS relay includes three measuring elements per phase:

AR Alarm relay to detect line CT open circuits.

SR Start relay, which in most cases is set as an overcurrent relay at about 90% of the largest line CT rating.

dR Differential relay, which is selective and operates only for internal bus faults. Its operating value is dependent on the selected stability S-value.

All of these relays are of the dry-reed type and operate in about 1 ms. They do not need any dc supply from the station battery.

Application (cont'd)

The AR has a fixed setting of about 30 mA, or 3% when based on a rated 1 A input current. About five seconds after operation the trip circuit is opened and the differential circuit shorted by an auxiliary latching relay RXMVB 2. This is manually reset.

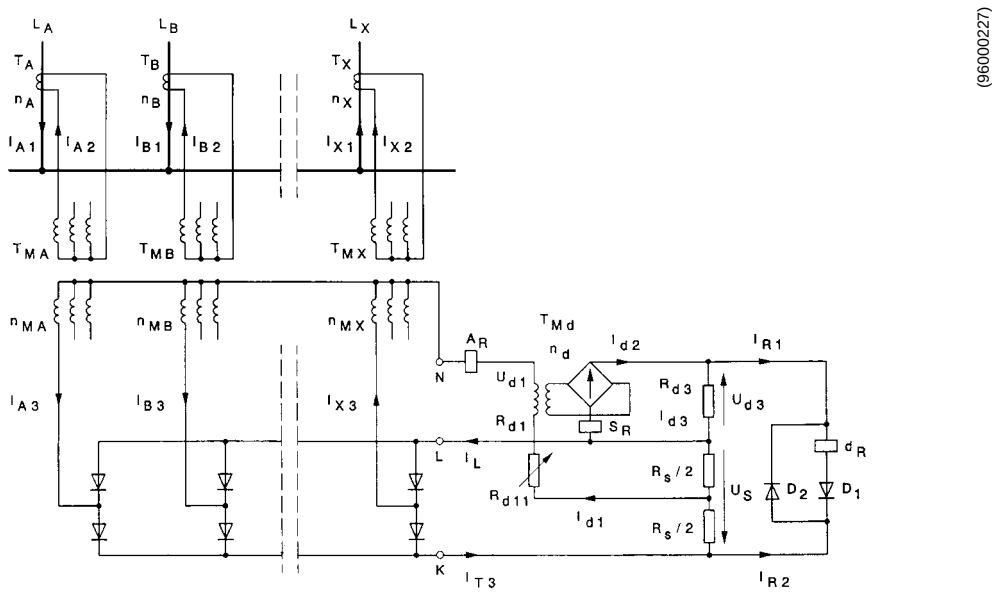
The SR element may be set to coincide with the dR element when maximum sensitivity is required. Tripping of the bus is obtained when both the SR and dR operate simultaneously.

All versions are available with an S-value of : 0.5, 0.66, 0.80 and 0.85. The stability setting applies only during external faults. During internal faults, the relay has a different characteristic with a greater operating area.

Any S-value, between: 0.5 and 0.85 may be selected in the field by adjustment of the $R_S/2$ comparator resistors. The relationship between the various relay features: stability, sensitivity, allowable maximum loop-resistance RLX and operating voltage UT3, is seen in Table 2.

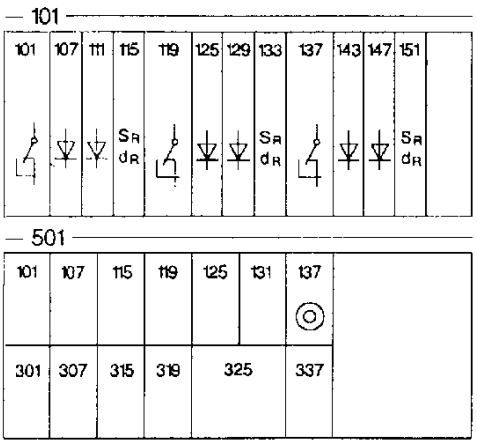
Auxiliary CT's are normally used in each main CT-circuit to bring down the secondary current to 1 A and to balance the ratios to the relay. Each input to the relay should be limited to two amps continuously.

The overall CT ratio should be selected to limit the total current (IT3) into the relay to four amps.

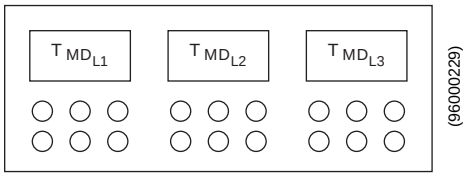


A_R	Alarm relay for CT open circuit
S_R	Starting relay
d_R	Differential relay
U_S	Restraint voltage
U_{d3}	Operate voltage
IR_1	Current through d_R-relay
IR_2	Blocking current through diode D2
T_{MA} T_{MX}	Auxiliary CT for line LA and LX with ratios: $n_{MA} = I_{A2}/I_{A3}$ = 5/1 A for main CT 2000/5 A $n_{MX} = I_{X2}/I_{X3}$ = 5/0.1 A for main CT 200/5 A
T_{MD}	$n_d = U_{d1}/U_{d2} = 10$
n_0	Overall CT ratio = $I_{A1}/I_{A3} = I_{X1}/I_{X3}$, e.g. = 2000/5 * 5/1 = 200/5 * 5/0.1 = 2000
R_s, R_{d3}	Restraint and differential circuit resistance
R_{d1}	Resistance R_{d3} referred to T_{Md} primary side, $R_{d1} = U_{d1}/I_{d1} = n_d^2 R_{d3}$
R_{dT}	Total resistance of differential circuit $R_{dT} = R_{d1} + R_{d11} = U_{dT}/I_{d1}$
U_{dT}	Total voltage of differential circuit
I_{d1}	Differential current
I_{T3}	Total incoming relay current at terminal K
I_L	Current leaving at terminal L
R_{A2}.. R_{X2}	Secondary loop-resistance of main CT's T_A..T_X
R_{LX}	Maximum permissible resistance seen at RADSS terminal L towards the smallest main CT TX
R_{X2}=	$R_{LX} / (n_{MX})^2$

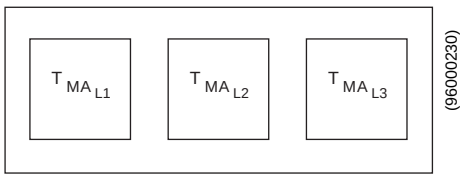
Fig. 4 Schematic diagram for one phase of a single-zone bus differential relay with feeders L_A, L_B and L_X



RADSS three-phase differential relay unit

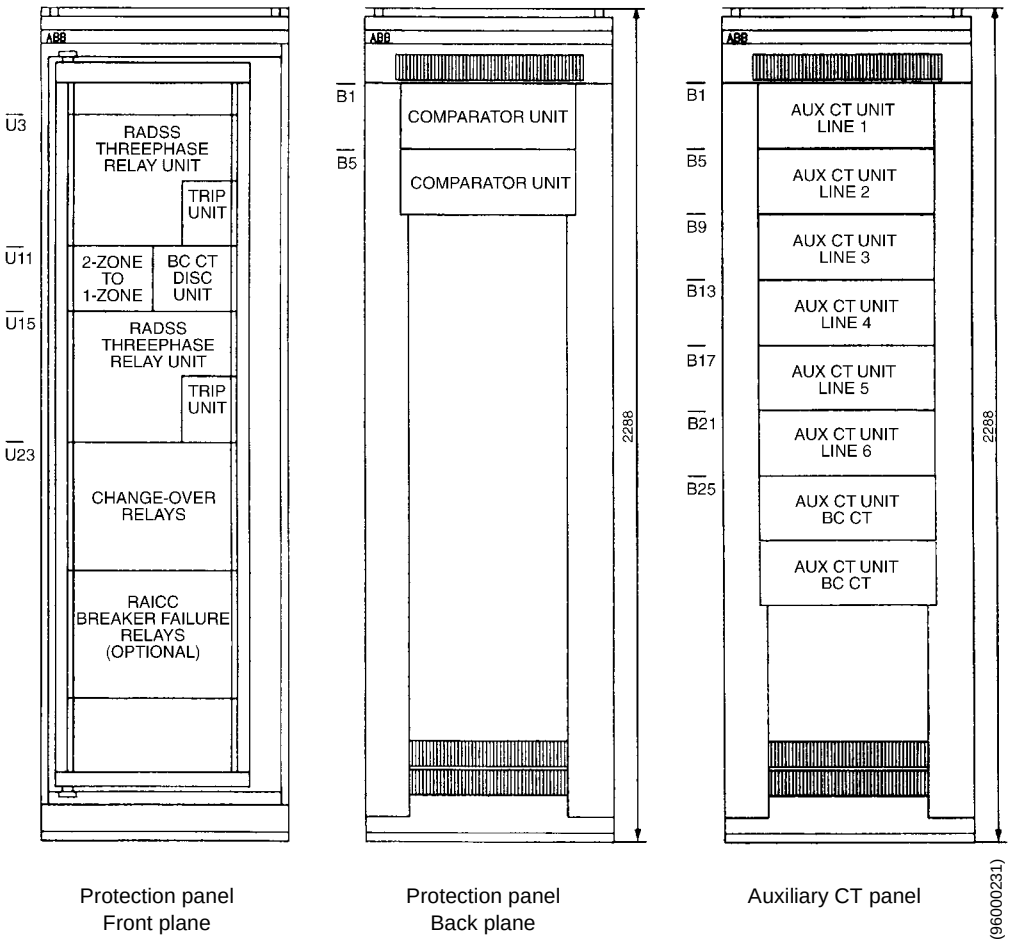


Comparator unit with aux CT's TMd and resistors



Mountingplate with 3-phase aux CT's for one line

Fig. 5 RADSS for 3-phase relay unit



Protection panel Front plane

Protection panel Back plane

Auxiliary CT panel

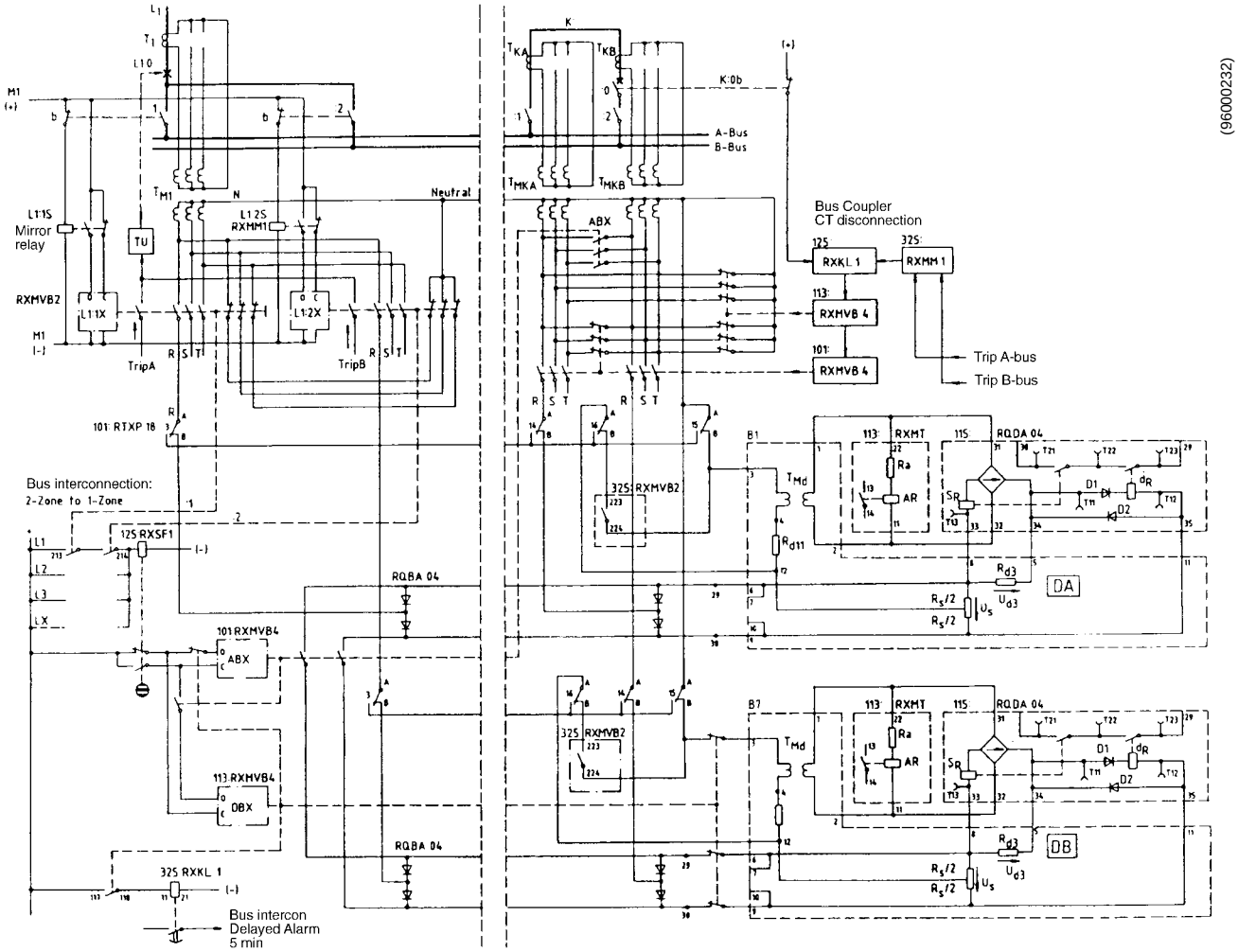
Fig. 6 Example of RADSS busbar protection for double-bus with 6-lines, bus-coupler and switching of CT secondary circuits. Also including RAICC Breaker Failure Relays

Application (cont'd)

Protection panels

The RADSS busbar protection can be delivered as a complete hardware for a certain bus configuration, mounted in panels fully wired and tested, or as separate units to be panel mounted and tested locally.

Switching scheme for a three-phase protection



L1:1b, :2b	Selector switch auxiliary contact
T_{M1}, T_{MK}	Auxiliary CT's
TU	Trip unit
L1:1S, :2S	RXMM 1 self reset mirror relay
L1:1X, :2X	RXMVB 2 auxiliary latching relay

101

RTXP 18	Test switch
RQBA 04	Line diode unit
RQDA 04	Relay unit with start + diff elements
B1. B7	Transformer + resistor unit

325

RXMVB 2	CT open-circuit blocking

113

RXMT 1	CT open-circuit measuring relay
ABX, DBX	RXMVB 4 latching relay

The main H.V. selector switch (disconnector) and it's auxiliary contact (b) should open and close as follows:

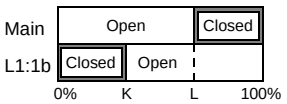


Fig. 7 RADSS 3-phase bus diff relays for two zones, 11-Lines and one bus coupler.

The line CT's (T1) may be switched to the DA or DB differential relays. In most stations a mirror relay (L1:1S) is available and arranged to be energized when the (L1:1b) selector switch is open. The auxiliary contact (L1:1b) must open and close as shown in Fig. 7.

When both selector switches (L1:1 and:2) are closed simultaneously it is advantageous to interconnect the DA- and DB-line diodes and disconnect the DB-measuring circuit. If the wire to the mirror relay should be inadvertently interrupted, the two relay zones will be switched to one overall zone.

This situation is supervised by a time lag relay RXKL 1, sounding an alarm after five minutes. Switching a line from one bus to the other normally takes less than five minutes and no alarm will then be obtained.

The bus-coupler (BC) CT-disconnection scheme serves the following purpose:

1) When the BC breaker K:0 is open, a fault which occurs between the CT's and the breaker will be disconnected instantaneously by the correct bus differential relay.

2) If this fault occurs when K:0 is closed the wrong bus will be tripped instantaneously and the faulty bus, approx. 150 ms later.

3) If the K:0 fails to open for a proper bus fault the adjacent bus will be tripped, approx. 150 ms later.

Technical data

Table 1: RADSS three-phase busbar differential relay

Rated frequency Rated current (IA3)	25 - 60 Hz 2 A per input
Maximum cont. current: through going restraint (IT3) differential circuit (Id1)	 4 A 0.5 A
Short time current differential circuit 50 s 1 s	 1 A 7 A
Insulation tests: Dielectric tests current circuits remaining circuits	 50 Hz, 2,5 kV, 1 min 50 Hz, 2,0 kV, 1 min
Impulse voltage test Disturbance test: 1 MHz burst test	1,2/50 µs, 5,0 kV, 0,5 J 2,5 kV, 2 s
Auxiliary dc voltage	48, 110, 125 or 250 V
Permitted ambient temperature	-5 °C to +55 °C
Input diode rating	10 A rms, 1200 V PIV
Operate time (S_R + d_R) to trip	1-3 ms 8-13 ms

Technical data (cont'd)

Auxiliary CT's:
Three different types may be used depending on required rated secondary current.
For example:

1 Type SLCE 12:
5/0.7 A, 140/1000 t, 0.3/16 ohms.
Knee-point (at 1.6 T) = 416 V rms

2 Type SLCE 16:
5/1 A, 160/800 t, 0.4/10 ohm.
Knee-point (at 1.6 T) = 416 V rms

3 Type SLXE 4:
5/2 A, 240/600 t, 0.5/3.5 ohm.
Knee-point (at 1.6 T) = 400 V rms

Note:
The given current ratios correspond to the permissible continuous thermal rated current. The number of secondary turns for each type of aux CT is always kept constant so as to obtain adequate secondary knee-point voltage. Different ratios are therefore obtained by varying the number of primary turns.

Table 2: RADSS three-phase differential relay. Settings and approx. operating values with: Rd3 = 1.1 ohm, Rd11 = 136 ohms, RdT = 301 ohms, Pn = 16 W and Id1(SR) = 0.88 A

Stab. S-value	Rs/2 ohm	K A	Rse ohm	Id1 min	RLX ohm	UT3 (dR) V	UT3 (SR) V
0.2	1.2	0.107	0.76	0.13	75	63	310
0.5	3.66	0.10	0.96	0.20	301	86	310
0.66	5.50	0.096	1.0	0.30	602	118	310
0.80	7.30	0.092	1.02	0.46	1204	171	310
0.85	8.15	0.091	1.03	0.61	1705	221	310

RADSS as separate units

Note:
When you need assistance to select the most suitable setting, please send us a simple single line diagram of the bus(es), indicating:

(1) Current rating of bus conductor
(2) Number of line circuits
(3) CT ratios of all lines
(4) Rated load current of all lines (required only when load current is much less than CT rating)
(5) Requested primary operating current

Having received this information we will advise the most suitable:

(1) Stability setting: S - value
(2) R_{d11} setting
(3) Start relay Id1(SR) setting
(4) Permissible maximum loop-resistance RLX as seen from relay terminal L
(5) Permissible max loop-resistance in line CT secondary circuits R_{A2}...R_{X2} (which includes CT winding resistance, dc resistance of other relays and pilot-wire 2-way resistance)
(6) Required line CT secondary knee-point voltage U_{A2k}...U_{x2k}
(7) Auxiliary CT type and ratio

Appendix

Operating equation for the dR element:

Id1 = S * IT3 + k

where S = Rs / (nd*Rd3 + Rs/2)
and the constant:
k =(0.03(Rd3+Rs+20)+0.6)/(10*Rd3+Rs/2)

Minimum dR operating current:
Id1 min = k / (1-S)

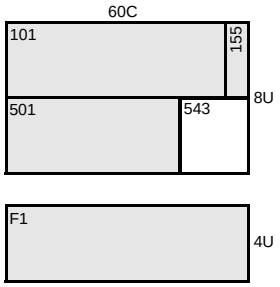
Example of permissible loop-resistance (ohms):

RLX = RdT *S/(1-S) =301 *0.8/(1-0.8) = 1204

RA2 = RLX / $(nMA)^2$ =1204/$(5/1)^2$ = 48

RX2 =RLX /$(nMx)^2$ = 1204/$(5/0.1)^2$ = 0.48

RADSS three-phase, 6 or 12 lines, one zone
Version A1
Ordering No. RK 637 016-AB

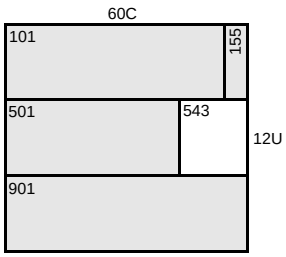


101 Measuring unit with
3-RTXP 18 test switch
3 or 6-RQBA line diodes
3-RQDA S_R + d_R relays
155 Blanking plate
501 Supervision + aux. relay unit
1-RXTCB 1 aux. relay
1-RXMS 1 aux. relay
3-RXMT 1 alarm relays
1-RXSP 14 flag indicator
1-RXTNT 1 push-button with lamp
2-RXKL 1 time lag relays
2-RXMM 1 aux. relay
1-RXMVB 2 aux. blocking relay
1-RXME 1 aux. relay

543 Space for trip relays
F1 Transf. + comparator unit with:
3-TMD aux. transformers
3 x 6-resistors, each 50 W

Note:
The F1-unit is normally mounted on the B-(back) plane of the panel and wiring must be made by purchaser to the (101 + 501) unit

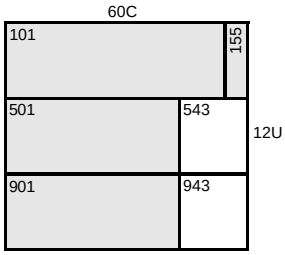
RADSS three-phase, 6 or 12 lines, one zone
Version A2
Ordering No. RK 637 016-CB



As version A1 but all the units are fully interconnected in one equipment frame: 12U, 60C.

Appendix (cont'd)

RADSS three-phase, 18 or 24 lines, one zone
Version B
Ordering No. RK 637 016-BB

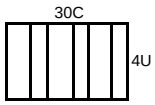


101 As 101 in version A1
155 Blanking plate
501 Extension unit for 6L or 12L with 3-RTXP 18 test switch 3 or 6-RQBA line diodes
543 Space for trip relays
901 As 501 in version A1
943 Space for trip relays

F1 As F1 in version A1

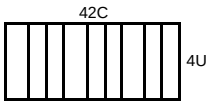
The version B of the RADSS can be connected with up to 24 lines. If more lines are needed, additional extension units must be added

Extension unit for 6 lines
Ordering No. 7451 299-B



3 - RTXP 18
3 - RQBA

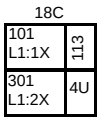
Extension unit for 12 lines
Ordering No. 7451 299-A



3 - RTXP 18
6 - RQBA

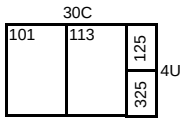
Switching Relay Units

Switching line CT's to DA, DB
Ordering No. 5651 131-EA



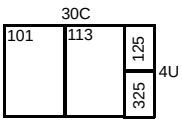
101, 301: RXMVB 2 latching relay
113: RXMM 1 auxiliary relay

Bus interconnection (two-zone to one-zone)
Ordering No. 5651 131-SA



101, 113: RXMVB 4 latching relay
125: RXSF 1 aux. flag indicator
325: RXKL 1 delayed alarm relay

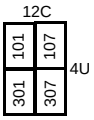
Bus coupler CT disconnection
Ordering No. 5651 131-RA



101, 113: RXMVB 4 latching relay
125: RXKL 1 time-lag relay
325: RXMM 1 aux relay

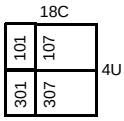
Trip Relays with rapid operation

Ordering No. RK 216 463-
(See catalogue 1MRK 508 015-BEN)



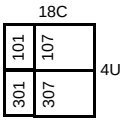
101, 301, 301,307:
RXMS 1 with 6 NO contacts

Strong contacts with latching relays
Ordering No. 5651 261-A



101, 301: RXMS 1 with 6 NO contacts
107, 307: RXMVB 2 latching relay with 6 NO contacts

Strong contacts
Ordering No. 5651 260-A



101, 301: RXMS 1 with 6 NO contacts
107, 307: RXMH 2 with 8 NO contacts

Auxiliary CT's

Three auxiliary CT's, suitable for one line, may be mounted on one 60 C apparatus plate. Each aux CT has top mounted compression type screw terminals suitable for 10 mm^2 copper wire. When multi-ratios are requested some 11-terminals may be mounted at the top. The secondary terminals S1-S2 are equipped with small screw-in type test devices, suitable for 4 mm^2 banana test-plug. The S1-S2 terminals may thus easily be shorted, or used to inject a test voltage.

Aux. CT	Ordering No.	Dimension U x C
3 x SLCE 12	5296 052-AF	4 x 60
3 x SLCE 16	5296 052-AE	4 x 60
3 x SLXE 4	5296 052-AD	6 x 60

Note:
A separate, special terminal board may be mounted on the 60 C plate when requested.

Ordering

Specify:

- Ordering No. for RADSS
- Quantity
- Number of lines (6 or 12, 18 or 24 L)
- Slope (0.5 or 0.66 or 0.80)
- $I_{d1(SR)}$ (start relay (0.88 standard))
- R_{d11} (0 or 136 ohms)
- Auxiliary dc voltage UL
- Desired wording on the lower half of the test switch face plate max. 13 lines with 14 characters per line

Accessories:		**Quantity**
6 additional lines	7451 299-B	
12 additional lines	7451 299-A	
Switching line CT's relay unit	5651 131-EA	
Bus interconnection unit	5651 131-SA	
Bus coupler CT's disconnection	5651 131-RA	
Trip relay unit with RXMS 1 and RXMH 2	5651 260-A	
Trip relay unit with RXMS 1 and RXMVB 2	5651 261-A	

Ordering (cont'd)

Three-phase auxiliary transformers.		**Quantity**
3 x SLCE 12, mounted on 4U, 60C plate	5296 052-AF	
3 x SLCE 16, mounted on 4U, 60C plate	5296 052-AE	
3 x SLXE 4, mounted on 6U, 60C plate	5296 052-AD	

Note: The current ratio must be stated

For our reference and statistics we would be pleased if we are provided with the following application data

Country:	End user	
Station name:	Voltage level:	kV

References

Basic theory of bus differential relay RADSS	RK 637-300E
Checking of operating and restraint characteristics	RK 637-104E
Commissioning:	
Single bus system	RK 637-101E
Double bus system	RK 637-102E
Maintenance test:	
Double bus system	RK 637-105E
Bus coupler CT's disconnection	RK 637-301E
Auxiliary CT's for RADSS bus protection	RK 637-302E
Schematic diagram for two zones	RK 637-359
User's Guide RADSS	1MDU 05003-EN
SLCE 12, SLCE 16 and SLXE 4	1MRK 513 011-BEN

Manufacturer

ABB Automation Products AB
Substation Automation Division
S-721 59 Västerås
Sweden
Tel: +46 21 342000
Fax: +46 21 146918