# Busbar protection with auxiliary summation CT's

# RADSS 1-phase

1MRK 505 009-BEN
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(SE980086)

## 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 10-80% 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
- Starting Relay (SR) for added security and normally set below the diff relay

## Application

**RADSS 1-phase bus diff relay with auxiliary summation current transformers**
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 High Voltage 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 make all the aux sum-CT's with the same ratio.

The complete gas insulated bus structure may thereby be included in the bus zone.

Aux sum-CT's have a 4-wire input and a 2-wire output. They are used for ratio correction, and to bring down the 5 A rated current to 1 A or less.

The aux sum-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 number of wires and, also 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, one isolating auxiliary CT may be installed at each end of the pilot-wire circuit.

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. This must be checked specially with 1 A secondary rated line CT's.

The reason being that the 1 /1 A aux sum-CT has a primary to secondary turns ratio of $4/\sqrt{3}$ and the operating voltage requirement is correspondingly higher on the primary side.

### 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.

### 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 a 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 always 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.

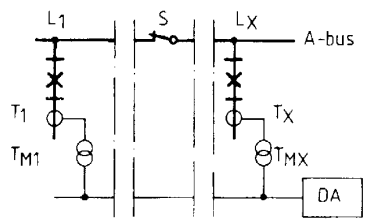


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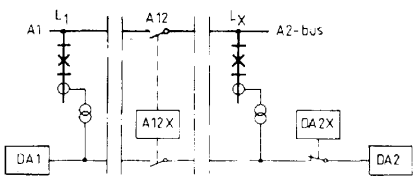
Fig. 1 Single-bus, one zone with bus section switch normally closed




(96000225)

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

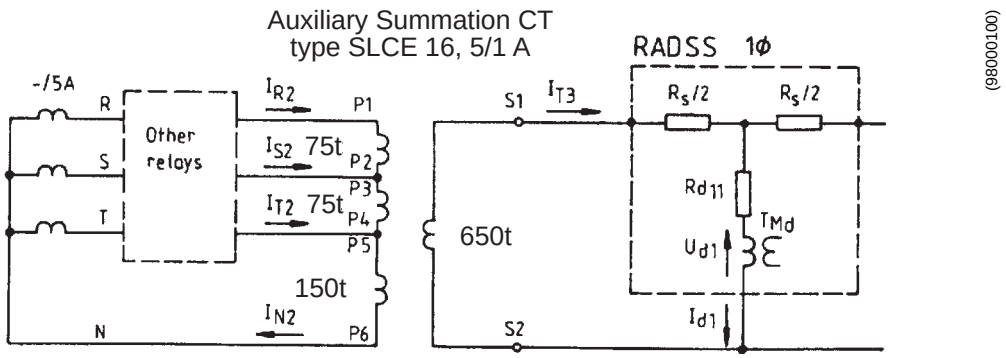



Fig. 3 For each line, one auxiliary summation CT is used

## Design

**RADSS 1-phase differential relay**
The RADSS 1-phase relay includes two measuring elements:

$S_R$ Start relay, which in most cases is set below the operating value of the $d_R$.

$d_R$ Differential relay, which is selective and operates only for internal faults.

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

Tripping of the bus is obtained when both the $S_R$ and $d_R$ relays operate simultaneously.

In the 1-phase design the starting relay $S_R$ is always set to operate at a value less than the $d_R$-element.

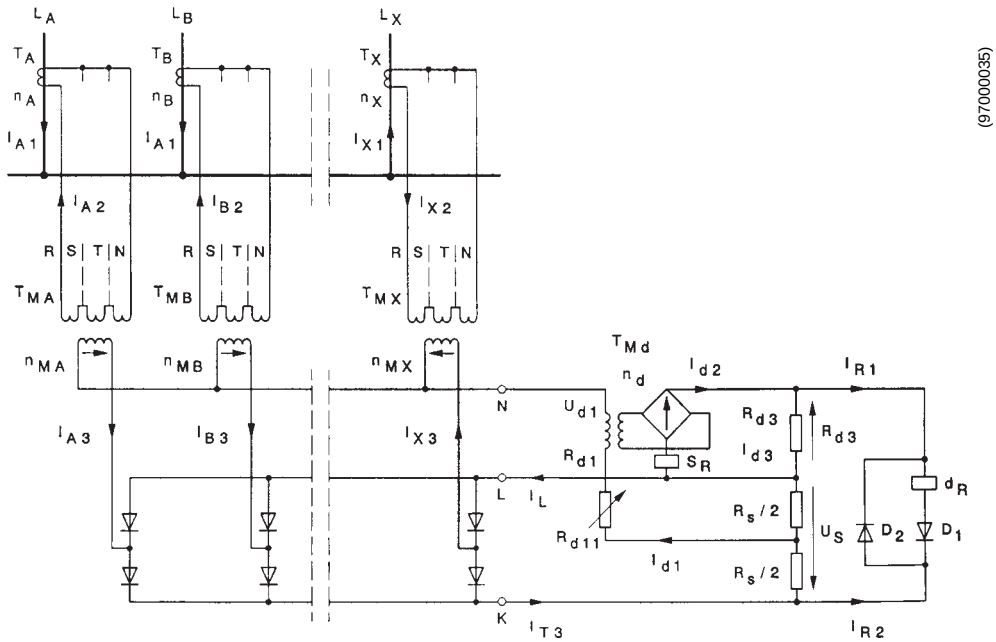
In the 1-phase design no standard alarm relay is included.

In networks with the system neutral earthed via a reactor or resistor, the internal earth fault current may be quite small and, also, the through going load current may cause extra restraint on the relay because of the way in which the summation transformer is working. Relay operation on internal earth faults may therefore be hindered and the stability setting is in these cases kept as small as possible, e.g. with S equal to 0.5 or 0.66. In directly earthed networks a stability setting of 0.8 is normally used.

Auxiliary summation CT's type SLCE 16 or SLCE 12 are normally used in each circuit to balance the ratios to the relay. Each input to the relay is limited to two amps continuously. The overall CT ratio should be selected to limit the total current into the relay to four amps.

The SLXE 4 may be used in some special cases, e.g. when the range of the largest and smallest line CT ratios exceeds 20:1.

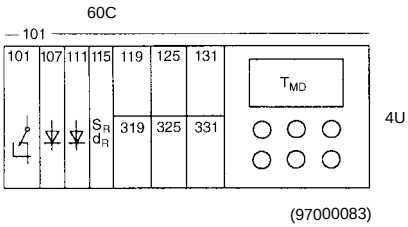
## Design (cont'd)




| | |
|---|---|
| $S_R$ | Starting relay |
| $d_R$ | Differential relay |
| $U_s$ | Restraint voltage |
| $U_{d3}$ | Operate voltage |
| $I_{R1}$ | Current through $d_R$-relay |
| $I_{R2}$ | Blocking current through diode D2 |
| $T_{MA}$ $T_{MX}$ | Aux sum-CT for line $L_A$ and $L_X$, e.g. with ratio: $n_{MA} = I_{A2}/I_{A3}$ =5/1 A for main CT 2000/5 A $n_{MX} = I_{X2}/I_{X3}$ = 5/0.1 A for CT 200/5 A |
| $T_{MD}$ | $n_d = U_{d1}/U_{d2} = 10$ |
| $n_0$ | Overall CT ratio = $I_{A1}/I_{A3} = I_{X1}/I_{X3}$ |
| $R_s$ $R_{d3}$ | Restraint and differential circuit resistances |
| $R_{d1}$ | 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 TA .. TX (which includes CT winding resistance, dc resistance of other relays and pilot-wire 2-way resistance |
| $R_{LX}$ | Maximum permissible resistance seen at RADSS terminal L towards the smallest main CT $T_X$ |
| $R_{X2}$ = | $1.33 * R_{LX} / (n_{MX})^2$, where the factor 1.33 is due to the aux sum-CT turns distribution |

Fig. 4 Schematic diagram for a single-zone bus differential relay type RADSS with feeders $L_A$, $L_B$ and $L_X$

**RADSS 1-phase, 6 or 12 lines, one zone**
Ordering number RK 637 019-BA




Measuring unit with
- 1-RTXP 18test switch
- 1 or 2-RQBAline diodes
- 1-RQDAS$_R$ + d$_R$ relay

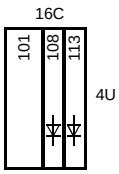
Supervision + aux. relay unit
- 1-RXTCB 1capacitor + resistor
- 1-RXMS 1aux. relay
- 1-RXSF 14flag indicator
- 1-RXKL 1time lag relay

Transf. + comparator unit with
- 1-TMD aux. transformer
- 1 x 6 resistors, each 50 W

Optional trip relay unit
- 1-RXMS 1aux. relay, or
- 2-RXMS 1aux. relay

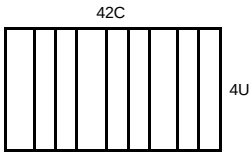
The RADSS 1-phase can be connected with up to 12 lines. If more lines are needed, extension units must be added.

**Extension unit for 12 lines**
Ordering number 1MRK 001 428-AA



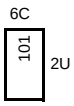

| | | |
|---|---|---|
| 101: | RTXP 18 | test switch |
| 108,113: | RQBA 040 | diode units |

**Extension unit for 36 lines**
Ordering number 7451 299-A



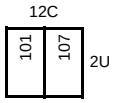

3 test switch RTXP 18
6 diode units RQBA

**Trip relays**




See catalogue1MRK 508 015-BEN

1O1 RXMS 1 with 6 NO contacts




101, 107: RXMS 1 with 6 NO contacts

**Protection Panels**
RADSS busbar protection of summation type can be delivered as a complete hardware supply for a certain bus configuration mounted in panels, with wiring and tested from the factory, or as separate units to be panel mounted, connected and tested locally.

**RADSS 1-phase**
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

Design (cont'd)

Having received this information we will advise:

(1) Slope setting
(2) $R_{d11}$ setting
(3) Start relay setting
(4) Permissible maximum loop-resistance as seen from relay $R_{LX}$
(5) Max. permissible loop-resistance in line CT secondary circuit $R_{A2}$...$R_{X2}$ (which includes CT winding resistance, dc resistance of extra burden or relays and pilot-wire 2-way resistance)
(6) Required line CT secondary knee-point voltage $U_{A2}$...$U_{x2}$
(7) Auxiliary summation CT type and ratio

**Auxiliary summation CT's**
Three different types may be used depending on the required rated secondary current.

For example:
1 SLCE 12, 5/0.7 A, 554 At, 12 W
2 SLCE 16, 5/1 A, 650 At, 14 W
3 SLXE 4, 5/2 A, 996 At 22 W

**Note:**
The current ratios refer to balanced three-phase load. The amp-turns are the approximate values normally used, and these correspond to the given total Cu-loss, i.e. the primary and secondary windings heat loss at rated current ratios.

When the relay is installed it must be checked that the line CT's have adequate knee-point voltage to make the relay work on internal faults, and also, the total secondary loop-resistance must be within the maximum permissible limit.

## Technical data

**Table 1: RADSS differential relay**

| | |
|---|---|
| Rated frequency<br>Rated current | 25-60 Hz<br>2 A per input |
| Maximum cont. current:<br>restraint circuit<br>differential circuit | <br>4 A<br>0.5 A |
| Short time current differential circuit<br>50 s<br>1 s | <br>1 A<br>7 A |
| **Insulation tests:** | |
| Dielectric tests<br>current circuits<br>remaining circuits | <br>50 Hz, 2,5 kV, 1 min<br>50 Hz, 2,0 kV, 1 min |
| Impulse voltage test | 1,2/50 µs, 5,0 kV, 0,5 J |
| **Disturbance test:** | |
| 1 MHz burst test | 2,5 kV, 2 s |
| Auxiliary dc voltage UL | 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 ($S_R$ + $d_R$)<br>to trip | 1-3 ms<br>8-13 ms |

**Table 2: RADSS 1-phase diff. relay. Settings and approx. operating values with $R_{d3}$ = 1.1 ohm, $R_{d11}$ = 136 ohms, $R_{dT}$ = 281 ohms, $P_n$ = 16 W and $I_{d1}(S_R)$ = 0.035 A**

| Slope<br>S | $R_{s/2}$<br>ohm | K<br>A | $R_{se}$<br>ohm | $I_{d1}$<br>min | $R_{LX}$<br>ohm | UT3<br>($d_R$) V |
|---|---|---|---|---|---|---|
| 0,2 | 1.2 | 0.107 | 0.76 | 0.13 | 70 | 60 |
| 0,5 | 3.66 | 0.10 | 0.96 | 0.20 | 281 | 82 |
| 0,66 | 5.50 | 0.096 | 1.0 | 0.30 | 562 | 113 |
| 0,80 | 7.30 | 0.092 | 1.02 | 0.46 | 1124 | 162 |
| 0.85 | 8.15 | 0.091 | 1.03 | 0.61 | 1592 | 208 |

## Ordering

Specify:

- Ordering No. RK 637 019-BA
- Quantity
- Number of lines (6 or 12)
- Slope (0.5 / 0.66 / 0.8)
- Auxiliary dc voltage UL
- $I_{d1}$ start relay (0.035 A standard)
- $R_{d11}$ (0 or 136 ohms)
- Desired wording on the lower half of the test switch face plate max. 13 lines with 14 characters per line.

| Accessories: | Ordering number | Quantity |
|---|---|---|
| Extension unit for 12 bays | 1MRK 001 428-AA | |
| Extension unit for 36 bays | 7451 299-A | |
| Summation transformers | | |
| SLCE 12 | 1MRK 002 406-AA | |
| SLCE 16 | 1MRK 002 407-AA | |
| SLXE 4 | 1MRK 002 408-AA | |
| Aux sum-CT's on mounting plate | | |
| 1, 2 or 3- SLCE 12 on apparatus plate 4U, 60C | 5296 052-BF | |
| 1, 2 or 3- SLCE 16 on apparatus plate 4U, 60C | 5296 052-BE | |
| 1, 2 or 3- SLXE 4 on apparatus plate 6U, 60C | 5296 052-BD | |

**Note:**
For each ordering No. the quantity: 1, 2 or 3 must be given
For each aux sum-CT the 3-phase current ratio must be given

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: | |
| RADSS 1-phase | RF 637-107E |
| 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 |
| Single-phase version with summation auxiliary CT | RK 637-329E |
| SLCE 12, SLCE 16 and SLXE 4 | 1MRK 513 011-BEN |

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