ASEA BROWN BOVERI

ABB Relays

INFORMATION

Info-No. RF 619-001 E

From/Date RFA, November 1988
Edition 4

Reg. 7435

Page 1

Ultra High Speed Line Protection type RALZA

Unaffected by current transformer saturation and capacitor voltage transformer transients.

Ultra high speed of fault detection, typical 2-5 ms.

Selective single-phase tripping capability.

Flexible operating characteristic with wide setting range.

Suitable for any length of line also series compensated and adjacent lines.

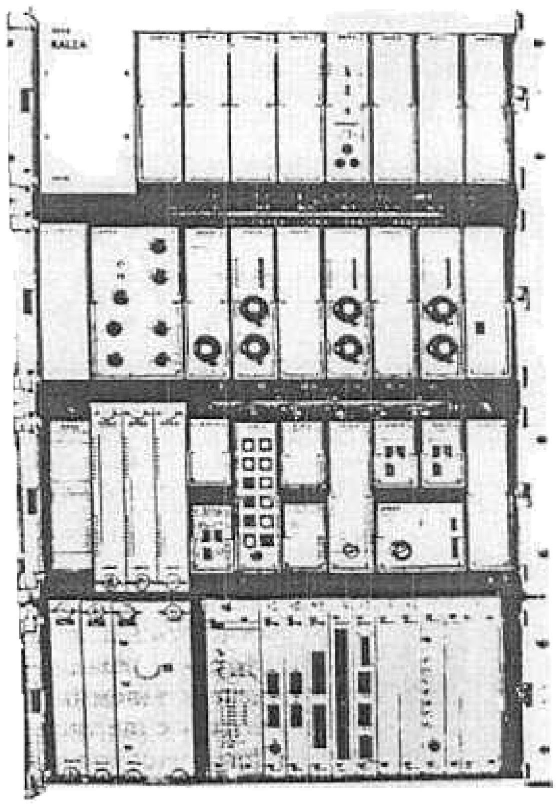
Can detect a loaded phase conductor rupture.

Directional comparison scheme.

Can be used with a single power line carrier or microwave channel.

Operates selectively and independently of the channel for close-in high level faults and for evolving faults.

Built-in circuit for functional tests.



CONTENTS

1. GENERAL

The demands made on relay protection are steadily increasing owing to such factors as the growing fault-MVA levels and the demand of consumers for greater reliability in their power supply.

Short relay and breaker operating times are needed to ensure that the power system will not run into transient stability problems and also to keep the damage due to thermal stresses to a minimum.

ABB offers in the field of transmission line protection an ultra-high-speed static relay type RALZA. RALZA is a complete line terminal with high speed primary protective relaying and delayed back-up relaying.

The relay combines the novel concept of directional wave detection with the impedance measuring principle, forming an outstanding line protection for EHV and UHV networks.

The directional wave detector section of RALZA can detect a fault and determine the direction to the fault in a basic time of a few milliseconds. This is done by observing the motion of the travelling-wave phenomena generated by a fault on the power system.

The RALZA relay operates as a directional comparison relay in a permissive tripping scheme and therefore needs a communication link (PLC or microwave).

For close in faults, the RALZA relay can operate indepently of the communication link.

The delayed back-up relaying is also independent of the communication link.

The relay can be obtained to perform the appropriate phase selection as required in a selective single-phase tripping scheme.

The operating principle maks it possible to detect high resistive earth faults.

Systems with series capacitors compensated to any degree can be fully protected with the RALZA relay.

Static circuits perform processing of all signal s and the use of modern semi-conductor technology and integrated circuits (ICs) contributes to a high reliability. High threshold logic (HTL) is used to enhance noise immunity.

2. PRINCIPLE OF OPERATION

The object of this chapter is to describe the general principle of operation of RALZA, in terms of working principles of the different sections of the relay and the co-operation between these sections.

2.1 Overview block diagram

Fig 1 shows an overview type of block diagram of RALZA.

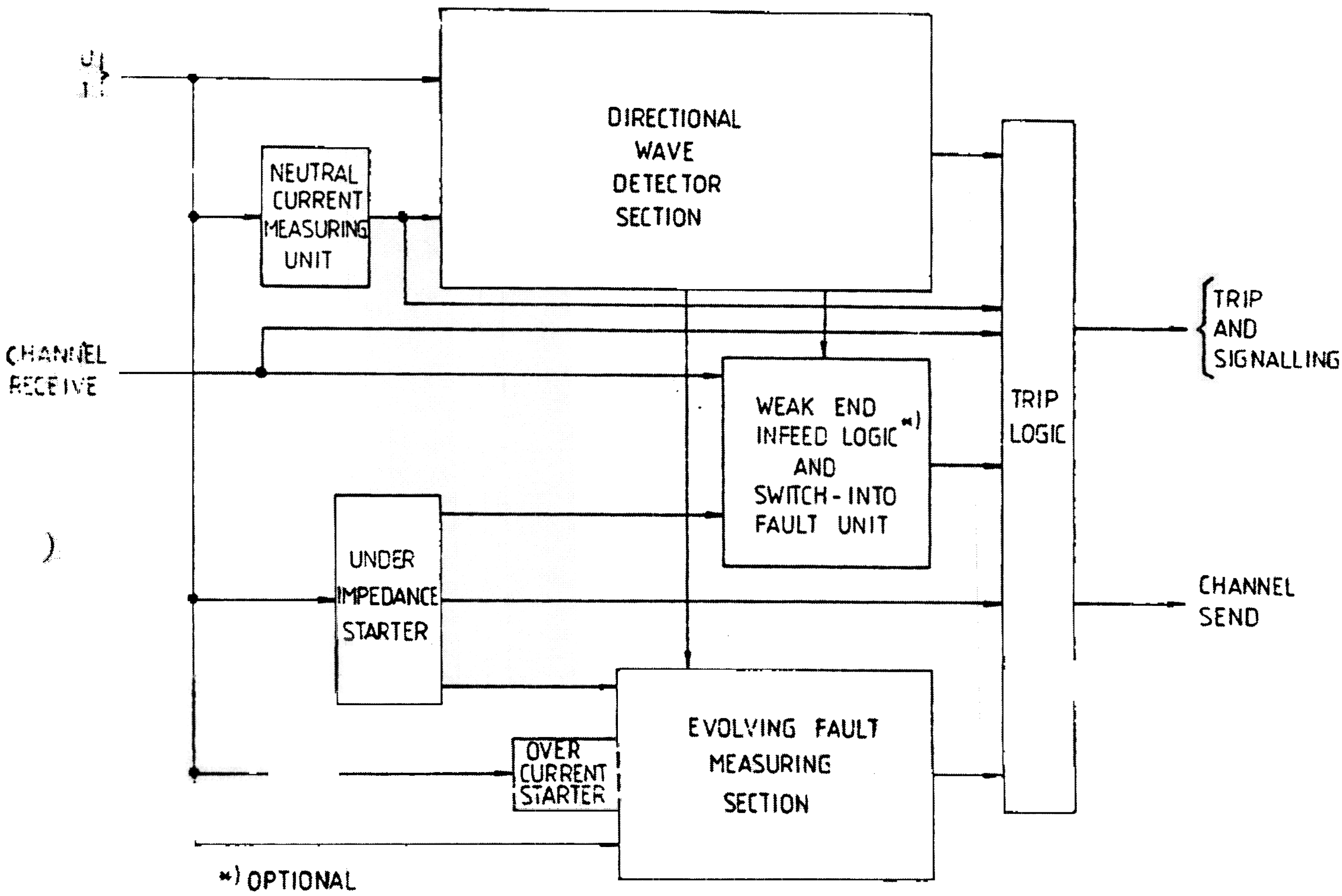


Fig 1:
Overview block diagram RALZA

2.2 Detection of initial faults

2.2.1 Directional wave detection

All initial faults are detected by the directional wave detector section of RALZA, see fig 1. Its operation is based on the principle of directional wave detection. This principle utilizes the fact that when a fault occurs, both the voltage and current disturbances are transmitted throughout the system at nearly the speed of light.

The direction to the fault is detected by the means of ordinary VT's and CVT's connected to the line side of the breaker. The change in current and change in voltage is measured. With convential CT and VT polarities a fault in the "forward" direction (on or beyond the line) gives a voltage change having opposite sign to the current change. A fault in the "reverse" direction gives voltage and current changes with the same sign.

A more detailed description of the measuring principle of the directional wave detector section of RALZA is given in chapter 3.

2.2.2 Modes of operation

There are three different ways of obtaining a directional wave detection operation:

- The dependent mode of operation provides (via the tripping logic).

  single-phase starting signals for single-phase faults and three-phase starting signals for multiphase faults

  channel send signal to the communication equipment

  The directional decision (forward/reverse) is made independently at each terminal. The two terminal conditions are then compared by means of the communication channel. For internal faults a trip is obtained. The RALZA relay works in a permissive tripping scheme.

- The independent mode of operation (optional) is less sensitive than the dependent mode of operation, thus coping with close-in faults only. The feature of this mode is that it works independently of the communication channel, providing very fast tripping operation.

- The neutral current control mode of operation is more sensitive than the dependent mode of operation. Moreover, it uses a neutral current criterion (implemented in the neutral current measuring unit, see fig 1) and a time criterion (besides the demands of changes in voltage and current) prior to bringing about starting signals. The purpose of this arrangement is to provide high resistive earth fault detection capability, still keeping the relay stable in case of lightning strokes or surge arrester discharges.

The three modes of operation are discussed in detail in section 3.1, 3.2 and 3.3.

2.2.3 CVT response

The use of the change in voltage offers the advantage of a simple solution to the problems normally caused by capacitor voltage transformer transient response. For a close-in fault the noise generated by the CVT could be many times larger than the actual remaining voltage. The change in voltage, however, is quite large for a close-in fault and since the directional wave detector section uses this change for measurements, the signal to noise ratio will be satisfactory and will ensure a correct operation.

CT saturation

Tests and practical experience have demonstrated that CT-saturation does not occur instantaneously. Even in the most adverse cases one can expect a closed-core CT to give a correct secondary output during the first 2-5 msec after fault inception. Since the directional wave detector decision time is in this range a correct decision can be made and remember before the CT saturates. This is a valuable feature because it means that the relay will trip dependably for internal faults and maintain full stability for external faults, even after saturation.

2.2.5 Series compensated lines

The directional wave detection principle of RALZA makes the relay applicable to the protection of series compensated systems even if the capacitors are close to the line ends and to parallel lines.

2.2.6 Loaded phase conductor rupture

An interesting feature is the possibility to descern between a loaded phase conductor rupture and normal de-energization of a loaded line. In the former case, by virtue of the travelling wave principle, relay operation can be obtained before the conductor rupture develops into an electrical short-circuit. Safety hazards to human beings are therefore reduced.

Weak-end-infeed mode of operation

The problem of weak-end infeed is discussed in detail in section 3.4. To cope with these problem, an optional weak-end-infeed unit, see fig 1, is offered, bringing about the necessary tripping and communication signals in case of a weak-end-infeed condition.

2.3 Detection of evolving faults

2.3.1 Evolving fault measuring section

All initial faults occuring on a line in service are detected by the directional wave detector section of RALZA (the case of switching a breaker into a fault is treated in section 2.5). When the direction to a fault is determined, all subsequent information is disregarded from until the relay resets (this is done in order to avoid the confusion that could be caused by multiple reflexions of the incident waves).

A fault, evolving during this directional wave detector resetting time, will not be perceived by the wave detector. The object of the evolving fault measuring section, see fig 1, is to make possible clearing of such an evolving fault.

When the line is without fault the evolving fault measuring section is disabled. In case of a line fault and a subsequent directional wave detector section operation and operation from either the underimpedance starter or the overcurrent starter, both shown in fig 1, the evolving fault measuring section is enabled after a time delay of 35 ms. Should the power system include series capcitors, the time delay is extended in order to ensure series capacitor gap flash over (recommended time delay is 50 ms).

Note that the evolving fault measuring section does not use any communication equipment.

The theory of the evolving fault measurement is described in detail in section 3.5.3.

Conclusively, the evolving fault measuring section has two directional impedance measuring zones, and a third zone that follows the setting of the underimpedance starter (see sections 2.3.2 and 3.5.8).

The first measuring zone is set to cover less than 100% of the line (in normal cases 80% of the line).

The second measuring zone operation is based on time selectivity; the reach is extended incrementally after a given time-lag which is governed by selective time setting.

The third zone is a back-up protection based on time selectivity, the reach is extended incrementally after a given time-lag which is giverned by selective time setting.

The evolving fault measuring section is of a switched-scheme type and consequently has only one measuring unit. In the event of a fault on the line, the underimpedance starter control a phase selector unit so that, depending on the type of fault, predetermined measuring quantities are fed into the measuring unit. The measuring unit has a directional function in which the measurement of direction is based on healthy phase polarization for single and two-phase faults and on memory for three-phase fault.

The operating range of the evolving fault measuring section is defined in the impedance plane by boundary lines in the reactive and resistive axes, both of which pass through the set impedance point, and the direction is defined by a mho-circle passing through the same point.

The reach in the reactive and resistive axes has the same setting range and can be set independability of each other. (However, the R/X ratio should not be greater than 3 times if a large portion of the protected line is to be covered by the first measurng zone).

When the reach is extended the operating range is increased uniformly.

2.3.2 Underimpedance starter

It is important to point out that, although the evolving fault measuring section is controlled by directional wave detection operation, the underimpedance starter works independently of the directional wave detector section of RALZA. This is due to the three different purposes (see fig 1) served by the underimpedance starter; it serves as a

starting relay to the evolving fault measuring section (together with the overcurrent starter)

impedance measuring unit, determining the line impedance status when the protected transmission line is energized by closing a breaker

iii back-up protection unit, providing zone 3 relaying; after a recommended time of 600-800 msec it can operate the tripping relays via the tripping logic.

The underimpedance starter is described in section 3.5.8.

2.4 Back-up relaying

The back-up relaying of RALZA may be divided into three different categories, as described below.

Zone 2 relaying: A fault in zone 2 brings about a trip signal, provided that the evolving fault measuring section is enabled, and that the time-lag criterion of zone 2 is fulfilled.

Zone 3 relaying: After a recommended time of 600-800 msec, the underimpedance starter or the overcurrent starter can operate the tripping relays via the tripping logic.

Neutral current back-up relaying: As shown in fig 1, the neutral current measuring unit, besides co-operating with the directional wave detector section, is able to bring about a back-up tripping signal via a time-lag relay (not shown in fig 1), with a recommended setting of 1.5-5 seconds.

The object of this feature is to provide back-up relaying for high resistive earth faults.

2.5 Switching into a fault

Switching a breaker into a fault or into forgotten working earth is a case that requires particular attention, due to the nature of the travelling waves generated. This is further explained in section 3.6.

To cope with this particular condition a special switch-into-fault unit is included. As indicated in fig 1, the unit processes data from the directional wave detector section (particularly phase voltage) and the underimpedance starter, and the latter may operate the tripping relays (via the tripping logic), should a fault or a working earth be present.

2.6 Shunt reactor switching

In some applicatios, a shunt reactor may be included in the power system to be protected. A switching of such a shunt reactor may be interpreted by the directional wave detector section of RALZA as an internal fault (if the current and voltage changes created are higher than the set operating values of the units involved).

To prevent such an unnecessary operation a temporary settable reduction of the operating value of the current changes can be made, by means of an input relay and an optional time-lag relay.

The independent made of operation for close-in fault is not affected by this reduction.

The setting of the reduction level is made via programming switches readily available on the front of a unit (section 4.12).

3. THEORY OF OPERATION

The object of this chapter is to supply a more thorough examination of the different fault detection and tripping principles used in the RALZA relay protection.

3.1 Dependent mode of operation

3.1.1 Fault analysis

In case of a fault at a point F in an electric power transmission network (Fig 2) the current and voltages at any point may be obtained using the superposition theorem.

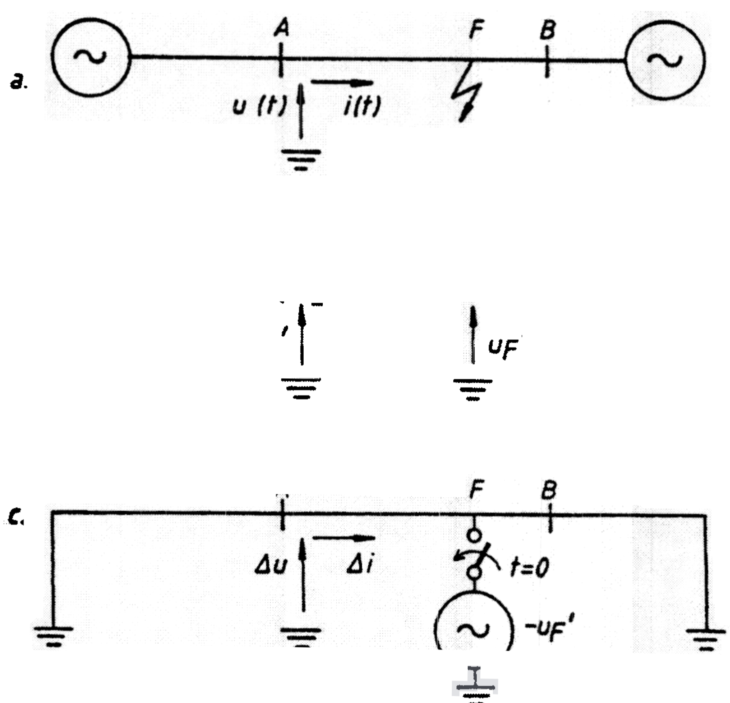


Fig 2:
Synthetisation using the superposition theorem

Consider a point A as shown in Fig 2a. The current i(t) and the voltage u(t) after fault occurrence ($t \geq 0$) can be split into prefault steady-state parts and fault parts of steady-state and transient nature.

The pre-fault steady-state parts i'(t) and u'(t) are caused by the original sources as shown in Fig 2b. The fault parts of i(t) and u(t) are caused by a fictitious source applied to the fault point at the instant of fault inception. Those parts are denoted Δ i(t) and Δ u(t) and contain changes of both steady-state and transient nature.

The fictitious source has voltages on faulted phases equal in magnitude and opposite in sign to the pre-fault voltages (u'_F) at the fault point. (Fig 2c).

The superposition theorem gives:

$$i = i' + \Delta i$$

$$u = u' + \Delta u$$

3.1.2 Measuring principle

The RALZA relay is designed to use Δ i and Δ u, i.e. the changes in current and voltage in order to detect a fault and the direction to the fault from the measuring point. The changes Δ i and Δ u are measured with standard CT's and CVT's and include changes of both steady-state (ss) and transient (tr) nature as mentioned earlier. One can therefore write the measurands as:

$$\Delta i = i_{ss} + i_{tr}$$

$$\Delta u = u_{ss} + u_{tr}$$

3.1.3 Fault detection

Fault detection is evident since Δ i and Δ u are caused by the occurrence of a change in the electrical state of the power network.

However, travelling waves are generated not only by faults but also by switching operations, lightning surges etc. It is therefore necessary that the relay can discriminate between changes due to faults and changes due to other causes.

Lightning strokes that do not lead to a fault, involve a transport of energy along the line in the form of coupled current and voltage waves exhibiting a high frequency character. The directional wave detector design is such that is damps heavily the amplitude of high frequency components, and requires also that a measuring signal if any, should last for a time longer than the directional wave detector minimum decision time. This time criterion coupled to the fact that the directional wave detector operates only if both Δ i and Δ u have magnitudes larger than set values (amplitude criteria), makes it possible to distinguish a lightning stroke that does not lead to a fault from one that does lead to a fault as well as from a fault due to any other cause. In the latter cases the transients will also contain power frequency and low frequency components, that are not so heavily damped by the relay circuits during the first moments after fault inception, and that last for an appreciable time, much longer than the relay decision time.

For discrimination against switching surges it is important to note that travelling waves originate from the point where the change in the electrical state of the power system was initiated. Thus simply by excluding the circuit breakers from the protected zone switching operations will always be interpreted as external events. This is obtained automatically in most EHV systems since voltage normally is measured on the line side of the breaker. The fact that most EHV breakers have pre-insertion resistors that damp the amplitude of the switching surge enhances this discrimination capability.

3.1.4 Directional determination

The application of the fictitious source at the fault point F, Fig. 3, causes travelling waves (voltage and current waves) moving from F towards the two terminals A and B. Positive current is defined locally as a current flowing from A to F and from B to F.

If the pre-fault voltage u'_F is positive the fictitious source causes negative voltages waves towards A and B, Fig. 3a. But the current waves are positive since the fictitious source causes currents from A to F and from B to F.

Type of fault	$u_F(t)$ Polarity	TERMINAL A Δi	A Δu	B Δi	B Δu
Internal	Pos.	+	−	+	−
Internal	Neg.	−	+	−	+
Ext. to A	Pos.	−	−	+	−
Ext. to A	Neg.	+	+	−	+
Ext. to B	Pos.	+	−	−	−
Ext. to B	Neg.	−	+	+	+

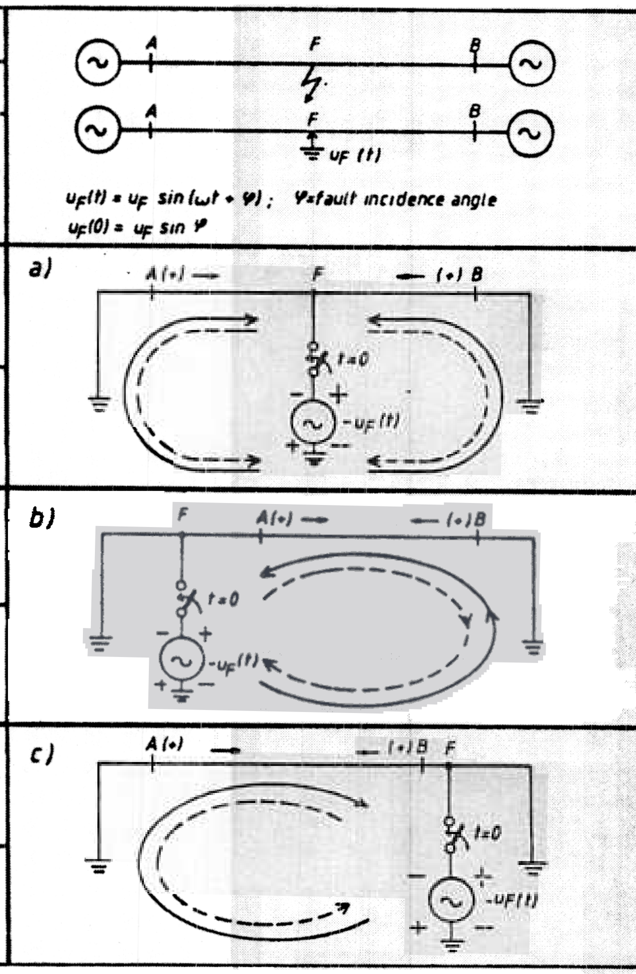


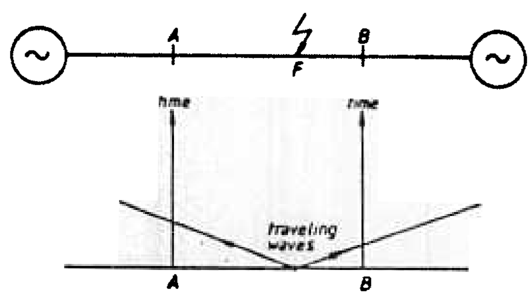
Fig 3:
Directional determination. The changes in current Δi and voltage Δu at terminal A and B are opposite in sign for internal faults but of equal sign for external faults at the terminal closest to the fault.

Thus at point A, Δ i is positive and Δ u is negative during the first moments after fault inception. Likewise at point B Δ i is positive and Δ u is negative.

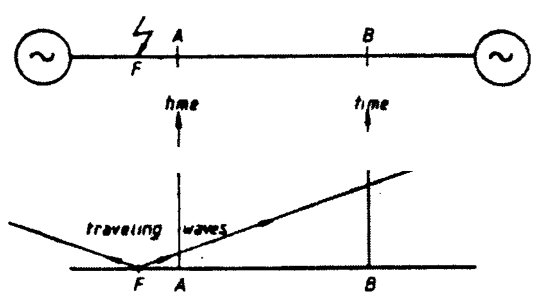
If the pre-fault voltage u'_F is negative, Fig 3a, dotted line, the current change Δ i is negative and the voltage change Δ u is positive during the first moments. Likewise at point B Δ i is negative and Δ u is positive.

In case of an external fault, Fig 3b, c, the fictitious source at F causes a current change Δ i and a voltage change Δ u having equal sign at the line end closest to the fault but a current change Δ i and a voltage change Δ u which are opposite in sign at the other line end.

From the principles outlined above it can thus be concluded that in the case of an internal line fault both line ends will have a change in current, Δ i, and a change in voltage, Δ u, which are opposite in sign, whereas in the case of an external fault one line end will have changes of equal sign.



a) Internal fault



b) External fault

Fig 4
Propagation of travelling waves.

The conclusion above can be visualized graphically as shown in Fig 4 in terms of the direction of motion of travelling waves generated by a change in the electrical state of the network (i.e. fault, breaker operation etc.).

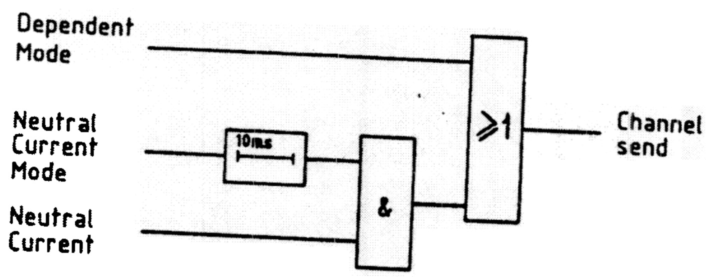
Fig. 4a shows an internal fault on line section AB and Fig. 4b shows an external fault. It is easily seen that at A the direction of motion of the travelling wave will be different for an external fault compared to an internal one.

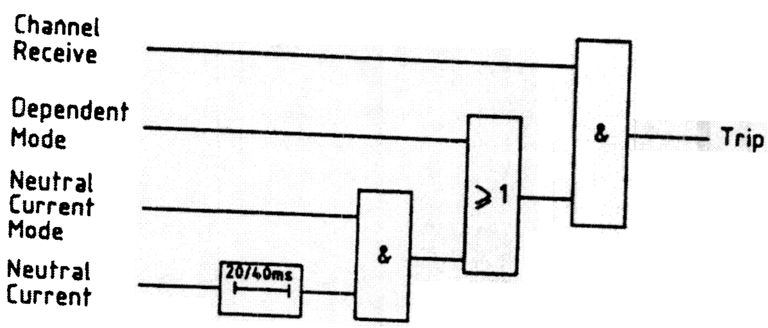
3.1.5 Co-operation with remote end protection

In order to clear all faults on 100 percent of the transmission line, a directional comparison scheme is adopted and a communication channel is required to link the RALZA relays at each end of the line, yielding the dependent mode of operation.

The communication channel ought to have as short channel delay as possible since it will directly influence the total operating time of the dependent mode of operation for the directional wave detector.

Below is shown the principle for the permissive overreach directional comparison scheme employed in RALZA.





3.2 Independent mode of operation (optional)

3.2.1 Similarities to dependent mode of operation

The independent mode of operation is identical to the dependent mode as far as fault detection and directional determination is concerned.

3.2.2 Features

The independent mode of operation yields a directional measurement with a limited reach along the line, thus coping with close-in faults and has the particular advantage of not requiring a communication channel between the RALDA relays at each end of the line and thus has an extremely short operating time.

3.3 Neutral current control mode of operation

The object of having this particular neutral current control mode of operation is the strive to detect high resistive earth faults within the protected zone.

This is achieved by linking the measurement of neutral current to the directional wave detecion.

The conditions required to obtain a neutral current control mode trip signal are as follows:

A disturbance on the line section to be protected causes a sensitive part of the directional wave detector section of RALZA to produce a channel send signal. Furthermore, after a time of 20 or 35 ms (depending on the position of a programming switch), a trip signal is generated, provided that a) the neutral current measuring unit (shown in fig. 1) continuously reveals the presence of neutral current in the system (i.e., as soon as the neutral current exceeds a set value), and b) a channel receive signal is obtained.

The delay of 20 or 35 ms is introduced to prevent tripping in case the disturbance is caused by surge arrester operation, lightning stroke, or else, bringing about a neutral current of limited duration.

(Finally, as described in section 2.4 a three-phase trip signal will be produced if the neutral current measuring unit senses a continuous neutral current during a rather long time, tentatively 1.5-5 seconds).

3.4
Weak-end infeed mode of operation (optional)

A weak-end infeed is a possible system configuration which can occur on a radial transmission line or as indicated in the figure below when B end generation is out of service, only a single line is in service and no parallel path exists and there is no possibility of infeed from the B end.

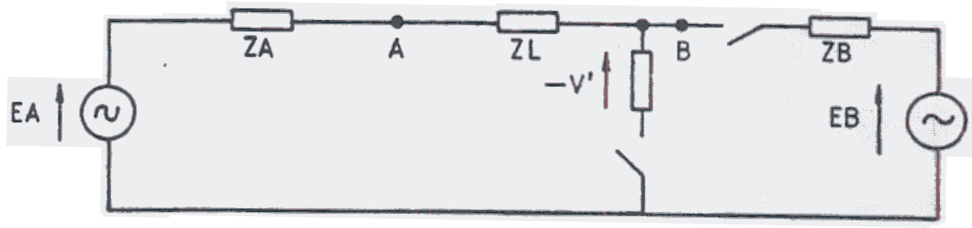


Fig. 5:
Weak-end infeed configuration

With no infeed from the B end it follows that if an internal fault occurs on the line A to B only the RALZA relay at line end A will detect the fault.

The RALZA relay at line end A can not trip the local breaker since no communication signal will be transmitted from line end B. Similary the RALZA relay at line end B will not trip the local breaker either, and the fault will stay on until tripped by the impedance measuring section of RALZA.

To speed up the tripping in such a situation it is possible to add an optional weak-end infeed logic to the RALZA relay at line end B, which will re-transmit the communication signal sent from line end A and also trip the local breaker at line end B.

The weak-end infeed logic operating principle can be described in logic symbols as follows:

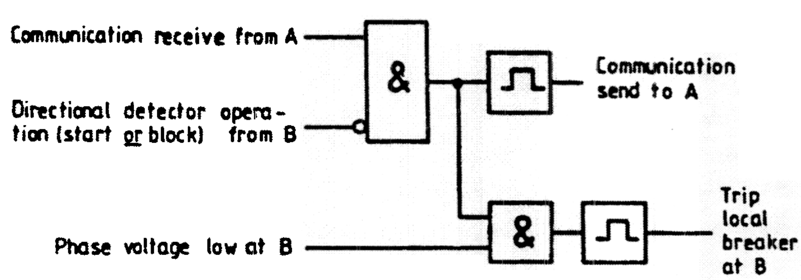


Fig. 6:
Weak-end infeed logic operation principle

The RALZA relay at line end A will now trip the local breaker since the communication signal sent to line end B is retransmitted and gives the impression that also the RALZA relay at line end B has detected the fault as internal.

The weak-end infeed logic will trip line end B.

3.5 Evolving faults mode of operation

3.5.1 Initial information

All initial fault occuring on a line in service are detected by the directional wave detector section of RALZA (the case of switching a breaker into a fault is treated in sections 2.5 and 3.6). When the direction to a fault is determined, all subsequent information is disregarded from until the relay resetts (this is done in oder to avoid the confusion that could be caused by multiple reflexions of the incident waves).

A fault, evolving during this directional wave detector resetting time, will not be perceived by the wave detector. The object of the evolving fault measuring section of RALZA is the clearing of such an evolving fault.

3.5.2 Control of evolving fault measuring section

Both of the following conditions must be fulfilled prior to enabling of the evolving fault measuring section of RALZA:

The directional wave detector section of RALZA has to operate (that is, react to an internal or external fault).

2 The underimpedance starter or the overcurrent starter has to activate a settable time-lag relay; and this time-lag relay must time out.

The reason for this twofold arrangement is to obtain the advantages of insensitivity to fuse failure, power swings and loading conditions. However, these features only apply to the evolving fault measurement in RALZA. The zone 3 back-up protection, on the other hand, constituted by the underimpedance starter and the overcurrent starter, may (after a settable time) act directly upon the tripping relays. Therefore, the zone 3 back-up protection behaves like classical impedance schemes.

3.5.3 Theory of evolving fault measurement

Provided that the conditions discussed in section 3.5.2 are fullfilled activation of timing circuits and a phase selector unit in the evolving fault measuring section will follow. The phase selector unit ensures that the correct current and voltage for measuring and the correct direction is used. To determine the direction, the evolving faults measuring section uses healthy phase polarisation in the case of single and two phase faults.

The starting relays influence the phase selector unit so that, depending on the type of fault, it transfers the measured quantities for a given measuring loop to the measuring unit. Table 1 shows which of the measuring loops is selected, depending on which-starting relays that are activated, and the position of the PS-switch. The choice between these loops is done according to fig. 7.

Starting relay	Selected measuring loop (dependent on position of PS-switch)	
	1	5
R	RN	RN
S	SN	SN
RS	SR	SR
T	TN	TN
TR	RT	RT
ST	TS	TS
RST	SR	SR
N	-	-
RN	RN	RN
SN	SN	SN
RSN	SN	SR
TN	TN	TN
TRN	RN	RT
STN	TN	TS
RSTN	SR	SR

Table 1

Table 2 shows the current, voltage and directional voltage which are used for each respective measuring loop.

The K_N symbol refers to a thumbweel switch, the purpose of which is to set the zero sequence compensation, see section 4.19 and 6.4.

Measuring loop	Current (I)	Voltage (U)	Directional (U_p)
RN	$I_R+K_NI_N$	U_{RN}	U_{ST}
SN	$I_S+K_NI_N$	U_{SN}	U_{TR}
TN	$I_T+K_NI_N$	U_{TN}	U_{RS}
RS	I_R-I_S	U_{RS}	$-(U_T-U_0)$
ST	I_S-I_T	U_{ST}	$-(U_R-U_0)$
TR	I_T-I_R	U_{TR}	$-(U_S-U_0)$

Table 2

In solidly earthed networks, the phase-to-phase loop is normally measured during two-phase faults to earth. It is also possible to let the relay measure the earth-fault loop during such faults, see fig. 7. For one and the same type of fault, the evolving fault measuring section can consequently be programmed to measure on different measuring loops, which can be an advantage in cases where redundant relays are required.

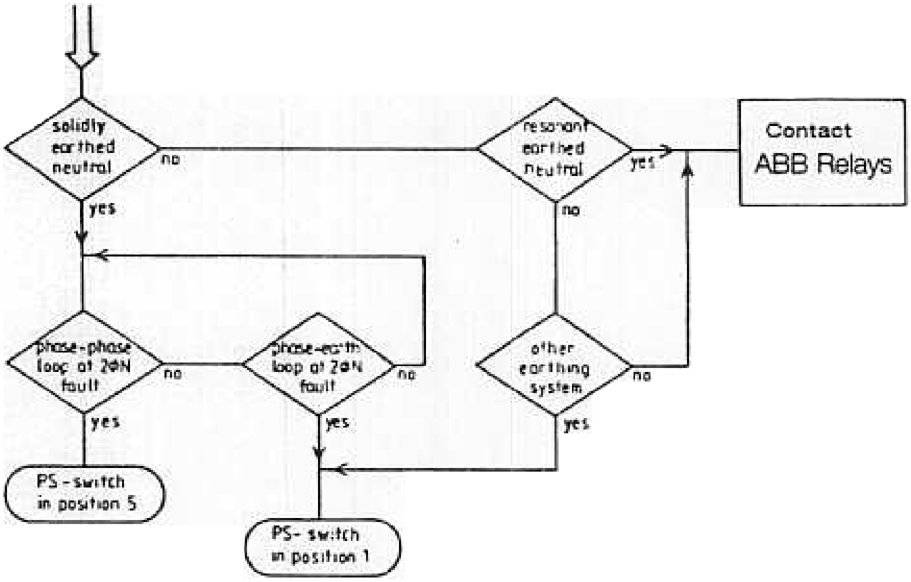


Fig. 7:
Flow diagram for setting the PS phase selector switch.

3.5.4 Operating characteristic

The operating characteristic of the evolving fault measuring section is determined by the setting of the reactive and resistive limits and the direction, see fig. 8.

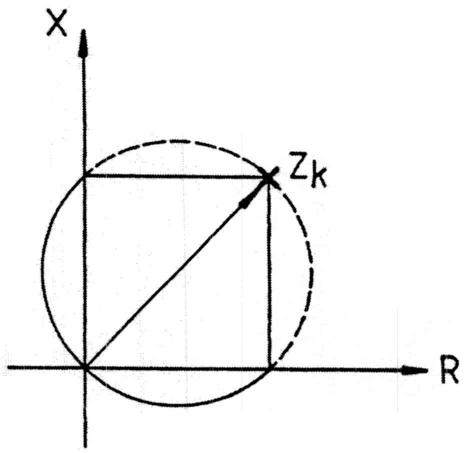


Fig. 8:
Operating characteristic

To acquire these three boundaries of operation, the polarity of four measured signals is compared at each half cycle and at a given time in a phase comparator.

The following signals are used for measuring purposes:

I = Fault current

= Reactive voltage drop across the model impdance

= Polarising voltage for determining the direction

= Compensating voltage $U-IZ_k$

where U = Voltage across the faulty loop

Z_k = Model impedance

3.5.5 Directional measurement

The compensated voltage is compared with the directional voltage.
The criteria governing function is:

$$\pi < \arg U_k - \arg U_p < 2\pi \qquad (1)$$

Condition (1) indicates that the boundary line for operation is a directional Mho-circle which passes through the setting point Z_k and through the origin at zero source impedance, see fig. 9.

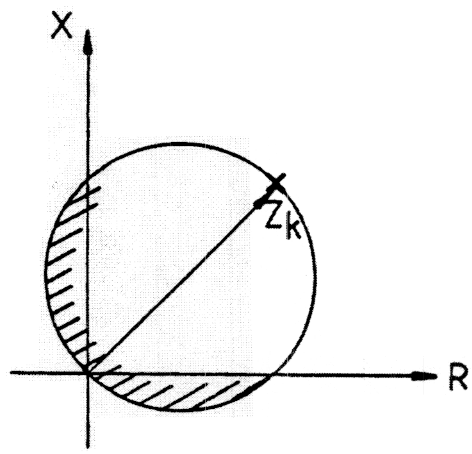


Fig. 9:
Direction

<u>Reactance measurement</u>

The compensated voltage is compared with the fault current. The criteria governing function is:

$$\pi < \arg U_k - \arg I < 2\pi \tag{2}$$

Condition (2) indicates that the boundary line for operation in the impedance plane is a straight line which passes through the setting point Z_k and is parallel to the R-axis, see fig. 10.

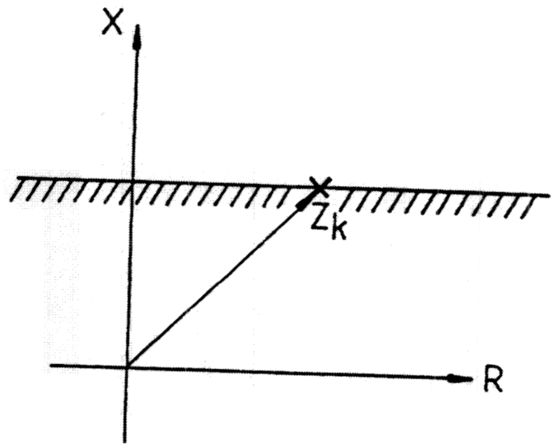


Fig. 10:
Reactive boundary line

<u>Resistance measurement</u>

The compensatsed voltage is compared with the reactive voltage drop caused by the fault current.

The criteria governing function is:

$$0 < \arg U_k - \arg IX_k < \pi \tag{3}$$

Condition (3) indicates that the boundary line for operation in the impedance plane is a straight line which passes through the setting point Z_k and is parallel to the X-axis, see fig. 11.

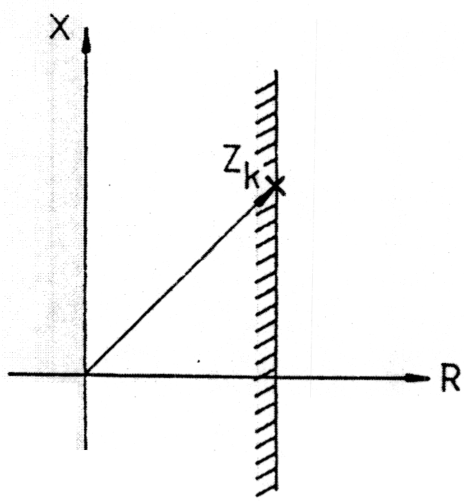


Fig. 11:
Resistive boundary line

3.5.8 Underimpedance starter and overcurrent starter

The underimpedance starter is a three-phase relay and is available with either a circular or an oval characteristic as shown in fig. 12. The oval characteristic is more advantageous in that it provides a greater margin to the load current.

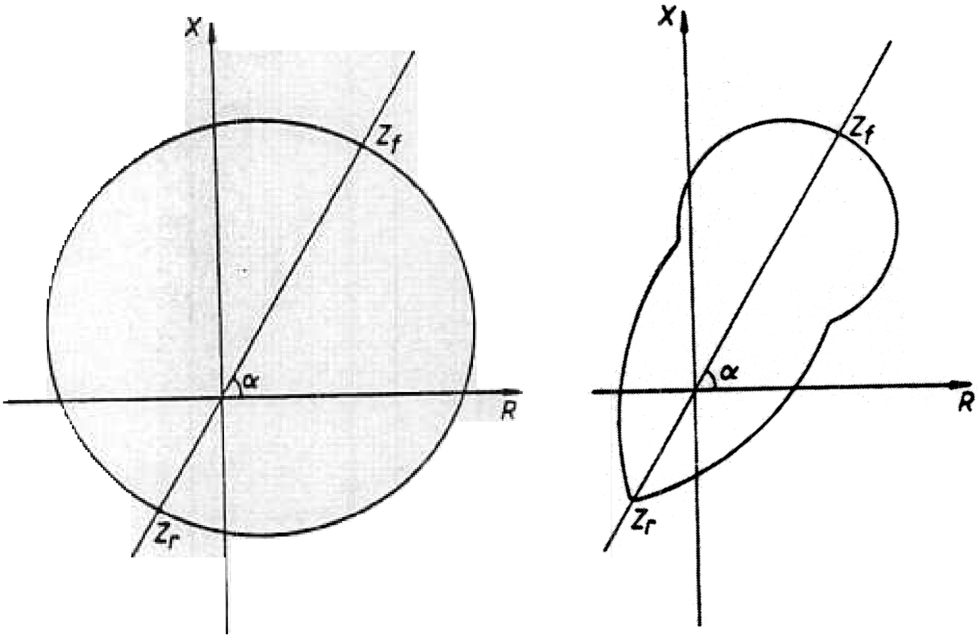


Fig. 12:
Operating characteristic of the underimpedance starter

The reach values of each phase are individually adjustable in the forward direction (Z_f) and in the reverse direction (Z_r). The underimpedance starter has normally a characteristic angle of 60^o.

In normal operation, the underimpedance starter measures the phase current and line-to-line voltage but in the event of an earth fault it is reconnected to measure the phase current and voltage to neutral. This reconnection is brought about via a built-in input relay in the underimpedance starter and is controlled from the zero-sequence current relay incorporated in the evolving fault measuring section.

The underimpedance starter has a built-in input relay which, when energized, blocks the measuring function of the relay; this relay is used for blocking from a power-swing blocking relay (optional).

Further information about the underimpedance starter is provided in section 4.15.

The overcurrent starter has measuring functions for overcurrent in the respective phases.

Since underimpedance starting is used, the operating value of the phase overcurrent starters is increased to 10 times the set operating value. Consequently, this unit merely serves as a back-up protection to the underimpedance starter, in the event of close-in faults resulting in high fault currents.

Further information about the overcurrent starter is provided in section 4.18.

3.6
Switch-into-fault mode of operation

Switching a breaker into a fault or into a forgotten earthing device is a case that requires particular attention; consider the following:

If the voltage measurement is done on the busbar side of the breaker, the breaker is included in the protected zone. The reason is, that voltage will be prevailing prior to the switching operation; consequently, the switching of a breaker into a fault will give a voltage drop and a current increase, i.e. Δ i and Δ u will have different signs and the directional wave detector system will trip.

If the voltage measurement is done on the line side of the breaker, the breaker is not included in the protected zone. There will be no appreciable voltage prior to the switching operation; consequently, when the breaker is switched into a fault both the voltage and the current will increase, i.e. Δ i and Δ u will have equal signs and the directional wave detector system will block.

The above mentioned voltage changes, appearing in a network upon the closing of a breaker, are (according to Thevenius theorem) found by inserting a voltage source U_{BC} (voltage before closing) with the polarity shown in fig. 13. The voltage change on the busbar and line side of the breaker is indicated as ΔU_B and ΔU_L.

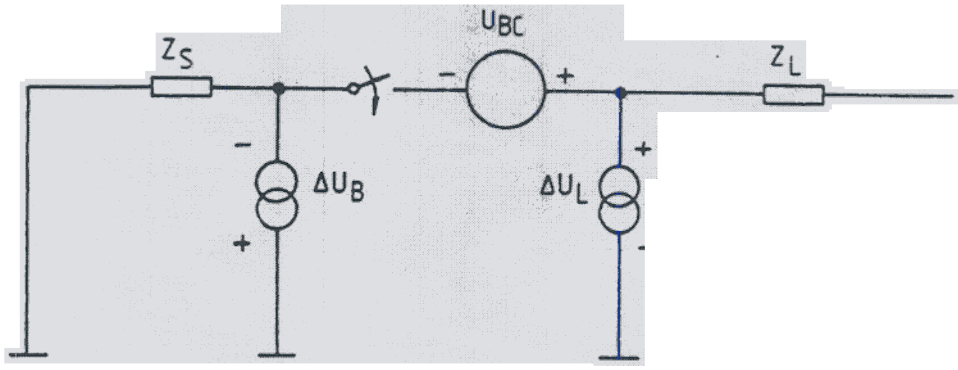


Fig. 13

Thus, switch-into-fault protection must be provided as a separate fault measurement in RALZA.

NOTE ! The standard design of RALZA assumes voltage measurement on the line side of the breaker.

The following units are involved in detecting a switch-into-fault condition:

- The underimpedance starter (see fig. 1 and section 3.5.8) provides the measurement of the line impedance status.

- The switch-into-fault unit (see fig. 1), containing

  1) the voltage level detectors, sensing if any line voltage drops under a set value.

  2) circuits for enabling the underimpedance starter to act directly upon the tripping relays.

The switch-into-fault mode of operation is enabled as a result of (1) low line voltage and (2) a nonactive state of the underimpedance starter and the directional wave detectors.

The switch-into-fault unit will stay enabled as long as any line voltage remains below the set value, and 200 msec afterwards; under these circumstances, the underimpedance starter is able to operate directly upon the tripping relays.

As all line voltages exceed the set value, and the 200 msec have passed, the switch-into-fault mode of operation is disabled.

It should be noted that the switch-into-fault detector always gives a three-phase tripping signal.

4. DESIGN

4.1 COMBIFLEX modular system

RALZA is housed in two COMBIFLEX equipment frames, one of size 12S (21" high) with three apparatus frames, 60C wide (16.8"), and one of size 4S (7" high) with one apparatus frame, 60C wide (S = 44.45 mm = 1.75 in, C = 7 mm = 0.28 in); see figure 15 and enclosed dimension print 5283 0263-AA. Further particulars of the modular system COMBIFLEX can be found in Catalogue RK 92-10 E.

The relay is of static design and is built up of COMBIFLEX modular units as follows:

- The RQ- and RX-type units are screwed to the apparatus frame via terminal bases.
- The test switch and the transformer units RTTF and RTQTC are screwed directly on the apparatus frames.
- The RG-type units and the transformer unit RTTG are mounted in an equipment frame. The internal connections between the units within the equipment frame are made via a mother board with edge connectors and flat cables. The connections to the equipment frame are made on the rear of the frame of RTXG-type pin connectors with COMBIFLEX socket leads and screw-type terminals.

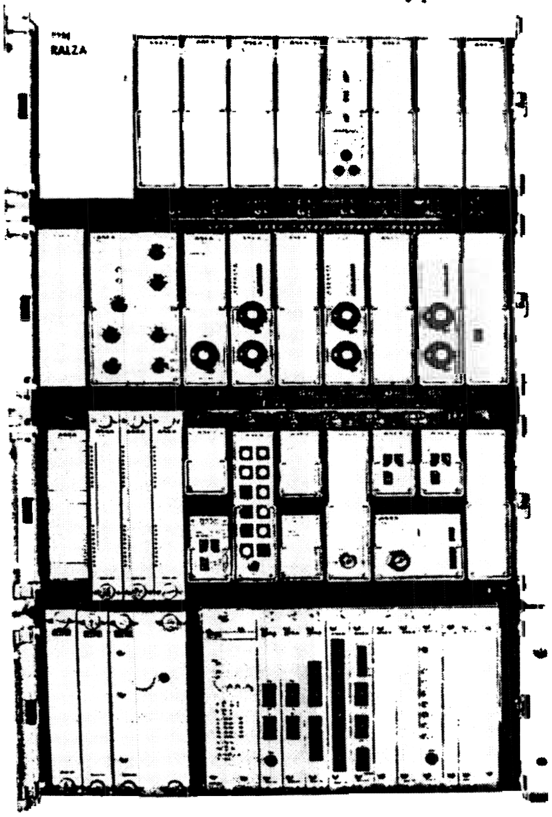


Fig 14:
RALZA designed for single-phase tripping; the optional units for phase selection, independent mode directional detection and weak-end-infeed logic are included.

4.2
Units included in RALZA (their type, position and designation)

The position of units included in a RALZA relay are presented in fig 15 (below); in table 3 (over) the designation and type of each unit is presented as well.

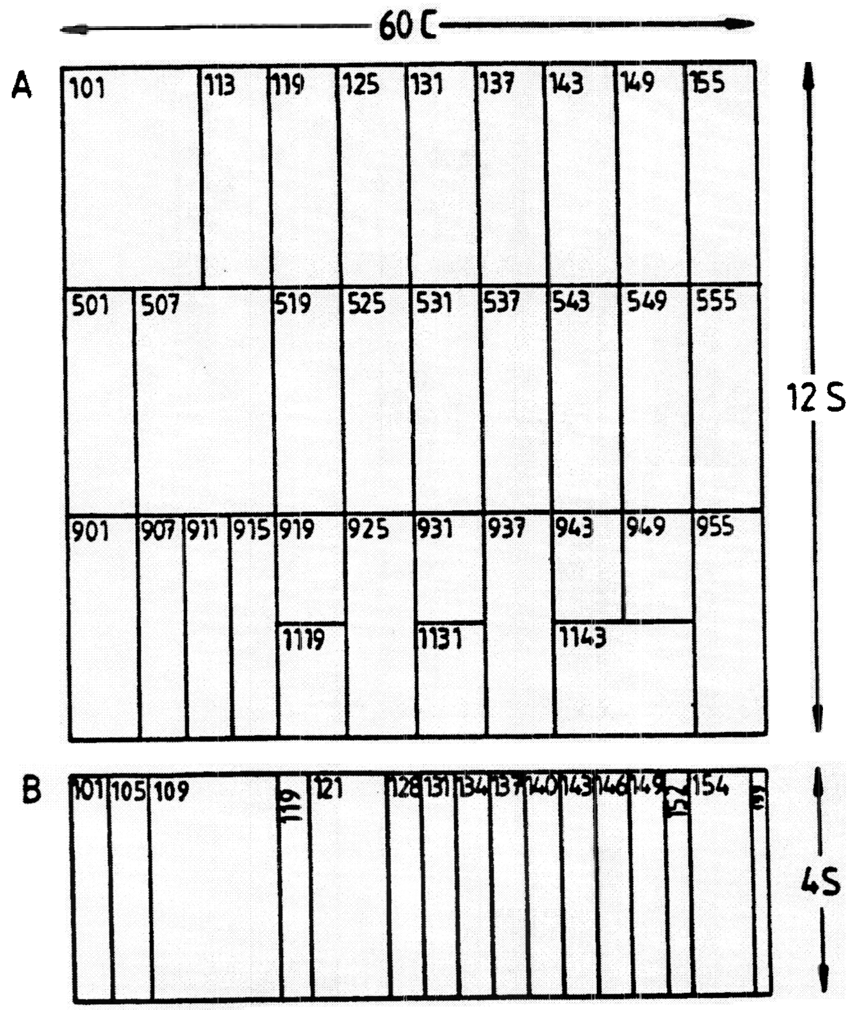


Fig. 15:
Position of units included in RALZA

12S equipment frame:

	Position	Designation	Type
A	101	Transformer unit	RTTF
	113,119,125	Passive filter units	RXTFG 2H
	131	Phase selector unit (optional)	RXTEL 2H
	137	Test unit	RXTEN 2H
	143,149,155	Active filter units	RXTFH 2H
	501	Transformer unit	RTQTC 060
	507	Underimpedance starter	RXZK 4
	519	Tripping logic unit	RXTEH 2H
	525	Directional detector (optional)	RXPA 2H
	531	Fault detection and phase selection logic unit	RXTEG 2H
	537	Directional detector	RXPA 2H
	543	Fault detection and phase selection logic unit	RXTEG 2H
	549	Directional detector	RXPA 2H
	555	Amplifier unit	RXTEN 2H
	901	Test switch	RTXP 18
	907,911,915	Interface relays	RQKA 040
	913	Interface relay	RXMT 1
	919	Interface relay	RXMBB 1
	1119,943,949	Time-lag relays (two optional)	RXKE 1
	925	Indication and signalling unit	RXSK 2H
	931,1131	Driver units	RXTEK 1
	937	Voltage measuring unit	RXEDB 2H
	1143	Neutral current measuring unit	RXIB 22
	955	Weak-end-infeed logic unit (optional)	RXTEM 2H

4S equipment frame:

	Position	Designation	Type
B	101	DC/DC converter	RQMB 040
	105	DC/DC converter	RQMB 041
	109	DC/DC converter	RQMA 100
	121	Internal interface input unit	RGKC 070
	128	Overcurrent starting unit	RGIC 030
	131	Phase selector unit	RGGB 030
	134	Current setting unit	RGAA 030
	137	Voltage setting unit	RGAB 030
	140	Time-lag unit	RGTA 030
	146	Memory-circuit unit	RGLA 030
	149	Measuring and indicating unit	RGSB 030
	152	Space reserved for extension board	
	154	Internal interface output unit	RGKD 050
	7123	Transformer unit (on the rear of the relay)	RTTG

Table 3:
Units included in RALZA

4.3
Block diagram

The block diagram in fig. 16 roughly illustrates the signal flow within the relay at one terminal of the protected line. The figures within brackets in the text below refer to the positions of the units.

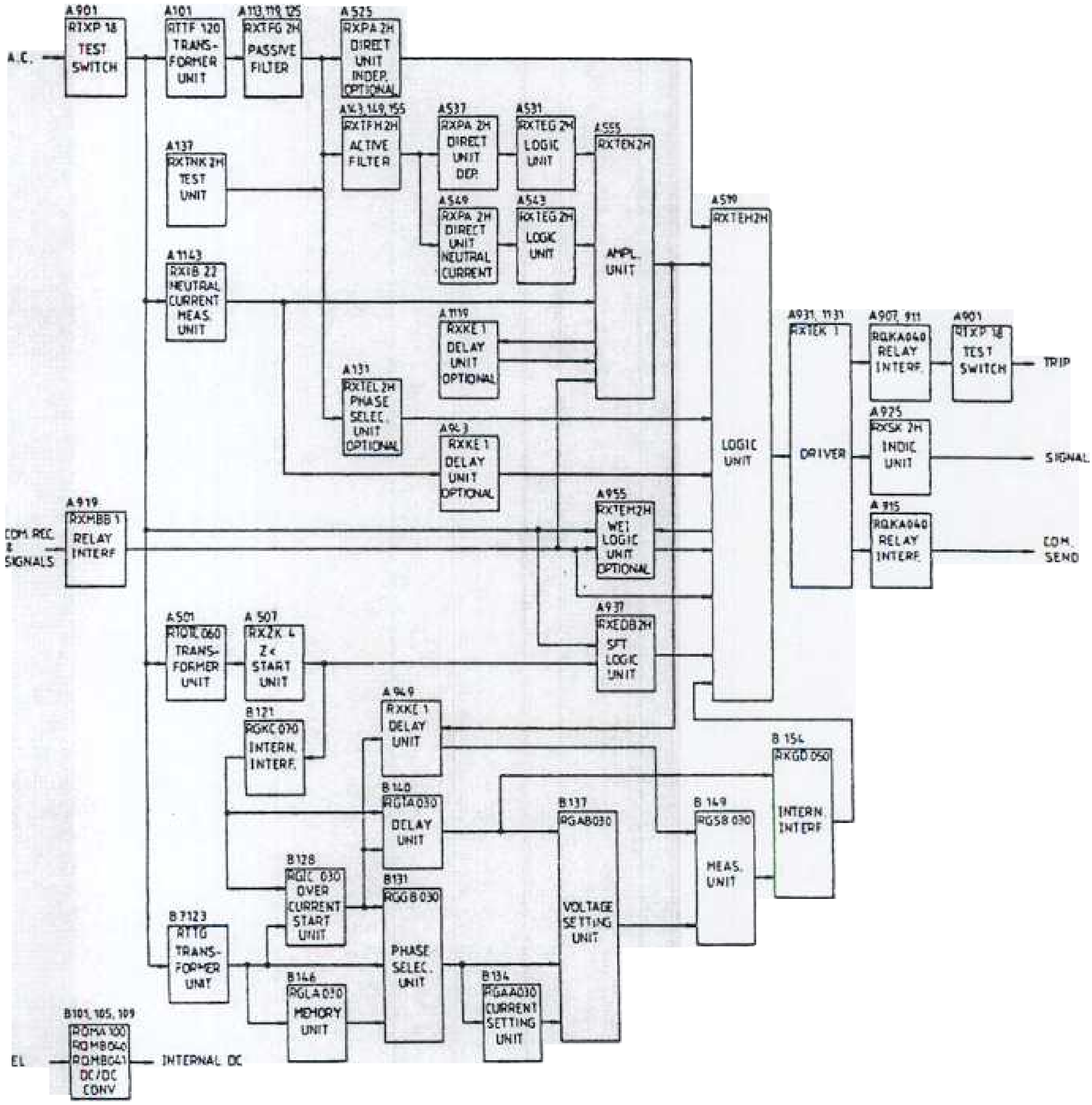


Fig 16:
Block diagram of RALZA

4.4 Test switch

The input signals from the instrument transformers as well as the auxiliary voltage and the tripping outputs from the relay are connected via a test switch type RTXP 18 (A901). The test switch, which is part of test system COMBITEST, enables secondary injection tests to be conviently performed with a testplug handle type RTXH 18.

4.5 Transformer units

The transformers are isolated and furnished with an earthed screen between the primary and secondary windings and this enhances the relay's immunity to transients.

4.5.1 Transformer unit for directional wave detector section

The analog current and voltage signals from the instrument transformers are fed into the directional wave detector section through isolating transformers in the transformer unit type RTTF 120 (A101).

The transformed signals are fed to the passive filter units.

4.5.2 Transformer unit for underimpedance starter

The transformer unit RTQTC 060 (A501) contains three air-gap transformers (transactors) that are used in the current circuit and three voltage transformers in the voltage circuits.

4.5.3 Transformer unit for the evolving fault measuring section

The RTTG-type transformer unit is mounted on the rear of the relay (B7123) and includes the input transformers. Altogether, there are four current transformers, one for each phase and one for the neutral, and three voltage transformers.

The primary windings of the transformers are connected to the test switch while the secondary windings are connected to the mother board of the relay.

4.6 Filter units

4.6.1 General

In the filter units the steady-state frequency components i' and u' of the current $i = i' + \Delta i$ and the voltage $u = u' + \Delta u$ are suppressed, on a segregated phase basis.

The time constant of the circuits is selected in such manner that only the initial changes generated by a fault may influence the directional wave detectors.

Passive filter units

There are three passive filter units type RXTFG 2H (A113,119,125), one per phase, with passive components. The units are identical and interchangeable.

Active filter units

There are three active filter units type RXTFH 2H (A143,149,155), one per phase, with active components. The untis are identical and interchangeable.

4.7 Phase selection unit (optional)

If single-phase tripping is required, a phase selection unit type RXTEL 2H (A131) is offered as an option. The unit uses the output current signals of the passive filter untis in determining the faulty phase/phases; the outcome is fed to the tripping logic unit.

4.8 Test unit

Through the functional test unit, type RXTNK 2H (A137), a built-in test facility of the directional wave detector hardware is provided. The switches and pushbuttons on the front determines the test condition and type of fault (see chapter 8). The unit also comprises a DC-power-failure monitoring circuit, see section 4.29.

4.9 Directional detectors

4.9.1 Initial information

There are three identical, three-phase directional detectors type RXPA 2H. The purpose of each one of these are discussed below. First, though, a discussion about their common principle of operation is presented.

Information about the changes in current, Δ i, and voltage, Δ u, are fed to an amplification stage on a segregated phase basis. A suitable amplitude criterion is obtained through setting of the two tenturn potentiometers (the a- and b-setting), located on the front of each RXPA 2H unit.

The signals are then fed to the directional detection logic, shown in fig 17, where the direction to the fault is determined by comparing the signs of Δ i and Δ u. The forward looking detectors give a "tripping direction" signal (T) if the current and voltage changes are opposite in sign, while the reverse looking detectors give a "blocking direction" signal (B) if the changes are of equal sign. As illustrated in fig 17, the nominal signals S_i (V/kA) and S_u (V/kV) derived from Δ i and Δ u respectively are combined to yield T and B according to the following relations:

$$T = \max \left\{ \min \ (S^+_i, S^-_u), \min (S^-_i, S^+_u) \right\}$$

$$B = \max \left\{ \min \ (S^+_i, S^+_u), \min (S^-_i, S^-_u) \right\}$$

where upper index +/- refer to the signal polarity. All signals are ≥ 0.

This particular arrangement enhances security since both Δ i and Δ u must have a certain magnitude before the detectors give an output signal.

Further security is added by comparing the resulting signals T and B between the phases.

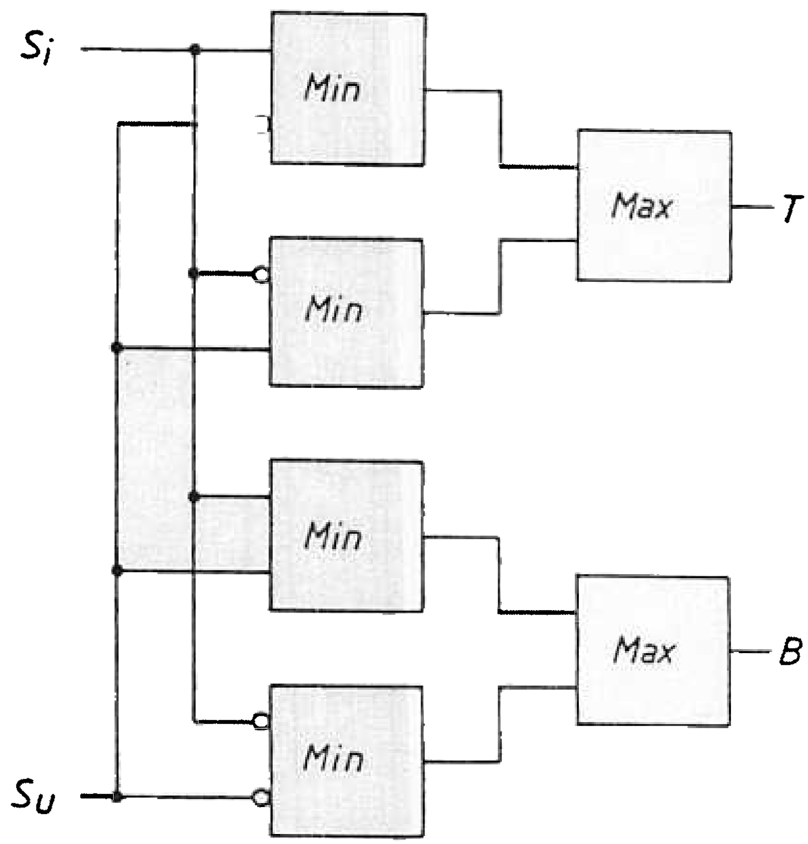


Fig 17:
Directional detection logic

4.9.2 Independent mode directional detector (optional)

The independent mode directional detector (A525) makes use of the output signals of the passive filters; the processed signals are then fed to the tripping logic unit.

The independent mode directional detector is normally set so that is does not operate (overreach) even for the maximum Δ i and Δ u obtained locally for faults at the remote end of the line. Thus an independent mode trip is selective for close-in faults on an amplitude basis without directional information from the remote end relay terminal.

4.9.3 Dependent mode directional detector

The dependent mode directional detector (A537) processes signals that have passed through the passive and active filters, and also (not shown in block diagram in fig 16) through a buffering stage in the amplification unit. The output signals of the detector are fed to one of the fault detection and phase selection units.

The dependent mode difectional detector is set to give output signals of sufficient magnitude even during a condition of minimum local change of Δ i and Δ u for remote phase to phase and three phase faults.

4.9.4 Neutral current control mode directional detector

The neutral current control mode directional detector (A549) uses the same input signals as the dependent mode directional detector, and feeds its output signal to a fault detection and phase selection unit.

This detector is always set sensitive enough to detect remote end single-phase faults with the higher estimated fault resistance, thus ensuring high-resistive earth fault clearing capability.

4.10
Faul detection and phase selection units

The analog signals from the dependent mode directional detector and the neutral current mode directional detector must exceed a certain level determined by input level detectors in the fault detection and phase selection logic units, type RXTEG 2H (A531,543), before a blocking (B) or tripping direction (T) signal is accepted. T and B are processed on a segregated phase basis in a logic circuit having sequential properties. The first signal to exceed the level determines whether the relay will trip or block i.e. the direction of motion of the very first travelling wave to reach the measuring point is acknowledged.

If the first signal that exceeds the level criteria is a blocking signal all subsequent signals are interpreted as blocking signals until the relay resets and vice versa for a tripping signal. This is done in order to avoid the confusion that could be caused by multiple reflexions of the incident waves.

4.11
Neutral current measuring unit

The neutral current measuring unit is an instantaneous overcurrent relay type RXIB 22 (A1143), with short operating (4 ms) and resetting time.

With the aid of a knob, accessible through a hole in the plastic cover, the operating value can be continuously adjusted between 1-3 times a scale constant, which is reconnectible (screw connection) for three different values.

In the amplifier unit, the neutral current measuring unit output signal is coordinated with the output signal of the logic unit connected to the neutral current control mode directional detector.

Furthermore, the neutral current measuring unit output is fed to the tripping logic, via a time-lag relay. This provides non-selective tripping possibilities in case of sustained neutral current indication.

4.12
Amplfiier unit

The amplifier unit RXTEN 2H (A555) is divided in two main sections.

A. One section is providing the necessary buffering between the active filter units and the dependent mode and the neutral current control mode directional detectors (this particular signal flow is not shown in the block diagram in fig 16).

By setting the appropriate switches (on the front of the unit) a temporary reduction of the output amplitude of the buffering amplifiers (current signals only) can be made.

(Note that the measures does not affect the independent mode of operation, and that the measure inhibits the neutral current control mode of operation).

The measure is executed by activating a particular interface relay, see section 4.27.1 and the external connection diagram 7435 179-CG, and the duration of the reduction/disabling is controlled by an optional time-lag relay. The object of this facility is to prevent directional wave detector operation in case of shunt reactor switching with the transmission line in service.

B. The orther section is co-ordinating the signals originating from

- the dependent mode directional detector operation
- the neutral current control mode directional detector operation
- the neutral current measuring unit operation

Furthermore, all these signals have to interact with the communication signal, in order to obtain an adequate cooperation with the remote end protection.

Another important result of the interaction is the generation of an evolving fault measuring section enable signal.

By setting one of the switches on the front of the unit, it is possible to shorten the time-lag used for disabling of the neutral current measuring unit output signal.

4.13
Time-lag relays

The time-lag relays, with pick-up delays, are of type RXKE 1 (A943,949,1119). This unit has a time-measuring LSI-circuit for delayed pick-up operation.

The time-lag, 1 ms-99 s, is set with the aid of two scale-value selector switches and four scale-constant selector switches, located on the front of the relay.

4.14
Weak-end-infeed logic unit (optional)

The weak-end-infeed unit type RXTEM 2H (A955) brings about a trip signal, and forwards this to the tripping logic unit, upon a particular combination of line voltage level, starting and tripping conditions, and communication signals; see section 3.4.

4.15
Underimpedance starter

The underimpedance starter, type RXZK 4 (A507), is a three-phase impedance relay with a short operating time. It makes use of phase currents and voltages via the transformer unit RTQTC 060; if a phase impedance is found to appear within the operating characteristic range, this information is forwarded to the internal interface unit and the switch-into-fault unit.

The operating characteristics is of either circular of modified lens type. The characteristic angle is 60 deg.

The forward and the reverse reach are set with knobs A, B, D on the front of the unit.

The light emitting diods on the front indicate weather a phase voltage or line-to-line-voltage measurement (supervised by the overcurrent starting unit RGIC 030, pos B128) is performed.

4.16
Voltage measuring unit

The voltage measuring unit type RXEDB 2H (A937) provides trip signals to the tripping logic unit RXTEH 2H (A519) upon particular pre-fault combinations of line-voltage levels and under-impedance starter signals, see section 3.6.

To activate the switch-into-fault detector RXEDB 2H, the absolute value of the prefault voltage must be below a certain level; this voltage level is set on the front of the unit (d-setting).

4.17 Internal interface units

4.17.1 Internal interface input unit

The internal interface input unit type RGKC 070 (B121) includes dry-reed relays and c.b. mounted relays.

The operating characteristic of the evolving fault measuring section and the formula which are used for calculating the settings of the different measuring zones, are shown on the front plate of the unit.

4.17.2 Internal interface output unit

The internal interface output unit type RGKD 050 (B154) contains electromechanical auxiliary relays.

4.18 Overcurrent starting unit

The overcurrent starting unit type RGIC 030 (B128) has measuring functions for overcurrent in the respective phases and for zero sequence current.

The operating value for overcurrent is set with the aid of a thumbwheel switch marked K_s, mounted in the front of the unit. The setting range is 1 to 4 x I_n in increments of 0.2 x I_n.

Since under-impedance starting is used, the operating value of the phase overcurrent starting relays is increased to 10 times the set operating value with the aid of a programming switch. These relays then constitute a back-up protection to the underimpedance starting unit in the event of close-in faults resulting in high fault currents.

The operating value for the zero-sequence current is 0.2 or 0.5 times the set value of the phase overcurrent starters. The setting is made with a programming switch located on the p.c. board.

In the front of the unit is a thumbwheel switch and a push button, providing possibilities to test the logic circuits of the evolving fault measuring section of RALZA (see chapter 8).

4.19 Phase selector unit

The phase selector unit type RGGB 030 (B13), which is controlled by the starting relays, selects the measuring quantities applicable to the type of fault and transfers these to the measuring unit for evaluation of the fault. This transfer of quantities is performed statically and depending on the type of fault and the setting of the phase selector switch "PS".

The phase selector unit has two thumbwheel switches in the front, marked K_N and PS respectively.

The K_N thumbwheel switch is used for setting the zero sequence compensation.

The PS thumbwheel switch is used for adapting the evolving fault measuring unit to the network, with respect to the earthing system, phase selection and type of start. The switch can be set to the positions shown in the flow diagram in fig. 7, section 3.5.3.

4.20
Current setting unit

On the front of the current setting unit, type RGAA 030 (B134), there are four thumbwheel switches for 'a' and 'b' settings, where 'a' influences the reactive and 'b' the resistive reach of the measuring unit.

These switches are interrelated pair-wise; the upper shows the tens and the lower shows the units.

4.21
Voltage setting unit

In the front of the voltage setting unit, type RGAB 030 (B137), there are six thumbwheel switches for setting the reach of measuring zone one and two in the measuring unit.

For setting of the respective steps a combination of two thumbwheel switches is used, the upper showing the tens and the lower showing the units.

4.22
Time-lag unit

In the front of the time-lag unit, type RGTA 030 (B140), there are ten switches for the programming and three switches for setting the selective time of the second and third measuring zone.

4.23
Memory circuit unit

This unit, memory circuit unit type RGLA 030 (B146), incorporates a circuit for determining the level of the line voltage.

To ensure the proper function of the measuring, at least 0.8% of the rated voltage is required.

4.24
Measuring and indicating unit

The measuring and indicating unit, type RGSB 030 (B149), contains, besides the measuring element of the evolving fault measuring section, light emitting diodes for indicating starts, tripping and the different timing steps. Tripping is indicated by a red LED, all the others are yellow. The indications can be cancelled by depressing the push button marked "Reset", located at the bottom of the unit. The light emitting diodes are normally blocked and used only during testing.

4.25
Tripping logic unit

The tripping logic unit type RXTEH 2H (A519) coordinates the tripping signals originating in the directional wave detector section, the neutral current measuring unit, the weak-end-infeed logic unit, the switch-into-fault logic unit, and the evolving fault measuring section. Furthermore, it coordinates the local relay decision with the remote end relay (via the communication link).

The RALZA relay is designed for selective single phase tripping but can, via an input relay, be prepared to effect a three-phase tripping (see section 4.27.1); this is organized in the tripping logic unit.

The t_d-setting, on the front of the unit, should always be set to zero, due to the permissive scheme operational mode of the RALZA relay protection.

4.26
Driver units

The driver units type RXTEK 1 (A931,1131) merely serves as an interface between various logic outputs on the one hand, and the indicating unit and the output relays on the other hand. The driver units are interchangable.

4.27
Interface units

4.27.1 Inputs

In addition to the ac current and voltage inputs and the dc inputs for auxiliary power supply, three inputs are available through dry-reed relays in interface unit type RXMBB 1 (A919):

CR (Channel receiving). Received communication signal from the remote line end.

PTPT This input, whenever activated, will prepare a relay designed for single-phase tripping to give a three-phase tripping for example during reclosing into a permanent fault.

BCW When this input is activated, a reduction (depending on the position of a programming switch) of the dependent mode operation is obtained. Furthermore, the neutral current control mode directional detector is disabled. See section 4.12.

4.27.2 Outputs

The output relays for tripping the breaker, signals for indication and for communication equipment are fed via the driver units type RXTEK 1 (A931,1131).

RALZA is provided with two outputs (make contacts, free) in each phase (in case of single-phase tripping), implemented through two dry-reed relays in interface unit type RQKA 040 (A907,911).

The remaining part of the required tripping relay arrangements is located in a separate COMBIFLEX equipment frame. Combinations of electromechanical relays type RXME 1, relay units type RXMBA 1, and static thyristor relays type RXMEA 1, are offered in accordance to customer demands.

As standard, an interface unit type RQKA 040 (A915), supplied with two outputs (make contacts, free), is used as (a) interface relay to the communication equipment (channel-send), and (b) general-start output.

The one output relay in the interface unit type RXMBB 1 (A919) provides free contacts for three-phase tripping indication.

4.28
Indication and signalling unit

The indication and signalling unit type RXSK 2H (A925) is provided with 12 flag indicators, and the corresponding 12 make contacts. The indicators are reset electrically by a pushbutton in the front of the unit.

The indicators are labelled as follow:

DD	Directional wave detector operation (yellow)
Z<	Evolving fault measuring, section operation (yellow)
SFT	Switch-into-fault unit operation (yellow)
BU	Back-up protection operation (yellow)
WEI	Weak-end-infeed unit operation (yellow)
CR	Channel receiving (yellow)
GT	General tripping (red)
R	Start in phase R (yellow)
S	Start in phase S (yellow)
T	Start in phase T (yellow)
CS	Channel sending (yellow)
=	DC power supply interruption (red)

(The start in phase R, S or T may emanate from the directional wave detector section, the evolving fault measuring section or the back-up protection).

Note that the signalling contacts, when included, are not free. One contact member of each contact is connected to a common bus in the RXSK 2H unit. Additional or separated signalling contacts can be arranged on request by adding auxiliary relays in series or parallel.

4.29
Auxiliary voltage supply

The auxiliary dc-voltage for the static circuits and the output relays is supplied from the station battery via built-in dc/dc-converters type RQMA 100 (B109), RQMB 040 (B101) and RQMB 041 (B105), providing full galvanic isolation between the relay circuitry and the auxiliary power source, efficient surge suppression (in case of surges beeing impressed on the DC input), and an overcurrent protection for the converter.

A dc-power-failure monitoring circuit in unit RXTNK 2H (A137) blocks the operation of RALZA in case of loss of power supply from the dc/dc-convertor, and an alarm via a make contact and a flag indicator is obtained from the indicator unit RXSK 2H (A925).

5. ADDITIONAL EQUIPMENT

5.1 Phase selection unit

If selective single-phase tripping is required, a phase selector unit type RXTEL 2H is offered. The unit is static; it processes the current signals, and provides digital information about which phase/phases is/are faulty.

The unit requires a space equivalent to 4S, 6C. The necessary dc supply is provided in a standard RALZA.

5.2 Independent mode directional detector

The operation of this unit RXPA 2H is independent of the communication channel and is set to operate in the event of close-in faults. See sections 3.2 and 4.9

The unit requires a space equivalens to 4S, 6C. The necessary wiring of input and output signals and dc supply is done in a standard RALZA.

5.3 Weak-end-infeed logic unit

If a weak-end-infeed condition is possible in a particular power transmission system, a weak-end-infeed logic unit RXTEM 2H is offered as an option. The principal of operation of this unit is described in section 3.4.

The unit occupies a space equivalent to 4S, 6C. The necessary wiring of input and output signals and dc supply is done in a standard RALZA.

5.4 Power swing blocking relay

Taking into consideration the requirements inposed on the power distribution network, it is undesirable that the zone 3 back-up protection function gives a tripping impulse when a power swing occurs in the network, see section 3.5.2. The variations in voltage and current that arise during power swings are interpreted, by the measuring circuits of this back-up protection, as impedance variations and can make it impossible to determine whether the measured change in impedance was caused by a three-phased fault or a power swing.

To prevent the back-up protection from giving a tripping impulse (delayed 600-800 msec) during a power swing, a power swing blocking relay is offered as an option. This unit is of static design and incorporates an impedance measuring element which has two concentric ovals in the R- X plane, see fig. 18.

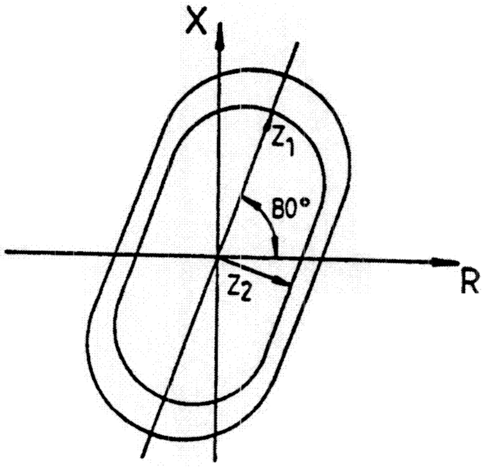


Fig 18:
Operating characteristic of power swing blocking relay

The reach of the inner oval is approximately 80% of that of the outer oval.

The reach in the reactive direction (Z_1) is approximately twice that in the resistive direction (Z_2).

The power-swing blocking relay incorporates an electromechanical output unit, which brings about the blocking function, and an indicating device. The output of the blocking relay is connected to the blocking input of the underimpedance starter.

The pwoer swing blocking relay contains a dc/dc converter, type RXTUG 2H, providing the necessary dc supply voltage. The blocking relay requires a space equivalent to 4S, 18C.

Note that there is no space available for this unit in a standard RALZA. It must be housed in an additional equipment frame.

5.5 Reclosing relay

RALZA can be made to cooperate with a reclosing relay. The following functions can be obtained depending on the type of reclosing relay used:

A. RALZA designed for three-phase tripping. Recloser with selector switch for

- Three-phase tripping and reclosing for all types of faults
- Definite three-phase tripping for all types of faults

B. RALZA designed for single- and three-phase tripping. Recloser with selector switch for

- Single-phase reclosing for single-phase faults
  Three-phase reclosing for multi-phase faults
- Single-phase reclosing for single-phase faults
  Three-phase definite tripping for multi-phase faults
- Three-phase tripping and reclosing for single-multi-phase faults
- Three-phase definite tripping for single-multi-phase faults

The reclosing relay is housed in a separate equipment frame.

5.6 Rear connection terminal strip

The relay can be delivered with a screw-type terminal mounted on the rear for connection of all incoming and outgoing leads. The depth of the relay will then be increased by 60 mm.

6. SETTINGS

6.1 General

This object of this chapter is to

- summarize the data needed, in order to obtain a properly set RALZA relay
- briefly describe the necessary setting calculations
- relate each setting figure to the appropriate hardware (potentiometer, thumbwheel switch or programming switch).

Note: A detailed description of the different measures taken and calculations performed in determining the settings of RALZA is given in the publication "SETTING CALCULATIONS", RF 619-002 E.

6.2 Directional wave detector section setting

Before setting the directional wave detectors of RALZA, the changes in current and voltage must be known for all types of fault. These changes can be calculated on a steady state basis using symmetrical components and Thevenin's theorem.

All types of faults ought to be calculated to find the minimum and maximum changes in current and voltage. The result of these calculations are then used as follows:

The maximum changes determine the independent mode settings.

The minimum changes of the two-phase faults, two-phase-to-ground faults and three-phase faults determine the dependent mode setting. However, this setting might allow tripping due to internal switching operations or surge arrester discharges; in such a case the level should be set high enough not to enable tripping evolving from such events.

The minimum changes of the single-phase faults determine the neutral current control mode setting. Note that in these calculations, due consideration is taken to the highest fault resistance estimated, thus assuring high resistive earth fault detection capability.

When the appropriate maximum and minimum changes are established, the "a" and "b" figures are calculated; consideration is taken to so called safety factors. The multiturn potentiometers on the front of the directional detectors are then set according to these "a" and "b" figures.

6.3 Neutral current measuring unit setting

A setting above the unbalance current for line section internal switching operations is normally recommended for the neutral current measuring unit.

This setting is done on a variable potentiometer on the front of the unit (1 to 3 times an alternative scale constant).

6.4 Evolving fault measuring section setting

Before setting of the evolving fault measuring section the line impedance shall be converted to the secondary side of the instrument transformer.

The reaches of each zone must be determined, and the setting factors a, b and p are to be calculated. The setting of the adequate thumbwheel switches are then performed according to these calculations.

(The zone 3 back-up protection setting is determined according to the setting instructions of the underimpedance starter, see section 6.5 below).

Furthermore, the positive and zero sequence reactances of the line is used in the calculation of the so called zero sequence compensation factor; the factor is then set by means of a thumbwheel switch.

The setting factor for the zero sequence current Δ /Y reconnection of the underimpedance starter is determined by means of a thumbwheel switch and a programming switch. The recommended figure is 0.2 x I_n.

6.5 Underimpedance starter setting

The reach setting of the underimpedance starter is calculated on basis of the positive- and zero-sequence impedance of the line, and the minimum load impedance. Note that this has to coordinate with the setting of the zones 1 and 2 of the evolving fault measuring section.

The appropriate values for the forward and reverse reach are suitably determined graphically, and the "A" and "D" factors are calculated; the underimpedance starter setting is then done by means of one switch and six potentiometers on the front of the unit.

6.6 Switch-into-fault unit setting

The underimpedance starter determines the reach in case of a switch-into-fault condition.

Moreover, one criterion for enabling of the switch-into-fault logic is that the line voltage of any phase falls short of a low phase voltage operating level "d" (see section 3.6). The "d"-setting is done by means of a potentiometer at the front of the voltage measuring unit.

This switch-into-fault condition line voltage level must be set at least 15% below the minimum transmission line voltage to be expected.

6.7 Time-lag settings

6.7.1 Directional wave detector section

There are two time-lag settings to be determined in the directional wave detector section of RALZA:

i The RALZA relay is used in a permissive tripping scheme; hence, the setting "t_d" for the tripping delay, determined by means of a potentiometer on the front of the tripping logic unit, is set to the channel nominal transmission time

ii The time lag of 20 or 35 ms used for disabling of the neutral current measuring unit output signal (see section 3.3) is determined in the amplifier unit, by means of a programming switch located on the front of the unit.

6.7.2 Evolving fault measuring section

A time delay is introduced prior to evolving fault measurement, see section 3.5.2. The setting of this time-lag relay is done by means of two scale-value selector switches, located on the front of the unit. Normally a setting of 35 ms is recommended. When series capacitors are included in the power system, a 50 ms setting is recommended.

6.7.3 Back-up relaying

Two thumbwheel switches on the front of the time-lag unit RGTA 030 are used for setting of the selective time of the second and third measuring zone. Recommended settings are

- 300-400 msec for zone 2
- 600-800 msec for zone 3

(Enabling of the selective time operation is performed via the programming switches on the front of the unit).

It is possible to obtain a non-selective tripping operation from the neutral current measuring unit, via a time-lag relay (see section 2.4). Normally a 1.5-5 seconds setting of this time-lag relay is recommended. The setting is done by means of two scale-value selector switches and four scale-constant selector switches, located on the front of the unit.

6.8
Shunt reactor switching settings

Switching of a shunt reactor while the line is in service might be detected by the directional wave detectors, see section 2.6 and 4.12. To prevent this a temporary reduction of the output amplitude of the buffering amplifiers (current signals only) can be effected. The degree of reduction (2, 4 or 7 times) is determined by means of top two programming switches on the front of the amplifier unit.

We normally recommend a reduction time of 500 ms. The setting of the (optional) time-lag relay involved is done by means of two scale-value selector switches and four scale-constant selector switches on the front of the unit.

7. COMMUNICATION EQUIPMENT

As RALZA works in a directional comparison permissive scheme (dependent mode), a communication channel is needed to protect 100% of the line.

RALZA incorporates input and output relays to enable cooperation with the relay at the remote end of the line. No additional equipment is therefore required for this purpose.

Basically the relay system can be used with any type of communication link with channel delays up to 35 ms although, to maintain the ultra high speed of operation even for remote-end faults, a fast channel is preferred. In terms of end-to-end communication only one signal is required to be transmitted from one line end to the other even when selective single-pole auto-reclosure is practiced. The transmitted signal has no bearing on starting or phase selection since this is accomplished locally. Due to that only one signal has to be transmitted the compromise between channel speed and channel reliability can easily be achieved.

On special request RALZA can be delivered with logic units permitting longer channel delays than stated above.

Note that the evolving fault measuring section works independent of the communication channel, in a standard RALZA. The first zone of this section is set to underreach, i.e., to less than 100% of the length of the protected line. This setting is chosen to ensure selective operation.

8. TESTING

Three test units are included in a standard RALZA:

A The test switch RTXP 18 enables complete secondary injection test of all the RALZA relay measuring functions. This is described in publication RF 619-003 E, "Commissioning instructions".

B. The functional test unit type RXTNK 2H makes it possible to test the directional wave detector section of RALZA. Internal, external, single- or multi-phase faults can be simulated on both the positive and negative half cycles. The test conditions are selected by switches on the front of the functional test unit and the type of fault is initiated by push-buttons.

It should be noted that the trip outputs should be isolated before testing.

C. Circuits for testing the evolving fault measuring section of RALZA is housed in the overcurrent starting unit RGIC 030.

In the front of the unit there is a thumbwheel switch marked F, for selecting the type of fault when testing the logic circuits of the evolving fault measuring section. The test is initiated by depressing the push button marked "Test", whereupon the output stage is blocked and the acquired function can be read off from the indicating unit. If the push button is kept depressed for a period corresponding to the time setting of measuring zone four the light-emitting diodes for the timing steps and for tripping, will light up.

9. INSTALLATION AND EXTERNAL DIAGRAM

The RALZA is designed for 19" rack or flush mounting. The dimensions are shown on the enclosed dimension print 5283 0263-AA.

All connections to the terminals of the relay are normally made with COMBIFLEX socket-equipped leads. On request, all external connections can be terminated on a screw connections terminal strip on the rear of the protection frame or, when rack mounted, within the 19" cubicle.

A general external diagram for single- and three-phase tripping is enclosed as supplement 7435 179-CG.

The rear of the RALZA relay should be accessible for inspection purposed and for enabling future modifications to the wiring when such may be required.

10. COMMISSIONING AND MAINTENCANCE

All units are of static design except those for indication and signalling (and tripping when electromechanical output relays are used). The maintenance has therefore been reduced to a minimum.

Instructions containing detailed information about settings and recommendations in connection with commissioning and routine testing of the relay are issued separately, see chapter 13.

The test switch type RTXP 18, together with the test plug handle of type RTXH 18 and relay testing equipment facilitates commissioning and routine testing.

Since the relay in normal service only operates at rather infrequent intervals, it will be of value to test it regularly, for example once a year or once every second year.

11. TECHNICAL DATA

11.1
Measuring entities

Rated frequency; 50, 60 Hz

Current inputs:

• Rated current	1,5 A
• Power consumption per phase	< 2 VA
• Tolerance range: Maximum permissible continuous current	$3 \times I_n$
• Maximum permissible current during 1 s	$70 \times I_n$

Voltage inputs:

• Rated voltage	$110/\sqrt{3}$ V
• Power consumption per phase	< 1.5 VA
• Tolerance range: Maximum permissible continuous voltage	$1.3 \times U_n$

11.2
Auxiliary voltage

110-125, 220-250 V DC

Tolerance range	+ 10% - 20%

Power consumption:

• normal service	appr. 60 W
• maximum	100 W

11.3
Tripping mode and operating times

Three-phase or single- and three-phase tripping

Operating time, typical values:

independent mode	5 ms
dependent mode	7 ms + channel delay
neutral current control mode	25 or 45 ms (programmable)
evolving fault mode	65 or 85 ms (programmable)

11.4
Setting range

11.4.1 Directional wave detector section

- Independent mode

  Current change $\frac{\Delta I}{I_n} = \frac{a+2}{20} = 0.10 - 5.1$
  $a = 0 - 100$

  (Lowest recommended setting a = 40)

  Voltage change $\frac{\Delta U}{U_n} = \frac{b+5}{100} = 0.05 - 1.05$
  $b = 0 - 100$

- Dependent mode

  Current change $\frac{\Delta I}{I_n} = \frac{a+2}{20} = 0.10 - 5.1$
  $a = 0 - 100$

  (Lowest recommended setting a = 8.0)

  Voltage change $\frac{\Delta U}{U_n} = \frac{b+5}{100} = 0.05 - 1.05$
  $b = 0 - 100$

  (Lowest recommended setting b = 5.0)

- Neutral current control mode

  Current change $\frac{\Delta I}{I_n} = \frac{a+2}{20} = 0.10 - 5.1$
  $b = 0 - 100$

  (Lowest recommended setting a = 2.0)

  Voltage change $\frac{\Delta U}{U_n} = \frac{b+5}{100} = 0.05 - 1.05$
  $b = 0 - 100$

- Low phase voltage setting

  $d = \frac{U_{set}}{U_n}$ where $U_{set} \leq 0.85\ U_{n\,min}$

11.4.2 Neutral current measuring unit

0.1 - 1.5 A or 0.2 - 3.0 A, continuously adjustable.

11.4.3 Evolving fault measuring section

Reach setting for zone 1 and 2	The table below shows the range of setting for the reactive reach at 50 Hz and 60 Hz. The resistive reach is not dependent of the frequency and corresponds to the reactive reach settings at 50 Hz.
	Ohms/phase, 50 Hz (60 Hz)

$I_n = 1$ A	$I_n = 5$ A
0.16 - 64	0,032 - 12,8
(0,19 - 77)	(0,038 - 15,4)

Reach zone 1

$X_1 = \frac{30,1}{I_n} \times \frac{f}{50} \times \frac{a}{P_1}$ ohms/phase

$a = 5,6,7....99$

$P_1 = 5,6,7....99$

$R_1 = \frac{3,2}{I_n} \times \frac{b}{P_1}$ ohms/phase

$b = 5,6,7....99$

Reach zone 2

$X_2 = X_1 \times \frac{P_1}{P_2}$

$R_2 = R_1 \times \frac{P_1}{P_2}$

$P_2 = 5,6,7....99$

Zero-sequence

$K_N = 0-1,5$ in steps of 0.1

$K_N = \frac{X_0 - X_1}{3 X_1}$

Zero-sequence current Δ /Y reconnection

0,2 or 0,5 times the setting of the over-current starter.

Over-current starter

1-4 times rated current I_n in steps of 0,2 x I_n

11.4.4 Underimpedance starter (zone 3)

Reach setting in the forward direction Z_f	Ohms/phase 50 Hz (60 Hz)	
	$I_n = 1$ A	$I_n = 5$ A
	2,8 - 102,6	0,6 - 20,5
	(3,3 - 123,2)	(0,7 - 24,6)
Reach setting in the reverse direction Z_r	$Z_r = D \times Z_f$ with $-0.2 \leq D \leq 1.0$	

11.5 Relays

11.5.1 Outputs relays

Reed relay type RQKA 040 — Free contacts for trip outputs, channel send and general start.

Operating time — 1 ms

Contact data:

- Maximum system range — 300 V DC/250 V AC
- Current carrying capacity, continuous
- Current carrying capacity for 1 s

Making capacity for 200 ms, inductive load L/R $\leq$ 10 ms;

- continuous for — 1 A
- for 1 s — 1 A

Breaking capacity at

- ac, max 250 V

  $\cos \varphi \geq 0.1$, U x I max 20 VA — 0.6 A

  $\cos \varphi = 1$, U x I max 40 VA

- dc, L/R $\leq$ 40 ms

48 V	0.3 A
110 V	0.1 A
125 V	0.08 A
220 V	0.04 A
250 V	0.03 A

- dc, L/R = 0 ms

48 V	0.9 A
110 V	0.35 A
125 V	0.28 A
220 V	0.12 A
250 V	0.10 A

Type RXMBB 1, output relay — For multi-phase fault indication.

Operating time	10-15 ms	
Contact data:		
Maximum system voltage	250 V DC or AC	
Continuous current carrying capacity	5 A	
Current carrying capacity for 1 s	15 A	
Making capacity for 200 ms, inductive load L/R $\leq$ 10 ms; continuous	30 A	
for 1 sec	10 A	
Breaking capacity:		
- ac, max 250 V, cos $\varphi \geq$ 0 4		8 A
- dc, L/R $\leq$ 40 ms	24 V	2.0 A
	48 V	1.0 A
	55 V	0.8 A
	110 V	0.4 A
	125 V	0.3 A
	220 V	0.2 A
	250 V	0.15 A

Type RXSK 2H — For signalling. All outputs except "loss of DC" have one common bus.

Contact data: See type RXMBB 1 above.

11.5.2 Input relays

Type RXMBB 1, input relay

For channel receive, blocking of wave detector, and prepare three-phase trip. (See section 4.27.1.)

Three versions available:

48-60 V
110-125 V
220-250 V

All inputs have one common bus connected to negative DC.

Operating time	1 ms
Power consumption per input relay	
48 V	0.4 W
60 V	0.6 W
110 V	0.9 W
125 V	1.2 W
220 V	1.4 W
250 V	1.8 W

11.6 General data

Dimensions: See enclosure 5283 0263-AA

Weight:	48 kg
Ambient temp. range	-5°C - +55°C

11.7 Test data

11.7.1 Insulation testing

Dielectric test	ANSI C37.90-1978	2/2.5 kV, 50 Hz, 1 min.
Impuls voltage withstand test	IEC Publ. 255-4, appendix E	5.0 kV, 1.2/50 us, 0.5 J

11.7.2 Disturbance testing

Nominal frequency disturbance test	SEN 36 15 03	500 V
Surge withstand capability test	ANSI C37.90a-1974	2.75 kV, 1MHz, decaying time 3-6 periods
Showering arc test	SEN 36 15 03	4-8 kV
Auxiliary voltage interruption test	SEN 36 15 03	To 0 % of aux. volt.

12. ORDERING PARTICULARS

The following information is required when ordering:

- Rated frequency
- Rated voltage
- Rated current
- Auxiliary voltage (station battery voltage)
- Auxiliary voltage for input relays - CR, PTPT, BCW (if different from station battery voltage)
- Tripping mode;

  three-phase or single- and three-phase - note that a phase selector unit is required if single-phase tripping is requested.
- Additional equipment demands:

  - Independent mode operation
  - Weak-end-infeed mode of operation
  - Power swing blocking relay
  - Reclosing device (number of shots)
- Tripping output relay arrangement - see section 4.27.2.
- Presentation of special requirements regarding the interface relays for the communication channel
- Rear screw connection terminal strip for external connection to the relay

13. REFERENCE PUBLICATIONS

Setting calculations	RF 619-002 E
Commissioning instruction	RF 619-003 E
Modular system COMBIFLEX	Catalogue RK 92-10 E
Equipment frames, cases and cubicles type VSG	SK 14-1 E
Test system COMBITEST	Catalogue RK 92-11 E
Auxiliary relays	Catalogue RK 21-10 E

ASEA

Description (English): RALZA

Description (own language): RALZA

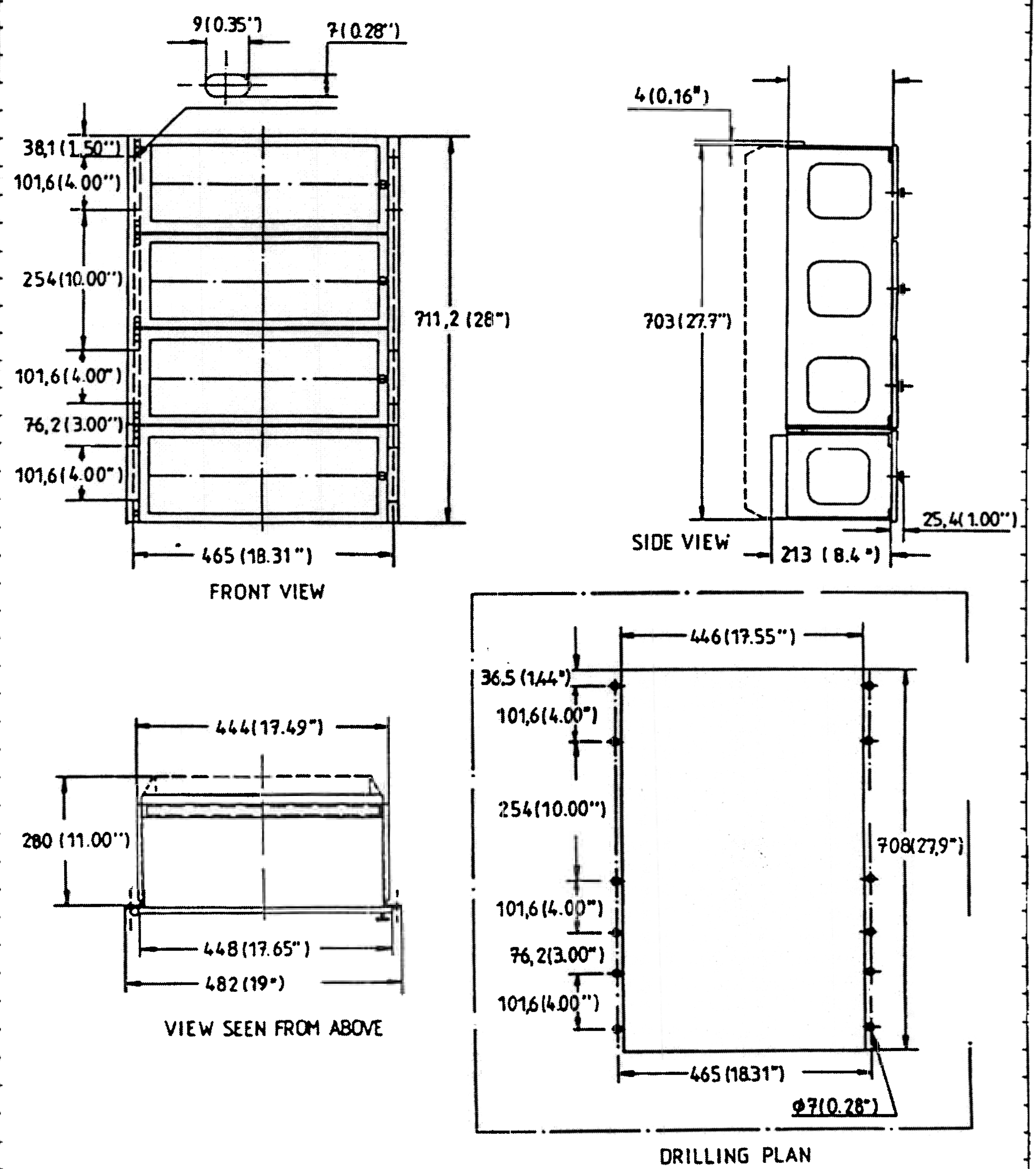
Accepted by Quality Control | Accepted for production by

5283 0263-AA	Sheet 1 / Cont —
Iss by dept: RKL	Year: 81 / Week: 51

Drawing checked by

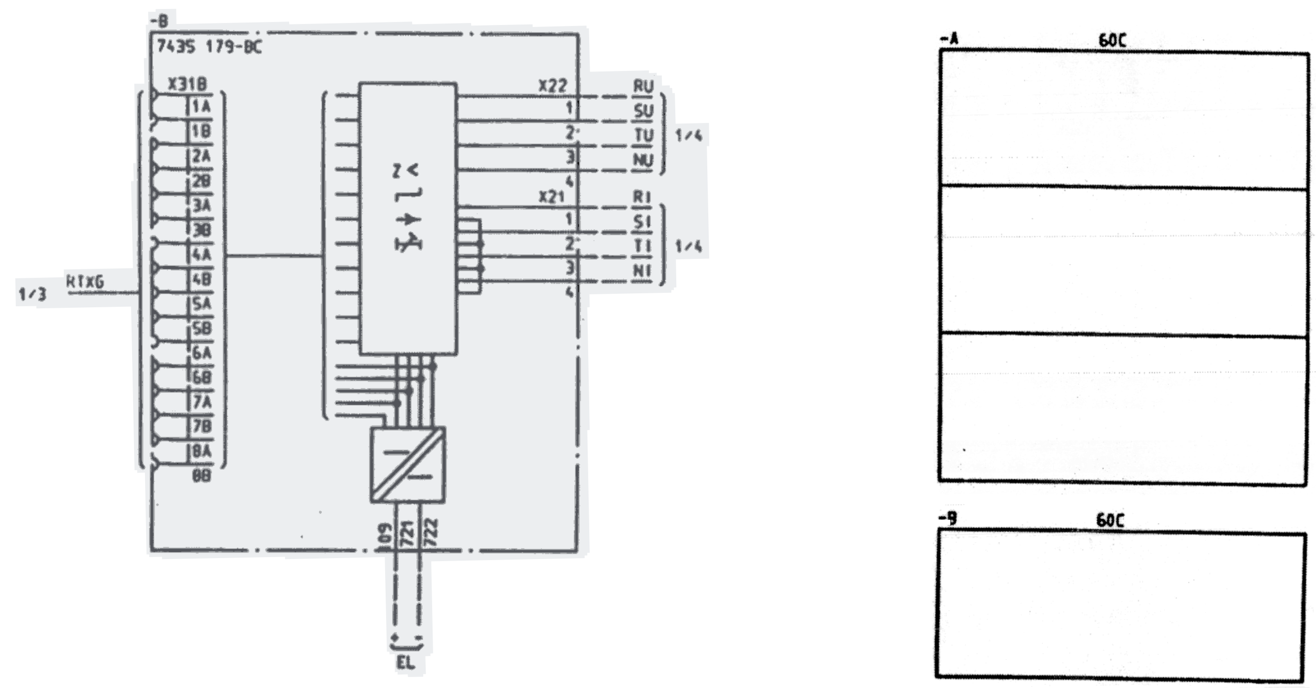
√ indicates R_a in µm

(inches)



No	Revision	Appd	Dept	Year Wk
2	ADJ.	CAS	RKL	85 09
1	CONT. 2. CANCELLED	AR	RKL	82 34

Sheet | Cont | VS | Year | Dept | Rev | Drawn by | Form No | Design checked by



KS-ADB ID /2:7435179-CG:2/0

Design checked by	T. JOHANSSON
Drawing checked by	A. ANDERSSON
Drawn by	R.P./ MN

CIRCUIT DIAGRAM
RALZA

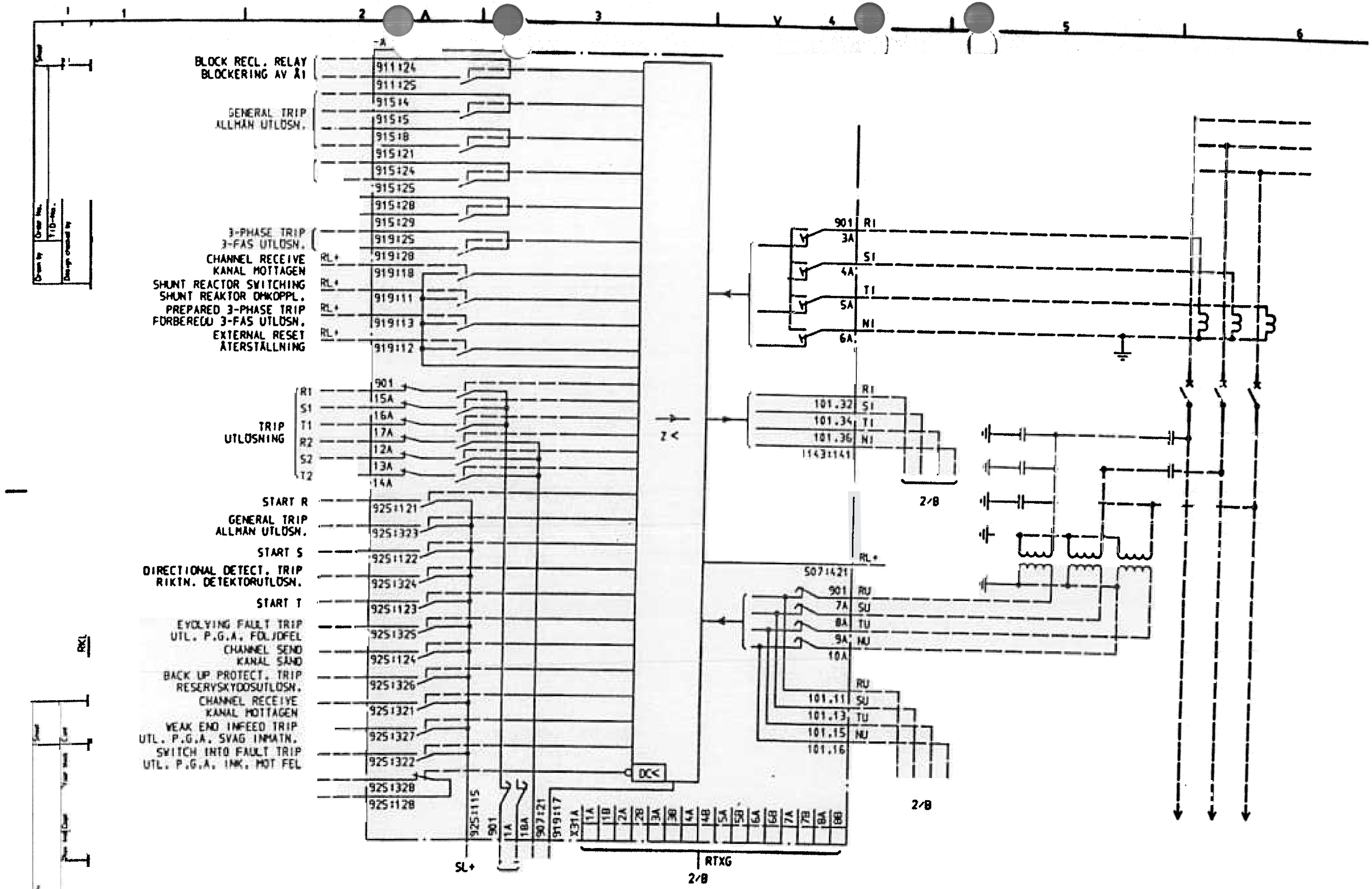
ASEA

Iss by Dept: RKL — Year Week: 84 05

7435 179-CG

Sheet 2, Cont -

RKL



CIRCUIT DIAGRAM
RALZA

179-CG