SETTING CALCULATIONS

for Ultra High Speed Line Protection type

RALDA

CONTENTS

GENERAL

The ultra high speed line protective relay type RALDA is based on the directional wave detector principle (see Information RK 617-300 E and Application Guide 61-35 AG). It is designed for three-phase tripping or single- and three-phase tripping in EHV and UHV networks.

The operating principle of the relay is based on the occurrence of travelling waves in case of fault that causes a change in voltage and current levels.

The relay operates as a directional comparison relay and therefore needs a communication link (PLC or microwave). This relay operation is called "dependent mode tripping".

However, for close-in faults, the relay can operate independently of the communication link. This latter type of relay operation is called "independent mode tripping".

The scheme for cooperating with the remote end relay can be according to several principles, for example, the directional comparison blocking scheme or directional comparison permissive tripping scheme.

In order to successfully achieve the above mentioned operating modes, the following setting philosophy is applied.

For the "dependent mode tripping" the RALDA relay shall be set to pick-up for minimum current and voltage change conditions for a fault at the remote end. ("overreach" is desired)

For the "independent mode tripping" the RALDA relay shall be set not to pick-up for maximum current and voltage change conditions for a fault at the remote end. ("overreach" is not permitted)

In series compensated lines the effects of the capacitor shall be considered.

2 NETWORK MODEL

2.1 Before setting the RALDA relay, 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.

The network can be reduced to a simple source impedance (ZA, ZB) and line impedance (ZL) model as shown in Fig. 1.

Definitions for abbreviations used can be found on page 21-23.

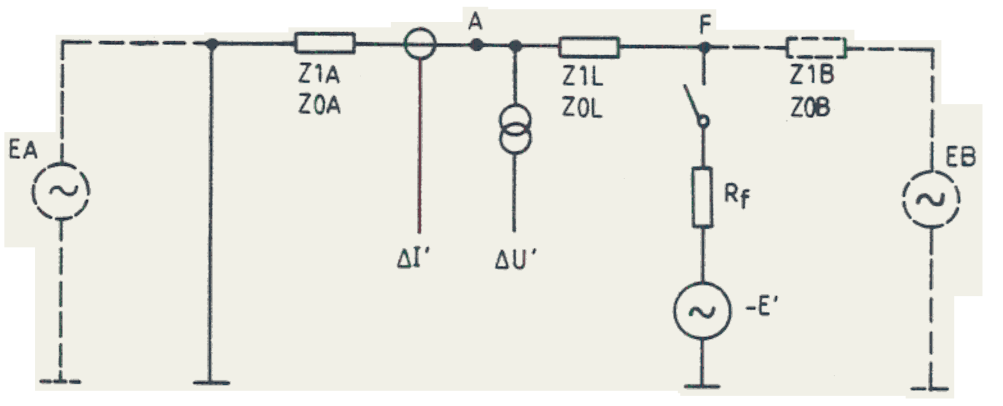


Fig. 1. Simple line model, line end A
F is the remote end of the protected line and A is the measuring end.

2.2 Fault calculations

All types of faults ought to be calculated to find the minimum and maximum of ΔI' and ΔU', as defined in Fig. 1 above. A simple procedure is shown in the following examples, assuming equal positive and negative sequence impedances for the sources.

For line section end A define:

Z_1 = Z1A + Z1L

Z_0 = Z0A + Z0L

RF = apparent fault resistance = $R_f \times (1 + \frac{ZA + ZL}{ZB})$

R_f = phase-to-earth fault resistance = $R_K + R_N$

$2R_K$ = phase-to-phase fault resistance

Single phase-to-earth fault in phase R (RN)

$$(\Delta I'_{LE})_{RN} = \frac{E'}{Z_1 + \frac{Z_0 - Z_1}{3} + RF}$$

$$(\Delta U'_{LE})_{RN} = (Z1A + \frac{Z0A - Z1A}{3}) \times (\Delta I'_{LE})_{RN}$$

Two-phase fault in phases S and T (ST)

$$(\Delta I'_{LL})_S = -(\Delta I'_{LL})_T = \frac{a^2 - a}{2} \times \frac{E'}{Z_1 + R_K}$$

$$(\Delta U'_{LL})_S = -(\Delta U'_{LL})_T = Z1A \times (\Delta I'_{LL})_S$$

where $a = e^{j\,2\pi/3}$

Two-phase-to earth fault in phases S and T (STN)

$$(\Delta I'_{LLE})_S = \frac{(a^2 - 1)\ (Z_1 + R_K) + (a^2 - a)\ (Z_0 + 3\ RF)}{(Z_1 + R_K)\ (Z_1 + R_K + 2\ Z_0 + 6\ RF)} \times E'$$

$$(\Delta I'_{LLE})_T = \frac{(a - 1)\ (Z_1 + R_K) + (a - a^2)\ (Z_0 + 3\ RF)}{(Z_1 + R_K)\ (Z_1 + R_K + 2\ Z_0 + 6\ RF)} \times E'$$

$$(\Delta U'_{LLE})_S = Z1A\ (\Delta I'_{LLE})_S + \left[(\Delta I'_{LLE})_S + (\Delta I'_{LLE})_T \right] \frac{Z0A - Z1A}{3}$$

$$(\Delta U'_{LLE})_T = Z1A\ (\Delta I'_{LLE})_T + \left[(\Delta I'_{LLE})_S + (\Delta I'_{LLE})_T \right] \frac{Z0A - Z1A}{3}$$

Three-phase fault (RST)

$$\Delta I'_{3L} = \frac{E'}{Z_1 + R_K}$$

$$\Delta U'_{3L} = Z1A \times \Delta I'_{3L}$$

2.3 For the "dependent mode tripping" the four types of fault located at the remote end from the relay to be set shall be analyzed to find the minimum change in current Δi in per unit (p.u.) value of rated current and the minimum change in voltage Δu in per unit (p.u.) value of rated voltage. The minimum Δi will then give the "dependent mode tripping" setting "a" and the minimum Δu will give the setting "b".

Thus determine

$$\Delta I'_{min} = \min \left(\left| \Delta I'_{LE} \right|, \left| \Delta I'_{LL} \right| \left| \Delta I'_{LLE\ S}, \Delta I'_{LLE\ T}, \right| \Delta I'_{3L} \right| \Big) \quad \text{and}$$

$$\Delta U'_{min} = \min \left(\left| \Delta U'_{LE} \right| \quad \Delta U'_{LL} \right| \quad \Delta U'_{LLE} \left| S, \right| \Delta U'_{LLE} \left| T, \right| \Delta U'_{3L} \Big| \Big)$$

For the "independent mode tripping" the four types of fault located at the remote end from the relay to be set shall be analyzed to find the maximum change in current Δi and voltage Δu. The maximum Δi will then give the "independent mode tripping" setting "a" and the maximum Δu will give the setting "b".

Thus determine

$$\Delta I'_{max} = \max\left(\left|\Delta I'_{LE}\right|, \left|\Delta I'_{LL}\right|, \left|\Delta I'_{LLE}\right|_S, \left|\Delta I'_{LLE}\right|_T, \left|\Delta I'_{3L}\right|\right)$$

and

$$\Delta U'_{max} = \max\left(\left|\Delta U'_{LE}\right| \quad \left|\Delta U'_{LL}\right| \quad \left|\Delta U'_{LLE}\right|_S, \ \Delta U'_{LLE} \quad \left|\Delta U'_{3L}\right|\right)$$

For the "switch-into-fault" feature the maximum primary fault voltages for the four types of fault located at the remote end from the relay to be set shall be analyzed. The "swith-into-fault" setting "d" is thereby determined.

Thus determine

$$\left|U'_{LE}\right| = \left|E' - \Delta U'_{LE}\right|$$

$$\left|U'_{LL}\right|_S = \left|a^2E' - (\Delta U'_{LL})_S\right|$$

$$\left|U'_{LL}\right|_T = \left|a\,E' + (\Delta U'_{LL})_S\right.$$

$$\left|U'_{LLE}\right|_S = \left|a^2E' - (\Delta U'_{LLE})_S\right|$$

$$\left|U'_{LLE}\right|_T = \left|a\,E' - (\Delta U'_{LLE})_T\right|$$

$$\left|U'_{3L}\right| = \left|E' - \Delta U'_{3L}\right|$$

Determine:

$$U'_{max} = \max\left(\left|U'_{LE}\right|, \left|U'_{LL}\right|_S, \left|U'_{LL}\right|_T, \left|U'_{LLE}\right|_S, \left|U'_{LLE}\right|_T, \left|U'_{3L}\right|\right)$$

The same procedure must be done for the relay at the remote end B, using the appropriate values of source impedances as shown in Fig. 2.

For line section end B define:

Z_1 = Z1B + Z1L

Z_0 = Z0B + Z0L

RF = apparent fault resistance = $R_f \times \left(1 + \frac{ZB + ZL}{ZA}\right)$

R_f = phase-to-earth fault resistance = $R_K + R_N$

$2R_K$ = phase-to-phase fault resistance

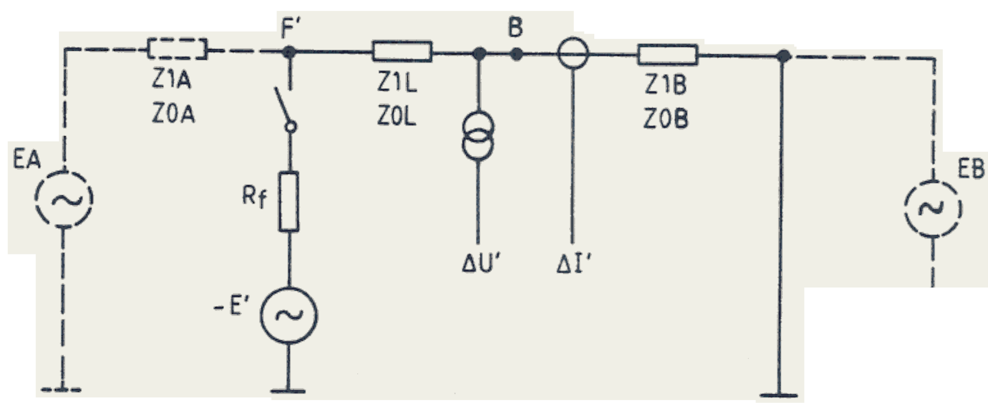


Fig. 2 Simple line model, line end B
F' is the remote end of the protected line and B is the measuring end.

Network conditions which may be expected to give minimum Δi for "dependent mode tripping" are:

A. Maximum near end source impedance
i.e. $Z1A_{max}$ and $Z0A_{max}$

B. Minimum remote end source impedance
i.e. $Z1B_{min}$ and $Z0B_{min}$

C. Maximum line impedance, series capacitors by-passed
i.e. $Z1L_{max}$ and $Z0L_{max}$

D. All parallel lines in service.

E. Maximum fault resistance at the remote end.

Network conditions which may be expected to give minimum Δu for "dependent mode tripping" are:

F. Minimum near end source impedance i.e. $Z1A_{min}$ and $Z0A_{min}$.

G. Minimum remote end source impedance i.e. $Z1B_{min}$ and $Z0B_{min}$.

H. Maximum line impedance, series capacitor by-passed i.e. $Z1L_{max}$ and $Z0L_{max}$.

J. Only a single line in service, all parallel lines out of service.

K. Maximum fault resistance at the remote end.

Network conditions which may be expected to give maximum Δi for "independent mode tripping" are:

L. Minimum near end source impedance i.e. $Z1A_{min}$ and $Z0A_{min}$.

M. Maximum remote end source impedance i.e. $Z1B_{max}$ and $Z0B_{max}$.

N. Minimum line impedance, series capacitor in service i.e. $Z1L_{min}$ and $Z0L_{min}$.

O. Only a single line in service, all parallel lines out of service.

P. Minimum fault resistance at the remote end.

Network conditions which may be expected to give maximum Δu for "independent mode tripping" are:

Q. Maximum near end source impedance i.e. $Z1A_{max}$ and $Z0A_{max}$.

R. Maximum remote end source impedance i.e. $Z1B_{max}$ and $Z0B_{max}$.

S. Minimum line impedance, series capacitor in service i.e. $Z1L_{min}$ and $Z0L_{min}$.

T. All parallel lines in service.

U. Minimum fault resistance at the remote end.

When the RALDA relay is used in a "blocking scheme" only the "worst case" for above faults at bus A or bus B must be calculated since both RALDA relay shall be identically set.

When the RALDA relay is used in a "permissive scheme" individual settings for the RALDA relays at each line terminal may be used.

The setting calculations shall normally consider only the worst practical case since academical parameter values may give a too sensitive setting. Please also note that minimum Δi and minimum Δu, maximum Δi and maximum Δu are not obtained with the same parameters.

When the RALDA relay is designed for selective phase tripping the change in current and voltage, at a single phase to earth fault, shall be checked not only for the faulty phase but also for the healthy phases. The check of the change in current and voltage for the healthy phases shall be made for a close up single phase to earth fault. The reason is that when a too low Δi and Δu setting is used the changes in currents and voltages in the healthy phases may cause the RALDA relay to pick-up and consequently a non-selective tripping may result. For the healthy phases we recommend that the changes in current and voltage shall not be higher than 0,5 times the Δi and Δu settings used.

2.6 When the line voltage transformer is located on the line side of the main circuit breaker the "switch-into-fault" feature shall be used since a closing of the main circuit breaker into a line with a persistent line fault or a line with working earth applied will block the normal relay operation (wave from behind).

The "fault" to be detected shall give $U_f < u_{set}$ and in addition the breaker closing must give a current change $> 0.2\ I_n$, which corresponds to the lowest recommended setting for the "dependent mode tripping".

To establish the setting value u_{set} for the "switch-into-fault" maximum primary fault voltage shall be used. i.e.

$u_{set} > U_{max}$ where $U_{max} = E - \Delta U_{min}$

Three situations shall be considered.

1. u_{set} shall be higher than U_{max} otherwise a high resistance fault can not be detected.

2. u_{set} shall be lower than the minimum system voltage otherwise an erronous operation can take place when closing onto a healthy line.

3. u_{set} shall be lower than the minimum system voltage otherwise the RALDA relay "dependent mode tripping" and "independent mode tripping" are blocked from a voltage supervision linked to u_{set}.

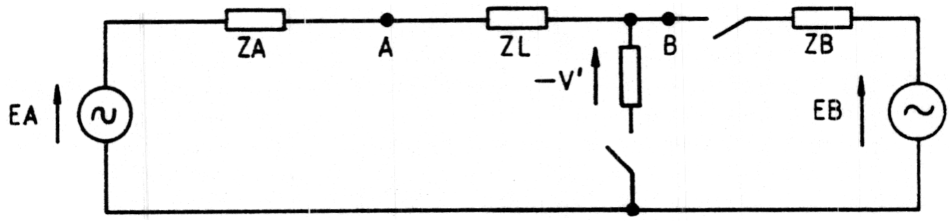
When the line voltage transformer is located on the bus side of the main circuit breaker the "switch-into-fault" feature shall not be used. Here it is necessary to consider situation 3 above and make sure that u_{set} is lower than the minimum system voltage.

When the line voltage transformer is located on the bus side of the main circuit breaker, it is also necessary to note that a closing of the main circuit breaker will be seen by the RALDA relay as an internal fault. (Wave from front). If the changes in current and voltage when closing the main circuit breaker are higher than the set pick-up values Δi and Δu on the RALDA relay a special "breaker closing" signal must be connected to the RALDA relay input "Block start" terminal 907:14.

The "breaker closing" signal shall be a single pulse signal which shall last during: 10 ms before the main circuit breaker closes + the main circuit breaker closing time + 50 ms after the main circuit breaker is closed. During the "breaker closing" signal time the RALDA relay forward (internal) start and trip functions are blocked.

2.7 Weak-end infeed

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.



This means that when the RALDA relays are working in a "directional blocking scheme" and an internal fault occurs on the line A to B only the RALDA relay at line end A will detect the fault.

The RALDA relay at line end A will now trip line end A after the set coordination delay since no communication signal will be transmitted from line end B.

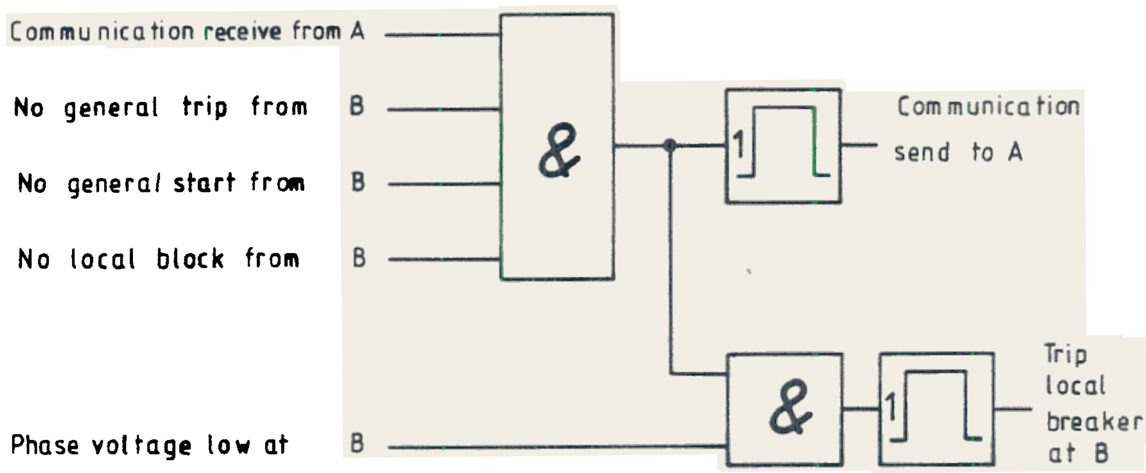
The RALDA relay at line end B will not trip the local breaker and therefore an inter-trip scheme shall be added to the relay system.

When the RALDA relays are working in a "directional permissive tripping scheme" and an internal fault occurs on the line A to B only the RALDA relay at line end A will detect the fault.

The RALDA relay at line end A can not trip the local breaker since no communication signal will be transmitted from line end B. Similary the RALDA rèlay at line end B will not trip the local breaker either and the fault will stay on until tripped by back-up relays.

To cope with such a situation it is possible to add an optional weak-end infeed logic to the RALDA 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:



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

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

3 SETTING CALCULATIONS

When the change in current ΔI_{min}, ΔI_{max} and in voltage ΔU_{min}, ΔU_{max} and the fault voltage U_{max} now are established for bus A and bus B the RALDA relay settings can be determined.

The RALDA relay accuracy is $\pm$ 10 % of set value $\pm$ 0.3 scale divisions for "dependent mode tripping", "independent mode tripping" and "switch-into-fault".

To cover for possible errors in the fault calculations and the relay accuracy, a safety factor of 0.85 is introduced in the setting calculations for the "dependent mode tripping" settings and the "switch-into-fault" setting.
For the "independent mode tripping" settings the safety factor is already introduced in the relay operation principle and no further "reduction" is done in the setting calculations.

Two more correction factors are added to the setting calculations

$k = \frac{I_n}{I_n''}$ and $n = \frac{U_n}{U_n''}$ where

I_n = CT secondary rating, I_n'' = RALDA nominal current

U_n = VT secondary rating, U_n'' = RALDA nominal voltage

3.1 Dependent mode tripping

The settings for the "dependent mode tripping" are made on two multiturn potentiometers with scale markings 0.0 to 99.8 on the relay module RXPA 2H in position 155.

ΔI_{min} is set on the top potentiometer marked "a"

ΔU_{min} is set on the bottom potentiometer marked "b"

$$a = 2 \left[10 \times \frac{\Delta I_{min}}{I_n} - 1 \right] \times 0.85 \times k$$

lowest permissible setting is 2.0

$$b = \left[100 \frac{\Delta U_{min}}{U_n} - 5 \right] \times 0.85 \times n$$

3.2 Independent mode tripping

The settings for the "independent mode tripping" are made on two multiturn potentiometers with scale markings 0.0 to 99.8 on the relay module RXPA 2H in position 555.

Δi_{max} is set on the top potentiometer marked "a"

Δu_{max} is set on the bottom potentiometer marked "b"

$$a = 2 \left[10 \times \frac{\Delta I_{max}}{I_n} - 1 \right] \times k$$

lowest recommended setting is 40.0

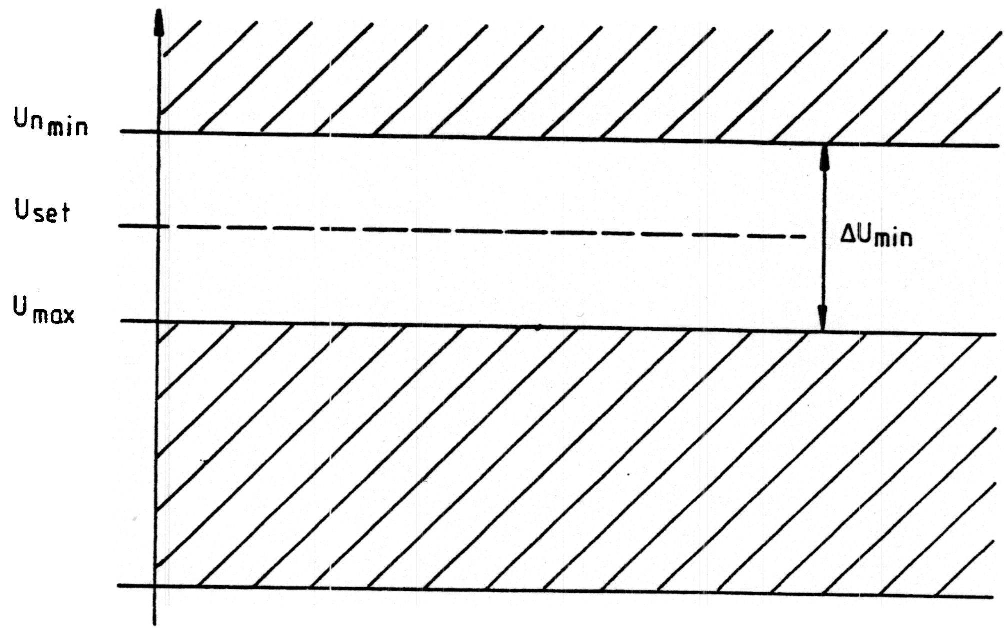
$$b = \left[100 \frac{\Delta U_{max}}{U_n} - 5 \right] \times n$$

3.3 Switch into fault

The settings for the "switch-into-fault" are made on two potentiometers on relay module RXEDA 2H in position 549.

The top potentiometer with scale markings 5 to 20 x 1 ms is labeled "t_b" and sets the time within which the phase to earth voltage should rise above the "d" setting during normal line energizing or auto-reclosing.
We normally recommend that the top potentiometer "t_b" is set $\geqslant$15 ms and when service experience is limited a setting of 20 ms can be necessary.

The bottom potentiometer with scale markings 0.4 to 1.0 x U_n is labeled "d" and sets the level of the low voltage detector u_{set} as indicated in the figure below.



From the figure above the setting of the potentiometer "d" can now be determined when the safety margin of 0.85 and the correction factor n are added.

$u_{set} \leqslant U_{n\ min}$ x 0.85 x n

$0.85\ u_{set} \geqslant U'_{max}$ and $U'_{max} = U_{n_{min}} - \Delta U_{min}$

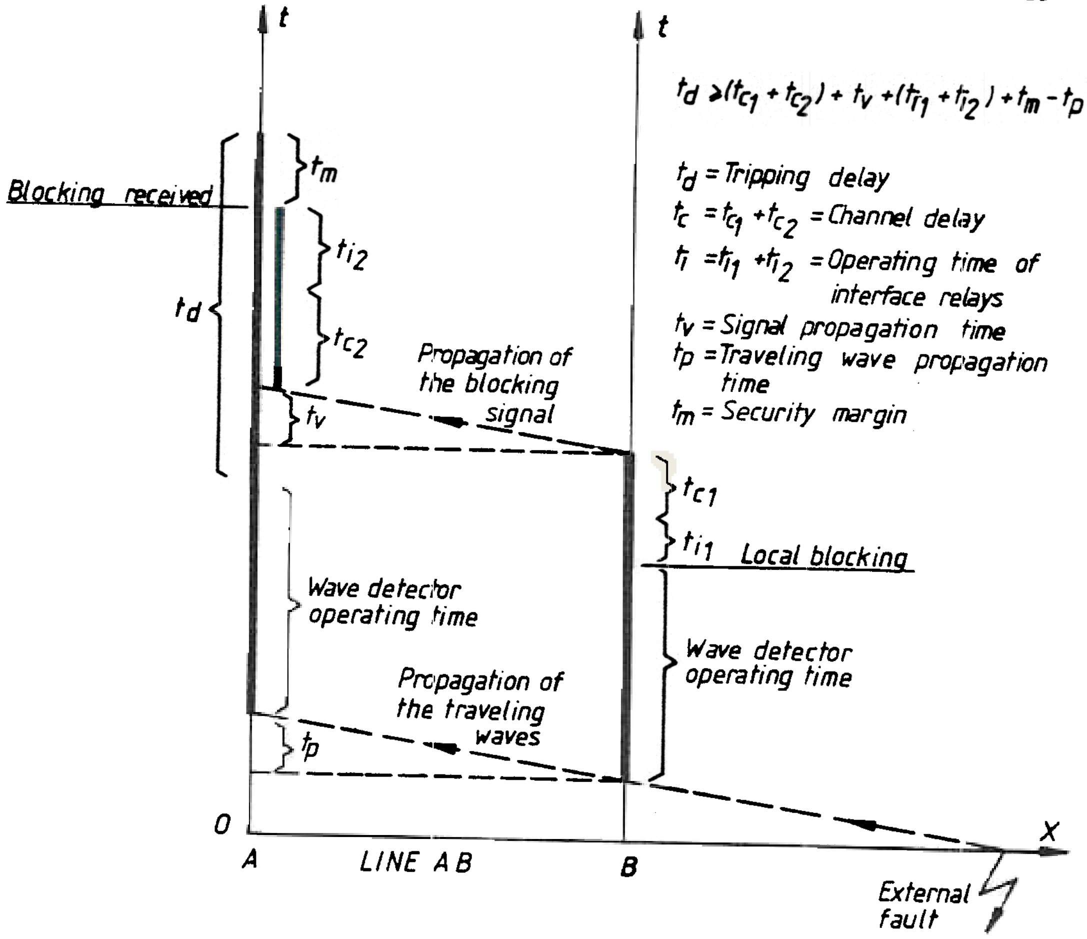
$d = \frac{u_{set}}{U_n}$ highest recommended setting is 0.85

3.4
Tripping delay

The setting for the tripping delay is made on one multiturn potentiometer with scale markings 0.0 to 99.8 x 0.3 ms on the relay module RXTEH 2H in position 537. The potentiometer is labeled "t_d".

When the RALDA relay is used in a "permissive tripping scheme" the potentiometer "t_d" shall be set to zero. (0.0).

When the RALDA relay is used in a "blocking scheme" the potentiometer "t_d" shall be set to the communication equipment total transmission time coordination delay as indicated in the figure below.



In a "directional blocking scheme" the coordination delay must be:

$$t_d = t_c + t_i + t_v + t_m - t_p$$

where

t_c = the total channel delay including operating time of channel interface relays

t_v = communication signal propagation time on the power line or microwave path

t_i = operating rime of RALDA interface relays (= 1 + 1 = 2 ms for dry reed relays type RXMT 1)

t_m = a margin which shall give the system an adequate security ($t_m \geqslant 3$ ms)

t_p = the travelling wave propagation time on the power line ($t_p = \dfrac{\text{line length in km}}{300}$ ms)

The coordination delay is set on the potentiometer "t_d"

t_d = 0.3 x c milliseconds

where c is the potentiometer setting.

Maximum setting possible is 30 milliseconds.

4 NUMERICAL EXAMPLE

Assume that the line section to be protected has the following data:

$Z1L = 4.2 + \quad 106$ ohms/phase

$= 57.9 + j\,430$ ohms/phase

Source impedances:

section end A: $Z1A_{max} = 0 + j\,556$ ohms/phase

$Z1A_{min} = 0 + j\,278$ ohms/phase

$Z0A_{max} = 0 + j\,570$ ohms/phase

$Z0A_{min} = 0 + \quad 285$ ohms/phase

Line section end B: $Z1B_{max} = 0 + j\,236$ ohms/phase

$Z1B_{min} = 0 + j\,118$ ohms/phase

$Z0B_{max} = 0 + j\,118$ ohms/phase

$Z0B_{min} = 0 + \quad 118$ ohms/phase

Fault resistance:

Phase to earth $R_f = 20$ ohms for dep. and indep. mode

$R_f = 0$ ohms for switch-into-fault

Phase to phase $R_K = 0$ ohms

Series capacitor:

Location from line end A	= 50 %
Series capacitor reactance	= -j 53 ohms/phase
Gap flash current	= 800 A

Primary voltage to neutral U'_n $= 750/\sqrt{3}$ kV

Ratio of instrument transformers:

CT: $\mathcal{H} = 800/1$ A, 60 Hz

VT: $\alpha = 750/\sqrt{3}/0.110/\sqrt{3}$ kV, 60 Hz

Relay data:

Rated voltage 110 V
Rated current 1 A
Rated frequency 60 Hz

The relay is intended for operation in a "blocking" system.

Below is shown the results from the fault calculations for all types of fault. Normally it is only required to calculated for single-phase to earth fault for dependent mode settings and for three-phase fault for independent mode settings.

4.1
Results from fault calculations

	Line section end A	Line section end B
$\Delta I'_{min}$	479 A	932 A
$\Delta U'_{min}$	243.6 kV	159.2 kV
$\Delta I'_{max}$	1373 A	2658 A
$\Delta U'_{max}$	415.1 kV	371.2 kV
U'_{max}	262.4 kV	311.7 kV

4.2
Setting procedure for the dependent mode of operation

Calculate Δi_{min}

$$\Delta i_{min} = \frac{\frac{1}{\alpha} \times \Delta I'_{min}}{I_n} = \frac{\frac{1 \times 479}{800}}{1} = 0.6$$

Calculate Δu_{min}

$$\Delta u_{min} = \frac{\frac{1}{\alpha} \times \Delta U'_{min}}{U_n} = \frac{\frac{0.11}{\sqrt{3}} \times 243.6}{\frac{750}{\sqrt{3}} \times \frac{0.11}{\sqrt{3}}} = 0.56$$

Calculate the value of "a" setting on the relay module RXPA 2H in position 155.

$$a = 2\left[10 \times \Delta i_{min} - 1\right] \times 0.85 \times k = 2\left[10 \times 0.6 - 1\right] \times 0.85 \times 1 = 8.5$$

Calculate the value of "b" setting on the relay module RXPA 2H in position 155.

$$b = \left[100 \times \Delta u_{min} - 5\right] \times 0.85 \times n = \left[100 \times 0.56 - 5\right] \times 0.85 \times 1 = 43.4$$

Since the relays are intended for operation in a "blocking" system, the relay settings at both ends of the line section shall be equal for the dependent mode of operation.

4.3
Setting procedure for the independent mode of operation

Line section end A

Calculate Δi_{max}

$$\Delta i_{max} = \frac{\frac{1}{\gamma} \times \Delta I'_{max}}{I_n} = \frac{\frac{1 \times 1373}{800}}{1} = 1.72$$

Calculate Δu_{max}

$$\Delta u_{max} = \frac{\frac{1}{\alpha} \times \Delta U'_{max}}{U_n} = \frac{\frac{0.11}{\sqrt{3}} \times 415.1}{\frac{750}{\sqrt{3}} \times \frac{0.11}{\sqrt{3}}} = 0.96$$

Calculate the value of "a" setting on the relay module RXPA 2H in position 555.

$$a = 2\left[10 \times \Delta i_{max} - 1\right] \times k = 2\left[10 \times 1.72 - 1\right] \times 1$$

a = 32.4   set a = 40   (lowest recommended setting)

Calculate the value of "b" setting" on the relay module RXPA 2H in position 555.

$$b = \left[100 \times \Delta u_{max} - 5\right] \times n = \left[100 \times 0.96 - 5\right] \times 1 = 91$$

Line section end B

Calculate Δi_{max}

$$\Delta i_{max} \quad \frac{\frac{1}{\gamma} \times \Delta I'_{max}}{I_n} = \frac{\frac{1 \times 2658}{800}}{1} = 3.33$$

Calculate Δu_{max}

$$\Delta u_{max} = \frac{\frac{1}{\alpha} \times \Delta U'_{max}}{U_n} = \frac{\frac{0.11}{\sqrt{3}} \times 371.2}{\frac{750}{\sqrt{3}} \times \frac{0.11}{\sqrt{3}}} = 0.86$$

Calculate the value of "a" setting on the relay module RXPA 2H in position 555.

$$a = 2\left[10 \times \Delta i_{max} - 1\right] \times k = 2\left[10 \times 3.33 - 1\right] \times 1 = 64.6$$

Calculate the value of "b" setting" on the relay module RXPA 2H in position 555.

$$b = \left[100 \times \Delta u_{max} - 5\right] \times n = \left[100 \times 0.86 - 5\right] \times 1 = 81$$

4.4 Setting procedure for the switch-into-fault detector

Line section end A

Calculate the value of "d" setting on the relay module RXEDA 2H in position 549.

$$d = \frac{\dfrac{\dfrac{1}{\alpha} \times \Delta U'_{max}}{0.85}}{U_n} = \frac{\dfrac{\dfrac{0.11}{\sqrt{3}} \times 262.4}{0.85}}{\dfrac{750}{\sqrt{3}} \times \dfrac{0.11}{\sqrt{3}}} = 0.71$$

Line section end B

Calculate the value of "d" setting on the relay module RXEDA 2H in position 549.

$$d = \frac{\dfrac{\dfrac{1}{\alpha} \times \Delta U'_{max}}{0.85}}{U_n} = \frac{\dfrac{\dfrac{0.11}{\sqrt{3}} \times 311.7}{0.85}}{\dfrac{750}{\sqrt{3}} \times \dfrac{0.11}{\sqrt{3}}} = 0.85$$

4.5 Setting procedure for the tripping time delay

Assume that the line section is 300 km, the channel delay time is 6 ms and the delay time due to the interface send and receive relays is 1 ms for each relay. The required security margin is choosen to 3 ms.

Calculate the tripping time delay

$$t_d = t_c + t_i + t_v + t_m - t_p$$

where

$t_c = 6 + 1 + 1 \text{ ms} = 8 \text{ ms}$

$t_i = 1 + 1 \text{ ms} = 2 \text{ ms}$

$t_v \approx t_p$ for all practical purposes

$t_m = 3 \text{ ms}$

giving

$t_d = 8 + 2 + 3 = 13 \text{ ms}$

Calculate the value of "c" setting on the relay module RXTEG 2H in position 543.

$$c = \frac{t_d}{0.3} = \frac{13}{0.3} = 43.3$$

5 COMPUTER FACILITIES

The RALDA relay settings can be determined by computer programs available at ASEA. A typical example of a computer programs print-out for the RALDA relay settings is shown on pages 18-20. When our computer facilities are required for RALDA relay setting determination please contact us for further information.

SETTING OF RALDA

CUSTOMER: FURNAS DATE: 80-11-04

STATION DATA

STATION NAME:	ELEVADORA		IVAIPORA	
PRIMARY SYSTEM				
MAX BUS VOLTAGE,KV	787.5		787.5	
MIN BUS VOLTAGE,KV	712.5		712.5	
SECONDARY SYSTEM				
VOLTAGE TRANSFORMERS				
PRIMARY VOLTAGE,KV	750.0		750.0	
SECONDARY VOLTAGE,V	110.0		110.0	
CURRENT TRANSFORMERS				
PRIMARY CURRENT,KA	0.8		0.8	
SECONDARY CURRENT,A	1.0		1.0	
	REAL	IMAG.	REAL	IMAG.
MAX SOURCE IMPEDANCE				
POSITIVE SEQUENCE,OHM	0.	556.0	0.	236.0
ZERO SEQUENCE,OHM	0.	570.0	0.	113.0
MIN SOURCE IMPEDANCE				
POSITIVE SEQUENCE,OHM	0.	278.0	0.	118.0
ZERO SEQUENCE,OHM	0.	285.0	0.	113.0

LINE DATA

LINE VOLTAGE,KV	750.0	
LINE CURRENT,KA	0.8	
	REAL	IMAG.
LINE IMPEDANCE		
POSITIVE SEQUENCE,OHM	4.2	106.0
ZERO SEQUENCE,OHM	57.9	430.0
LINE IMPEDANCE,PARALLEL LINE		
POSITIVE SEQUENCE,OHM	0.1E 31	0.1E 31
ZERO SEQUENCE,OHM	57.9	430.0
MUTUAL ZERO SEQUENCE REACTANCE,OHM	201.5	
FAULT RESISTANCE		
LINE TO EARTH,OHM	20.0	
LINE TO LINE,OHM	0.	
SERIES CAPACITOR		
LOCATION FROM LINE END A,%	50.0	
REACTANCE,OHM	-53.0	
GAP FLASH CURRENT,KA	0.8	

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CHANGES IN CURRENT (DELTA I) AND
VOLTAGE (DELTA U) USED IN SETTING CALCULATION
****

STATION NAME:	ELEVADORA	IVAIPORA
DEPENDANT MODE		
MIN DELTA I,KA	0.479	0.932
FAULT TYPE	1-PHASE	-PHASE
MIN DELTA U,KV	243.6	159.2
FAULT TYPE	-PHASE	-PHASE
MAX FAULT RESISTANCE	292.3	922.5
SER.CAP.SWITCHING		
DELTA I.KA	0.076	0.076
DELTA U.KV	27.9	11.8
INDEPENDANT MODE		
MAX DELTA I,KA	1.373	2.658
FAULT TYPE	3-PHASE	3-PHASE
MAX DELTA U,KV	415.1	371.2
FAULT TYPE	3-PHASE	3-PHASE
SWITCH-INTO-FAULT		
MAX FAULT VOLTAGE,KV	262.4	311.7
FAULT TYPE	2-PHASE	1-PHASE

The page gives the setting determining results from the fault calculations for all types of fault.

RELAY DATA
****

RATED VOLTAGE,V	110.0
RATED CURRENT.A	1.0
RATED FREQUENCY,HZ	60.0

****

SETTINGS
****

STATION NAME:	ELEVADORA		IVAIDORA	
COMMUNICATION MODE	PERMISSIVE	BLOCKING	PERMISSIVE	BLOCKING
DEPENDANT MODE				
A-VALUE	10.0	10.0	21.3	10.0
B-VALUE	51.3	31.8	31.8	31.8
INDEPENDANT MODE				
A-VALUE	32.3		64.5	
B-VALUE	90.9		80.7	
SWITCH-INTO-FAULT				
D-VALUE	0.61		0.72	

****

APPLICATION LIMIT

This page gives the RALDA relay settings determined by our computer program. The safety factors are not included in these settings.

When the RALDA relay is used in a "blocking scheme" both RALDA relays shall be identically set.

When the RALDA relay is used in a "permissivs scheme" individual settings for RALDA relays at each line terminal may be used.

When the weak infeed logic is added to the RALDA relay, both RALDA relays shall be identically set.

6 DEFINITIONS

E'	represents the voltage to neutral existing prior to the fault in the far end of the line.
	Positive sequence source impedance behind line section end A
	positive sequence source impedance behind line section end B
	positive sequence line impedance
Z0A	zero sequence source impedance behind line section end A
Z0B	zero sequence source impedance behind line section end B
Z0L	zero sequence line impedance
I'_n	rated primary current
U'_n	rated primary voltage to neutral
$\mathcal{H}$	current transformer ratio = rated primary current/rated secondary current
α	voltage transformer ratio = rated primary voltage/rated secondary voltage
I_n	rated secondary current
U_n	rated secondary voltage-to-neutral
ΔI	value of $\Delta I'$ referred to the secondary side
ΔU	value of $\Delta U'$ referred to the secondary side
ΔI_{min}	value of $\Delta I'_{min}$ referred to the secondary side
ΔU_{min}	value of $\Delta U'_{min}$ referred to the secondary side
ΔI_{max}	value of $\Delta I'_{max}$ referred to the secondary side
ΔU_{max}	value of $\Delta U'_{max}$ referred to the secondary side
U	value of U' referred to the secondary side

The relationship between primary and secondary values is obtained by introduction of the instrument transformer ratios as shown below:

$$\left.\begin{aligned} \Delta I_{min} &= \frac{1}{\chi}\,\Delta I'_{min} \\ \Delta U_{min} &= \frac{1}{\alpha}\,\Delta U'_{min} \end{aligned}\right\}\quad \text{Dependent mode}$$

$$\left.\begin{aligned} \Delta I_{max} &= \frac{1}{\chi}\,\Delta I'_{max} \\ \Delta U_{max} &= \frac{1}{\alpha}\,\Delta U'_{max} \end{aligned}\right\}\quad \text{Independent mode}$$

$U_{max} = \frac{1}{\alpha}\,U'_{max}$ Switch-into-fault protection

$\Delta I'$	change in primary phase current
$\Delta U'$	change in primary voltage to neutral
$\Delta I'_{LE}$	change in primary phase current for single line-to-earth fault
$\Delta U'_{LE}$	change in primary voltage to neutral for single line-to-earth fault
$\Delta I'_{LL}$	change in primary phase current for line-to-line fault
$\Delta U'_{LL}$	change in primary voltage to neutral for line-to-line fault
$\Delta I'_{LLE}$	change in primary phase current for line-to-line-to-earth fault
$\Delta U'_{LLE}$	change in primary voltage to neutral for line-to-line-to-earth fault
$\Delta I'_{3L}$	change in primary phase current for three-phase fault
$\Delta U'_{3L}$	change in primary voltage to neutral for three-phase fault

$\Delta I'_{min}$ minimum of changes in primary phase current $= \min. (|\Delta I'_{LE}|, |\Delta I'_{LL}|, |\Delta I'_{LLE}|, |\Delta I'_{3L}|$

$\Delta U'_{min}$ minimum of changes in primary voltage to neutral $=$ $\min. (|\Delta U'_{LE}|, |\Delta U'_{LL}|, |\Delta U'_{LLE}|, |\Delta U'_{3L}|)$

$\Delta I'_{max}$ maximum of changes in primary phase current $= \max (|\Delta I'_{LE}|, |\Delta I'_{LL}|, |\Delta I'_{LLE}|, |\Delta I'_{3L}|)$

$\Delta U'_{max}$ maximum of changes in primary voltage to neutral $=$ $\max. (|\Delta U'_{LE}|, |\Delta U'_{LL}|, |\Delta U'_{LLE}|, |\Delta U'_{3L}|$

U'_{LE} primary voltage to neutral of faulted phase for single line-to-earth fault

U'_{LL} primary voltage to neutral of faulted phase for to-line faults

U'_{LLE} primary voltage to neutral of faulted phase for line-to-line-to earth fault

U'_{3L} primary voltage to neutral for three-phase fault

U'_{max} maximum primary fault voltage $= \max. (|U'_{LE}|, |U'_{LL}|, |U'_{LLE}|, |U'_{3L}|)$

Δi_{min} p.u. value of ΔI_{min}

Δu_{min} p.u. value of ΔU_{min}

Δi_{max} p.u. value of ΔI_{max}

Δu_{max} p.u. value of ΔU_{max}