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Residual current protective devices

Technology primer

Edition 06/2018

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Be it protecting, switching, measuring or monitoring – components for low-voltage power distribution from Siemens offer just the right device for all applications in the electrical installation field. Whether for use in industry, infrastructure or buildings, these products guarantee a maximum of flexibility, ease of use and safety.
So you can keep the entire power supply safely under control.

This is especially important when it comes to selecting and installing the appropriate residual current protective device. With this primer, we provide you with a simple tool for perfectly adapting the respective residual current circuit breaker to the requirements of the electrical installation in question.

Apart from general information on residual current protective devices, it contains important details regarding installation and use. You are therefore sure of always selecting the right device.

Contents

1. Product portfolio

Residual current circuit breaker (RCCB)

5SM3 / 5SV

- Type AC, Type A and Type F
- I_n = 16 ... 125 A
- $I_{\Delta n}$ = 10 mA ... 1 A
- 2-pole (1+N) and 4-pole (3+N)
- N connection at left and right
- SIGRES version for harsh ambient conditions
- Version K and S
- Version for 500 V
- Version for 50 ... 400 Hz

SIQUENCE residual current circuit breaker (RCCB)

5SM3/5SV3

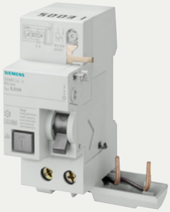
- Type B, Type B+
- I_n = 16 ... 80 A
- $I_{\Delta n}$ = 30, 300 and 500 mA
- 2-pole (1+N) and 4-pole (3+N)
- Version K and S
- including SIGRES functionality

SIQUENCE residual current breaker with overcurrent protection (RCBO)

5SU1

- Type B, Type B+
- I_n = 100 ... 125 A
- $I_{\Delta n}$ = 30, 300 mA and 1 A
- 4-pole
- Circuit breaker characteristic C and D
- Rated switching capacity 10 kA
- Version K and S

RC unit for combination with a miniature circuit breaker



5SM2

- For mounting on a miniature circuit breaker
- Combined electric shock and line protection
- Type AC, Type A and Type F
- I_n = 0.3 ... 100 A
- $I_{\Delta n}$ = 10 mA ... 1 A
- 2-, 3- and 4-pole
- Version K and S

RCBOs; combination units

5SU1

- Combined electric shock and line protection
- Type AC, Type A and Type F
- I_n = 6 ... 40 A
- $I_{\Delta n}$ = 10 ... 300 mA
- Circuit breaker characteristic B and C
- Rated switching capacity 4.5 kA, 6 kA and 10 kA
- 1+N-pole, 2-pole
- N connection at right and left

Residual current monitoring devices (RCM)

5SV8

- Residual current monitoring
- Type AC and Type A
- $I_{\Delta n}$ = 0.03 ... 30 A
- Response time 0.02 ... 10 s
- Summation current transformer 20 ... 210 mm

2. Introduction

When dealing with electricity, safety has top priority. Every electrician must be particularly conscientious when safety is concerned and must apply the required protective measures correctly. In consumer's installations, residual current protective devices must be given unreserved preference over alternative protective devices.

In addition to fault protection (protection against indirect contact), RCCBs with rated residual currents up to 30 mA also provide "additional protection" in cases of direct contact. Fires caused by ground-fault currents can also be prevented at a very early stage.

In many cases, the DIN VDE standards require the use of residual current protective devices. Electricians should therefore make sure that they are fully informed about RCCBs. In addition to information on the protective effect, an understanding of how the devices function is also conveyed.

In order to optimally adapt the use of the devices to the requirements of the electrical installation, the functionality of the different versions of RCCBs is discussed and the user is given practical installation and application tips.

3. Protection through residual current protective devices

The basic prerequisite for use of a residual current protective device in order to “automatically disconnect the power supply” as a protective measure is that an appropriately grounded protective conductor is connected to the system components and equipment to be protected. Current can then pass through a human body only when two faults occur (interruption of the PE conductor in addition to a fault in the insulation) or when there is unintentional contact between live parts.

3.1 Additional protection with $I_{\Delta n} \leq 30$ mA (previously “Protection against direct contact”)

Additional protection is understood to mean protection which takes effect if there is direct contact of a human body with a part normally live during operation in the event of basic and/or fault protection failing. If a person directly touches live parts, two series-connected resistors determine the level of the current – the internal resistance of the person R_m and the transfer resistance of the location R_{st}; see Fig. 1.

Direct contact

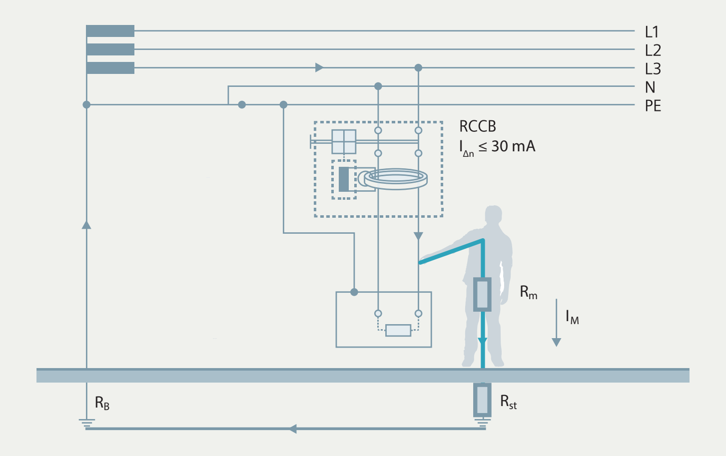


Fig. 1: Protection against direct contact: Additional protection means measures to protect against direct contact with an active part that is energized during operation.

For a proper assessment of the accident risk, it must be assumed that the contact resistance of the location is virtually zero.

The resistance of the human body depends on the current path and the contact resistance of the skin. Measurements have shown, for example, that a current path of hand/hand or hand/foot has a resistance of approx. 1000 Ω. Under these assumptions, a touch voltage of 230 V would produce a dangerous shock current of 230 mA. Fig. 2 shows the current intensity/exposure time curves in relation to the physiological reactions of the human body. Dangerous current intensities and exposure times are those which reach as far as zone ④, as they can cause death due to ventricular fibrillation. It also shows the tripping ranges of the residual current protective devices with rated residual currents of 10 mA and 30 mA. The maximum permissible tripping times according to VDE 0664-10 are also depicted. As can be seen from the tripping curves, residual current protective devices do not limit the intensity of the residual current but provide protection due to fast disconnection of the power and therefore a minimal time of exposure to the current.

Protection against direct contact (additional protection) with $I_{\Delta n} \leq 30$ mA

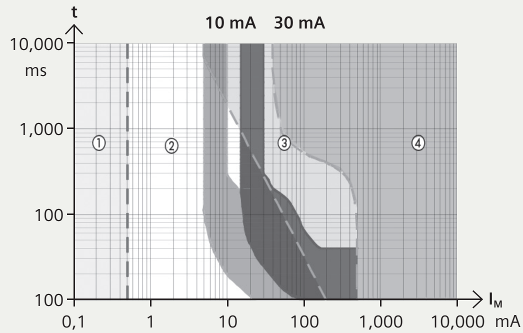


Fig. 2: Effects of 50/60 Hz alternating current on the human body

Zone ①:	Exposure is normally imperceptible.
Zone ②:	There are generally no injurious effects or muscle spasms.
Zone ③:	Muscle cramps can occur. There is normally no danger of ventricular fibrillation.
Zone ④:	Ventricular fibrillations may occur.

Residual current protective devices with a rated residual current of $I_{\Delta n} \leq 10$ mA have a tripping characteristic in zone ②, i.e. below the let-go current. There are generally no injurious effects or muscle spasms. They are therefore suitable for sensitive areas, such as bathrooms.

Residual current protective devices with a rated residual current of $I_{\Delta n} \leq 30$ mA meet the conditions for additional protection against electric shock (see Fig. 2):

- In the case of accidental direct contact with parts that are live under operating conditions (e.g.: failure of the basic insulation, operation for other than the intended purpose, ineffective basic protection)
- In the case of negligence on the part of the user (e.g. use of defective devices, inexpert repairs to systems and/or equipment)
- In the case of contact with faulty live parts (e.g. failure of fault protection in the event of interruption of the protective conductor)

The use of residual current protective devices with a rated residual current of up to 30 mA has proven to be effective as additional protection in the event of failure of the basic protection precautions (protection against direct contact) and/or fault protection precautions (protection against indirect contact) as well as in the event of carelessness on the part of the user when using electrical equipment. However, this should not be the only way of providing protection against electric shock. This does not replace the need for further protective measures as required by DIN VDE 0100-410.

The requirement for "additional protection" with residual current protective devices according to sections 411.3.3 and 415.1 of DIN VDE 0100-410 does not mean that how this protection is used is up to the user. This additional protection can be required in conjunction with other protection measures under certain external influences and in certain special areas.

In several parts of the standards for Groups 4 and 7 of DIN VDE 0100, this additional protection is required or explicitly recommended (see „Appendix“). Some important requirements are explained below in more detail as examples.

In the generally applicable standard for protection against electric shock DIN VDE 0100-410:2007-06, the use of residual current protective devices with a rated residual current of ≤ 30 mA is required as additional protection:

- For all socket outlets with a rated current of ≤ 20 A if they are intended for use by non-experts and for general use.
- For branch circuits for portable items of equipment used outdoors with a rated current of ≤ 32 A.

Note
While DIN VDE 0100-410:06-2007 specifies two exceptions to these requirements, these are not generally applicable to the majority of applications. The requirement of the standard for additional protection can be avoided only in the case of socket outlets which are only used by qualified electricians and persons who have received appropriate technical instruction (e.g. in electrical workshops) or if it has been ensured that the socket outlet is only used permanently for a "specific item of equipment".

According to standard DIN VDE 0100-723:2005-06 "Requirements for special installations, locations or plants – classrooms with experimental equipment", **Type B residual current protective devices** with a rated residual current of ≤ 30 mA must be used for supplying power to the experimental equipment and its circuits in TN or TT systems.

3.2 Fault protection (previously "Protection against indirect contact")

Fault protection is understood to mean measures to protect against the contact of a human body with a part that is not live in operation but is electrically conductive. In these cases, the demand is for automatic disconnection of the power supply when a fault can pose a risk due to the intensity and duration of the touch voltage.

Residual current protective devices with rated residual currents of over 30 mA are also suitable for this purpose. The tripping conditions must be complied with to achieve the protective effect. In addition, the dangerous touch voltage must not be present for an impermissible length of time, taking into consideration the grounding resistance and the rated residual current.

Indirect contact

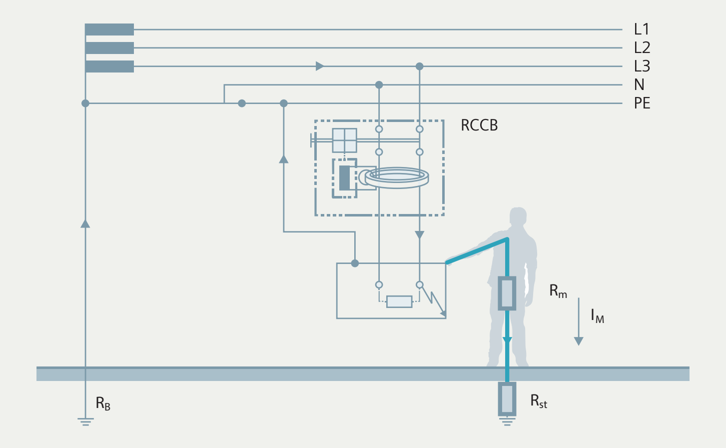


Fig. 3: Protection against indirect contact: Fault protection is understood to mean measures to protect against the contact of a human body with a part that is not live in operation but is electrically conductive.

3.3 Fire protection

DIN VDE 0100-482 requires measures for the prevention of fires which can be caused by insulation faults in "locations exposed to fire hazards". This stipulates that cables and conductors in TN and TT systems must be protected by means of residual current protective devices with a rated residual current of $I_{\Delta n} \leq 300$ mA. This does not include mineral-insulated cables and busbar systems.

In the case of applications where resistance-related faults may cause a fire (e.g. ceiling heating with panel heating elements), the rated residual current must be $I_{\Delta n} = 30$ mA. The fire protection provided by residual current protective devices, however, should not be limited to locations exposed to fire hazards but should always be provided.

4. Residual current protective devices

4.1 Types of RCCBs

Residual current circuit breakers are distinguished from one another in respect of their suitability for detecting different forms of residual current (Table 1).

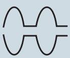
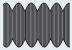
Proper function of the RCCBs						
Current wave-form	**Type AC**	**Type A**	**Type F**	**Type B**	**Type B+**	**Tripping current**
	•	•	•	•	•	0.5 … 1.0 $I_{\Delta n}$
		•	•	•	•	0.35 … 1.4 $I_{\Delta n}$
		•	•	•	•	Start angle 135° 0.11 … 1.4 $I_{\Delta n}$
		•	•	•	•	max. 1.4 $I_{\Delta n}$ +6 mA (Type A) +10 mA (Type F) +0.4 $I_{\Delta n}$ (Type B/B+)
			•	•	•	0.5 … 1.4 $I_{\Delta n}$
				•	•	0.5 … 2.0 $I_{\Delta n}$

Table 1: Classification of RCCBs into different types with tripping ranges

Residual current with different waveforms can occur depending on the electronic switching in the circuit. Since RCCBs differ in their suitability for detecting residual current waveforms, the relevant load input circuit must be taken into account when such a device is chosen.

Table 2 shows electronic circuits and their possible load and residual currents, along with the suitable types of RCCB in each case.

Suitable RCCB type	Circuit	Load current	Residual current

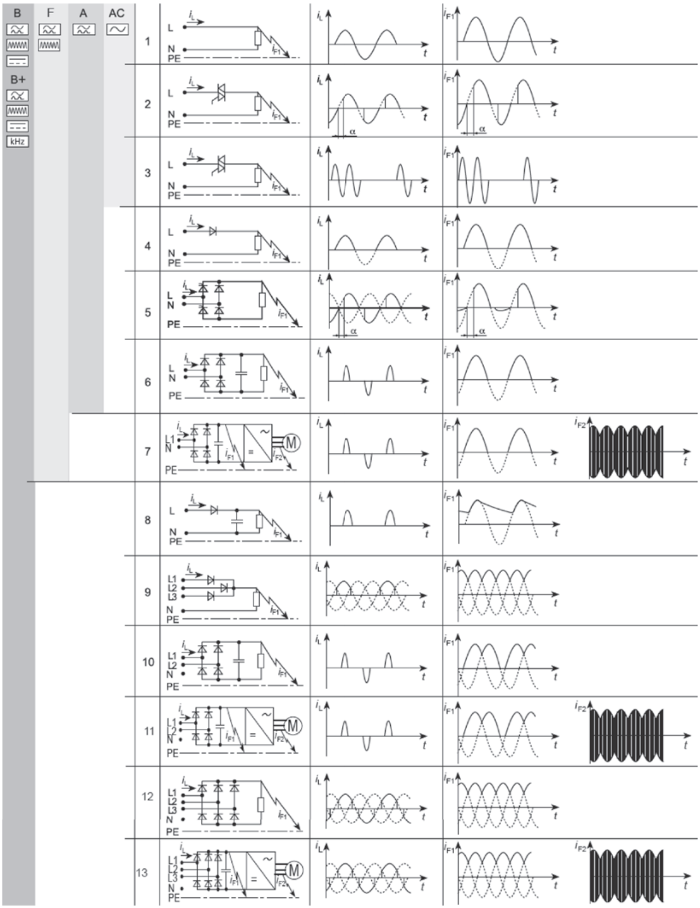


Table 2: Possible residual current waveforms and suitable RCCBs

4.1.1 Type AC

Type AC RCCBs are suitable only for detecting sinusoidal AC residual currents (see circuits 1 to 3 in Table 2). This device type is not authorized in every country (e.g. Germany as per DIN VDE 0100-530) for residual current protection and cannot carry the VDE mark of conformity.

4.1.2 Type A

Type A RCCBs detect pulsating DC residual currents in addition to sinusoidal AC residual currents. This type of device is the most commonly used pulse current-sensitive residual current protective device in Germany. It can therefore also handle the residual current waveforms which can occur in the power supply units of single-phase loads with electronic components (e.g. ECG, dimmer switches). Smooth DC residual currents up to 6 mA do not affect the trip properties unacceptably. This type of RCCB is suitable for electronic equipment with input circuits 1 to 6 in Table 2.

4.1.3 Type F

Type F RCCBs detect all residual current types, as do Type A. Additionally, they are suitable for detecting residual currents with mixed frequencies up to 1 kHz. They will also be able to cope with the possible residual current waveforms on the output side of single-phase connected frequency converters (e.g. in washing machines, pumps). Smooth DC residual currents up to 10 mA do not affect the trip properties unacceptably. Type F RCCBs additionally have short-time delayed tripping and an enhanced current withstand capability. They are suitable for electronic equipment with input circuits 1 to 7 in Table 2.

4.1.4 Type B

In addition to detecting residual current waveforms of Type F, RCCBs of Type B are used to detect smooth DC residual currents. Residual current protective devices of this type are suitable for use in 50/60 Hz three-phase AC systems, but not in DC voltage systems or where frequencies differ from 50/60 Hz, such as on the output side of frequency converters. They can be used for all input circuits listed in Table 2, i.e. also for those identified with numbers 8 to 13. Tripping values are defined up to 1 kHz.

4.1.5 Type B+

The same conditions apply for Type B+ RCCBs as for Type B residual current protective devices. It is only that the frequency range for the detection of residual currents is extended to 20 kHz: The device will trip within this frequency range below 420 mA.

4.2 Classification of residual current protective devices

Residual current protective devices are classified according to their various versions (see Fig. 4).

- **RCD** is the generic term for all types of residual current protective devices.
- **RCCBs** are residual current circuit breakers without integral overcurrent protection, known in Germany as Fehlerstrom-Schutzschalter (FI-Schutzschalter).
- **RCBOs** are devices which feature an integrated overcurrent protection unit for overload and short-circuit protection in addition to protection against residual currents. Another version in this device group is the residual current unit (RC unit). The customer can then mount the miniature circuit breaker versions suitable for a particular application (characteristic, rated current, switching capacity) on these RC units. Once assembled, these devices perform the same functions as an RCBO. The RC unit provides residual-current detection but has no contacts of its own; in the event of a fault, it trips the miniature circuit breaker which opens the contacts and interrupts the circuit.

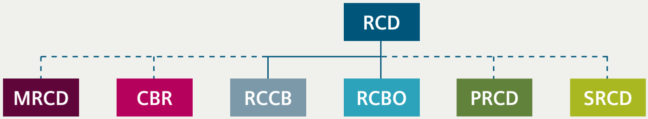
Given their tripping conditions, only versions of RCCBs and RCBOs which are **independent of the supply voltage** are approved for AC residual currents and pulsating residual currents (Type A) in Germany and in most other European countries as a means of providing protection with disconnection of the supply. Only such RCCBs and RCBOs are permitted to bear the VDE mark of conformity.

- **CBRs** are miniature circuit breakers with residual current protection in accordance with EN 60947-2 (VDE 0660-101), Appendix B. In this case, a residual-current detector is permanently installed on a miniature circuit breaker, thus ensuring residual current protection.
- **MRCDs** are modular devices, i.e. separate modules are provided for residual current detection (via current transformers), evaluation and tripping (via miniature circuit breakers) (in accordance with EN 60947-2 (VDE 0660-101), Appendix M).

CBRs and MRCDs are especially intended for applications with higher rated currents (> 125 A).

- **PRCDs** are portable residual current protective devices which are integrated, for example, in connectors or in multiple socket outlets.
- **SRCDs** are, according to DIN VDE 0662, non-portable residual current protective devices which are integrated in a socket outlet or form a single unit with a socket outlet.

PRCDs and SRCDs can be used to raise the level of protection for applications in which the required protective measure is ensured in some other manner. They are not permissible as a protective measure with disconnection of the supply.



Protection objectives

- Additional protection with rated residual current $I_{\Delta n} \leq 30$ mA
- Fault protection with rated residual current $I_{\Delta n} > 30$ mA
- Fire protection with a rated residual current of $I_{\Delta n} \leq 300$ mA

All residual current protective devices comply with the DIN VDE standards

Not for protective measure according to DIN VDE 0100-410, only local enhancement of protection level

Fig. 4: Classification of residual current protective devices (RCDs)

- Modular residual current devices (without integral current breaking devices)
- Circuit breakers incorporating residual current protection
- RCCB *
- RCBO *
- Portable residual current protective device
- Socket-outlet residual current protective device

* System voltage-independent detection and tripping

4.3 Basic design and method of operation

4.3.1 Type A RCCB

An RCCB of Type A essentially consists of the following function groups:

- Summation current transformer for detecting residual current
- Tripping circuit with components for evaluation and holding magnet release for converting the electrical measured variable into a mechanical latch release
- Breaker mechanism with contacts

Note
With the exception of the tripping circuit, the design of the Type AC and Type F RCCBs is identical to that of Type A.

The summation current transformer comprises all conductors of the circuit to be protected, including the neutral conductor. In a fault-free system, the magnetic effects of the current-carrying conductors are canceled out in the summation current transformer. There is no residual magnetic field which could induce voltage onto the secondary winding of the transformer.

A residual magnetic field remains in the transformer core only if residual current is flowing, e.g. due to an insulation fault in the system to be protected (from the electrical point of view, downstream of the RCCB). This generates a voltage in the secondary winding, effecting disconnection of the circuit with the excessive touch voltage by means of the holding magnet release and the breaker mechanism (see Fig. 5).

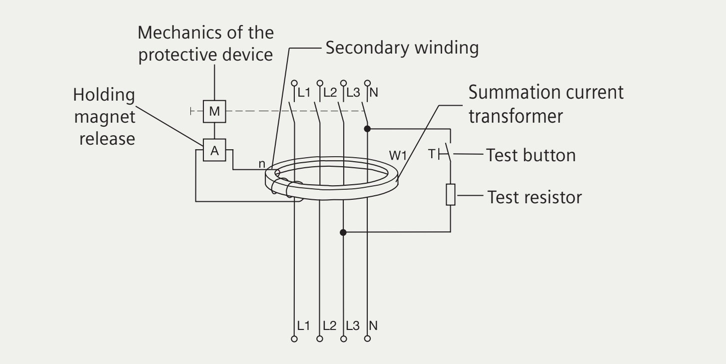


Fig. 5: Schematic representation of an RCCB

In accordance with the product standard EN 61008-1 (VDE 0664-10), the device must disconnect within 300 ms at the rated residual current. As per the product standard applicable in Germany, Type A and Type F residual current circuit breakers must function reliably and independently of supply voltage and auxiliary voltage in all function groups (detection, evaluation, disconnection) in order to achieve a consistently high level of reliability of the device protection function.

The function of the release element, which works independently of the supply or auxiliary voltage, is shown in Fig. 6.

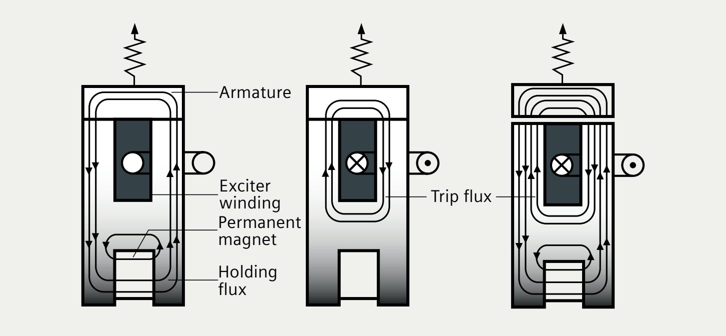


Fig. 6: Principle of operation of a holding magnet release

Immediately above the permanent magnet lies a magnetic shunt whose primary task is to stabilize the permanent magnet's magnetic flux. On one pole core, there is an excitation winding, which is connected to the secondary winding of the summation current transformer. If there is a ground fault in the main circuit, a voltage is induced in the secondary winding of the summation current transformer.

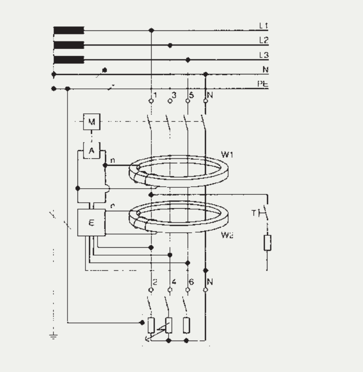
The left part of the illustration shows the rest position when the system is in a fault-free state. The permanent magnet drives a magnetic flux between two cores of magnetically soft material and stabilizes the armature through counteraction of a spring force. When a voltage is generated in the secondary winding of the transformer (middle part of the illustration), this voltage drives a current through the excitation winding. This generates a second magnetic flux. The effect of the permanent magnetic field is canceled out in a half-wave by the second magnetic field (right-hand part of the illustration).

This allows the spring to pull the armature from the pole face. The armature triggers the separation of the contacts by means of the breaker mechanism. The transformer need only generate the small amount of energy needed to cancel out the holding flux, which trips the latch release of the energy store in the breaker mechanism by means of the falling armature, and not the large amount of energy needed to open the contacts.

The functionality of the residual current protective device can be tested using the test button available on any device. Pressing the test button generates an artificial residual current which must trip the residual current protective device. In order to guarantee protection against dangerous shock currents, the reliability of the RCCB must be tested when the installation is commissioned and at regular intervals, depending on the corresponding operating conditions.

4.3.2 SIQUENCE universal current-sensitive RCCB Type B and Type B+

This device type has two detection systems. In accordance with the DIN VDE 0664-100 specification applicable in Germany, detection, evaluation and disconnection according to Type A requirements are independent of the supply voltage. For physical reasons, a power supply is required only for the detection of smooth DC residual currents. The voltage is supplied by all supply cables.



A Holding magnet release
M Mechanics of the protective device
E Electronics for tripping in the event of smooth DC residual currents
T Test equipment
n Secondary winding
W1 Summation current transformer for detection of sinusoidal residual currents
W2 Summation current transformer for detection of smooth DC residual currents

Fig. 7: Structure of a SIQUENCE Type B and Type B+ universal current-sensitive RCCB

4.4 Features and application areas

4.4.1 RCCB

RCCBs are residual current protective devices without integrated protection against overcurrent (overload and/or short circuit). A corresponding overcurrent protective device must therefore be assigned to them for overcurrent protection. The expected operational current of the circuit can be used as a basis for assessing the level of overload protection needed. The overcurrent protective device must be selected according to the information provided by the manufacturer of the RCCB. In order to meet these requirements regarding the availability of the electrical installation (see 5.1.2), final circuits are to be divided up among several residual current protective devices.

If the protective device trips in the event of a fault or if manual disconnection is necessary, all the circuits downstream from the RCCB are disconnected from the power supply, whereby the phase conductor and the neutral conductor are disconnected. This is an advantage when troubleshooting is carried out in an installation with faulty neutral conductors.

If RCCBs with a rated residual current of 30 mA or less are used for additional protection, fault protection is to be provided with an upstream selective residual current protective device with a higher rated residual current or with an overcurrent protection device. The protective device must be installed at the beginning of the circuit.

4.4.2 RCBO Type AC, Type A and Type F

Residual current circuit breakers with overload protection (RCBOs) include residual current detection and overcurrent protection in one device and thus enable a combination of electric-shock protection, fire protection and line protection. The use of RCBOs has a series of advantages:

- Each circuit is assigned its own RCBO:
  If the device is tripped due to a residual current, only the affected circuit is disconnected. This is done in the same way as it has been for years when the miniature circuit breaker exclusively assigned to a circuit trips due to overcurrent.
- Due to division of the circuits, the user profits from increased operational safety and equipment availability because leakage currents produced by electronic equipment, such as parts of power supply systems, for operating reasons do not add up to produce non-permissible values and exceed the tripping value of the RCCB.
- Planning is simplified in that demand factors as in the case of loads on RCCBs do not have to be taken into account. The RCBO protects itself against overload.
- In the event of a fault, all poles are disconnected from the power supply. All live parts are thus reliably disconnected from the supply and troubleshooting is simplified.

These advantages led to a note in DIN VDE 0100-410 recommending the use of RCBOs as additional protection in final circuits for outdoors and for socket outlets. The requirements indicated above, namely that the circuits in an electrical installation must always be divided up among several residual current protective devices, can also be complied with optimally by using RCBOs. In the following comparison of the different methods of installation, the differences are described.

Installation with central RCCBs

Fig. 8 shows a frequent type of installation with two central RCCBs, downstream of which several miniature circuit breakers are connected for each phase conductor.

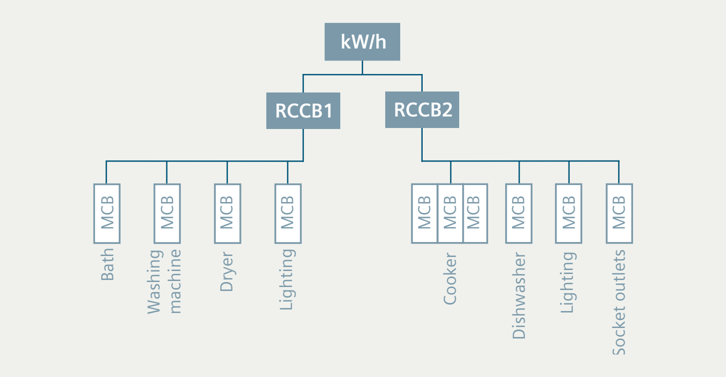


Fig. 8: Installation with a central RCCB and miniature circuit breakers for feeders

The RCCB provides electric-shock protection and fire protection as well as the additional protection with $I_{\Delta n} \leq 30$ mA against direct contact as required for certain circuits (e.g. in bathrooms). The miniature circuit breaker prevents damage due to overloads or short circuits. If the RCCB is tripped in one of the downstream circuits due to a ground fault, all other circuits, even the fault-free circuits, are disconnected from the voltage supply. Operation of these parts of the installation can only be resumed after the fault has been eliminated. The following factors must be taken into account with this type of installation:

- For correct dimensioning of the installation in respect of the residual current circuit breaker (RCCB), it must be ensured that the RCCB is not overloaded due to excessively high load currents (see 5.5).
- In de-energized state, the single-pole miniature circuit breakers only disconnect the phase conductor from the network. The neutral conductor remains connected to the load side.
- The tripping of a residual current protective device is not allowed to lead to the failure of all circuits in a system.

Installation with RCBOs

Fig. 9 shows an example of a future-oriented installation that meets all the requirements of the installation regulations and planning stipulations.

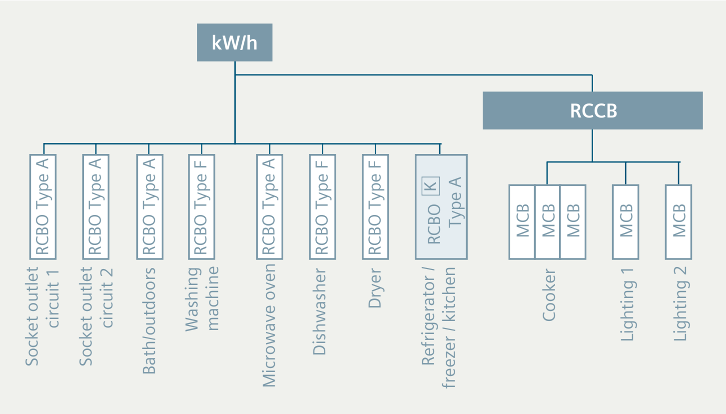


Fig. 9: Example of an installation with RCBOs

Each individual socket-outlet circuit now has its own RCBO, which provides complete fault, fire and line protection as well as additional protection against direct contact. In the event of a fault, only the affected circuit is disconnected from the supply. The use of Type F RCBOs is recommended for washing machine, dryer and dishwasher circuits. In the event of a fault in such appliances, currents with frequencies other than 50 Hz can occur for which Type A RCBOs are not designed. In order to obtain increased safety against inadvertent disconnection from the supply, e.g. due to lightning overvoltages, the use of a super-resistant RCBO, Type K, is recommended for protection of socket outlet circuits for refrigerators and freezers. If RCBOs with a rated residual current of 30 mA or less are used, the additional protection and fault protection can be provided with the same RCBO. The RCBO must be installed at the beginning of the circuit to be protected.

As an option, a selective RCCB with $I_{\Delta n}$ = 300 mA can be connected upstream of the entire installation. This RCCB protects installations with branches against faults and fire. If the stipulations of DIN 18015-2:2000-08 and RAL RG 678:2004-09 are taken as the basis for the same extent of equipment and for the same living area, the additional space required in the circuit distribution board when the recommended RCBOs are used is only slightly more than the space required in an installation with separate RCCBs and miniature circuit breakers.

4.4.3 SIQUENCE universal current-sensitive RCCB Type B and Type B+

Type A RCCBs – for sinusoidal AC residual currents and pulsating DC residual currents – are not capable of detecting possible smooth DC residual currents. Due to pre-magnetization of the transformer, DC residual currents can even result in the inability of Type A RCCBs to detect AC residual currents. For these reasons, Siemens introduced the universal current-sensitive Type B RCCB, which is also used for smooth DC residual currents, in 1994 – the first manufacturer to do so. Since then, the required residual current circuit breaker technology can be used in many applications in which smooth DC residual currents occur. As universal current-sensitive residual current circuit breakers are used for the widest variety of applications, these are always also designed for use under harsh ambient conditions like our SIGRES version (see section 4.4.6).

The new generation of SIQUENCE universal current-sensitive RCCB (5SV) features an internal self-test.
This self-test is automatically initiated every 13 hours in order to test the analog electronics and the detection algorithms. The software in the microcontroller generates synthetic signals, which are similar to the signals of a residual current. These signals are fed into the system's detection path behind the sensors and are assessed by the analog circuit and the microcontroller.

It is now imperative, therefore, for the microcontroller to create the trip command. During the self-test, the trip command to the tripping relay is blocked for a short period (ms) in order to prevent real tripping. This tripping path is enabled again when the test reaches a positive conclusion. A negative test result will cause the device to be tripped immediately. The test concept is rounded off by an external watch-dog which checks the program flow and the firmware integrity every 20 ms.

In addition to the residual current waveforms described above, AC residual currents with a wide range of frequencies may also occur on electronic equipment, such as at the outgoing terminal of a frequency converter (see also section 5.3.2). Type A RCCBs are not designed for these conditions.

The Type B RCCBs intended for use in three-phase systems (not in DC voltage systems) are therefore specified in EN 62423 (Type B) on the extended tripping conditions up to 1 kHz. The tripping characteristics of the SIQUENCE universal current-sensitive Type B RCCBs with rated residual currents of 30 mA and 300 mA are shown in Fig. 10. The tripping value of the circuit breaker always lies within the limit values of the device specification and, for 30 mA rated residual current, is well below the limit curve for dangerous ventricular fibrillation (according to IEC 60479-2).

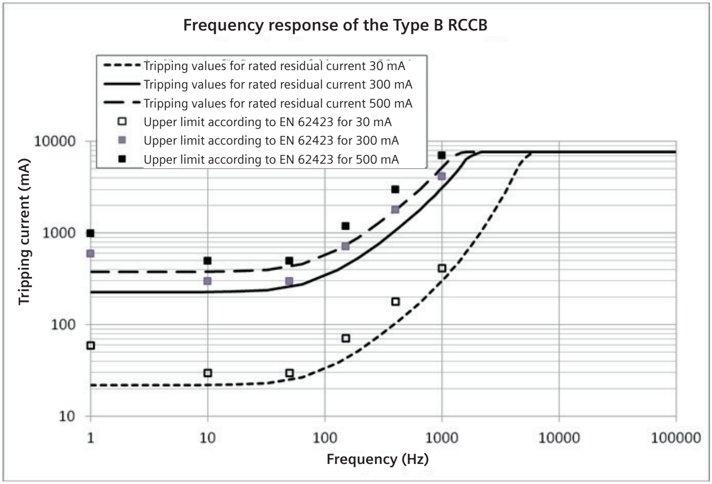


Fig. 10: Type B frequency-dependent tripping current

To protect against fires caused by ground-fault currents, the use of RCCBs with a rated residual current of up to 300 mA has proven itself to be effective. This is derived from the assumption that approximately 70 W is sufficient to cause a fire. The tripping values of the SIQUENCE Type B RCCB increase with higher frequencies. However, since residual current contains high-frequency and low-frequency components (see section 5.3.2), an effective contribution to fire protection in the case of ground-fault currents can also be achieved with a tripping characteristic which rises with the frequency. The positive effect of the increasing tripping current is a higher degree of operational safety for the system as a whole, since leakage currents from capacitors can lead to a reduced level of unwanted tripping of the RCCB.

The dimensioning of the SIQUENCE Type B RCCB's frequency response takes these boundary conditions into account, and represents a solid compromise between fire protection and operational safety. Since the influence of existing capacitive leakage currents on the tripping of the RCCB is clearly limited, the RCCB can be used in a significantly larger number of applications.

The use of Type B+ RCCBs is recommended if the use of RCCBs with rated residual currents of max. 300 mA is required in accordance with DIN VDE 0100-482 "Fire protection against special risks or hazards" in connection with DIN VDE 0100-530. They meet all requirements of the well-known Type B, but remain below the tripping value of 420 mA at up to 20 kHz in accordance with product standard DIN VDE 0664-400 as well as VdS Guideline 3501, thus offering an increased level of preventive fire protection.

High-intensity leakage currents can occur briefly when capacitors connected to the PE protective conductor are switched on (e.g. in the case of EMC filters in conjunction with frequency converters). In order to ensure trouble-free operation in such cases, the SIQUENCE universal current-sensitive Type B and Type B+ RCCBs are always super-resistant and feature short-time delayed tripping (Type K).

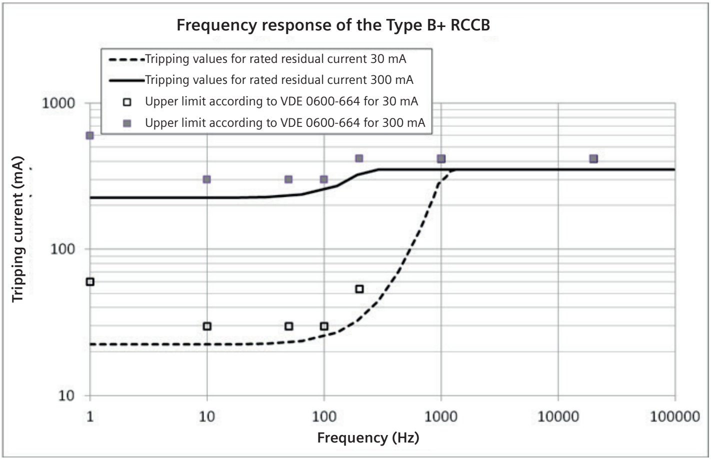


Fig. 11: Type B+ frequency-dependent tripping current

In order to fulfill the tripping conditions for protection against indirect contact (fault protection) using the SIQUENCE RCCB, its tripping characteristics at different frequencies and the frequency spectra occurring in the application at the fault location must be taken into account. On the assumption of unfavorable conditions (high clock pulse rate of a frequency converter; also see section 5.3.2), the maximum permissible grounding resistances listed below are recommended.

Rated residual current	Maximum permissible grounding resistance at touch voltage	
	50 V	25 V
30 mA	120 Ω	60 Ω
300 mA	Type B: 16 Ω Type B+: 120 Ω	Type B: 8 Ω Type B+: 60 Ω
500 mA	10 Ω	5 Ω

Table 3: Recommended maximum grounding resistance for SIQUENCE Type B and Type B+ RCCBs

4.4.4 SIQUENCE universal current-sensitive RCBO Type B and Type B+

The principle of detection on which the SIQUENCE Type B universal current-sensitive RCBO is based is identical to that on which the SIQUENCE universal current-sensitive RCCB is based and operates in accordance with EN 62423 (Type B) and DIN VDE 0664-410 (Type B+).

With regard to the response to residual currents and the protective functions, the same statements and specifications which apply to the SIQUENCE Type B / Type B+ RCCB are applicable. RCBOs combine in one unit the protection functions of electric-shock and fire protection along with line protection. Thanks to the integrated overcurrent protection feature, intrinsic thermal protection of the device is ensured automatically without further adaptation to upstream/downstream overload protection systems.

In addition to those advantages mentioned in section 4.4.3, direct allocation of a SIQUENCE Type B universal current-sensitive RCBO to a circuit offers the following special advantages over an RCCB and multiple miniature circuit breakers in the outgoing circuit:

- The maximum possible leakage current (0.3 * $I_{\Delta n}$) can be used in each feeder.
- As in the case of overcurrent, tripping due to residual current disconnects only the affected branch from the supply voltage.
- High system availability, since the fault-free part of the system is still supplied with power.

4.4.5 RC units for installation on miniature circuit breakers

RC units are suitable for installation on miniature circuit breakers in accordance with EN 61009-1 (VDE 0664-20), Appendix G. The customer can combine these RC units with a suitable MCB for the same functionality as ex-works RCBOs.

A large number of different combinations can be made up from the available RC unit and miniature circuit breaker product ranges without having to stock a large number of products. This results in important advantages:

- High degree of application flexibility
- Customized combination of device features from RC unit (rated residual current, instantaneous or selective) and miniature circuit breaker (rated current, characteristic, switching capacity)
- The device combination offers all advantages of an RCBO as regards electric-shock, fire and line protection.

4.4.6 SIGRES RCCBs (for harsh ambient conditions)

When residual current protective devices are used under severe environmental conditions with increased emissions of corrosive gases, for instance in

- indoor swimming pools (chlorine gas; ozone),
- agriculture (ammonia),
- industry (sulfur dioxide)

the RCCBs are subject to a significantly higher load. These gases, in conjunction with humidity, have a corrosive effect on all metal components and therefore also on the metal surfaces of the holding magnet release.

The SIGRES residual current circuit breakers are suitable for such applications and their patented active condensation protection feature gives them a significantly longer service life. Direct heating of the holding magnet release produces a slightly higher temperature on the metal components with only minimum power required. Since condensation of the humid air enriched with corrosive gases is thereby avoided, corrosion cannot take place, resulting in a longer service life of the devices. A power supply is required for heating. If the RCCB is also used for a longer period of time while in a disconnected state, the direction of the incoming supply must be observed. This ensures that heating is possible in this case as well. The protective function of the RCCB continues to remain absolutely independent of the supply voltage as required by the product standard.

4.4.7 Type [K] super-resistant

Leakage currents and residual currents arising from the operation of electrical equipment cannot be distinguished. The reaction to both is the same. If a temporary high leakage current occurs, it is neither necessary nor desirable to disconnect the load from the supply. If electronic equipment is used with capacitors connected against the protective conductor in order to suppress interference, inadvertent tripping of the RCCB can occur when the equipment is switched on.
In order to avoid this disconnection, the use of super-resistant residual current protective devices is recommended. They trip with a time delay and are designated as Type [K] devices.

As far as the product standards EN 61008-1 (RCCBs) and EN 61009-1 (RCBOs) are concerned, there are only two types of device:

- Standard
- Selective [S]

For these types of device, the limit values for the break times are defined. In accordance with the standard, the super-resistant RCCBs are instantaneous versions.

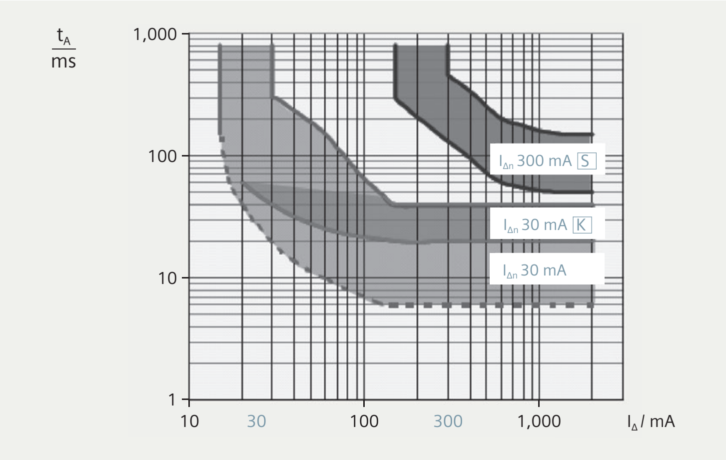


Fig. 12: Break time t_A as a function of the tripping current I_Δ

Fig. 12 shows the tripping ranges of the various versions of residual current protective devices. It can be clearly seen that the tripping ranges of the standard version and the super-resistant version are identical in terms of the maximum value. Only the minimum value is higher in the case of Type K. The Type S responds selectively to these two versions.

The Type K super-resistant RCCBs exploit the maximum permissible tripping range of the standard. They have a minimum time delay of approximately 10 ms. In other words, short-time leakage currents and high surge currents (8/20 µs) are ignored for this length of time. Only when a residual current flows for longer than the delay time is disconnection from the supply initiated. Protection against electric shock is provided by this residual current protective device too. The devices can be used without restriction for all the protective measures (with disconnection from the supply) required in the installation regulations. The installation is not disconnected unnecessarily and its availability is considerably increased.

4.4.8 Type [S] selective

In order to achieve selective tripping in the case of series-connected residual current protective devices in the event of a fault scenario, both the rated residual current $I_{\Delta n}$ and the tripping time of the devices must be staggered. The different permissible break times of the standard and selective residual current protective devices can be taken from Fig. 13. Appropriate staggering of the rated residual currents can also be seen in Fig. 13. Type [S] selective RCCBs also have a very high current withstand capability of 5 kA (8/20 µs current waveform). They are identified by the symbol [S].

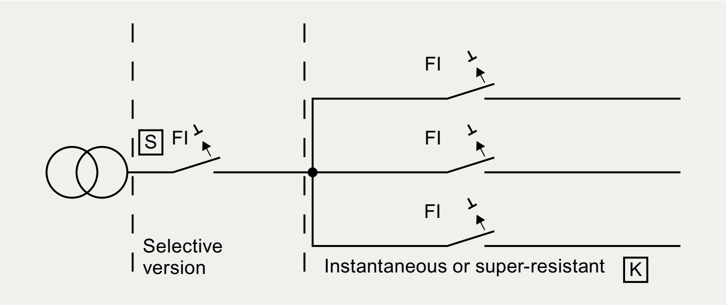


Fig. 13: Layout of various residual current protective devices and their tripping times

Upstream RCCB for selective disconnection [S]		Downstream RCCB		
			instantaneous version	super-resistant version [K]
$I_{\Delta n}$	Break time with $5 \times I_{\Delta n}$	$I_{\Delta n}$	Break time with $5 \times I_{\Delta n}$	Break time with $5 \times I_{\Delta n}$
100 mA 300 mA 500 mA 1000 mA	50 - 150 ms	10 mA 30 mA 100 mA 300 mA	≤ 40 ms	20 - 40 ms

4.4.9 Versions for 50 to 400 Hz

Because of the principle according to which they function, residual current protective devices in their standard version are designed for maximum efficiency in a 50 Hz network. The device specifications and tripping conditions also relate to this frequency. With increasing frequency, sensitivity normally decreases. In order to be able to implement effective residual current protection in networks up to 400 Hz (e.g. industrial systems), suitable devices must be used. Such RCCBs fulfill the tripping conditions up to the specified frequency and provide corresponding protection.

4.4.10 Versions for 500 V operational voltage

The standard versions of residual current protective devices, with their creepage and clearances, are designed for networks up to 240/415 V alternating voltage. Suitable residual current protective devices are available for networks up to 500 V.

4.4.11 RCCB with left-side N connection

Because RCCBs, particularly in Germany, are normally placed at the left of the miniature circuit breakers but have the N-conductor connection on the right, 4-pole RCCBs are also provided with their N connection on the left-hand side. RCCBs used in conjunction with miniature circuit breakers therefore require a special busbar.
In order to make it possible to use standard busbars whenever required, four-pole RCCBs with the N connection on the left are also available. The custom of installing RCCBs to the left of miniature circuit breakers using standard busbar joints can therefore be continued.

4.5 Additional components for RCCBs

4.5.1 Remotely controlled mechanism (RC)

Favored locations for remote-controlled operating mechanisms are spacious or not continually manned work areas, such as water treatment plants or radio stations as well as automated plants for energy and operations management.

Remotely controlled mechanisms are used for remote ON/OFF switching of miniature circuit breakers with or without RC unit, RCCBs, RCBOs or flush-mounting switches, and also allow local manual switching of these devices.
A tripped combination must be acknowledged prior to switching back on.
In the event of a fault, the device combination of the type Auto Reclose Device (ARD) attempts to switch on again up to three times. If the fault is still present, the combination remains disconnected. The remotely controlled mechanism has an operating mode selector switch with the functions: “Locked”, “Manual” and “Remote switching”.
Selector switch position:

OFF For units with 177 - 270 V: Power to the remotely controlled mechanism is switched off, blocked mechanically and can be sealed and/or locked.
RC OFF Only manual operation is possible.
RC ON Both manual and remote actuation (except for the Basic 12 - 48 V devices) is possible.

In the event that a device is tripped by a fault, the handle of the basic unit and remotely controlled mechanism switch to the OFF position. If, depending on the device version, the combination has been switched off, an attempt can be made to switch it on again via ARD or remotely.
If the fault persists, the device combination is switched off and can only be switched on again manually on site.
Suitable adapters must be ordered so that the remotely controlled mechanisms can be combined with the residual current circuit breakers, miniature circuit breakers, RCBOs and on/off switches.

Benefits of the remotely controlled mechanism

Remote-controlled operating mechanisms with ARD and Power have integrated auxiliary switches and fault signal contacts.

More additional 5ST3… components, such as AS, FC, ST and UR, can be added to the right-hand side of the remotely controlled mechanism in line with the Siemens mounting concept.

Remote-controlled operating mechanisms with ARD and Power have an LED display on the front of the device for displaying the switching state and for diagnostics.

Fig. 14: Example of a remotely controlled mechanism with 5SV3 RCCB

The use of a remotely controlled mechanism allows the user direct and immediate access to the system even in remote or hard-to-access locations. Fast reconnection to the power supply following a fault saves considerable time and costs.

4.5.2 Auxiliary switches

Auxiliary switches can usually be retrofitted on the RCCB by the customer. They indicate the circuit breaker's switching state. Three variants are possible (1 NO/1 NC; 2 NCs; 2 NOs).

4.5.3 Additional components

Depending on the version of the residual current protective device, the following additional components can be retrofitted where required:

- Fault signal contacts
- Undervoltage releases
- Shunt trips
- Arc fault detection devices (AFDDs; see also the corresponding technology primer)

5. Notes on installation and use

5.1 General notes

5.1.1 Selection of protective devices

When selecting a suitable protective device for the protective measure “automatic disconnection of the power supply” in accordance with DIN VDE 0100-410 for fault protection, the conditions of disconnection depending on the supply system must be taken into account. Table 4 summarizes the relevant characteristic variables for the conditions of disconnection from the supply.

Characteristic		Values in the TN system	Values in TT system
Fault loop impedance Z_S (measured values)		Several 10 mΩ to approx. 2 Ω	Up to 100 Ω
Residual current	$I_F = \frac{230\ V}{Z_S}$	Approx. 115 A to several 1,000 A	At least 2.3 A
Maximum permissible break time t_a according to table 41.1 in DIN VDE 0100-410 *		**0.4 s**	**0.2 s**
Touch voltage U_T (empirical values)		80 V up to 115 V	160 V up to 230 V
Touch current	$I_T = \frac{U_T}{1{,}000\ \Omega}$	80 mA up to 115 mA	160 mA up to 230 mA
Impedance of the human body for hand-to-foot flow of current (guide value)			
* For final circuits with a rated current not greater than 32 A in a 230/400 V system (50 Hz)			

Table 4: Characteristic variables for the conditions of disconnection in TN and TT systems with rated voltages of 230/400 V AC

Table 4 shows the clear differences in respect of touch voltages and the resulting touch currents in TN and TT systems. These differences explain why the maximum permissible break times in the TT system must be shorter than in the TN system in order to provide the same protection.

Suitable protective devices are to be selected on this basis. Table 5 provides an overview.

<table>
<tr><th></th><th colspan="3">TN system</th><th colspan="3">TT system</th></tr>
<tr><td rowspan="5">Trip currents I_a of overcurrent protection devices for ensuring the required disconnecting time t_a</td><td colspan="3">$I_a \geq \frac{230\ V}{Z_S}$</td><td colspan="3">$I_F = \frac{230\ V}{Z_S}$</td></tr>
<tr><td>Protective device</td><td>I_a</td><td>t_a *</td><td colspan="3" rowspan="4">The necessary trip currents I_a of overcurrent protection devices are generally not reached by the residual currents I_F.</td></tr>
<tr><td>MCB Type B</td><td>$\geq 5\ I_n$</td><td>< 0.1 s</td></tr>
<tr><td>MCB Type C</td><td>$\geq 10\ I_n$</td><td>< 0.1 s</td></tr>
<tr><td>Melting fuse gG</td><td>ca. $> 14\ I_n$</td><td>< 0.4 s</td></tr>
<tr><td rowspan="4">Tripping conditions of residual current protective devices for ensuring the required disconnecting time t_a</td><td colspan="3">$I_a \geq \frac{230\ V}{Z_S}$
In the TN system, the residual currents I_F are considerably higher than $5\ I_{\Delta n}$</td><td colspan="3">$I_{\Delta n} \leq \frac{50\ V}{R_A}$
In the event of a fault, there is 230 V at the fault location.. The following therefore applies to the trip current I_a:
$I_a = \frac{230\ V}{50\ V}\ I_{\Delta n} = 4.6\ I_{\Delta n}$</td></tr>
<tr><td>Type</td><td>I_a</td><td>t_a *</td><td>Type</td><td>I_a</td><td>t_a *</td></tr>
<tr><td>RCCB general</td><td>$> 5\ I_{\Delta n}$</td><td>≤ 0.04 s</td><td>RCCB general</td><td>$> 2\ I_{\Delta n}$</td><td>≤ 0.15 s</td></tr>
<tr><td>RCCB selective</td><td>$> 5\ I_{\Delta n}$</td><td>≤ 0.15 s</td><td>RCCB select.</td><td>$> 2\ I_{\Delta n}$</td><td>≤ 0.2 s</td></tr>
<tr><td colspan="7">* The values for t_a relate to the stipulations in the relevant product standards.
R_A – the sum of the resistance in Ω of the ground electrode and the protective conductor of the exposed conductive parts
$I_{\Delta n}$ – the rated residual current in A of the residual current protective device.</td></tr>
</table>

Table 5: Selection of protective devices in TN systems and in TT systems with rated voltages of 230/400 V AC

5.1.2 Use of residual current protective devices

Residual current protective devices can be combined with any other protective devices. Even if other protective measures are already installed in an existing system, residual current protection can still be used for this system or parts of it. Almost any type of protective measure can be converted to residual current protection with comparatively little effort.

According to the standard DIN VDE 0100-530, it is permissible, where a residual current protection device with a rated residual current of $I_{\Delta n} \leq 30$ mA is being used, to also use this simultaneously to provide fault protection in the form of automatic disconnection of the power supply and additional protection in the event of direct contact. However, because this additional protection by means of residual current protective devices with a rated residual current that does not exceed 30 mA is envisaged as additional protection for the event that precautions for basic protection and/or precautions for fault protection are not successful, it is nevertheless recommended that the protective functions be split up among different devices in order to fulfill both of these protection goals. In order to achieve maximum availability and operational safety, the circuits must be divided up appropriately among several RCCBs. These requirements are specified in various documents:

- DIN 18015-1:2013-09 “Electrical Installations in Residential Buildings – Part 1: Planning Principles” requires that connection points for items of current-using equipment be assigned to a circuit in such a way that automatic tripping of the protective device assigned to this circuit (e.g. overcurrent protective device, residual current protective device) in the event of a fault or necessary manual disconnection from the power supply only cause a small part of the customer’s installation to be disconnected from the supply.
- TAB 2007 (Technical Connecting Conditions) states that when circuits are divided up, connection points for items of current-using equipment be assigned to a circuit in such a way that automatic tripping of the protective device assigned to this circuit in the event of a fault or necessary manual disconnection from the power supply only cause a part of the customer’s installation to be disconnected from the supply.

This means that: Except when selective residual current protective devices are used, the circuits are to be divided up in such a way that tripping of a residual current protective device does not lead to the failure of all circuits.

If a residual current protective device for other protection tasks (fault protection, fire protection) is connected upstream of an RCD for additional protection (rated residual current ≤ 30 mA), this second RCD should always have a selective tripping characteristic (e.g. Type [S]).

As shown in Table 5 , selective and standard RCCBs achieve the maximum permissible tripping times in both power supply systems. The following points must be noted when residual current protective devices are used in Germany for fault protection, fire protection and (in accordance with DIN VDE 0100-530) additional protection:

- All poles of all active conductors – i.e. including the neutral conductor – must always be disconnected.
- Only voltage-independent RCCBs (Type A) are allowed.
- Purely AC-sensitive RCCBs (Type AC) are not allowed.

5.2 Choosing the right residual current protective device

Fig. 15 can help users to select a suitable residual current protective device:

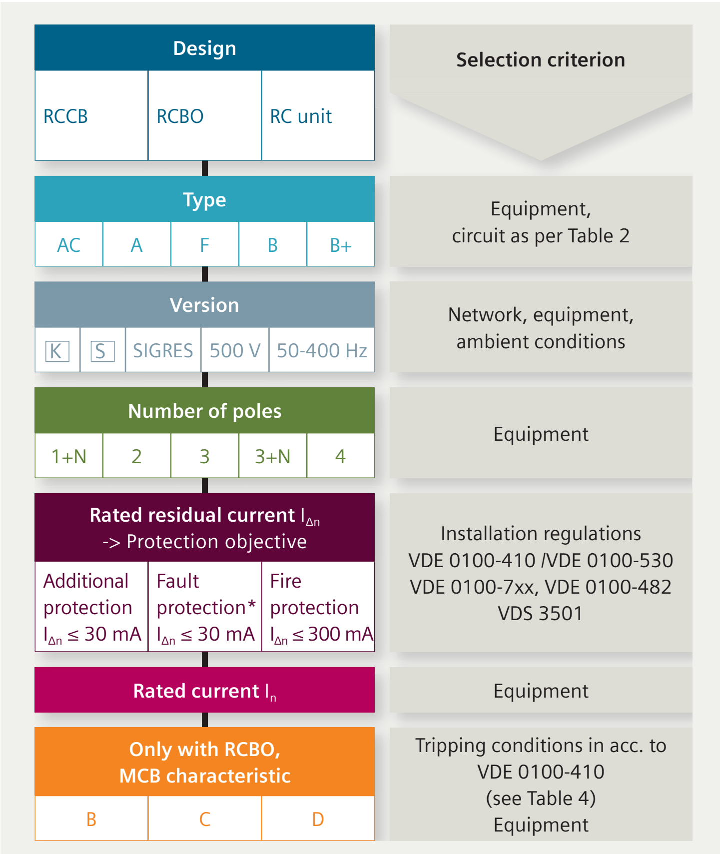


Fig. 15: Selection aid for finding the suitable residual current protective device

Details are explained below.

5.2.1 Type A, Type F or Type B / Type B+?

The correct type of residual current protective device for each application can be selected with the help of Table 2 (in accordance with EN 50178/VDE 0160 "Electronic equipment for use in power installations" and DIN VDE 0100-530).

If the electronic equipment (e.g. a frequency converter) is operated directly on the three-phase system and input circuits 8 to 13 are connected (see Table 2), universal current-sensitive RCCBs (Type B or B+) must be used. Type F residual current protective devices must be used (input circuit 7 in Table 2) if higher frequencies are to be expected in the residual current (e.g. frequency converter in a 1+N network). It is sufficient to use Type A residual current protective devices (sensitive to pulsating current) for all other applications.

5.2.2 What protection goal must be achieved?

Various protection goals must be achieved depending on the application and location of use:

- **Additional protection** with a rated residual current of $I_{\Delta n} \leq 30$ mA:
  These RCDs are intended to provide additional protection against electric shock in case of a failure of the other basic protective measures (protection against direct contact) and/or for protection against faults (protection against indirect contact) or in the event of carelessness by the user. Their protection is effective up to a maximum frequency of 100 Hz.
  All statements concerning the risk of ventricular fibrillation (up to 1 kHz) are at present only of limited validity at higher frequencies. No reliable evidence is available regarding the impact of other effects (thermal, electrolytic) on the human organism.
- **Fault protection** with a rated residual current of $I_{\Delta n} > 30$ mA:
  Protection against electric shock can be provided with these rated residual currents under fault conditions. The tripping conditions of the respective power system must be complied with.

At frequencies higher than 100 Hz, protection in the event of indirect touching must be provided and account must be taken of the frequency response of the residual current operated circuit breaker, the maximum permissible touch voltage (e.g. 50 V), the critical frequency components in the residual current and the maximum permissible grounding resistance determined from these components (see also 4.4.3).

Fire protection with a rated residual current of $I_{\Delta n}$ ≤ 300 mA
In installations
- at particular risk of fire (premises exposed to fire hazards),
- that are primarily made of flammable construction materials,
- containing irreplaceable goods of great value

the installation of RCCBs with rated residual currents of no more than 300 mA is required in accordance with DIN VDE 0100-482 in connection with DIN VDE 0100-530. Exceptions are only permitted if mineral-insulated cables and busbar systems are used.

Type B+ residual current protective devices must be used in the above-mentioned systems to increase the preventative fire protection of electrical equipment with input circuits 8 through 13 (see Table 1).

5.2.3 What electrical interference occurs and how is it handled?

Leakage currents
Leakage currents are currents that are leaked to ground although the insulation is not faulty. They can be either static or dynamic, and they trip the RCCB if the tripping value is exceeded.
These currents must therefore be taken into account when the rated residual current $I_{\Delta n}$ of an RCCB is selected and, if necessary, minimized, in order to ensure that the specified protection requirements are met.

- **Static leakage currents**
  Static leakage currents are continuously leaked to ground or the PE conductor during normal operation of the load, even though the insulation is not faulty. These currents are mainly leaked from line and filter capacitors.

For problem-free use of RCCBs in practical applications, the stationary leakage current should be $\leq 0.3 * I_{\Delta n}$.

- **Dynamic leakage currents**
  Dynamic leakage currents are transient currents to ground or the PE conductor. They occur in the range from a few µs to a few ms, especially when devices with filter circuits are switched. Their duration depends on the time constant that is derived from the circuit impedances, and above all on the switching device that is used to connect the filter to the power supply. Depending on the design of the filter circuit, short-time high capacitance values to PE can arise because of the non-uniform contact of the various switching contacts which are reduced to low residual values to PE owing to the star connection of the capacitors after the device has been fully closed.

These dynamic leakage currents can have a magnitude of a few amperes and hence also trip instantaneous RCCBs with $I_{\Delta n}$ = 300 mA.
The peak value of the dynamic leakage current must be determined in the PE conductor by means of an oscilloscope. The equipment must be arranged in an insulated setup, so that the complete leakage current is able to flow back along the measurement path. The use of super-resistant RCCBs (Type [K]) is recommended to prevent unwanted tripping in these kinds of application.

High load currents
Even if no leakage currents are present, an RCCB can still be spuriously tripped as a result of high load currents (> 6x I_n). These high load current peaks can lead to different magnetizations in the magnetic strip core because the arrangement of the primary conductors is not absolutely symmetrical and the secondary winding on the circumference of the summation current transformer for residual current detection is not completely closed, so that a tripping signal is produced. Tripping can also result if the magnetic field around the current carrying conductor is directly irradiated onto the holding magnet release. High load current peaks are especially common in conjunction with the direct-on-line start of motors, lamp loads, heater windings, capacitive loads (capacitances between L and N), and medical equipment such as CT machines or X-ray equipment.

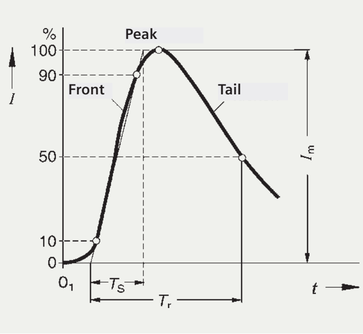
According to the product standard, RCCBs are resistant to spurious tripping at up to six times the rated current.

Overvoltages and surge current load
During thunderstorms, atmospheric overvoltages in the form of traveling waves can penetrate the installation via the supply system and inadvertently trip residual current protective devices. To prevent these spurious tripping operations, our residual current protective devices must pass a test with the standardized 8/20 µs surge current waveform (see Fig. 16). In the product standard EN 61008 (VDE 0664), this test is only stipulated for selective residual current protective devices (i = 3 kA).
All versions of our Type A and B RCCBs offer a significantly higher current withstand capability. They consequently have a greatly reduced tendency to trip falsely in practice.

The current withstand capabilities of the individual product series are as follows:

- instantaneous at least 1 kA
- Type F and super-resistant Type [K] at least 3 kA
- selective (Type [S]) at least 5 kA

Even in the standard versions, these values ensure good resistance to false tripping, and this form of protective measure with rated currents up to 30 mA can also be used for sensitive load circuits (e.g. refrigerators).



Characteristics of a current impulse acc. to DIN VDE 0432 Part 2

T_s Front time in s
T_r Virtual time to half-value on tail in s
0_1 Virtual origin
I_m Peak value

Fig. 16: Surge current characteristic 8/20 µs

5.3 Special features regarding the use of SIQUENCE universal current-sensitive RCCBs (Type B and Type B+)

5.3.1 Applications

Typical applications that are vulnerable to smooth DC residual currents:

- Frequency converters with a three-phase current connection
- Medical equipment such as X-ray equipment or CT machines
- Photovoltaic or UPS systems
- Connection points (wall boxes, charging stations) for electric vehicles
- Elevator controllers
- Pipeline trace heating
- Test setups in laboratories
- Construction sites in accordance with BGI 608 information leaflet (Electrical installations and equipment on construction sites)
- Charging stations for battery-powered forklift trucks
- Cranes of all kinds
- Mixing plants if relevant loads are connected
- Variable-speed machine tools, such as milling and grinding machines or lathes

5.3.2 Residual currents at various fault locations, with a frequency converter (FC) as an example

A frequency converter (FC) is considered below as a typical example of equipment where different residual current waveforms can occur depending on the fault location (see Fig. 17).

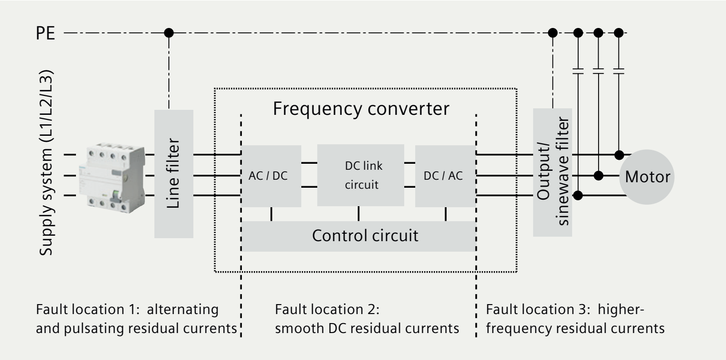


Fig. 17: Circuit with a SIQUENCE RCCB and a frequency converter

Fault locations in section 1 (upstream of the FC)
Line-frequency AC residual currents occur between the RCCB and the frequency converter (see figure 18). Protection against these purely sinusoidal 50 Hz residual currents is provided by all RCCBs (types AC, A, F and B). The section at risk is disconnected when the tripping value in the range 0.5 to 1 $I_{\Delta n}$ is reached.

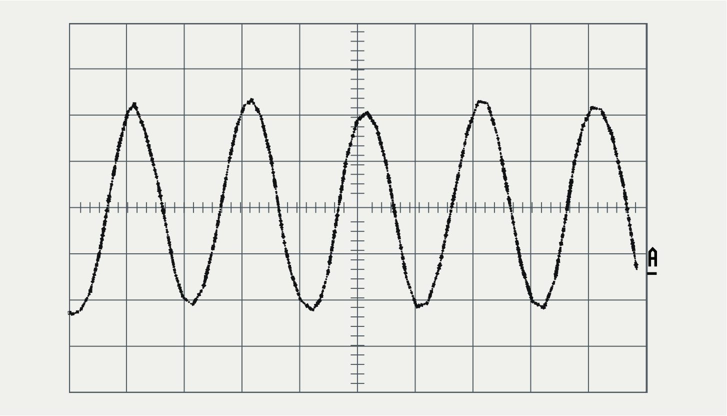


Fig. 18: Residual current waveform at fault location 1

Fault locations in section 2 (in the FC)

Practically smooth DC residual currents occur in the frequency converter (between the input rectifier and the output electronics, i.e. in the DC link circuit) (see Fig. 19). There is reliable disconnection in the range from 0.5 to 2 $I_{\Delta n}$ if a Type B universal current-sensitive RCCB is used.

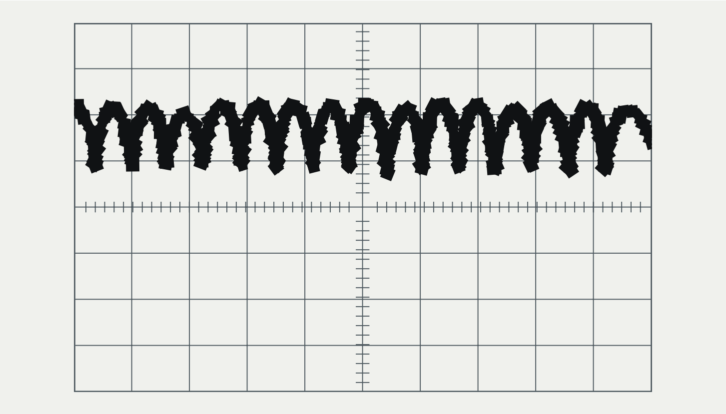
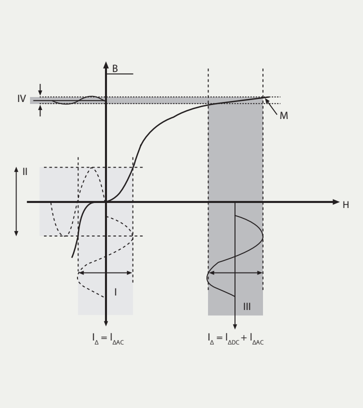


Fig. 19: Residual current waveform at fault location 2

Types AC, A and F RCCBs are unable to offer protection in these cases. The device does not trip because the DC residual current does not cause any change over time in the transformer induction of the RCCB which operates according to the induction principle. A smooth DC residual current (or leakage current) due to a creeping insulation fault leads to pre-magnetization of the transformer material of Type AC, A and F residual current protective devices. Figure 20 shows the difference between a transformer signal without and with DC residual current superimposition. Without DC residual current ($I_{\Delta DC}$)), an AC residual current ($I_{\Delta DC}$) causes modulation on the field strength axis H of magnitude I. In accordance with characteristic magnetization curve M of the transformer a voltage of magnitude II is induced. A DC residual current ($I_{\Delta DC}$) flowing via the residual current protective device shifts the working point of the transformer on the H axis. An AC residual current ($I_{\Delta DC}$) with the same value as in the case without DC residual current causes modulation of the same magnitude on the field strength axis H of magnitude III. Although the change III has the same value as I, a significantly smaller voltage of magnitude IV is induced in the transformer. If it is assumed that a signal of size II is necessary for tripping, it becomes clear that the considerably smaller signal IV is not sufficient for this.
Only much higher AC residual currents would lead to attainment of the necessary signal level. This shows that Type AC, A or F residual current protective devices are no longer able to trip if a purely sinusoidal residual current, which could otherwise be tripped without any problems, occurs simultaneously. The desired protective function of the residual current protective device is therefore no longer guaranteed.



I	Modulation with AC residual current $I_{\Delta AC}$
II	Tripping signal generated by $I_{\Delta AC}$
III	Superposition of DC residual current $I_{\Delta DC}$ with AC residual current $I_{\Delta AC}$
IV	Tripping signal on superimposition of DC residual current $I_{\Delta DC}$ with AC residual current $I_{\Delta AC}$
I_Δ	Total residual current
B	Inductance
H	Field strength
M	Magnetization characteristic of the transformer

Fig. 20: Pre-magnetization due to DC residual current

Fault locations in section 3 (downstream of the FC)
AC residual currents which deviate from the line frequency and the sinusoidal waveform occur between the outgoing terminal of the frequency converter and the motor. These currents represent a frequency spectrum with different frequency components (see Fig. 21). Smooth DC residual currents can also occur, depending on the operating mode of the frequency converter (e.g. as a DC brake or a DC pre-heater)

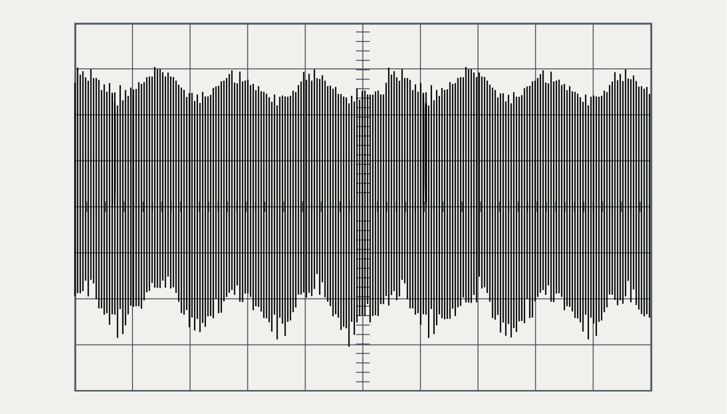


Fig. 21: Residual current waveform at fault location 3

According to the product standard, Type AC, A and F RCCBs are only designed to detect residual currents at 50 Hz or 50/60 Hz. The tripping value is therefore increased in an undefined way for higher frequency components of the residual current. The intended protective effect is usually lost as a result. Tripping conditions for frequencies up to 2 kHz are defined for Type B RCCBs.

Frequency components in the residual current of a frequency converter
The frequency components in the residual current must be taken into account in addition to the tripping characteristics of the RCCB in order to assess the protective effect of this RCCB in conjunction with a frequency converter. The following critical frequency components occur at fault location 3:

- Clock frequency of the frequency converter (a few kHz)
- Motor frequency (normally 0 to 50 Hz, maximum frequency 1 kHz)
- 3. harmonic of 50 Hz (150 Hz if the frequency converter has a three-phase connection)

Fig. 22 shows a typical example of the frequency components that can flow across a fault impedance of 1 kΩ in the area of fault location 3 (see Fig. 21).
The clock frequency accounts for a smaller percentage of the total residual current as the motor frequency increases, while the motor frequency accounts for a correspondingly higher percentage.
This behavior is characteristic of many different frequency converter versions.

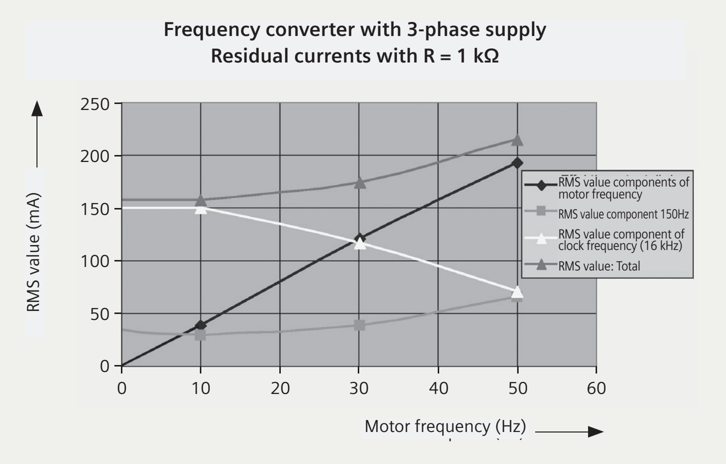


Fig. 22: Frequency components in the residual current based on the example of a frequency converter

5.3.3 Configuration

Type B / Type B+ universal current-sensitive RCCBs must be used if smooth or nearly smooth DC residual currents can occur in the event of a fault when electronic equipment is operated (input circuits 8 to 13 in Table 2).

In these cases, Type AC, A or F RCCBs may not be used to provide protection, as their tripping function can be impaired by the potential smooth DC residual currents to the extent that they are no longer able to trip even when those residual currents for which they are designed occur.

For this reason, it is essential to ensure that if Type A or F RCCBs are coordinated with Type B (or B+) in installations with several load circuits, a Type B or B+ RCCB is always connected upstream of each Type A or Type F RCCB. Fig. 23 shows an example configuration.

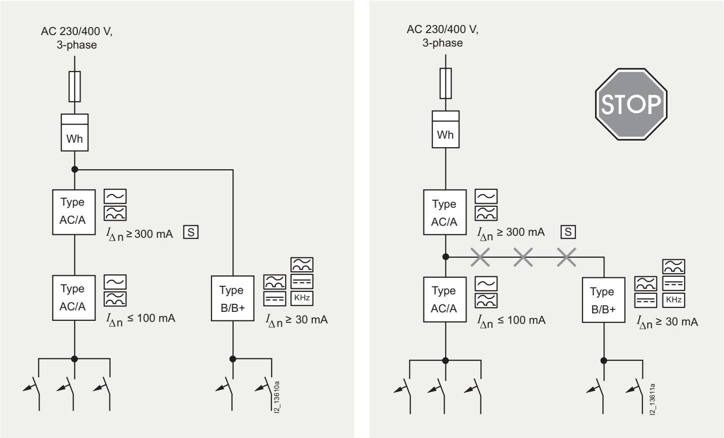


Fig. 23: Configuration example with Type A and B RCCB

5.3.4 Causes of excessive leakage currents and possibilities of reducing them

Causes of leakage currents	Consequences
EMC (input) filter capacitances between phase conductor and PE conductor	Highly dynamic and static leakage currents
Conductor capacities	Mainly static leakage currents
Making/breaking asymmetries	Highly dynamic leakage currents possible
Summation of leakage currents due to connection of several loads (especially frequency converters) to an RCCB	Highly dynamic and static leakage currents
Clock frequency of frequency converters	Static leakage currents via cable capacitance
Grounding conditions	Static leakage currents
Harmonic component of the output voltage of the frequency converter	Static leakage currents via cable capacitance

Table 6: Causes of leakage currents

Corrective measures

- Use low leakage current filters.
- Clarify with converter manufacturer whether filters with lower degree of interference suppression (class B or C3/C4 instead of class A or C1) are possible or EMC input filters can be dispensed with if, for instance, output-side sinewave filters or dv/dt filters or motor chokes can be used.
- Minimize cable lengths (the overall capacity and thus the leakage current flowing to PE increase with the length of the cable corresponding to the capacitance per meter – leakage current of shielded cables from approximately 0.2 mA/m to 1 mA/m).
- Select cables with low conductor-ground capacitance. Symmetrical cables achieve favorable values. Single conductor configuration yields higher leakage currents.
- The use of shielded cables can be dispensed with if the EMC requirements are also met with unshielded cables, for instance (i.e. with sinewave filters at the output).

- Connect existing cable shield according to the manufacturer's information regarding the frequency converter.
- Avoid the use of manually operated switching devices for normal switching in order to reduce the duration of making and breaking asymmetries to a minimum.
- Use all-pole contactors or switching devices with a snap-action mechanism.
- Own power supply connection for the actuator (asymmetry in the network causes additional leakage currents).
- Inrush current limitation can reduce the dynamic leakage currents upon making.
- Distribute the circuits over a number of RCCBs (keep the number of actuators after an RCCB as low as possible).
- Avoid switching on several frequency converters downstream of one RCCB simultaneously (or at least use inrush current limitation).
- Use a common EMC filter for several loads (leakage current is usually lower than the sum of individual filters).

Select as low a clock frequency as possible, in particular for Type B+ RCCBs (if usable for the application). Depending on the circumstances, an overall more favorable behavior can be achieved with higher clock frequencies with Type B RCCBs which exhibit a tripping value which increases with the frequency, in spite of higher capacitive leakage currents. In any case, care must be taken to avoid resonance frequency ranges when setting EMC filters.
If possible, return all leakage currents to the frequency converter via the PE connection in order to maximize the effect of the filtering measures and prevent the occurrence of undefined leakage currents.
Sinewave filters in the outgoing feeder of the frequency converter reliably filter out the switching frequency and its harmonics to produce almost sinusoidal output voltages and currents. EMC requirements can then usually also be satisfied with unshielded cables. This leads to a significant reduction in capacitive leakage currents downstream of the frequency converter (e.g. due to the cable capacitance per unit length). In some cases, it is even possible to dispense with the line filter on the input side and thus reduce the stationary and dynamic leakage currents still further. Output reactors, dv/dt filters, or Nanoperm filters can be used as an alternative to sinewave filters, although they are less effective.

5.4 Back-up protection

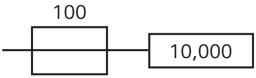
Short circuit and residual currents can be up to several hundred amperes, depending on the network and system configuration. Thus, for instance, in the event of an insulation fault to the grounded exposed conductive parts of electrical equipment with a correspondingly low resistance, a short circuit-like current flows via the residual current protective device. The contacts that open in this event must be able to withstand this stress.

This requires a correspondingly high rated switching capacity. The rated switching capacity I_m of residual current operated circuit breakers shall, according to the applicable device standards (EN 61008-1/VDE 0664-10) be at least 500 A or 10 * I_n, whichever is the higher. The rated switching capacity of our RCCBs is predominately 800 A and hence clearly exceeds the minimum requirements of 500 A or 630 A for devices of up to 63 A rated current.

In accordance to the installation regulations (VDE 0100-410; DIN VDE 0100-530), residual current protective devices can be installed in all system types (TT, NT and IT). Residual currents that are in excess of the rated switching capacity of the RCCB can occur alongside short-circuit currents in a TN system in particular. An overcurrent device shall be connected as a back-up protective device to restrict the energy and strength of the short-circuit current to compatible levels.

The conditional rated short-circuit current is stated on the RCCB in the form of a symbol in conjunction with a maximum permissible rated current for the fuse (gG operational class melting fuses).

This will be explained based on the following example:



The conditional rated short-circuit current of the RCCB where a fuse rated at a maximum of 100 A is used is 10 kA.
In cases in which no rated fuse current is stated, a minimum value of 63 A applies automatically in Germany. A minimum value of 6 kA is required for the conditional rated short-circuit current.

In the case of Siemens residual current protective devices, rated switching capacity and rated residual switching capacity are not differentiated and nor are rated conditional short-circuit current and rated conditional residual short-circuit current. The reason for this is that the values for the residual and short-circuit currents can be identical in the relevant cases.

The use of miniature circuit breakers or circuit breakers instead of the specified fuses will result in markedly lower rated values in some cases due to the higher throughput values until the circuit is disconnected. A direct specification for the permissible rated current of these circuit breakers cannot be given here due to the great differences in design and tripping characteristics. But the maximum permissible rated current of the allocated overcurrent protective device can be determined in consideration of the maximum permissible limit values of the RCCB. The rated current of the allocated overcurrent protective device can be determined based on the maximum permissible short-circuit back-up fusing specified for the RCCB. In the process, the following maximum values must be complied with.

Series	Maximum permissible short-circuit back-up fuse	Maximum I^2t value	Maximum current peak value I_p
5SM3	63 A	25,000 A^2s	6.0 kA
5SM3	80 A	40,000 A^2s	7.0 kA
5SM3	100 A	70,000 A^2s	7.5 kA
5SM3	125 A	94,000 A^2s	8.0 kA

Series	Maximum permissible short-circuit back-up fuse	Maximum I^2t value	Maximum current peak value I_p
5SV	63 A	15,000 A^2s	5.4 kA
5SV	80 A	30,000 A^2s	6.2 kA
5SV	100 A	55,000 A^2s	7 kA

Table 7: Maximum values

The rated switching capacity of RCBOs is considerably higher than that for RCCBs as the MCB component, which is specially provided for short-circuit protection, performs short-circuit clearing. Should this switching capacity not be adequate, a back-up protection must also be provided here in accordance with the manufacturer's information.

5.5 Protection against thermal overload

Protection against thermal overloading of an RCCB shall primarily be provided by careful planning of the load circuits downstream of the RCCB taking the manufacturer's information into consideration.

A note in DIN VDE 0100-530 states that it is permissible to use the expected operational current as a rating selection criterion to prevent overloading of RCCBs as long as the instructions of the manufacturer regarding the rated current and type of overcurrent protective device are used to form the basis for the estimation.

The following points must be noted in order to avoid overloading the RCCB:

- The rated current of the RCCB is the maximum permissible uninterrupted load current and must not be permanently exceeded.
- The back-up fuse value indicated on the rating plate (63 A to 125 A) only provides back-up protection for the RCCB (see section 5.4).

The considerations regarding thermal loading no longer apply if RCBOs are used as the MCB part provides overload protection through its thermal release.

5.6 Troubleshooting

If a residual current protective device trips, the first troubleshooting step should be to follow the procedure outlined in the diagram below (Fig. 24).

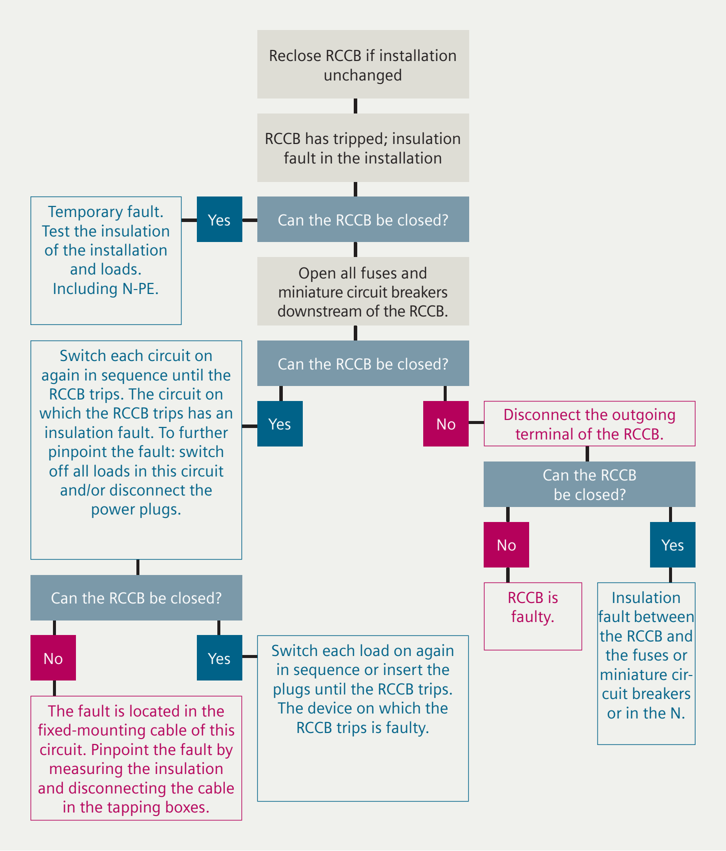


Fig. 24: Troubleshooting flowchart

5.7 4-pole RCCBs in a 3-pole network

The 4-pole (3+N) version of the RCCB can also be operated in 3-pole systems. In this case, the 3-pole connection must be at terminals 1, 3, 5 and 2, 4, 6.

The device function is not impaired as a result. Functioning of the test circuit is only ensured if a jumper is fitted between terminals 3 and N (this is also described in the operating instructions).

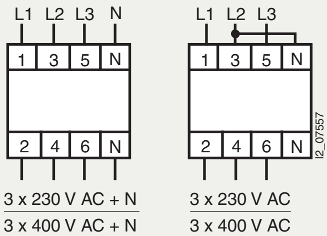


Fig. 25: 4-pole RCCB in a 3-pole network

6. MRCDs and RCMs

Standards differentiate between modular residual current devices (MRCD, IEC 60947-2, Appendix M) and residual current-monitoring devices (RCMs, IEC 62020) and hence determine their usage.

MRCDs function in the same way as RCMs do. For both MRCDs and RCMs, the residual current is measured via external summation current transformers. The external summation current transformers are available with various inside diameters. This even makes it possible to monitor installations with rated currents of several hundred amperes.
To prevent false tripping in plants with high starting currents (e.g. welding systems), shielded summation current transformers are available.

6.1 Modular residual current devices (MRCDs)

The MRCD (modular residual current device) belongs to the family of RCDs. All devices are able to detect a residual current and disconnect the monitored circuit from the voltage source in the event of a fault.
Tripping therefore takes place as stipulated by DIN VDE 0100-410 or IEC 60364-4-41. These devices are required and recommended in many areas (VDE 0100-530). They are particularly suitable if no RCCB or CBR can be used due to high load currents or mains voltages.

Fig. 26: MRCD Type B and summation current transformer

Siemens specifies tested combinations of MRCDs, circuit breakers and shunt trips or undervoltage releases for which disconnection is guaranteed within 40 ms at 5 times the rated residual current, so that these combinations of devices meet the requirements for “protection through automatic disconnection of the power supply”.

In addition, an alarm value (in % of the set residual current) and a time delay for tripping (except for personal safety) can be set. The possibility of setting an alarm is useful because when the alarm threshold is reached, the MRCD does not yet switch off. A system fault is detected early and the operator has the option of shutting down the electrical system or terminating production processes and only then switching off the system so that the fault can be localized and rectified.
An MRCD – combined with an alarm – provides safe and reliable personal safety and system protection.

6.2 Residual current monitoring devices (RCMs)

The situation is different with a residual current monitor (RCM). An RCM is only able to monitor and report residual currents if they exceed a specified value. In the event of a fault, no shutdown takes place, only a message. These devices do not belong to the RCD product group.

In addition to personal protection by means of residual current protection devices (RCD), permanent residual current monitoring is becoming more and more important in terms of increasing system and operational safety and power supply monitoring.

Residual current monitoring devices (RCM) monitor residual currents in electrical systems and report when they exceed a determined value. RCMs are not approved for implementing the “automatic power supply shutoff” protective measure according to the product standard for residual current monitoring devices EN 62020 (VDE 0663) and/or IEC 62020. However, an RCM can be used in conjunction with protective devices.

Continuous residual current monitoring can already detect and signal faults before the protective device responds. Sudden system disconnection can frequently be avoided this way. For that reason, residual current monitoring devices are primarily used in systems in which a signal, but not a disconnection, should be carried out in the event of a fault. In addition, the residual current monitoring counts as a preventative maintenance measure in electrical systems.

The residual current monitoring devices function the same way as residual current protective devices do. The summation current transformer covers all conductors needed to carry current, i.e. the neutral conductor as well, if necessary. In a fault-free system, the magnetizing effects of the current-carrying conductors are canceled out for the transformer, and the sum of all currents is equivalent to zero (Kirchhoff's 1st law of circuits). A residual magnetic field will only remain in the transformer core if a residual current is flowing as a result of an insulation fault and is generating voltage. The voltage will be evaluated by the RCM electronics and the switched contact can be used to control such elements as an acoustic/optical signaling device, a higher-level control system or a circuit breaker.
RCMs are not equipped with a direct shut-off function.

RCMs are widely available with both integral current transformers and external summation current transformers. External summation current transformers are available with different inside diameters. This even makes it possible to monitor installations with rated currents of several hundred amperes. Furthermore, residual current monitoring devices are also associated with adjustable values for response residual current, response time and, if applicable, the display of the present residual current value.

The ability to adjust the response residual current and time behavior constitutes a significant advantage of the RCMs. This enables system-specific adjustment and makes it possible to take leakage currents which are permanently present into account. These leakage currents are caused by capacitances in the cables and lines or in electrical equipment, for instance.

RCMs as additional fire protection

In accordance with DIN VDE 0100-530, RCMs coupled with switching devices with an isolating function can be used as an alternative to fire protection if residual current protective devices (RCDs) cannot be used for fire protection, because the operating current of the circuit to be protected is greater than the greatest rated current of the residual current protective devices (RCDs). A prerequisite for this is that the response residual current does not exceed 300 mA and that the monitored network is disconnected in the event of a failure in the residual current monitoring device's (RCM) control supply voltage.

7. Outlook

There is a growing demand for residual current protective devices in electrical installations owing to the high level of protection they afford.

At the same time, the widespread use of RCCB to protect a large variety of different loads means that even more complex functional requirements need to be met. The use of Type B universal current-sensitive RCCBs for harsh ambient conditions exemplifies how requirements have increased. This trend is predicted to continue in future.

Combinations of RCBOs are also increasing in popularity – either as a compact unit or as an RC unit in conjunction with miniature circuit breakers that can be installed where required.

These RCBO combination units are installed in all circuits of modern electrical installations, combining maximum operating safety with electric shock and line protection.

8. Sources

The following sources and publications were among those used in drawing up this technology primer and can be consulted for additional information:

- DIN 18015-1:2013-09
- DIN 18015-2:2000-08
- EN 50178 (DIN VDE 0160)
- EN 60947-2 (VDE 0660-101)
- EN 61008-1 (VDE 0664-10)
- EN 61009-1 (VDE 0664-20)
- EN 62020 (VDE 0663)
- EN 62423
- DIN VDE 0100-300
- DIN VDE 0100-410
- DIN VDE 0100-482
- DIN VDE 0100-530
- DIN VDE 0100-530
- DIN VDE 0662
- DIN VDE 0664-100
- DIN VDE 0664-400
- DIN VDE 0664-410
- IEC 60479-2
- IEC 62020
- RAL RG 678:2004-09
- VdS Guideline 3501

9. Appendix

9.1 Key terms and definitions (according to DIN VDE 0100-200)

Phase conductors (symbol L1, L2, L3)
Conductors that connect current sources to current-using equipment but that do not originate at the center point or neutral point.

Neutral conductor (symbol N)
Conductor that is connected to the center point or neutral point and that is suitable for transmitting electricity.

Protective conductor (symbol PE)
Conductor required for certain protective measures against hazardous electric shock currents in order to establish an electrical connection with one of the following parts:

- Exposed conductive part of the electrical equipment
- External conductive parts
- Main ground terminal
- Ground electrode
- Ground point of the current source or artificial neutral point

PEN conductor
Grounded conductor that simultaneously functions as the protective conductor and the neutral conductor.

Rated voltage (in an installation)
Voltage that characterizes an installation or part of an installation.

Touch voltage
The voltage that can occur between two simultaneously exposed components in the event of an insulation fault.

Live part
Conductor or conductive part that is intended to be live during normal operation, including the neutral conductor but (according to agreement) not the PEN conductor.

Exposed conductive part (of electrical equipment)
Touchable, conductive component of an electrical device that is not normally live, but which may be live in the event of a fault.

Electric shock
Pathophysiological effect caused by an electric current flowing through the body of a person or animal.

Additional protection
Supplementary measure to reduce the risks that may arise to persons and livestock if the basic and/or fault protection is rendered ineffective.

Basic protection
Protection against electric shock in a non-faulty system. Basic protection usually corresponds to the protection against direct contact described in DIN VDE 0100-410.

Fault protection
Protection against electric shock if a single fault occurs (e.g. faulty basic insulation).
Fault protection usually corresponds to the protection against indirect contact described in DIN VDE 0100-410.

Dangerous body current
Current flowing through the body of a person or animal with characteristics that are likely to trigger a pathophysiological (harmful) effect.

Leakage current (in an installation)
Current flowing in a non-faulty circuit to ground or to an external conductive part.

Residual current
Sum of the instantaneous values of all currents flowing through all active conductors in a circuit at a defined point in the electrical system.
In connection with residual current protective devices, the differential current is referred to as “residual current” in accordance with the standards in the DIN VDE 0664 (VDE 0664) series.

Operational current
Current that should flow in the circuit during normal operation.

Ground
Conductive mass of ground whose electric potential is set to zero at all points according to agreement.

Ground electrode
Conductive part or parts that make good contact with ground and form an electrical connection with it.

Total grounding resistance
Resistance between the main ground terminal/busbar and ground.

9.2 Power systems and protective devices

The various power systems are defined in DIN VDE 0100-300. The permissible protective devices for these systems are listed in DIN VDE 0100-410.
The power systems are identified by means of codes where the individual characters have the following meanings:

1. character	Relationship of power system to ground
T	Direct grounding of a point
I	Either insulation of all live parts from ground or connection of one point with ground via impedance

2. character	Relationship of the exposed conductive part of the installation to ground
T	Exposed conductive part directly connected to ground, independently of the grounding of any point of the power system
N	Exposed conductive part directly connected with the ground electrode (the grounded point in AC networks is generally the neutral point)

Subsequent characters	Arrangement of the neutral and protective conductors in a TN system
S	Separate conductors for neutral and protective earth functions
C	Neutral and protective conductor functions combined in a single conductor (PEN conductor)

9.2.1 TN system

All exposed conductive parts in the system must be connected by protective conductors to the grounded point of the supply network, which must be grounded on or in the vicinity of the associated transformer or generator. The various versions of TN system are shown in Fig. 27, Fig. 28 and Fig. 29.

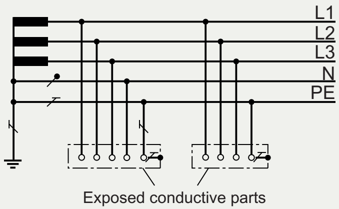


Fig. 27: TN-S system

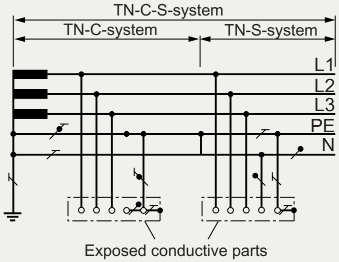


Fig. 28: TN-C-S system

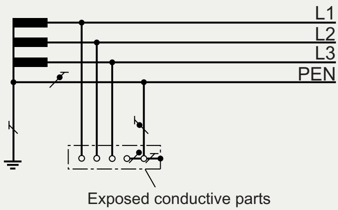


Fig. 29: TN-C system

Permissible protective measures in TN systems:

- Overcurrent protective devices
- Residual current protective devices (but not in the TN-C system)

9.2.2 TT system

All exposed conductive parts protected by the same protective device must be connected to a common ground electrode by means of protective conductors (see Fig. 30).

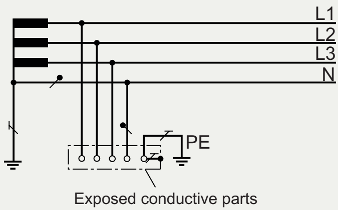


Fig. 30: TT system

Permissible protective measures:

- Residual current protective devices
- Overcurrent protective devices

Where residual current protective devices are used, different maximum permissible grounding resistances are specified as a function of the rated residual current to meet the disconnection conditions (see Table 8).

Rated residual current $I_{\Delta n}$	Maximum permissible grounding resistance at a maximum permissible touch voltage of	
	50 V	25 V
10 mA	5,000 Ω	2,500 Ω
30 mA	1,660 Ω	830 Ω
100 mA	500 Ω	250 Ω
300 mA	170 Ω	85 Ω
500 mA	100 Ω	50 Ω
1 A	50 Ω	25 Ω

Table 8: Maximum permissible grounding resistances as a function of $I_{\Delta n}$

The specifications of section 4.4.3 shall be observed for SIQUENCE Type B and Type B+ universal current-sensitive RCCBs if the equipment used has different frequency components in the possible residual current.

9.2.3 IT system

Live parts in IT systems (see Fig. 31) must either be insulated to ground or designed with a sufficiently high impedance. The exposed conductive parts must be grounded individually, or in groups, or with a common ground.

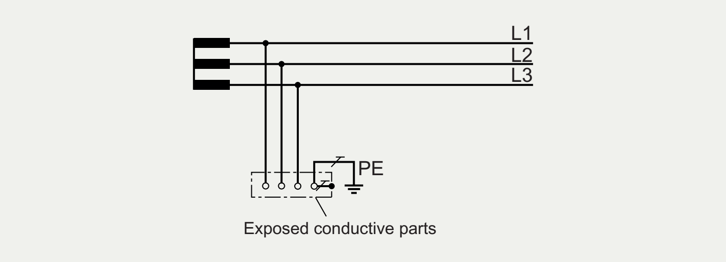


Fig. 31: IT system

Permissible protective measures:

- Insulation monitoring devices
- Overcurrent protective devices
- Residual current protective devices

Tripping is not required for the first fault. However, measures must be taken to preclude all risk of pathophysiological effects on persons when the second fault occurs. It is essential that an insulation monitoring device is fitted to enable the first fault to be indicated by an acoustic or visual signal and eliminated as quickly as possible.
Certain conditions must be satisfied after the first fault, depending on how the loads are grounded (individually, in groups, or with a common ground). If these conditions cannot be met with overcurrent protective devices, either separate RCCBs must be provided for each item of current-using equipment or additional equipotential bonding must be provided. No mutual interference results if insulation monitoring devices and RCCBs are used in the same system.

9.2.4 Summary

Residual current protective devices can be used in all AC or three-phase network systems (TN, TT, or IT system, see Fig. 32). The protection afforded by residual current protective devices is superior to that offered by other approved protective devices, because in addition to fault protection (protection in case of indirect contact) when residual current protective devices with $I_{\Delta n} \leq 30$ mA are used, they also provide additional protection (protection in the event of direct contact), and with their $I_{\Delta n} \leq 300$ mA play an important role in preventive protection against electrically ignited fires caused by ground fault currents.

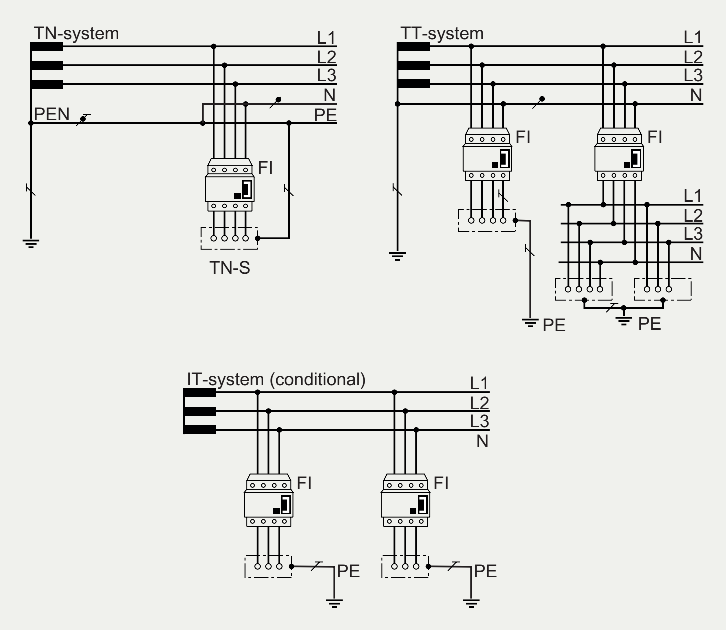


Fig. 32: Residual current protective devices in all network systems

9.3 Key terms and definitions for specifying the switching capacity

Rated switching capacity I_m of the RCCB (EN 61008-1)
Prospective rms value of the **short circuit current** which an RCCB can make, carry and break under defined conditions.

Rated switching capacity I_{cn} of an RCBO (EN 61009-1)
The rated switching capacity of an RCBO is the limit short-circuit breaking capacity specified by the manufacturer.

Rated residual switching capacity $I_{\Delta m}$ (EN 61008-1, EN 61009-1)
Prospective rms value of the **residual current** which the residual current protective device can make, carry and break under defined conditions.

Rated conditional short-circuit current I_{nc} (EN 61008-1)
Prospective current which the RCCB, protected by a **short-circuit back-up fuse**, can withstand without suffering functional impairment.

Rated conditional residual short-circuit current $I_{\Delta c}$ (EN 61008-1)
Prospective **residual current** which the RCCB, protected by a **short-circuit back-up fuse**, can withstand without suffering functional impairment.

9.4 Installation regulations for electrical installations with residual current protective devices

Standard (DIN VDE ... or BGI ...)	Application	Required $I_{\Delta n}$ [mA]	Recommended Siemens RCCB (taking into consideration the possible nature of the residual currents in the equipment)			
			Type A	Type F	SIQUENCE Type B/B+	SIGRES
0100-410	Protection against electric shock	30 ... 500	+	+	+	+
	Socket outlets up to 20 A, outdoor installations	10 ... 30	+	+		
0100-482	Fire protection for particular risks or safety hazards	30 and 300	+	+	+	
0100-701	Rooms with baths or showers, socket outlets in zone 3	10 ... 30	+	+		
0100-702	Pools in swimming baths and other pools	10 ... 30	+			+
0100-703	Rooms and cabins with sauna heating systems	10 ... 30	+			+
0100-704 and BGI 608	Construction sites, socket outlet circuits up to 32 A and for hand-held tools, plugs and sockets I_n > 32 A	≤ 30 mA ≤ 500 mA	+ +	+ +	+ +	+ +
0100-705	Agricultural and horticultural, general, socket outlet circuits	≤ 300 10 ... 30	+ +	+ +		+ +
0100-706	Conductive areas with limited freedom of movement, fixed equipment	10 ... 30	+			
0100-708	Electrical installations on camping sites, fixed feeding points for every socket outlet and every final circuit	10 ... 30	+			+
0100-710	Medical premises with a TN-S system, depending on application group 1 or 2 and equipment	10 ... 30 or ≤ 300	+ +		+ +	
0100-712	Solar PV power supply systems (without simple isolation)	≤ 300			+	

Standard (DIN VDE … or BGI …)	Application	Required $I_{\Delta n}$ [mA]	Recommended Siemens RCCB (taking into consideration the possible nature of the residual currents in the equipment)			
			Type A	Type F	SIQUENCE Type B/B+	SIGRES
0100-723	Classrooms with experiment equipment	10 … 30			+	
0100-739	Additional protection against direct contact in homes	10 … 30	+			
DIN EN 50178 (VDE 0160)	Electronic equipment for use in power installations	General requirements for correct selection when using res. current protection	+	+	+	
0832-100	Traffic signals Class T1 Class U1	 ≤ 300 ≤ 30	 + +			 + +
	Foodstuffs and chemical industry	recommended ≤ 30 mA	+			+

Table 9: Installation regulations for electrical installations with residual current protective devices

Note

For reasons of basic fire protection, we recommend a maximum rated residual current of 300 mA for residual current protection devices.

10. List of figures and tables

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