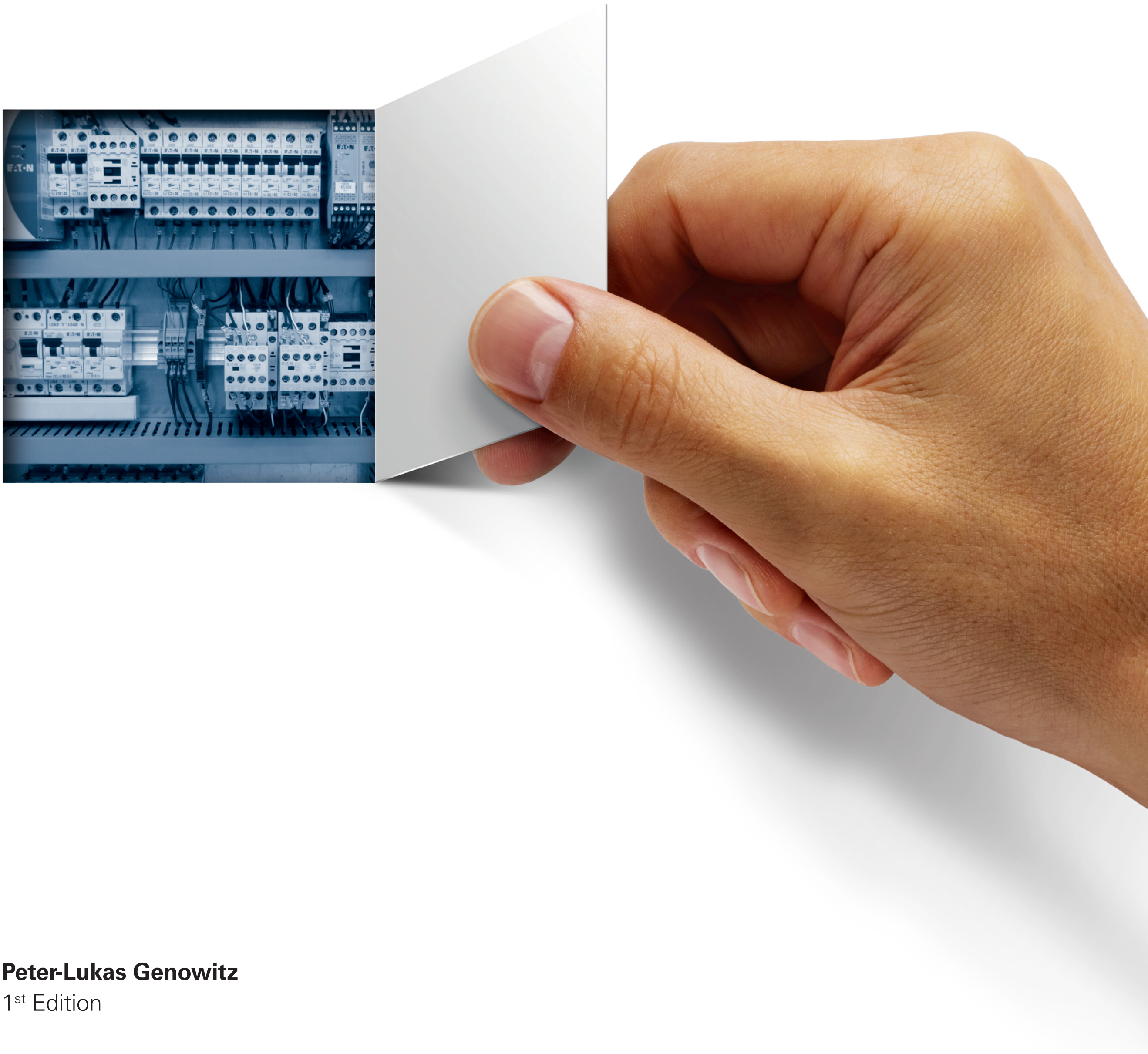
Residual Current Devices
White Paper

Protecting man and machine against damaging residual currents

Build it in.



Peter-Lukas Genowitz
1st Edition

EATON
Powering Business Worldwide

Protecting man and machine against damaging residual currents

As technical boundaries are continually pushed in a changing marketplace, machine builders are looking for solutions that help them and their manufacturing customers to produce faster and more efficiently and at a lower cost. Manufacturing end users are experiencing shorter product lifecycles; this is placing demands on machine builders to design and develop highly customized machines that give customers what they need in terms of performance, energy efficiency and reliability.

Machine builders today face increased pressure not just to meet these objectives but also to develop equipment that is extremely reliable while ensuring high safety levels for the operator. It is also essential that such builders realise the importance of thoroughly understanding the electric faults that can impact the machines and manufacturing process. Residual and leakage currents can be caused by fault conditions that occur within an electrical circuit. They can have devastating effects on the human body, causing cardiac arrest or worse, and lead to machine failure, which affects the bottom-line. They can also lead to fires.

Balancing circuit protection requirements is a complex area to navigate, especially as in-house circuit protection expertise is becoming increasingly rare due to engineering team size reductions. End users as well as machine builders are looking for more support from their suppliers to help them and there is a trend for working with suppliers that have complete systems expertise and a global consulting presence.

Furthermore, as machine builders export and supply equipment worldwide, they need to be assured that their machines and components meet the various international standards and regulations. Working with a partner that understands the global requirements and delivers a product that adheres to the relevant standards means the machines will be fit-for-purpose.

In this paper Peter-Lukas Genowitz, Product Manager RCCB at Eaton, reviews the devastating effects of electrical current on the human body, the functioning of Residual Current Devices (RCDs), their installation and role within an overall protection strategy. It is the first of three white papers that explores the topic of residual current

Introduction

Residual or earth leakage currents can arise for many reasons and take many forms. Within the context of machine design, the biggest challenge is to define the possible forms of residual currents which can occur during the operation and during a fault condition. Guaranteeing a safe power disconnection in the event of a fault is absolutely essential to protect operators and assets from danger of electric shock or fire; at the same time, however, nuisance tripping related to system- caused earth leakage currents has to be prevented to guarantee machine uptime. The solution is to recognise the different forms of earth leakage current that can occur, and design in residual current protection devices (RCDs) suitable for managing them.

Effects of electric current on the human body

Electric current can be exceptionally harmful to a human body and damage inflicted is related mainly to its intensity and duration. Fig. 1 shows the intensity and exposure time curves in relation to the physiological reactions of the human body.

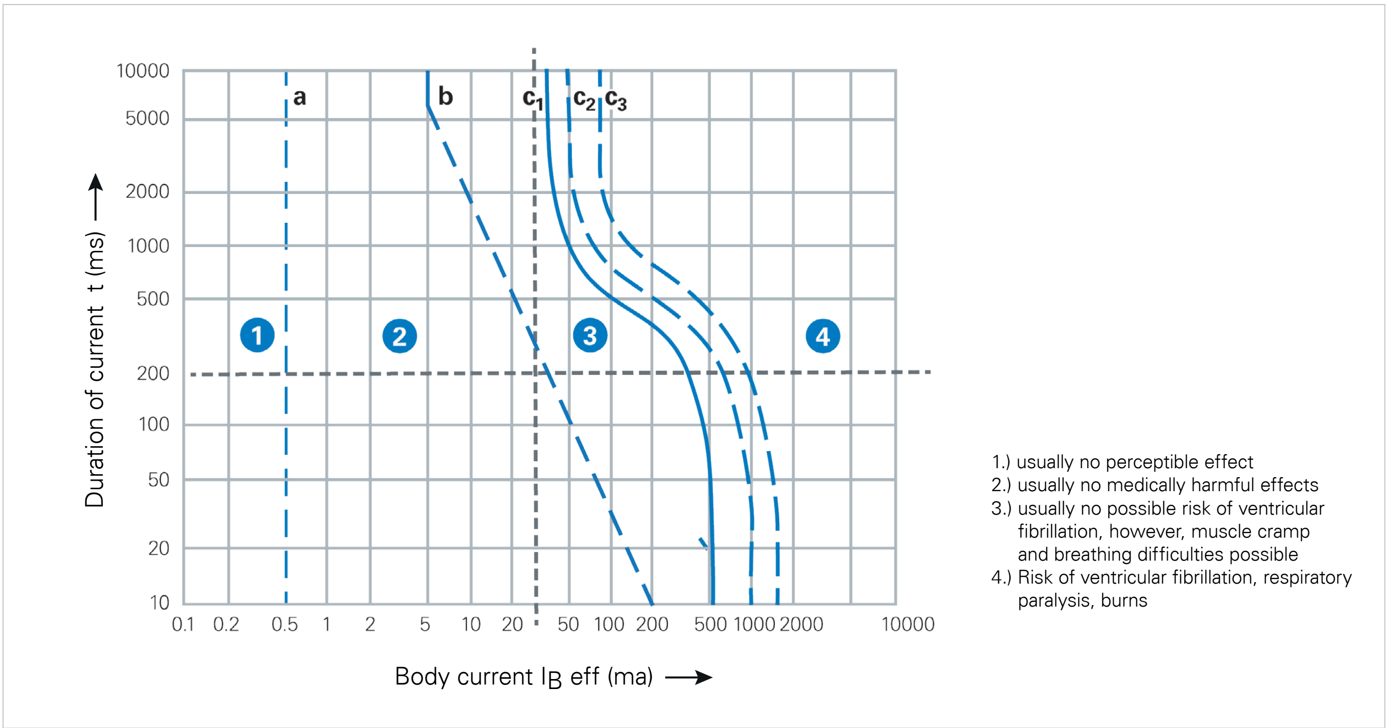


Fig.1: Ventricular fibrillation depending on amperage and duration of flow

Although ventricular fibrillation is considered as the main cause of death when electrocuted, there are also other cases of respiratory and cardiac arrest. Pathophysiological effects such as muscle contractions, respiratory difficulties, elevated blood pressure, disruption of generation and transmission of impulses in the heart, including atrial fibrillation and temporary cardiac arrest, can also occur without ventricular fibrillation. These effects are not lethal and generally reversible, although electrical marks may occur. Serious burns, other internal damage and even death may result from currents of over a few ampere and of several seconds' duration.

Functioning of RCDs

The task of an RCD is to protect people against electric shock while also protecting equipment against damage caused by residual currents (e.g. fires). They are protection devices that detect residual currents in electrical systems which may be caused by either fault conditions or generated by system components such as frequency converters.

An RCD basically consists of a summation current transformer, a tripping circuit, a switching mechanism and a test circuit.

The summation current transformer compares the currents which flow via the phase conductors downstream and via the neutral conductor back upstream. If there is a difference in the sum of the downstream and upstream flowing currents a magnetic field arises which induces a voltage in the secondary winding. The current flowing in the primary winding weakens the magnetic field of the magnetic tripping unit. This leads to operation of the switching latch and disconnection of the circuit when the switching contacts open.

Protective measures with RCDs

It is clear that machines need protective measures to shield operators and technicians from the dangers of electric current, both during normal use and in the event of a fault condition. An accident can result from either direct or indirect contact. Direct contact refers to when a person touches a live electrical part, which is defined as a conductor or conductive part that is intended to be live during normal operation. Indirect contact concerns a situation when a conductive but normally non-live exposed and touchable part becomes live due to an electrical fault. These are referred to as exposed conductive parts.

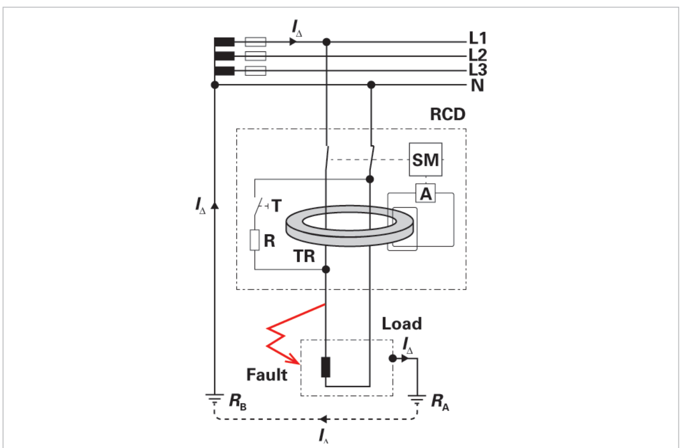


Fig.2: RCD principle of operation

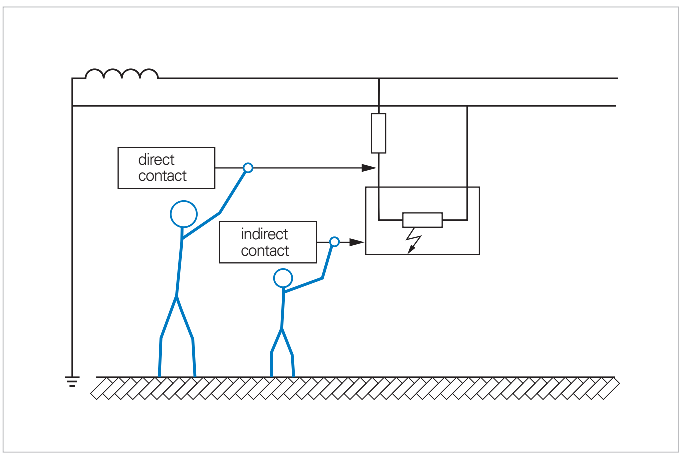


Fig.3: Direct and indirect contact risks

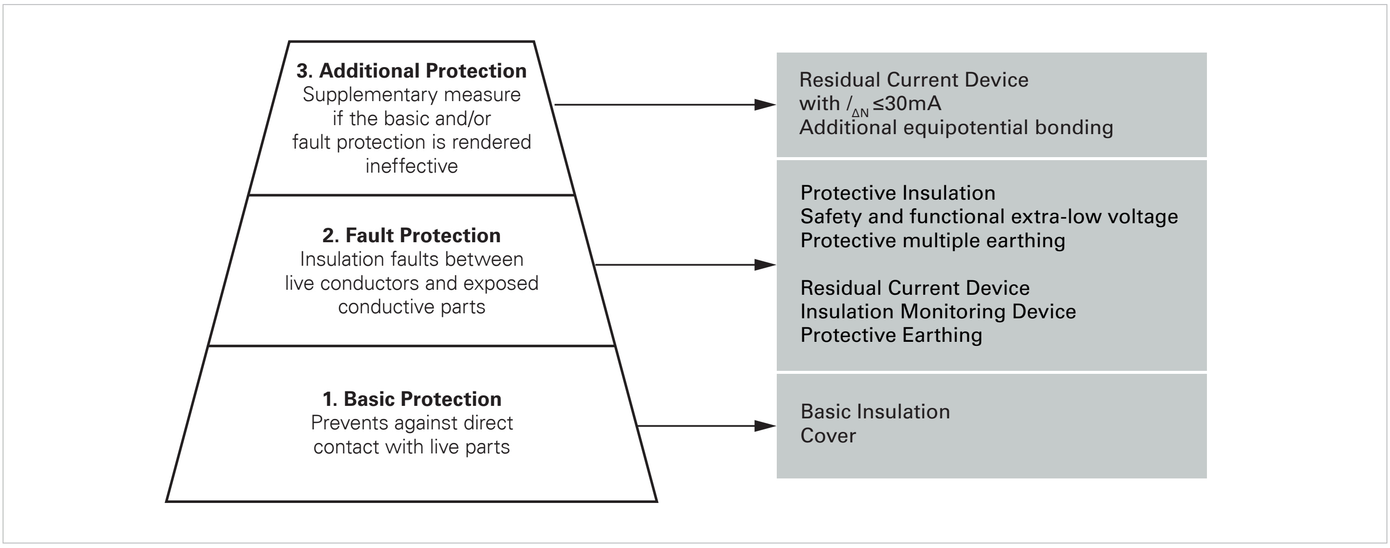


Fig.4: Three-stage protection strategy (Source: Elektroschutzkonzept der ÖVE)

Eaton recommends to use a three stage protection strategy to shield people from electric shock, as shown in Fig.4. It combines maximum safety for humans with maximum protection of systems and equipment. This protection strategy shows the possible protective measures as RCDs for the different protection levels. In addition RCDs are also used for protection from fire risk.

Basic protection Basic protection is focused on preventing direct contact with live parts through insulation and covers. A typical example is the insulation of a wire or a cover for bus bars; these should be shielded so that no-one can accidently touch them after opening the doors of the cabinet housing.

Fault protection If someone does happen to touch an exposed conductive part which has become live due to an insulation fault, the RCD's role is to automatically disconnect the power supply if the fault can pose a risk because of the intensity and duration of the touch voltage.

Additional protection The strategy also includes additional protection that operates if the basic and/or fault precautions fail and the operator comes into direct contact with a live part, for example, if the user is careless when using the protected machinery or equipment. RCDs with a rated residual current of up to 30 mA have proven to be effective in this role.

Fire protection RCDs are also essential for 'locations exposed to fire hazards' as described in IEC 60364-4-482. These standards require measures for preventing fires that can be caused by insulation faults. They state that cables and lines in TT and TN earthing systems must be protected by RCDs with a rated residual current of 300 mA or less.

RCD types

RCDs are characterised by the residual current waveforms they can detect and respond to, whether they are voltage dependent or independent, and whether their trip response is instant or delayed.

RCDs' ability to respond to various waveforms is important, as residual currents with different waveforms and frequencies can be generated by several electronic consumers which are used in our electronic circuits. These waveforms are summarised in Table 1, which shows the RCD Types and their suitability for each waveform type. It is also very important to note the different tripping level for each waveform.

Kind of current	Current profile	Correct use/application filed of RCCB types				Tripping current
		AC	A (U)	F	B/Bfq/B+	
Sinusoidal AC residual current		•	•	•	•	0,5 to 1,0 $I_{\Delta n}$
Pulsating DC residual current (pos. or neg. half-wave)		–	•	•	•	0,35 to 1,4 $I_{\Delta n}$
Cut halve-wave current Lead angel 90° Lead angel 135°		–	•	•	•	Lead angel 90° 0, 25 to 1 4 $I_{\Delta n}$ Lead angel 135° 0, 11 to 1 4 $I_{\Delta n}$
Halve-wave current with smooth DC current of 6mA		–	•	•	•	max. 1,4 $I_{\Delta n}$ + 6 mA
Halve-wave current with smooth DC current of 10mA		–	–	•	•	max. 1,4 $I_{\Delta n}$ + 10 mA
Smooth DC current		–	–	–	•	0, 5 to 2, 0 $I_{\Delta n}$

Table 1: Different Residual current waveforms and appropriate RCCB devices

Table 2 shows the different residual current waveforms generated by various electronic circuits and components, together with suitable RCDs.

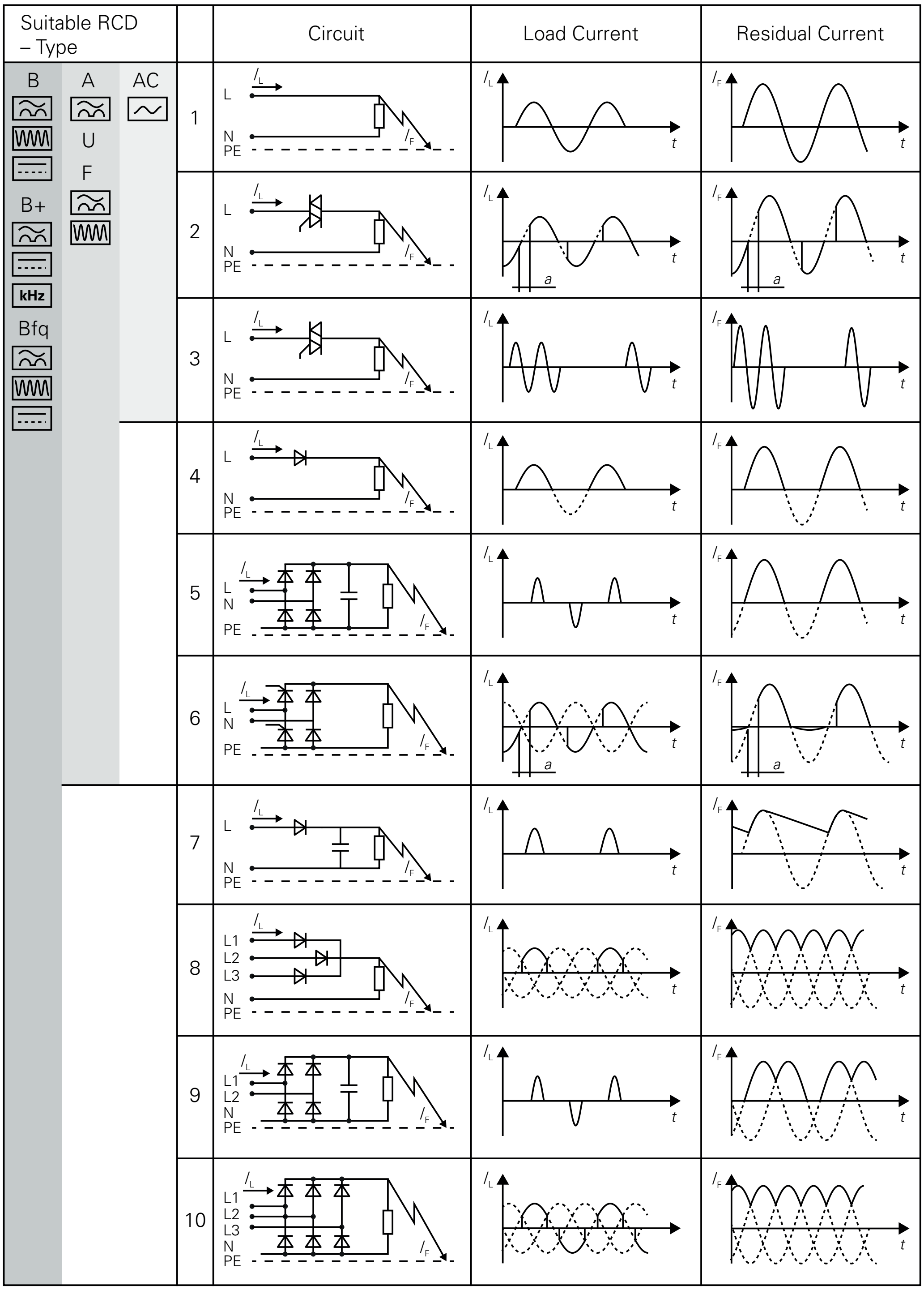


Table 2: Possible residual current waveforms and suitable residual current protective devices (Source: EN 61800-5-1 standard)

The above Tables are mostly self-explanatory, but there are other points to be noted for each RCD type:

Type AC

Type AC RCDs are suitable for detecting sinusoidal AC fault currents. In some regions such as Belgium, Denmark, Finland, Germany, Ireland, Luxembourg, Netherlands, Norway, Sweden and Switzerland this type of RCD is no longer permitted for protective measures.

Type A

RCDs of Type A detect sinusoidal AC fault currents and pulsating DC residual currents. They can also handle the residual current waveforms often generated in the power supply units of single-phase loads with electronic components. Type A RCDs are also available as digital RCDs (see Digital RCDs whitepaper for more details.)

Type F

Type F RCDs have been specifically designed for single phase inverter applications, to assure an adequate protection level in the event of an earth fault associated with inverter-generated harmonic content, offering at the same time an increased resistance to nuisance tripping.

Type F RCDs offer the same range of protection and functionality as Type A RCDs; accordingly they detect sinusoidal AC currents as well as pulsating DC currents.

In addition they detect multi-frequency residual currents up to 1 kHz according to IEC/EN 62423. The Type F RCDs have a surge current withstand capacity of 3kA and tolerate superimposed smooth DC residual currents of up to 10 mA without affecting their protection functionality.

Type U

Type U RCDs are a special Eaton type. It is similar to Type F RCDs and designed for use in applications with frequency converters. Type U RCDs are sensitive to sinusoidal AC currents as well as pulsating DC currents.

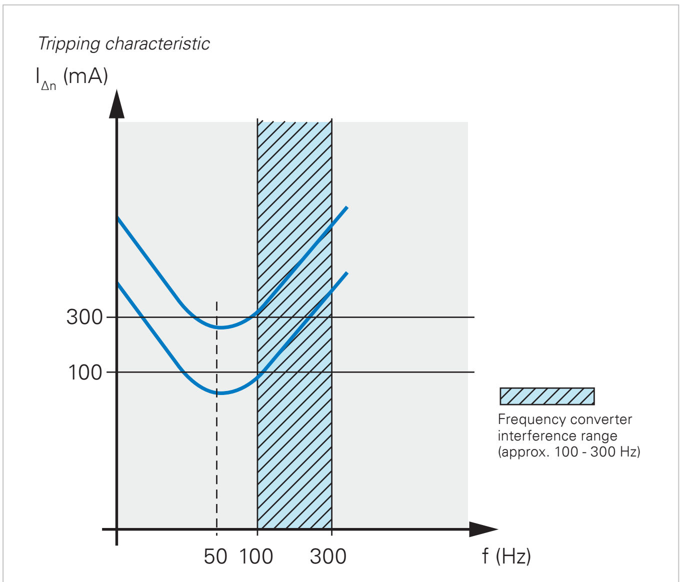


Fig.5: Type U RCD tripping characteristic

Fig. 5 shows the tripping characteristic of a 100 mA and a 300 mA RCD Type U. In the frequency range around 50 Hz, the RCDs trip as required according the standard (50- 100 % of the indicated IΔn). In the range shown hatched in the diagram, i.e. from approx. 100 to 300 Hz, unwanted tripping occurs frequently due to the use of frequency converters. Frequency converter-proof RCDs are much less sensitive in this frequency range than in the 50- 60 Hz range, which leads to a vast increase in the reliability of systems.

Type U RCDs are also available as digital RCDs (see digital RCDs whitepaper for more details).

Types B, Bfq and B+ kHz

Type B residual protective devices can detect sinusoidal AC and pulsating DC as well as smooth DC fault currents, making them suitable for all kinds of applications and occurring waveforms according to IEC/EN 62423. RCDs of this type are designed for use in 50/60 Hz three-phase systems. Additionally, trigger conditions for fault currents with different frequencies from 50 Hz up to 2 kHz are defined for Type B residual current devices.

Type Bfq RCDs comply with Type B requirements (IEC/EN 62423) while being designed for use in circuits that include frequency converters for speed-controlled drives. They have specially-adapted tripping curves, defined up to 50 kHz and are designed to avoid nuisance tripping. The curves exhibit a decreased sensitivity to leakage currents of higher frequencies.

Type B+ RCDs comply with the requirements of VDE 0664-400 and have a frequency tripping response defined up to 20 kHz. Their maximum tripping current at higher frequencies is limited to 420 mA. This provides superior protection from fire risk caused by ground fault currents in applications with electronic drives.

Note that if a complex current waveform is drawn through an RCD, the RCD will trip if even one single frequency reaches the tripping curve. This effect can lead to RMS values higher than the rated RCD tripping current- which is the value for 50 Hz tripping.

Type B, Bfq and B+ RCDs (up to 63A) are equipped as standard with the digital RCD features. See Digital RCDs whitepaper for more details.

RCDs Type G, “Li” and S

While A, B etc are used to define the current waveforms that RCDs can respond to, there are also other type definitions – G, Li and S – that specify whether the RCD has a trip delay and an increased surge current withstand capacity.

G and Li devices have a trip delay of at least 10 ms, allowing time for a temporary fault condition to clear and avoid an unwanted trip. Eaton’s G devices offer a further enhancement to security against nuisance tripping by offering a peak withstand current of at least 3 kA.

Selective or S devices have a tripping delay of at least 40 ms, providing selectivity to downstream RCD´s and high security against unwanted tripping. Selective RCDs are so-called because they are used to generate selectivity between RCDs in series to a G-type or instantaneous type RCD connected downstream within the power distribution system. The downstream device will always trip first, to minimise the amount of equipment disconnected, and production time lost, during a residual current fault. The residual tripping current of the main S device must always be at least three times that of the downstream device – for example, 100 mA Type S is selective to 30mA. Eaton S devices offer a peak withstand current of at least 5 kA to minimize again nuisance tripping; this compares favourably with IEC 61008 and IEC 61009 standards, which demand that Selective RCDs satisfy the 8-20 μs surge current test with 3 kA peak current.

Voltage dependent and voltage independent devices

RCDs can be classified in addition according to whether they are voltage dependent or voltage independent.

Voltage dependent devices are so-called because they use electronic controls that require a certain level of voltage to operate; voltage independent devices, by contrast, use mechanical and magnetic components that do not need a certain level voltage supply. Some manufacturers have argued that voltage dependent technology is unsafe, but in fact the devices are proven to provide just as much protection as the independent types, and offer many advantages in addition.

For over 20 years, both voltage dependent and voltage independent RCDs have been operating within electrical installations throughout Europe and beyond, protecting people against electric shock hazards from residual fault currents. The global IEC standard 60364 considers both types as appropriate to do so. The devices can now detect sinusoidal and pulse sensitive currents as well as currents with mixed frequencies and DC components thanks to the introduction of electronic components.

One argument often advanced is that if the neutral line suffers a break then the subsequent loss of supply voltage will compromise a voltage-dependent device. However the probability of a neutral break in an installation is negligibly small, especially in LV systems.

Additionally, there are robust designs available that can utilise the voltage drop between the RCD and point of failure. And the RCD is not working in isolation; e.g. POP-devices detect temporary changes of the voltage level from a break in the neutral, and disconnect the power circuit.

The idea that we should not consider RCDs as if they are acting in isolation is extended if we consider the earthing system used. In TN systems, the RCD is never solely responsible for protection. Overall, the set of components used for an electronic voltage-dependent device is considered to be as reliable as a voltage-independent device’s mechanical and electrical components

Classification		IΔN	2xIΔN	5xIΔN	500A
Standard RCD Conditionally charged current-proof 250 A	Max. tripping time (s)	0,3	0, 15	0, 04	0, 04
RCCB Type Li (Short-time delayed) Conditionally surge current-proof 250 A	Min. non tripping time (s) Max. tripping time (s)	0,01 0,3	0, 01 0, 15	0, 01 0, 04	0, 01 0, 04
RCCB Type G (Short-time delayed) Conditionally surge current-proof 250 A	Min. non tripping time (s) Max. tripping time (s)	0, 01 0,3	0, 01 0, 15	0, 01 0, 04	0, 01 0, 04
RCCB Type S (Selective) Surge current-proof 5 kA	Min. non tripping time (s) Max. tripping time (s)	0, 13 0,3	0, 06 0,2	0, 05 0, 15	0, 04 0, 15

Table 3: Standard and time-delayed RCD classification

Classification of RCDs

RCD is the general term for all types of residual current protective devices. A standard residual current circuit breaker is called an RCCB and some further types of RCD exist; these are described in this chapter.

1. RCD Relays

RCD relays are devices with a separate current transformer and contactor to handle higher current ranges up to 400 A. External residual current relays are also available for moulded case circuit breakers (MCCBs), with capacities to 1800 A. These devices require an external auxiliary voltage.

2. RCBOs

A residual current operated circuit breaker with overcurrent protection (RCBO) is a combination of an RCCB with a miniature circuit breaker (MCB). It provides overload, short circuit, shock protection and fire prevention from a single device.

The use of an RCBO has many advantages. The RCBO protects itself against overload. The user profits from increased operational safety and equipment availability due to the split of the circuits (one RCBO per feeder compared to one RCCB for a couple of feeders). As a result, system-caused leakage currents produced by electronic consumers do not reach non-permissible levels and exceed the rated tripping current.

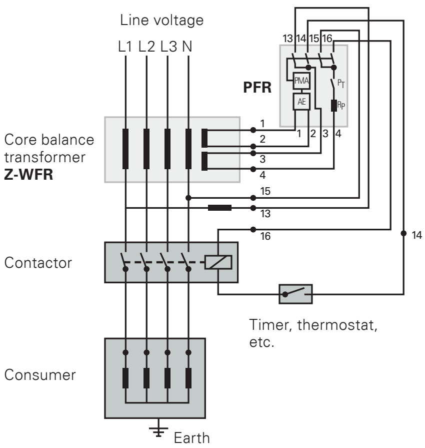
3. RCD add-on blocks

RCD units can be combined with an appropriate MCB to generate the same functionality as a preassembled RCBO.

Many different combinations can be made from available RCD add-on blocks and MCBs without having to stock a large number of products. This gives a high degree of application flexibility and makes it easy to customize the combination of RCD and MCB devices.

RCD add-on blocks are also available for combining with MCCB devices including NZM1 and NZM2, with a current capacity of up to 250 A.

Continuous Contact Control



Two possible switching examples.
Attention:

- Connect terminals 1-4 of the relay to the terminals 1-4 of the transformer (see switching examples)!
  1+2: secondary winding; 3+4 test winding
- Supply terminals 13 and 15 as shown, so that the test circuit can work correct!

Fig.6: RCD relay switching example

4. Digital RCDs

Digital RCDs combine protection functionality with a set of digital features- unique within the circuit protection market – that work together to provide maximum circuit status information and increase the protected system or machine's availability. The digital technology is applied to both RCCBs and RCBOs. The devices continuously measure the residual current value in real time, and use the results to drive local pre-warning LEDs and remote pre-warning potential-free outputs. These pre-warnings allow maintenance staff to resolve creeping problems before they lead to interruptions or failures. System status is always available at a glance, and cost savings accrue due to the reduction in unscheduled service callouts. Further savings arise because test intervals can be extended to once a year only.

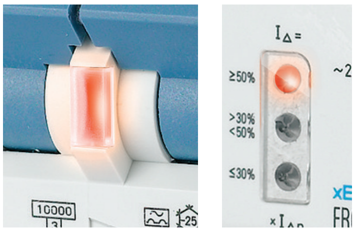
System availability is further enhanced, as the digital protection devices have a short time delayed tripping characteristic and optimised tripping thresholds to ensure that malfunctions of brief duration do not cause nuisance tripping and loss of system availability.

5. Digital RCCB

The digital RCCB is equipped with a voltage independent protection function and voltage dependent digital features. Digital RCCBs are available as Type A, U, B, Bfq and B+.

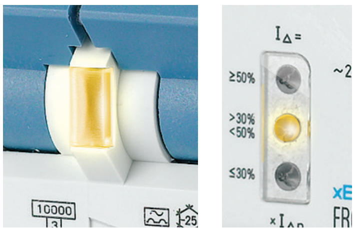
6. Digital RCBO

In contrast the digital RCBO is a voltage dependent RCD. This means the protection function and the additional digital features are voltage dependent and must be supplied with a certain level of voltage. Digital RCBOs are available as Type A.



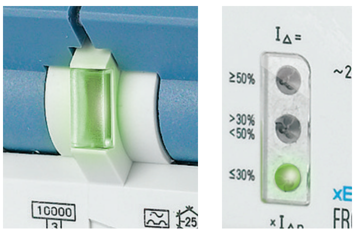
Red

When the red LED lights up, the leakage current is already higher than 50 percent of the nominal fault current. Therefore the system is in a critical status – the digital RCCB only trips when the fault current continues to increase.



Yellow

The yellow LED shows a residual current in the ambit of 30 to 50 percent of the nominal fault current. Before the system is shut down, professional countermeasures can be taken.



Green

If the current flow in the system to ground is in the ambit from 0 to 30 percent of the nominal fault current, the green LED indicates the proper status.

Fig. 7: Digital RCDs alert maintenance staff of problems before a blackout occurs

Global standards for RCDs and export worldwide

The common goal of component manufacturers and planners, installers and operators is the protection and trouble-free operation of modern electrical installations. Achieving this depends on paying attention to compliance with all relevant standards and guidelines while allowing for the various factors and physical conditions involved. Having discussed the various types of RCDs it is important to understand the current standards:

- IEC 60364-1:2005: Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions
- IEC/EN 61008-1: Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – Part 1: General rules
- IEC/EN 61009: Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) – Part 1: General rules
- IEC 62423 – Type F and Type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses
- VDE 0664-400 – Residual current operated circuit-breakers Type B without integral overcurrent protection to operate at residual alternating and residual direct currents for advanced preventative protection against fire- Part 400: RCCB Type B+
- IEC/EN 60947-2 Low-voltage switchgears and controlgear – Part 2 Circuit-breakers
- UL 1053 Standard for Ground-Fault Sensing and Relaying Equipment
- UL 943 Ground-Fault Circuit-Interrupters

Standard RCDs can be used worldwide except in the USA and Canada. In the North American market, UL standards are used instead of IEC standards, and so for export to this region RCDs must be available in special UL approved versions.

Country specific approval is also required in a number of other countries including Argentina, China, Russia, South Africa, and the Ukraine. Marking is partly mandatory for these countries, however, as in other European countries, the IEC rating data is accepted here.

Ensuring that the RCDs conform to international standards, such as IEC/EN 61008 or UL1053, and that they carry the corresponding marks, as Eaton's do, is essential for guaranteeing safety. By specifying one product that is a world market product and can be used globally will ultimately save time and associated costs when exporting.

Installation and application of RCDs

Types of earthing systems and protective devices

When installing RCDs it is vital to understand what earthing system it is going in to. There are three different types of main earthing arrangements as defined by IEC 60364 – TT, TN and IT. TN systems can be further divided into TN-C, TN-S and TN-C-S where C is Combined and S is Separated.

RCDs can be used on all three types of system grounding – TN, TT and IT – for an AC or three-phase system, as shown in Fig. 8 (with the exception of TN-C configurations). RCDs offer superior protection to that of other approved devices, because in addition to protection in the event of indirect contact when RCDs of $I\Delta n \leq 30$ mA are used, they also provide protection if direct contact occurs, and with their $I\Delta n \leq 300$ mA play an important role in preventative protection against electrically ignited fires caused by ground fault currents.

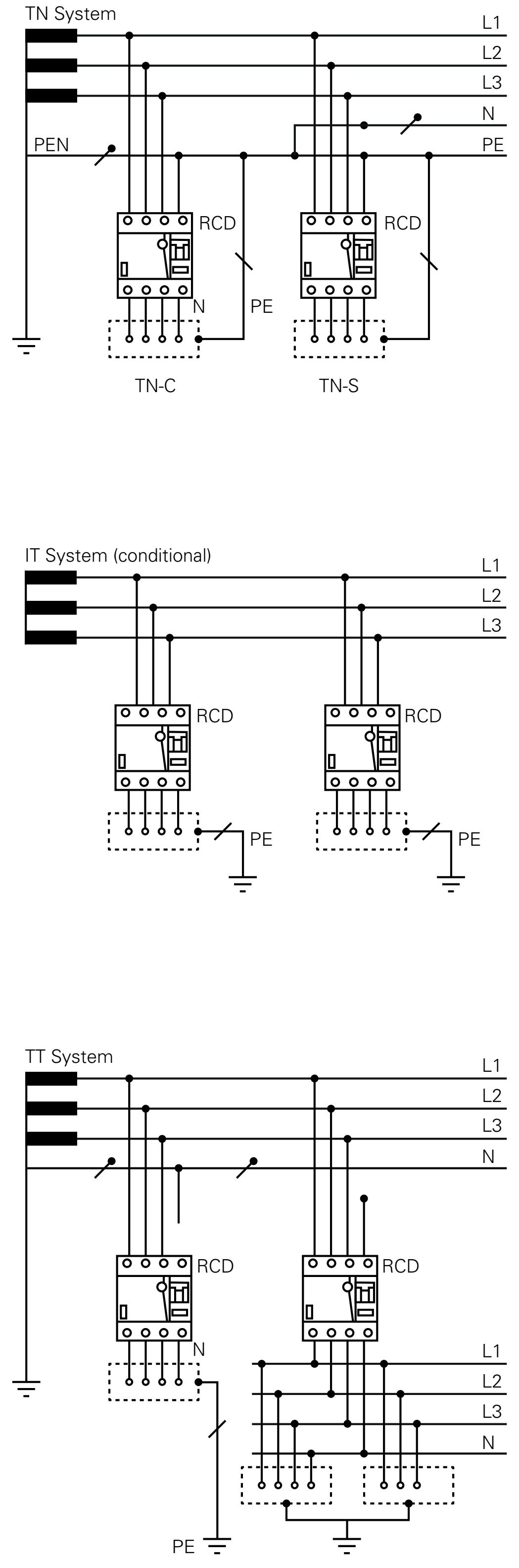


Fig.8: Residual current protective devices in different earthing systems

Installation standards for electrical systems with RCCBs

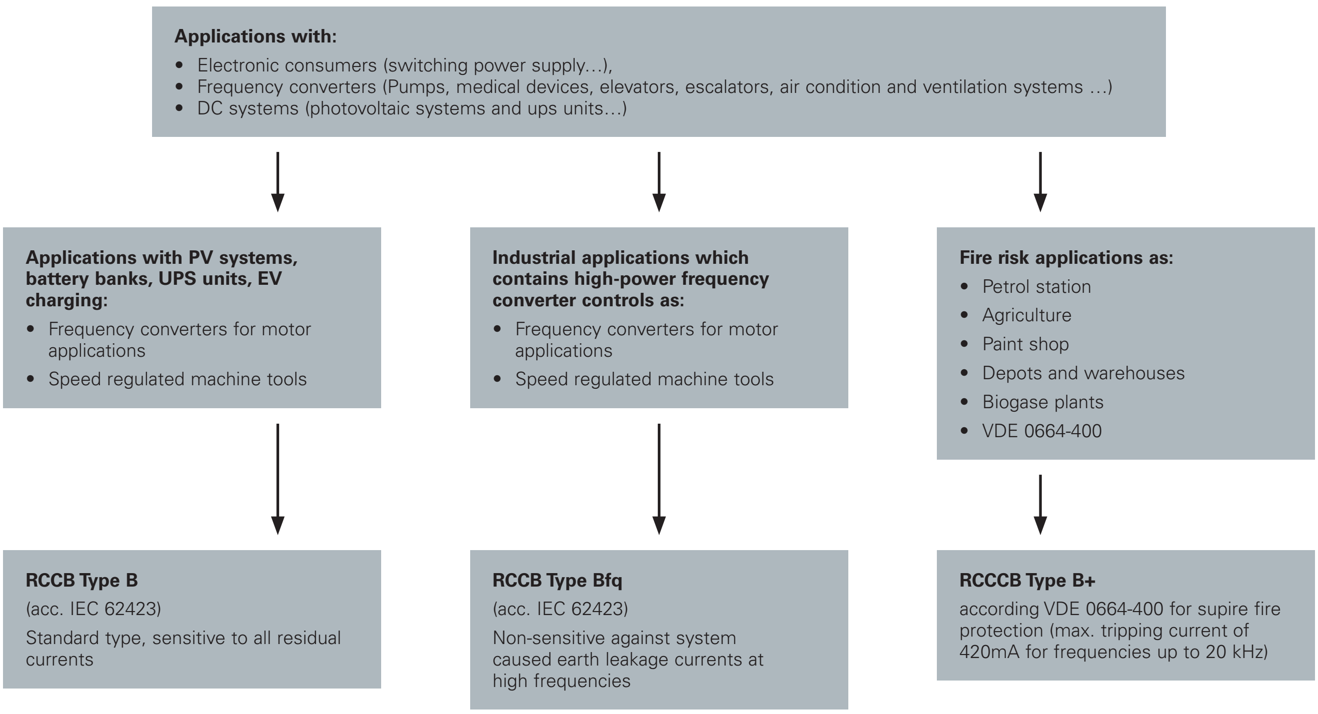
Standards	Application	Protection goal	Required IΔn (mA)	Recommended RCD
IEC 60364-4-41	Protection against electrical shock	Fault protection	30…500	Type A or Type B
	Socket outlets up to 20A, outdoor installations	Additional protection	10…30	Type A
IEC 60364-4-482	Fire protection against special risks or hazards	Fire protection	30 and 300	Type A or Type B
IEC 60364-5-551	Low-voltage power generating installations	Additional protection	10…30	Type A
IEC 60364-7-701	Rooms with bathtubs or showers, outlets in zone 3	Additional protection	10…30	Type A
IEC 60364-7-702	Swimming pools and other pools	Additional protection	10…30	Type A
IEC 60364-7-703	Rooms with cabins with sauna heating	Additional protection	10…30	Type A
IEC 60364-7-704	Construction sites, socket outlet circuits up to 32A and for hand-held equipment	Additional protection	≤30	Type A or Type B
	Plug-and-socket devices up to In > 32A	Fault protection	≤500	Type A or Type B
IEC 60364-7-705	Agricultural and general horticultural premises	Fault protection	≤300	Type A
	Socket outlet circuits	Additional protection	10…30	Type A
IEC 60364-7-706	Conductive areas with limited freedom of movement	Additional protection	10…30	Type A
IEC 60364-7-708	Electrical equipment on camping sites, each socket outlet individually	Additional protection	10…30	Type A
IEC 60364-7-712	Solar PV power supply systems (without a simple means of disconnection)	Fault protection	≤300	Type B
EN 50178	Equipment of heavy current installations with electronic components (1phase)	Fault protection	≤300	Type F (U)
	Equipment of heavy current installations with electronic components (3phase)	Fault protection	≤500	Type Bfq
OVE E 8001-1:2010	Charging Stations for Electrical vehicles	Additional protection	≤30	Type A or Type B
OVE E 8001-4-95	Elevators	Additional protection	≤30	Type F (U) or Type B
VDS 3501	Insulation protection for installations with electronic components	Fire protection	≤300	B+

Table 4: Installation standards for electrical systems with RCCBs

Protection goal	Required IΔn (mA)	Recommended RCD
Protection against electric shock	< 6	RCDs according to UL 943
Protection of equipment	30 and 300	RCDs according to UL 1053

Table 5: North American Installation standards for electrical systems with RCCBs

Choosing between types B, Bfq and B+ RCCBs



Correct installation of Type B with Type A RCCBs

Type A and Type B RCDs can be mixed within power circuits, subject to Type A limitations. Type A devices cannot detect smooth DC residual currents, and an excessive DC current drawn through them will disrupt their ability to respond to AC residual currents as well. Therefore no load requiring type B protection, or associated type B RCD, must ever be installed downstream of a Type A device. Fig 9 shows permissible and non-permissible scenarios for Types A and B RCDs working together.

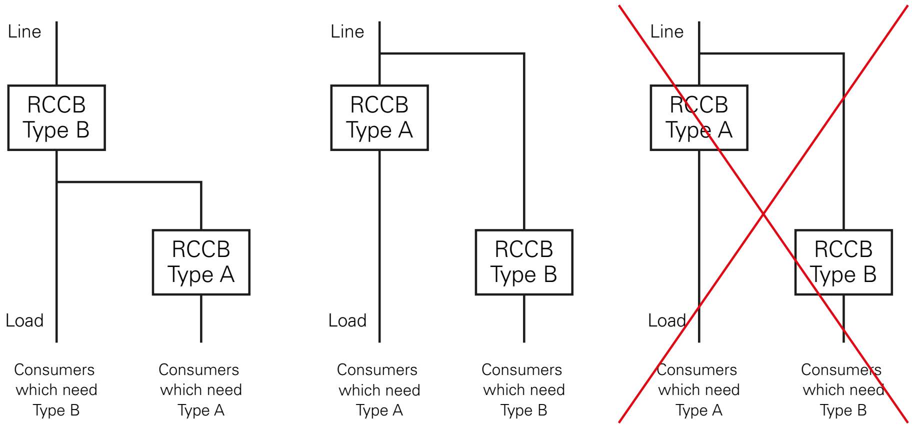


Fig. 9: Permissible and non-permissible RCD Type A/Type B scenarios

Electrical interference problems and solutions

There are various electrical interference problems that can occur and machine builders need to consider when specifying RCDs.

Leakage currents

Leakage currents are static or dynamic currents that leak to ground without any insulation fault. However RCDs cannot distinguish between leakage currents and fault currents, and will trip if the currents' sum exceeds their tripping value. Accordingly, leakage currents must be considered when specifying the RCD's rated residual current IΔn. If necessary, these currents should also be minimised to ensure proper operation of the RCD.

Static leakage currents flow continuously to ground or the PE conductor during normal operation without any insulation fault. They typically originate from line and filter capacitors. Type U or Bfq RCDs have tripping curves that are set to be insensitive to system caused earth leakage currents at higher frequencies. This prevents nuisance tripping errors in industrial plant with powerful frequency inverter controllers, without compromising personal protection.

Dynamic leakage currents are transient currents to ground or the PE conductor. With a duration up to a few ms and a magnitude of possibly a few amperes, they are liable to trip instant-acting RCBs. To prevent this unwanted tripping, the use of short-time delayed RCDs Type G or Li recommended.

High load currents

Nuisance tripping in RCDs can also be caused by high load currents. Causes of these currents include direct starting motors, lamp loads, heaters, capacitive loads and medical equipment. According to the product standard RCDs must tolerate up to six times their rated current to provide resistance to nuisance tripping.

Overvoltage and surge current load

Atmospheric overvoltages created by thunderstorms can enter an installation via the supply system and lead to nuisance tripping of the RCD. Eaton offers the Type G RCD specified according to ÖVE E 8601 to avoid this problem. Eaton RCDs have surge current withstand capabilities as defined here:

- Instantaneous: Conditionally surge current-proof 250 A
- Type Li: Conditionally surge current-proof 250 A
- Type G: Surge current-proof ≥ 3 kA
- Type S: Surge current-proof ≥ 5 kA

Short-circuit capacity and Conditional short-circuit current

Eaton residual current circuit breakers with corresponding fuse have a conditional rated short-circuit current capacity of 10 kA. The value of the short-circuit fuse refers to fuses of operational class gG. The Rated breaking capacity Im or Rated fault breaking capacity IΔm correspond to the valid device standard IEC/EN 61008.

In	Short Circuit	Rated breaking capacity I_m or Rated fault breaking capacity I_{Am}	
16A	63A gG/gl	I_n = 16-40 A	500 A
25A	63A gG/gl	I_n = 63 A	630 A
40A	63A gG/gl	I_n = 80 A	800 A
63A	63A gG/gl	I_n = 100 A	1,000 A
80A	80A gG/gl		
100A	100A gG/gl		

Table 6: Maximum backup fuse capacity and breaking capacity

RCD thermal protection

Careful planning of downstream load circuits is essential to protect RCDs against thermal overload. To avoid damaging the RCCB it is important to ensure that the maximal possible operating current of the load circuit downstream does not exceed the rated current of the RCD. Alternatively an upstream fuse can be used according to Table 7.

	xPole RCCBs	xEffect + xPole X RCCBs
In	Overload	Overload
16A	10A gG/gl	16A gG/gl
25A	16A gG/gl	25A gG/gl
40A	25A gG/gl	40A gG/gl
63A	40A gG/gl	63A gG/gl
80A	50A gG/gl	80A gG/gl
100A	63A gG/gl	80A gG/gl

Table 7: Upstream fuse ratings for thermal overload protection

Conclusions

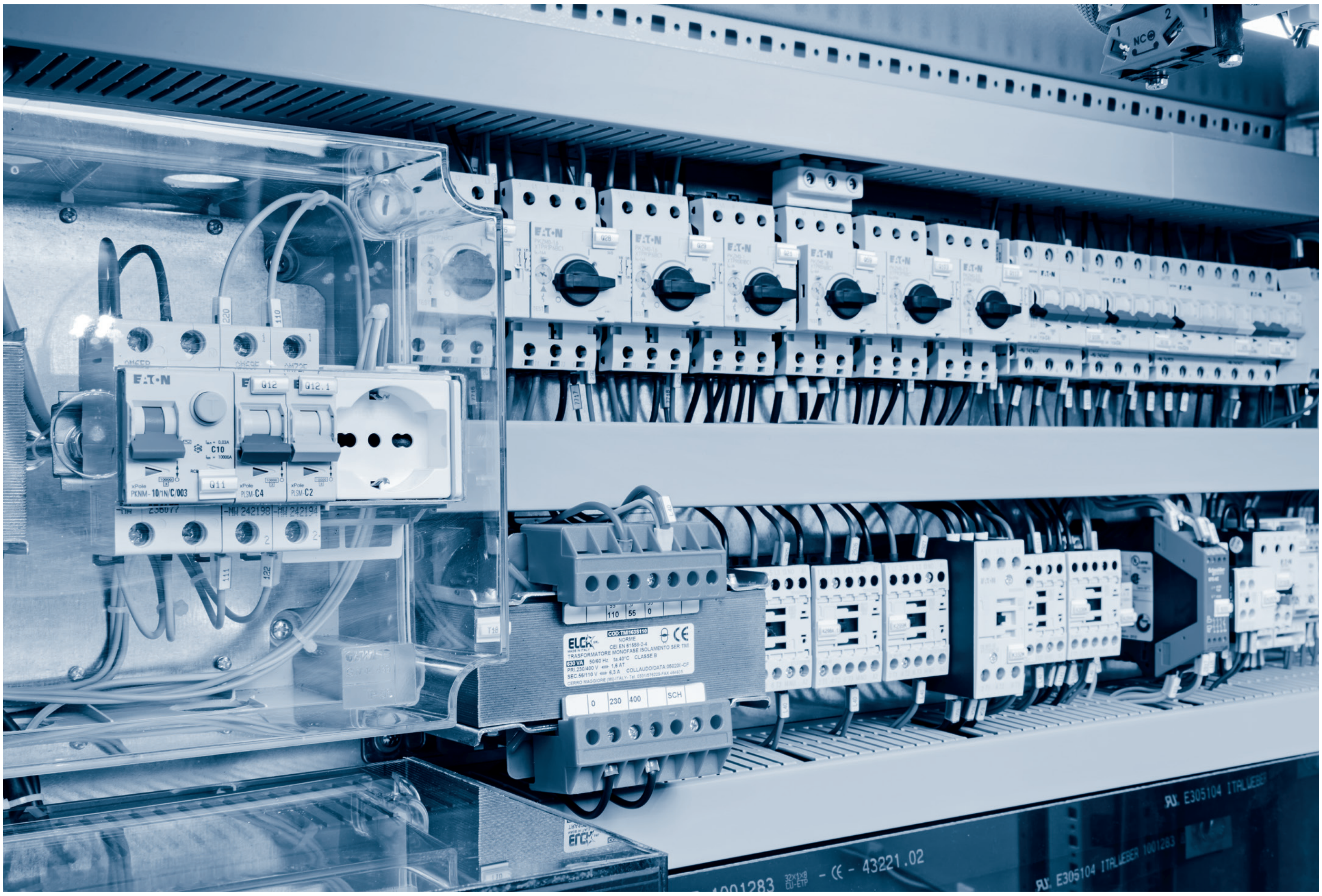
In this whitepaper the possible consequences if electric current is allowed to flow along inappropriate paths have been outlined. Such risks must therefore be eliminated both for health and safety and to ensure maximum productivity and machine uptime.

RCDs can protect machines and people from harm, eliminate the risk of fire and reduce machine downtime by detecting and reacting to residual currents. However these currents can arise for many reasons and take many forms, and it is essential to choose RCDs with tripping characteristics that ensure protection from genuine fault conditions, while avoiding lost production time due to nuisance tripping.

Accordingly the whitepaper has reviewed the different residual current waveforms generated by various electronic circuits and discussed the RCD types available to handle them. We have seen how devices are characterised not only by their waveform trip response but also by whether they are voltage dependent or independent, and if they have an instant or delayed response. Different RCD devices offer an easy integration of additional advantages and functions in the protection concept.

The paper also summarised the relevant international legislation and discussed installation aspects of power protection systems that machine builders must consider; these include the type of earthing system being used, installation standards, and electrical interference problems and solutions.

This whitepaper is intended to offer useful guidance for machine and system builders seeking to understand the issues involved in selecting and installing RCDs. It is part of Eaton's commitment to providing circuit protection solutions, from initial design steps through to installation, maintenance and spares holding. Eaton's global organisation and portfolio of internationally approved, innovative components and technologies is complemented by local production facilities, expertise and support.



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