

Technical guide | 2015

Protection against earth faults with Residual Current Devices

Protection against earth fault with Residual Current Devices

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Introduction

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Brief history

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1

The manufacturer has the responsibility to issue a self-certification, which states that the product has been assessed and satisfies all health, safety and environmental requirements of the Directives (European declaration of conformity).

RCD's assure a protection against fault current to earth in residential, commercial and industrial applications, reduce the risk of death or serious injury when accidentally a person who is grounded touches the energized part of the circuit and prevent the risk of fire caused by faulty wiring or other appliances.

They are installed in the consumer unit (fusebox) and having a modern one fitted with RCD's can provide the best safety to people and installations.

The aims of this ABB technical guide are raising general awareness of electrical safety and encouraging the upgrade of old installations with safer consumer units.

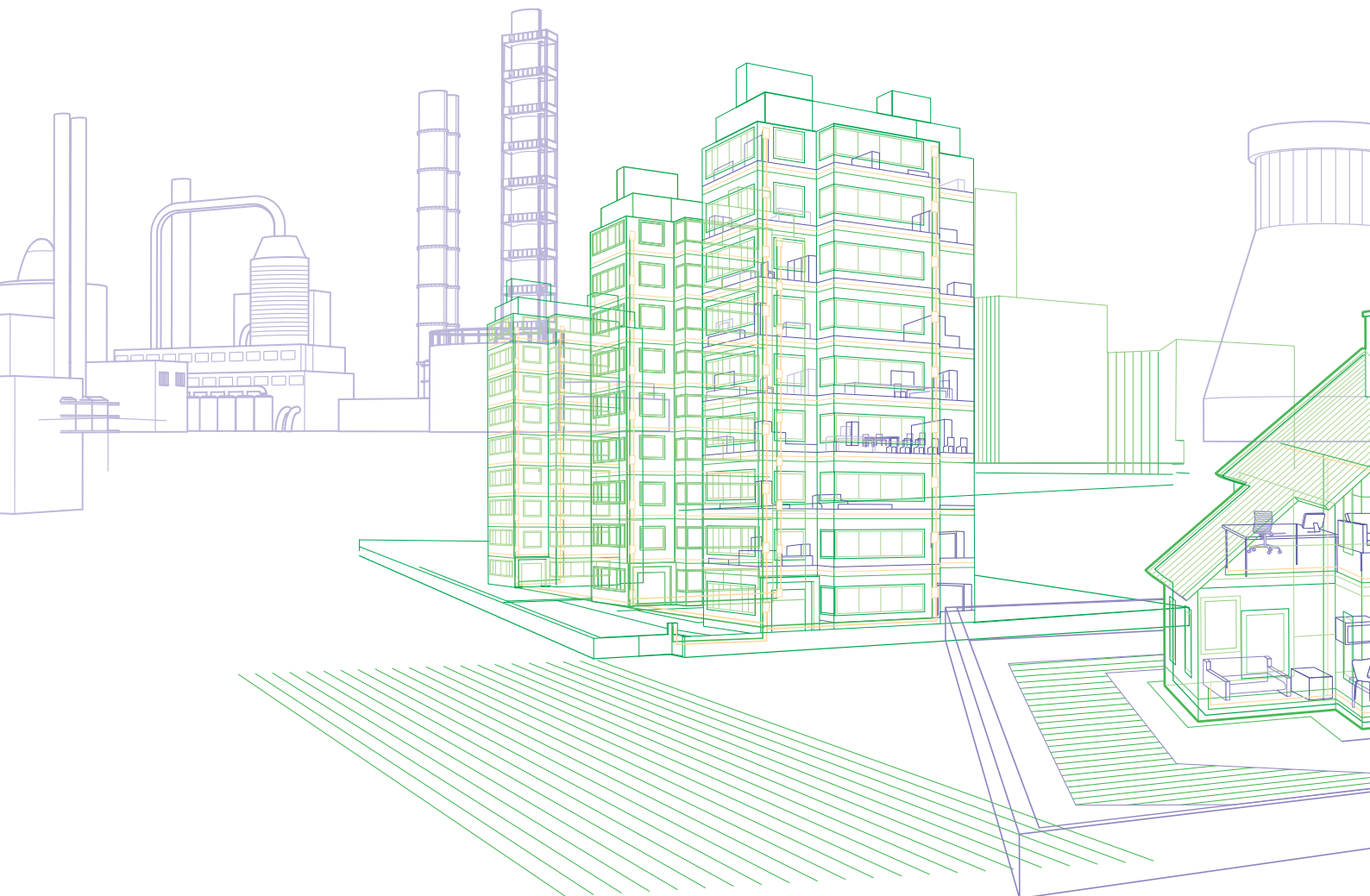
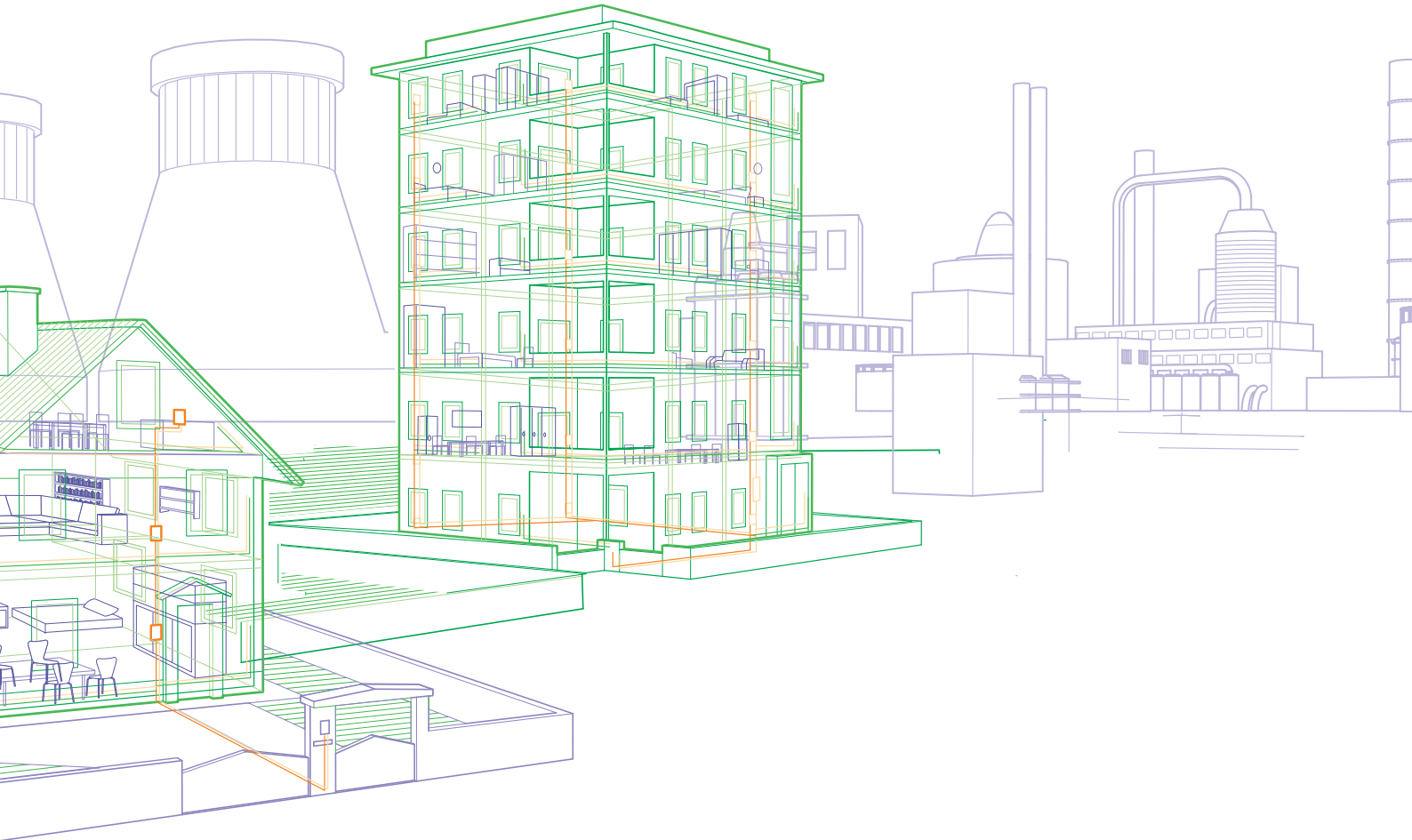


ABB has always played a leading role in the development of Residual Current Devices, introducing ever more innovative devices in the market to comply with its increasing requirements. Today, RCDs are widely used all over the world. They ensure high safety in the use of electrical equipment.

It is not clear when and by whom the first RCD was developed, but it certainly appeared on the market in the 1950s. It was initially used by some utility companies to fight “energy theft” who used to drag some energy out of the line.

ABB built the first low sensitivity RCD in 1953 and a high sensitivity device in 1956. Residual Current Devices were later adopted to protect people against electric shocks.

RCDs are now widely used in most of the world; in some cases this is mandatory, while in others their use is optional.



Protection against earth faults

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Protection against earth faults

Effects of current on the human body

2

Injuries to people are caused by the current flow through the human body.

These effects are:

- tetanic contraction: the muscles affected by the current flow involuntary contract, making letting go of conductive parts difficult. Note: very high currents do not usually induce tetanic contraction because when the body touches such currents, the muscular contraction is so strong that the involuntary muscle movements generally throw the subject away from the conductor;
- respiratory arrest: if the current flows through the muscles controlling the respiratory system, the involuntary contraction of these muscles alters the normal respiratory process and the subject may die due to suffocation or suffer the consequences of traumas caused by asphyxia;
- ventricular fibrillation: the most dangerous effect is due to the superposition of the external currents with the physiological ones which, by generating uncontrolled contractions, induce alterations of the cardiac cycle. This anomaly may become an irreversible phenomenon since it persists even when the stimulus has ceased;
- burns: due to the heating deriving, by Joule effect, from the current passing through the human body.

The IEC 60479-1 Standard "Effects of current on human beings and livestock" is a guide about the effects of current flowing through the human body to be used for the definition of electrical safety requirements. This Standard shows, on a time-current diagram, four zones (Figure 1) to which the physiological effects of alternating current (15 – 100 Hz) passing through the human body have been related. Such zones are illustrated in Table 1.

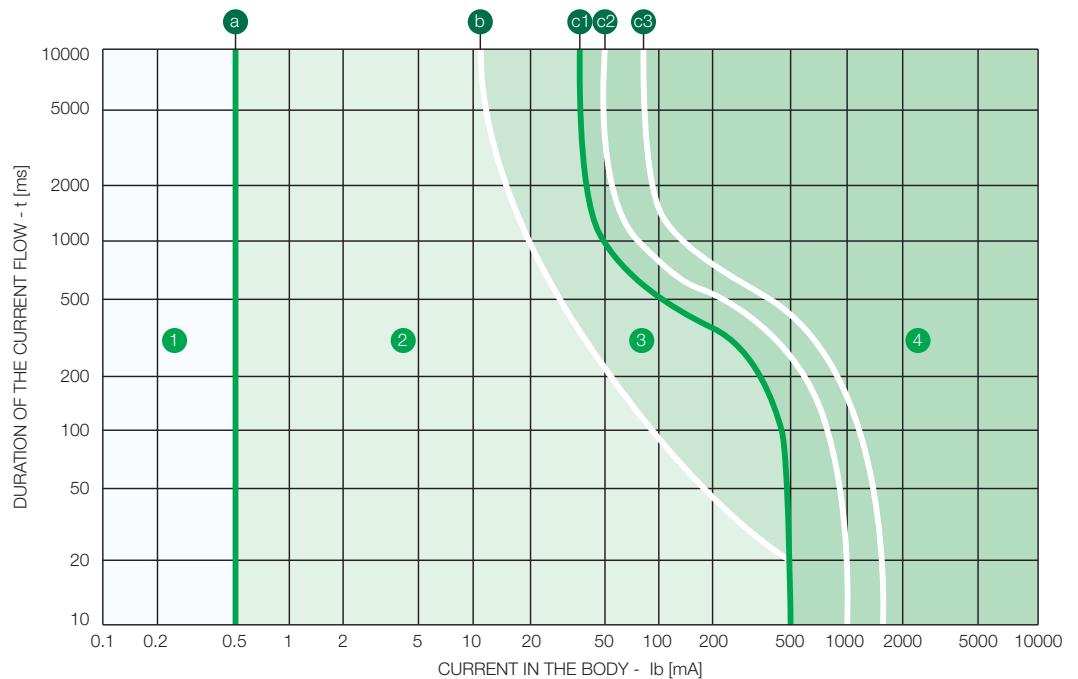


Figure 1: Time-current zones of the effects of alternating current on the human body

Zone	Effects
1	Usually no reaction
2	Usually no harmful physiological effects
3	Usually no organic damage to be expected. Likelihood of cramp-like muscular contractions and difficulty in breathing; reversible disturbances of formation and conduction of impulses in the heart, including atrial fibrillation and transient cardiac arrest without ventricular fibrillation increasing with current magnitude and time
4	In addition to the effects of zone 3, the probability of ventricular fibrillation increases up to about 5% (curve c2). 50% (curve c3) and above 50% beyond the curve c3. Pathophysiological effects such as cardiac arrest, respiratory arrest and severe burns may occur, increasing with current magnitude and time

Table 1: Effects of alternating current on the human body

Electricity causes a “shock” in us because it is an outside force that interferes with the internal electricity generated by our nervous system.

In scientific terms, electricity is considered a fundamental force, one that is extremely basic, and has been existing since the beginning of time.

Unfortunately, since the human body consists primarily of water, is utterly conductive.

Any voltage that may be applied externally to our body can interfere and affect the ordinary function of our system. The higher the voltage, the worse its effect.

An electric shock is the pathophysiological effect of an electric current through the human body.

Its passage essentially affects the muscular, circulatory and respiratory functions and sometimes it results in serious burns. The dangerousness for the victim is a function of the magnitude of the current, the part of the body through which the current passes, and the duration of current flow.

Curve C1 shows that when a current is greater than 30 mA and passes through a human being from one hand to the feet, the person is likely to be killed, unless the current is interrupted in a relatively short time.

The point 500 ms/100 mA close to the curve C1 corresponds to a probability of heart fibrillation equal to 0.14%.

Protection of people against electric shock must be provided for LV installations in conformity with appropriate national standards and statutory regulations, codes of practice, official guides and circulars, etc. Relevant IEC standards include: IEC 60364 series, IEC 60479 series, IEC 60755, IEC 61008 series, IEC 61009 series and IEC 60947-2.

Protection against earth faults

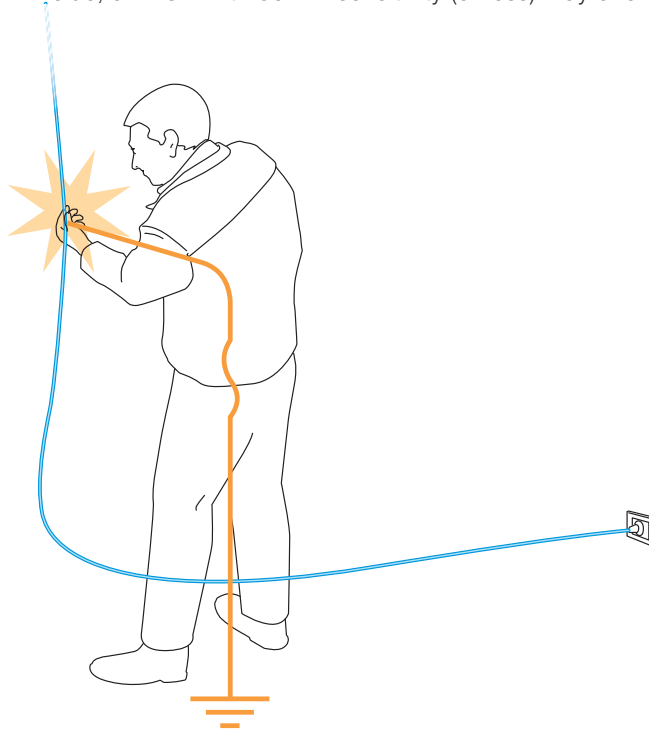
Direct and indirect contact

2

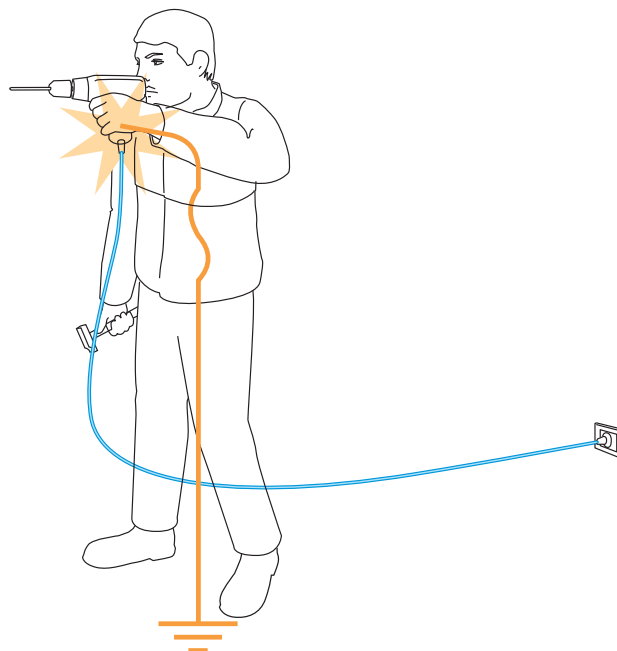
There are two possible types of electric shocks:

Direct contact: an electric shock results from the contact with a conductor which belongs to a circuit and it would be expected to be live.

For instance, if someone removes the plate from a switch and touches the live conductors inside, an RCD with 30 mA sensitivity (or less) may offer protection.



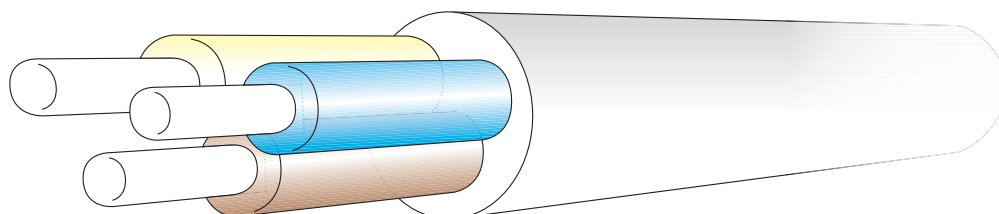
Indirect contact: an electric shock is received from contact with something that is connected to the electrical installation which normally is not expected to be live, but has become so as a result of a fault.



Direct contact protection

It consists of making sure that people cannot touch live conductors. These methods include:

- insulation of live parts, this is the standard method.



- enclosures or barriers to prevent from touching



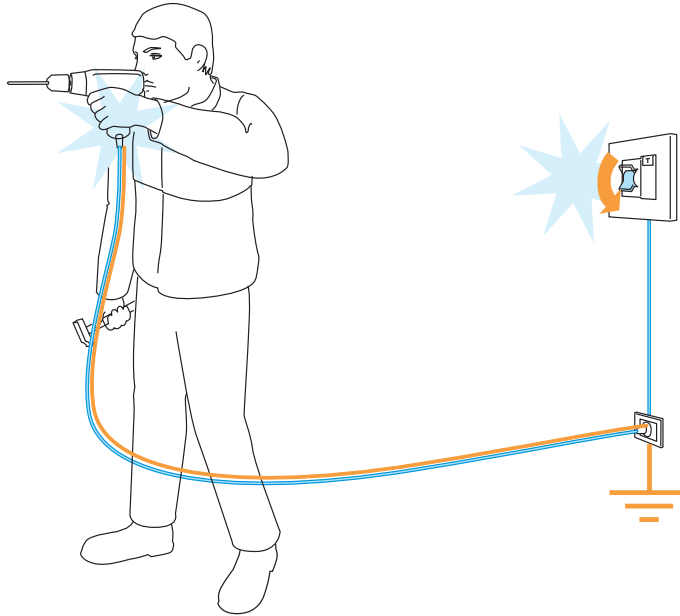
- placing parts out of reach or using obstacles to prevent people from reaching live parts.
This protection is reserved for locations in which only skilled or trained people have access to.

Protection against earth faults

Direct and indirect contact

- the provision of residual current devices (RCDs) provides supplementary protection, but only when contact is from a live part to an earthed part.

2



Indirect contact protection

The methods of protection against indirect contacts are classified as follows:

- protection by automatic disconnection of supply;
- protection without automatic disconnection of the circuit (double insulation, electrical separation and local bonding);
- extra low voltage power supply.

Protection against earth faults

Additional protection

An additional protection against the hazards of direct contact is provided by the use of Residual Current Devices rated at 30 mA or less.

According to IEC 60364-4-41, additional protection by means of high sensitivity RCDs ($I_{\Delta n} \leq 30 \text{ mA}$) must be provided for circuits supplying sockets with a rated current $\leq 20 \text{ A}$ in all locations and for circuits supplying mobile equipment with a rated current $\leq 32 \text{ A}$ for use outdoors. This additional protection is required in certain countries for circuits supplying sockets rated up to 32 A and even higher if the location is wet and/or temporary (such as work sites, for instance).

Why 30mA is the preferred value for $I_{\Delta n}$?

High sensitivity RCDs ($I_{\Delta n} = 30 \text{ mA}$) provide both protection against indirect contact hazards and the additional protection against the dangers of direct contact. They guarantee complete protection!



Protection against earth faults

Fire protection

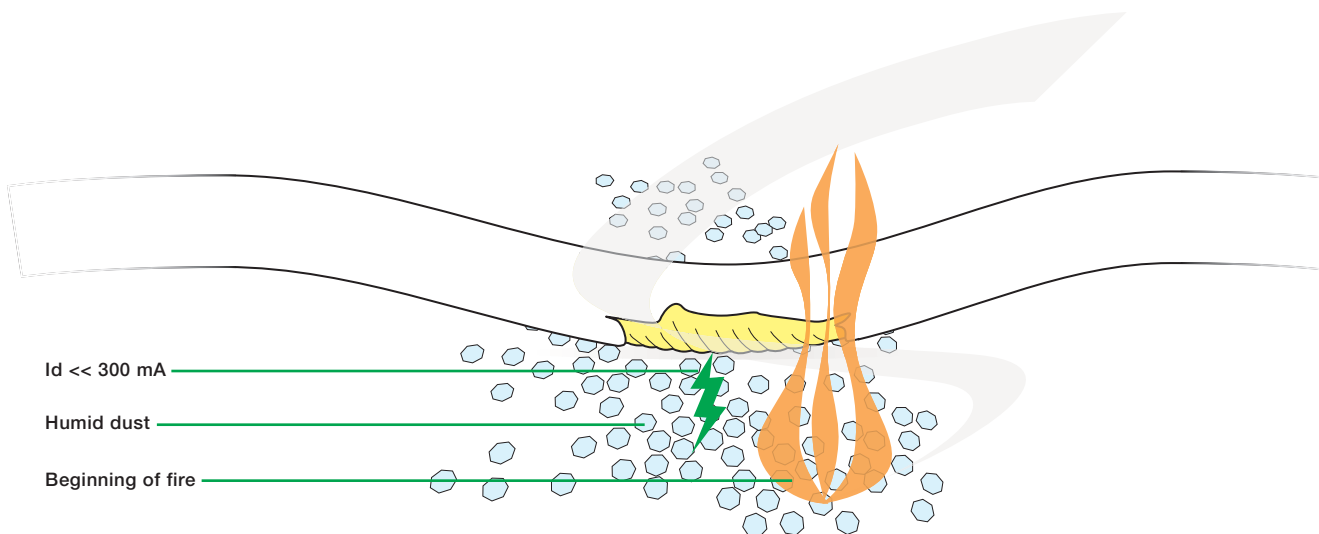
2

RCDs are very effective devices in providing protection against fire risk caused by insulation faults because they can detect leakage currents (ex: 300 mA) that are too low for other protective devices, but strong enough to set a fire (i.e. overcurrent protection devices). For TT and IT TN-S systems in which leakage current can appear, the usage of a 300 mA sensitivity RCDs provides good protection against fire risk due to this type of fault. Investigations have shown that the cost of the fire damages in industrial and tertiary buildings can be very high.

This phenomenon shows that fire risk due to electricity is linked to overheating due to a poor coordination between the maximum rated current of the cable (or insulated conductor) and the overcurrent protection setting.

Overheating can also be generated by some modifications of the initial method of installation (addition of cables on the same support).

This overheating can be the origin of electrical arcing in humid environments. That evolves when the fault current-loop impedance is greater than 0.6Ω and exist only when an insulation fault occurs. Some tests have shown that a 300 mA fault current can cause a real risk of fire. This problem raises in case of



Some tests have shown that a very low leakage current (few mA) can evolve and, from 300 mA, it may set a fire in humid and dusty environments.

Protection against earth faults

Classification of electrical distribution systems

The extent of the earth fault and the consequences deriving from touching live exposed-conductors are specifically related to the neutral condition of the power system and to the different types of earthing. As a consequence, to select the proper device for protecting against earth faults, it is necessary to know the installation distribution system. The International Standard IEC 60364-3 classifies electrical systems with the combination of two letters.

The first letter indicates the relationship of the power system to earth:

- T = direct connection to earth of one point, usually the neutral, in a.c. systems;
- I = all live parts isolated from earth or one point, usually the neutral, connected to earth through an impedance.

The second letter indicates the relationship of the exposed conductors of the installation to earth:

- T = direct electrical connection of exposed conductors to earth;
- N = direct electrical connection of the exposed conductors to the earthing point of the power system.

Subsequent letters, if any, indicate the arrangement of neutral and protective conductors:

- S = neutral and protective functions provided by separate conductors
- C = neutral and protective functions combined in a single conductor (PEN conductor).

With reference to the definitions above, the main types of power systems are described below.

Protection against earth faults

Classification of electrical distribution systems

2

TT system

In TT systems the neutral and the exposed conductors are connected to electrically independent earth electrodes (Figure 1); therefore, the earth fault current returns to the power supply node through the soil (Figure 2).

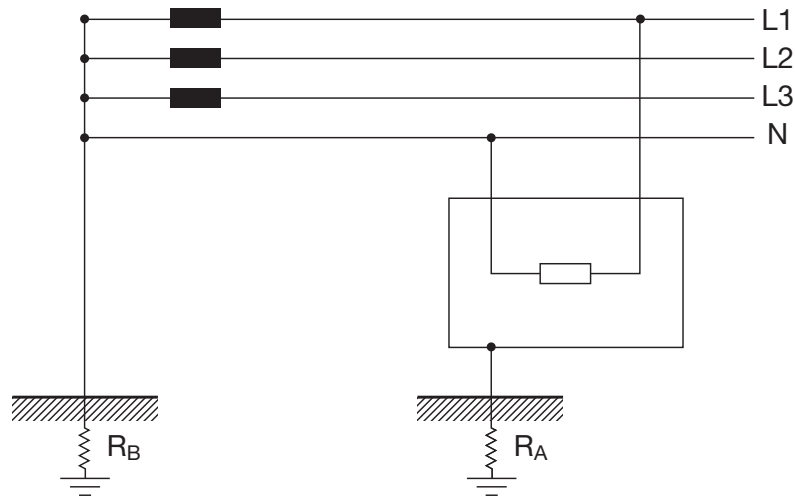


Figure 1

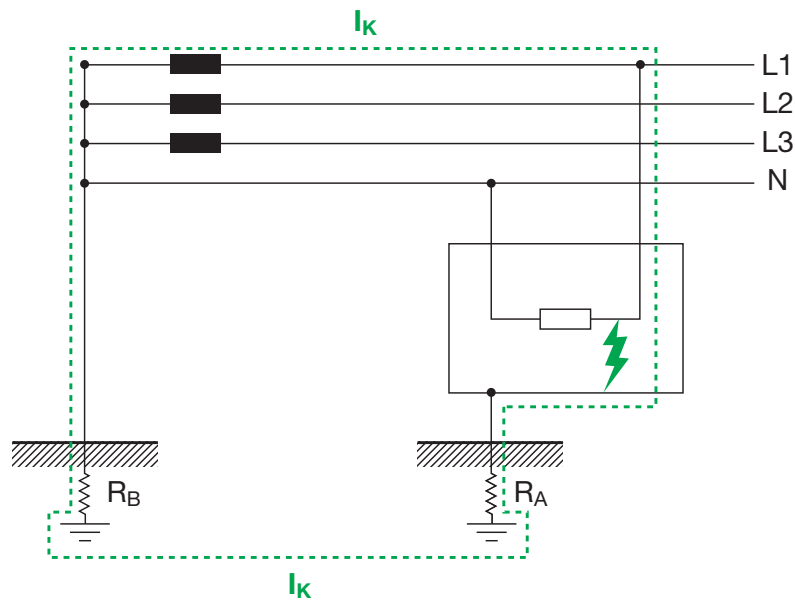


Figure 2

In this type of electrical installation, the neutral is usually distributed and its function is making the phase voltage (e.g. 230 V) available for the supply of the single-phase loads of residential installations.

TN system

In TN systems, the neutral is directly earthed, whereas the exposed conductors are connected to the same earthing arrangement of the neutral. TN electrical systems can be divided into three types depending on whether the neutral and protective conductors are separate or not:

- 1. TN-S: the neutral conductor N and the protective conductor PE are separated (Figure 3)

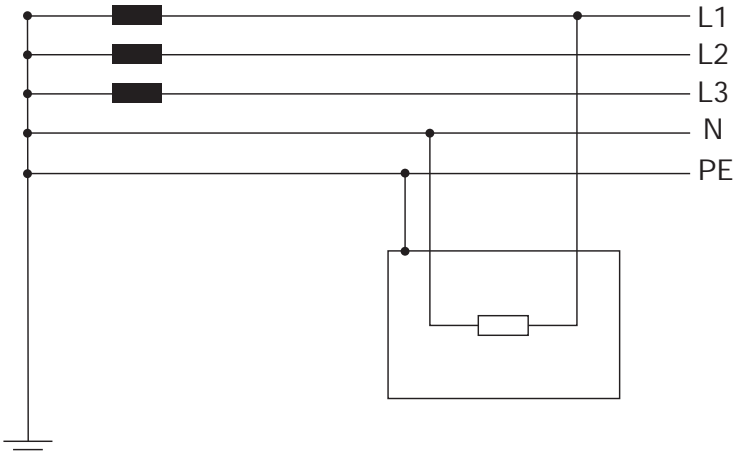


Figure 3

- 2. TN-C: the neutral and protective functions are combined into a single conductor, called PEN (Figure 4)

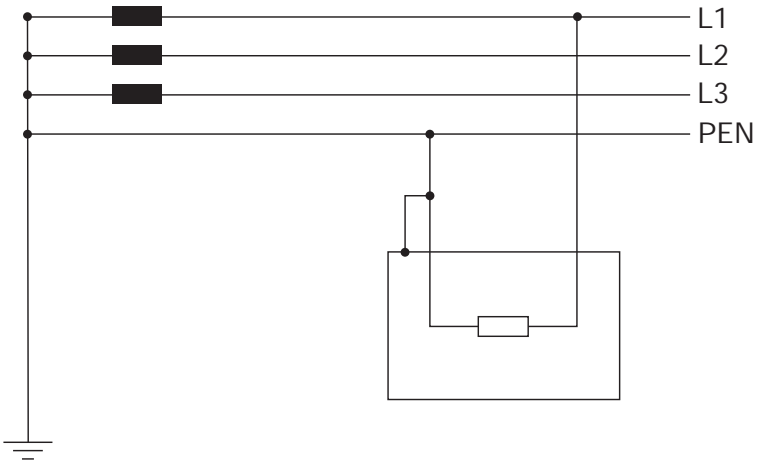


Figure 4

Protection against earth faults

Classification of electrical distribution systems

2

3. TN-C-S: the neutral and protective functions are partially combined into a single PEN conductor and partially separated PE + N (Figure 5).

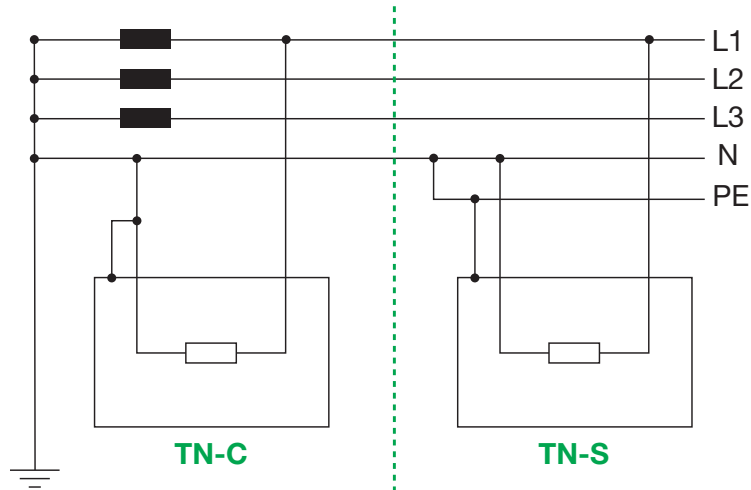


Figure 5

In TN systems, the earth fault current returns to the power supply node through a direct metal connection (PE or PEN conductor) without practically affecting the earth electrode (Figure 6).

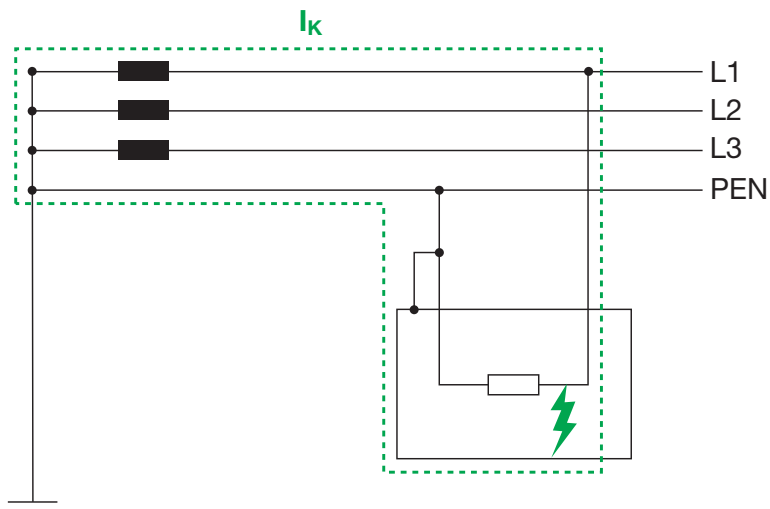


Figure 6

IT system

IT systems have no directly earthed active parts, but may have live parts connected to earth through high impedances (Figure 7). All the exposed-conductive-parts, separately or in a group, are connected to an independent earth electrode.

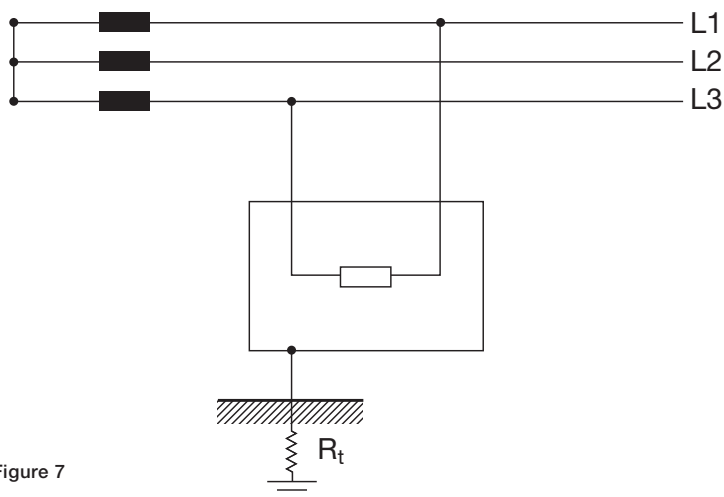


Figure 7

The earth fault current returns to the power supply node through the earthing arrangement of the exposed conductors and the line conductors earth capacities.

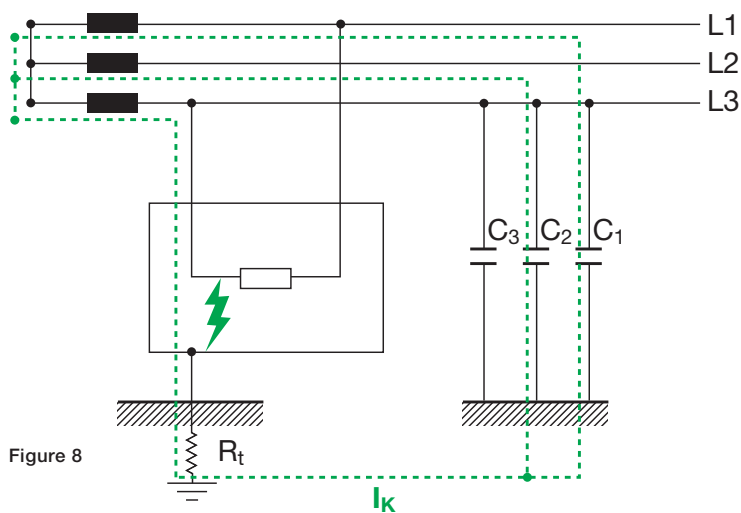


Figure 8

Protection against earth faults

Classification of electrical distribution systems

Summarising:

Distribution system	Main application	Typical value of the fault currents	Remarks
TT	domestic installations and similar; small industries with LV power supply	10÷100 A	TT distribution systems are used when assuring the distribution of the protective conductor (PE) is impossible and when it is advisable to leave to the user the responsibility for the protection against indirect contact
TN	industries and big installations with MV power supply	values similar to those of the single-phase fault	TN distribution systems are the systems through which power supply is distributed to users having their own transformer substation; in these cases, the protective conductor can be easily ensured
IT	chemical and petrochemical industries, i.e. plants for which service continuity is fundamental	$\mu\text{A} \div 2 \text{ A}$ dependent on the size of the installation; in case of double earth fault, the fault current takes values typical of TT or TN systems depending on the connection of the exposed conductors to earth	This type of system is particularly suitable for the cases in which service continuity must be assured since the presence of a first fault does not cause high currents and/or currents dangerous for people

Use of RCDs in different electrical distribution systems

- **TN system.** RCDs are mainly used in this system for protection against direct contact, and they also provide protection against indirect contact. The rated residual operating current of RCDs intended for protection against direct contact must not exceed 30mA. RCDs are recommended for very long circuits on TN systems.
- **TT system.** The TT system differs from the TN-C-S system in that there is no connection between the protective earth conductor (PE) and the neutral, and instead protection relies on local earth electrodes. Resultant impedances in the earth return path between the load and the origin of the supply may prevent the operation of overcurrent protection devices in the event of an earth fault. This can result in bonded metalwork reaching voltages dangerous to the touch and also give rise to fire hazards due to the sustained flow of earth fault currents if the overcurrent protection device fails to operate.
The use of RCDs on TT systems for earth fault protection is therefore compulsory in all cases. RCDs are used to provide protection against Direct Contact and Indirect Contact in TT systems.
- **IT system.** Generally used where continuity of supply is required. The use of IT systems is confined to special applications such as hospital operating theatres, mines, etc., where continuity of supply under a first earth fault condition is of paramount importance. IT systems are characterised by the absence of a direct connection of the supply to earth or connection to earth via a relatively high impedance which negates the use of RCDs on such systems. In IT system the first fault to earth should not cause any disconnections, while on the appearance of the second fault a quick disconnection becomes a must. RCDs are suitable for disconnections in case of second faults.

Residual current protective devices

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Residual current protective devices

Reference standard for RCDs use

3

Founded in 1906, the IEC (International Electrotechnical Commission) is the world's leading organization for the preparation and publication of International Standards for all electrical, electronic and related technologies. These are known collectively as “electrotechnology”.

All IEC International Standards are fully consensus-based and represent the needs of key stakeholders of every nation participating in IEC work. Every member has one vote and a say in what goes into an IEC International Standard. IEC standards are recognised by almost all countries in the world.

The IEC standard is covered in Europe by CENELEC (European Committee for Electrical Standardisation) which publishes the relevant EN standards. Every nation, referring to the CENELEC, transposes and translates EN standards into national standards.

Standard IEC 60364 “Electrical Installations for Buildings” is today the main reference for Low-voltage electrical installations around the world.

The requirements in term of protection remain its fundamental basis.

The standard has been adopted by many countries, as-is or with local adaptations. Habits and regulations differ widely from country to country. Internally, the standards are different in Europe.

At present, Residual Current Devices are mandatory in almost all parts of the world.



International Electrotechnical Commission:
IEC standard



European Committee for Electrotechnical Standardisation:
EN standard

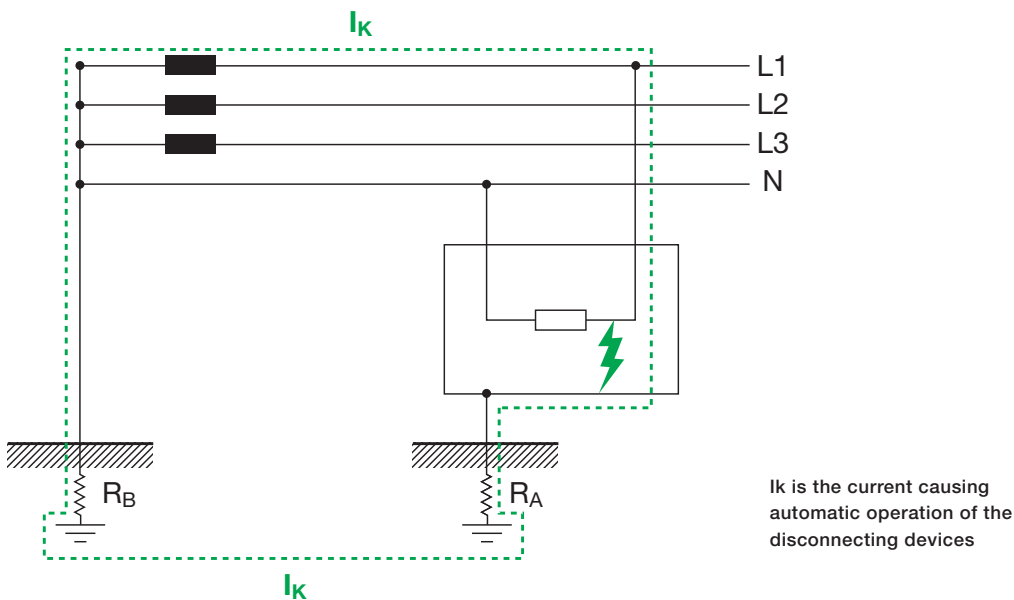
Every nation, referring to the CENELEC, transposes and translates EN standards into national standards.

Residual current protective devices

Protection with RCDs

TT system

According to IEC 60364-4 requirements, the protective devices must be coordinated with the earthing arrangement.



Protection by automatic disconnection of the supply used in TT system is with RCDs of sensitivity:

$$I_{\Delta n} \leq \frac{50 \text{ V}}{R_A}$$

Where:

- R_A is the resistance of the earth electrode for the installation [Ω]
- $I_{\Delta n}$ is the rated residual operating current of the RCD

For temporary supplies (to work sites, ...) and agricultural and horticultural premises, the value of 50 V is replaced by 25 V.

The tripping times of RCDs are generally lower than those required in the majority of national standards. The IEC 60364-4-41 specifies the maximum operating time of protective devices used in TT system for protection against indirect contact as:

- For all final circuits with a rated current not exceeding 32 A, the maximum disconnecting time will not exceed the values indicated here below:

U_o^1 [V]	T [s]
$50 < U_o \leq 120$	0.3
$120 < U_o \leq 230$	0.2
$230 < U_o \leq 400$	0.07
$U_o > 400$	0.04

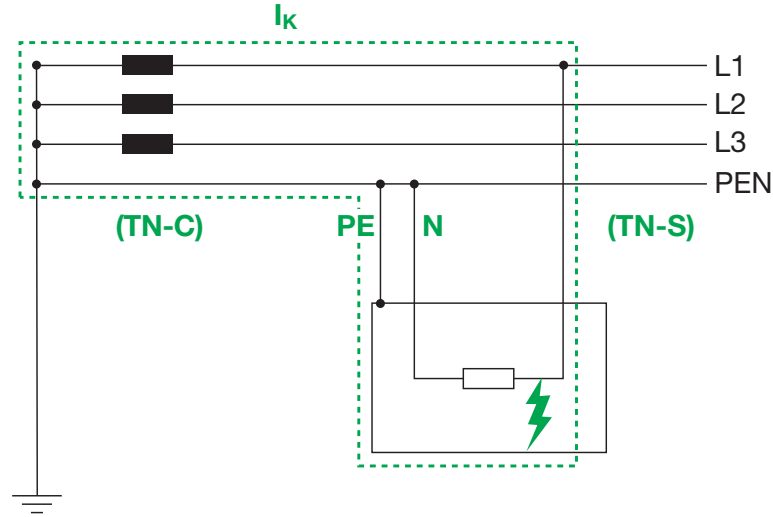
¹ U_o is the nominal phase to earth voltage

Residual current protective devices

Protection with RCDs

3

TN system



I_k is the current causing the automatic operation of the disconnecting devices

To provide a protection for TN systems with automatic disconnection of the circuit, according to IEC 60364-4 requirements, the following condition shall be fulfilled:

$$Z_s \times I_a \leq U_o$$

Where:

- Z_s is the impedance of the fault loop comprising the source, the live conductor up to the point of the fault and the protective conductor between the point of the fault and the source [Ω];
- U_o is the nominal a.c. r.m.s. voltage to earth [V]
- I_a is the current causing the automatic operation of the disconnecting protective device

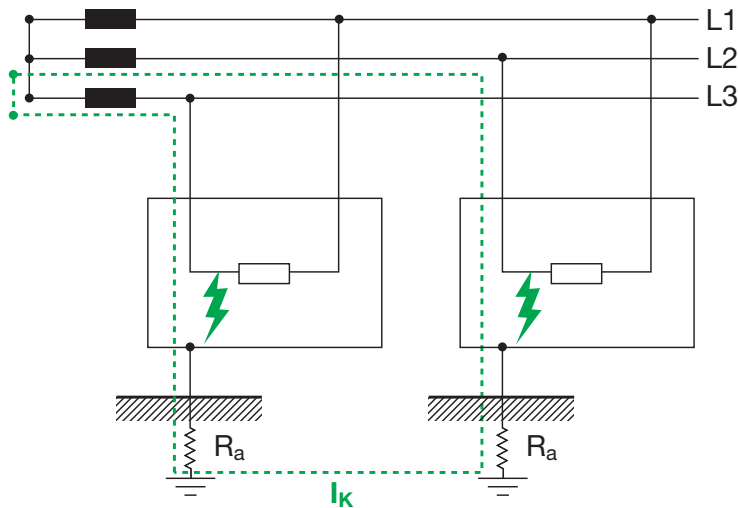
IEC 60364-4-41 specifies the maximum operating time of protective devices used in TN system for protection against indirect contact:

For all final circuits with a rated current not exceeding 32 A, the maximum disconnecting time will not exceed the values indicated in the table below:

U_o ¹ [V]	T [s]
$50 < U_o \leq 120$	0.8
$120 < U_o \leq 230$	0.4
$230 < U_o \leq 400$	0.2
$U_o > 400$	0.1

¹ U_o is the nominal phase to earth voltage

IT system (second fault)



I_k is the current causing the automatic operation of the disconnecting devices

A second earth fault on an IT system (unless occurring on the same conductor as the first fault) results in a phase-phase or phase-to-neutral fault, and whether occurring on the same circuit as the first fault, or on a different circuit, overcurrent protective devices would normally operate an automatic fault clearance.

$$I_k = U_r / R_t$$

Where:

- R_t is the total resistance, equal to the sum of the earth electrode (R_a) and the protective conductor for the exposed conductive parts [Ω];
- U_r is the rated voltage between phases [V]

Disconnecting times for IT system depends on how the different installation and substation earth electrodes are interconnected.

For final circuits supplying electrical equipment with a rated current not exceeding 32 A and having their exposed conductors bonded with the substation earth electrode, the maximum tripping time is given in the table below:

U_o ¹ [V]	T [s]
$50 < U_o \leq 120$	0.8
$120 < U_o \leq 230$	0.4
$230 < U_o \leq 400$	0.2
$U_o > 400$	0.1

¹ U_o is the nominal phase to earth voltage

Residual current protective devices

Protection with RCDs

3

Standards for electrical installations with RCDs

Standards IEC	Application	Required $I_{\Delta n}$ [mA]	Recommended RCD	
			A/AC type	B type
60364-4-41	protection against electric shock	30...500	■	■
	socket outlets up to 20 A, outdoor installations	10...30	■	
60364-4-482	fire protection against special risks or hazards	30 and 300	■	■
60364-5-551	low-voltage power generating installations	10...30	■	
60364-7-701	rooms with bathtubs or showers, outlets in zone 3	10...30	■	
60364-7-702	swimming pools and other pools	10...30	■	
60364-7-703	rooms with cabins with sauna heating	10...30	■	
60364-7-704	construction sites, socket outlet circuits up to 32 A and for hand-held equipment, plug-and-socket devices up to $I_n > 32$ A	≤ 300	■	■
		≤ 500	■	■
60364-7-705	agricultural and general horticultural premises, socket outlet circuits	≤ 300	■	
		10...30	■	
60364-7-706	conductive areas with limited freedom of movement	10...30	■	
60364-7-708	electrical equipment on camping sites, each socket outlet individually	10...30	■	
60364-7-712	solar PV power supply systems (without a simple means of disconnection)	≤ 300		■

Residual current protective devices

Standard of RCDs

The relevant standards covering RCD products are as follows:

- IEC 61008-1: Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) - General rules
- IEC 61009-1: Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) - General rules
- IEC 60947-2: Low Voltage Switchgear and Controlgear – Circuit Breakers
 - Annex B, Circuit Breakers Incorporating Residual Current Devices
 - Annex M, earth leakage relay
- IEC 62423 ed.2: Type F and type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses
- IEC 62020: Electrical accessories - Residual current monitors for household and similar uses (RCMs)
- IEC/TR 60755 ed 2: General requirements for residual current operated protective devices
- IEC/TR 62350: Guidance for the correct use of residual current-operated protective devices (RCDs) for household and similar use

Residual current protective devices

Types of RCDs

3

The following devices are all RCDs, equipped with additional functions and features, offering cost effective solutions in different applications.

Residual Current Circuit breaker (RCCB)

This device is essentially a mechanical switch with the residual current tripping characteristic attached to it. So basically it breaks the circuit only when there is a leakage current flowing to earth. The tripping time is such as to minimise the risks for human life.

As RCCBs are unable to detect or respond to overcurrents or short circuits, they must be connected in series with an overcurrent device such as a fuse or MCB (Miniature Circuit breaker). This gives the RCCB and the rest of the circuit the protection required to respond to overcurrents or short circuits.

RCCBs usually have a fault making and breaking capacity of 1 kA. This means that they can manage a fault of 1 kA on their own if it is a fault to earth. For overloads and line to neutral short circuits, the Wiring Rules require additional devices to provide protection. The device used for short circuit protection may improve the short circuit rating of the RCCB when they operate together. This allows an RCCB rated at, for example, 1000 A to be used in circuits where the actual fault level is higher than 1000 A.

In summary, RCCBs provide earth leakage protection, however a major point to remember when applying them is that they must always be installed in conjunction with an appropriately rated Short Circuit Protective Device (SCPD).



Residual Current Circuit Breaker with Overload protection (RCBO)

This is a residual current device that has an MCB embedded in it. Therefore RCBO is the equivalent of an RCCB + MCB. The main functions that an RCBO is able to provide are:

- (a) Protection against earth fault currents;
- (b) Protection against overload and short-circuit currents

The best way to use an RCBO is to use one on each circuit, this way if one circuit exhibits a fault it will not affect the other circuits. As the price of these devices is dropping year by year, the RCBO is an effective way of protecting lives and the installation.



Earth leakage relay

This kind of residual current device has been designed to satisfy the requirements of industry. They suit three-phase circuits and high current loads. The residual current threshold and tripping delay is often adjustable, thus allowing selectivity among different circuit breakers. Earth leakage relays work in combination with a circuit breaker that opens the circuit in the case of a circuit breaker ground fault.

Phase and neutral conductors go through a toroidal transformer, creating a magnetic field proportional to its current.

In normal situations the vector sum of the currents is zero. In case of fault, the toroidal transformer detects the imbalance and sends a signal to the relay and compares it with the preset threshold value. The output contact of the relay is turned on when the fault detected value is higher than the preset threshold and lasts more than the preset tripping time value.

Earth leakage relay can be classified according to IEC 62020 or in the first case the relay is suitable for “monitoring” the circuit and providing information about the network’s insulation. In the second case the relay is appropriate to protect people against the effect of electric shock hazards.

According to new Annex M of IEC 60947-2, the Manufacturer of residual current relays must check and guarantee protection performance for the entire chain, composed by toroidal transformer+ relay+ shunt trip + circuit breakers.

In addition, they can be used only with circuit breakers certified by the manufacturer, who is responsible for the tripping time, considering the entire chain of components.

The devices according to this new standard are tested by the factory in “ready to use” configuration and they can make easier the installers’ work easier.



Residual current protective devices















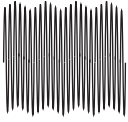
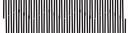

Types of wave form detected by RCDs and classification

Residual current protective devices are distinguished from one another in respect of their suitability for detecting different forms of residual current.

Below is a table giving RCD classification according to the waveform of the earth leakage currents:

- Type AC, sensitive to alternating current only
- Type A, sensitive to alternating and/or pulsating current with DC components
- Type B to provide protection in case of alternating residual sinusoidal currents up to 1.000 Hz, pulsating direct residual currents and smooth direct residual currents
- Type F, with rated frequency 50 Hz or 60 Hz are intended for installations when frequency inverters are supplied between phase and neutral or phase and earthed middle conductor and are able to provide protection in case of alternating residual sinusoidal at the rated frequency, pulsating direct residual currents and composite residual currents that may occur.

3

Current waveform	Proper functioning of residual current protective devices of type				Tripping current
	AC	A	F	B	
					
	■	■	■	■	0.5 to 1.0 I _{Δn}
	-	■	■	■	0.35 to 1.4 I _{Δn}
	-	■	■	■	Current delay angle 90°: 0.25 to 1.4 I _{Δn}
	-	■	■	■	Current delay angle 135°: 0.11 to 1.4 I _{Δn}
	-	■	■	■	max. 1.4 I _{Δn} + 6 mA
	-	-	■	■	max. 1.4 I _{Δn} + 10 mA
	-	-	■	■	0.5 to 1.4 I _{Δn}
	-	-	-	■	0.5 to 2.0 I _{Δn}
	-	-	-	■	
	-	-	-	■	
	-	-	-	■	Current frequency 150 Hz 0.5 to 2.4 I _{Δn}
	-	-	-	■	Current frequency 400 Hz 0.5 to 6 I _{Δn}
	-	-	-	■	Current frequency 1000 Hz 0.5 to 14 I _{Δn}

AC type RCDs are suitable for all systems where users have sinusoidal earth current. They are not sensitive to impulsive leakage currents up to a peak of 250 A (8/20 wave form) such as those which may occur due to overlapping voltage impulses on the mains (e.g.: switching of fluorescent bulbs, X-ray equipment, data processing systems and SCR controls).

A type RCDs are not sensitive to impulsive currents up to a peak of 250 A (8/20 wave form). They are particularly suitable for protecting systems in which the user equipment has electronic devices for rectifying the current or phase cutting adjustment of a physical quantity (speed temperature, light intensity etc.) supplied directly by the mains without the insertion of transformers and class I insulated (class II is, by definition, free of faults to earth). These devices may generate a pulsating fault current with DC components which the A type RCD can recognise.

In addition to detecting residual current waveforms of type A, residual current protective devices of type B are used to detect smooth DC residual currents. type B RCDs are recommended for use with drives and inverters for supplying motors for pumps, lifts, textile machines, machine tools etc., since they recognise a continuous fault current with a low level ripple. Tripping values defined up to 100 kHz.

Type AC and A RCDs comply with IEC 61008/61009; type B for RCDs is not mentioned in these reference standards: an international standard, IEC 62423, has been introduced in 2007, specifying additional requirements for type B RCDs.

This new standard, IEC 62423, should only be referred to together with IEC 61008-1 (for RCCBs) and IEC 61009-1 (for RCD-blocks and RCBOs), this means that B type RCDs must be compliant with all the requirements of IEC 61008/9.

In addition there are other two type of RCDs according to the wave form of the earth leakage currents:

- Type F
- Type B+

Type F RCDs are for loads with single-phase inverters and similar equipment (e.g. modern washing machines), as an extension of type A.

or type F RCDs, additional tests have been added to those for type A, in order to simulate the ground fault in presence of a single phase inverter.

Type F is characterised by a strong immunity to unwanted tripping.

Type F RCDs are not sensitive to impulsive currents up to a peak of 3,000A (8/20 wave form).

Type F RCDs give better protection with the spread of modern electronic appliances in domestic installations, where type A RCDs could not properly cover them. It effectively fixes, in an "official" way, the problem of unwanted tripping with a non-selective RCD.

In IEC 61008-1 and IEC 61009-1 (RCDs for household and similar applications) only type AC and A RCDs are covered, types F and B are not mentioned. IEC 62423 ed. 2 covers both type F and B RCDs and it can only be used together with IEC 61008-1 and IEC 61009-1.

At the moment, type B+ are only introduced in a DIN VDE 0664-100 specification applicable in Germany. Like type B residual current protection devices, type B+ residual current protection devices are suitable for use in alternating current systems. Tripping conditions for type B+ residual current protection devices are defined at up to 20 kHz and lie within this frequency range below a tripping value of 420 mA. Type B+ are mostly used to prevent fire protection risk as they are recommended by the Association of German Insurance Companies.

Residual current protective devices

Types of wave form detected by RCDs and classification

In summary, to choose the right type of Residual current device, two different aspects must be considered:

1)The type of protection required:

Type of RCD	Type of protection		
	protection against indirect contacts (if I _{dn} is coordinated with ground system)	additional protection (if I _{dn} < 30 mA)	protection against fire risk (if I _{dn} < 300 mA)
AC	■	■	■
A	■	■	■
F	■	■	■
B	■	■	■
A S (selective)	■		■
B S (selective)	■		■

2)The type of fault current wave form:

Type of RCD	Types of wave form detected by RCDs				
	alternating current 50/60Hz	alternating current up to 1000 Hz	pulsating current with DC components	multifrequency current generated by the single-phase inverter	multifrequency current generated by the three-phase inverter
AC	■				
A	■		■		
F	■		■	■	
B	■	■	■	■	■
A S (selective)	■		■		
B S (selective)	■	■	■	■	■

Residual current protective devices

RCDs with or without switched neutral

Advantage of RCDs with switched neutral

If a neutral to earth fault occurs in a circuit fed through an RCBO with a solid neutral which is backed up by an upstream selective RCD, the selectivity or discrimination will be lost and the main RCD will also trip as it will still detect the fault which has not been resolved.

The main requirements of RCD protection are:

- Additional protection against direct contact with live parts
- Protection against direct connection with live parts
- Protection against fire in the case of a fault to earth

If a fault occurs between neutral and earth where a solid RCBO is protecting a circuit, the RCBO will trip. However, as previously stated, the fault will still be in the circuit within the rest of the installation.

As the neutral will be common through the installation, it is possible that current could still flow through the fault and lead to a fire hazard. This would mean that the RCBO would not offer full protection against fire and therefore does not comply with one of its main protection requirements.

Testing of outgoing circuits is easier with RCBOs incorporating a switched neutral as an electrician does not have to disconnect terminals before testing.



DS271: example of RCBO without switched neutral (solid neutral)



DS201 and DSN201: examples of RCBO with switched neutral

Residual current protective devices

Difference between voltage dependent and voltage independent

3

Voltage Independent RCD

Voltage independent RCDs use the energy of the earth fault current to trip the mechanism directly. In this type of RCD, the output from the sensing coil operates a specially constructed magnetic relay and so releases the RCD mechanism, independently of the mains voltage. Voltage independent RCDs normally use a polarised (field weakening) relay construction. This operates by cancellation of the permanent magnetic flux (which holds the relay ON) by the excitation flux (produced by the fault current). This can only occur in one half-cycle of the a.c. supply because the magnetic flux will be reinforced in the other half cycle. Operating times can vary from 20 to 120 ms at rated tripping current.

Voltage Dependent RCD

Voltage dependent RCDs generally employ an electronic amplifier to provide an enhanced signal from the sensing coil to operate a trip solenoid or relay. RCDs of this type are defined as “voltage dependent” because they rely on a voltage source, derived from the mains supply, or an auxiliary supply, the amplifier with power. The basic principle of operation is, however, the same as voltage independent RCDs.

What are the advantages of voltage independent RCDs?

Loss of neutral

The loss of neutral may happen for several reasons and it can occur anywhere (unless we are in a TN-C system!), both in multiphase and phase to neutral supply lines.

The causes of unwanted interruptions to the neutral conductor can be: defective breakers that do not close the neutral pole properly, loose connections, works on electrical lines or nearby electrical conductors etc.

In case of loss of the neutral, hazardous voltage is still present but voltage dependent RCDs cannot trip in case of fault, with risk for human life.

It is commonly said that the probability of loss of the neutral is negligible. Cenelec has prepared a new standard for a new kind of protective device: protection against power frequency overvoltages (POP devices), that are mainly caused by the loss of neutral in the upstream three-phase supply. This kind of protection has been asked vividly by public utilities and by a raising awareness of the market itself.

Generally, it is said that loss of neutral conductor in a phase to neutral network is not a risk because nothing works, and even unskilled users understand that something is wrong with it and an electrician must be called. This is not true. Firstly because an unskilled user can believe that, if the installation is without supply, it is in a very safe condition, while it is not. Secondly, because in an installation you can have separate RCDs for several terminal circuits (as requested in some new national rules) and every appliance works correctly except a single one (e.g. washing machine), that is not protected and it is in a dangerous state. A voltage independent RCD is able to detect a fault current also in the absence of neutral. For all these reasons, ABB warns not to underrate risks concerning electrical installation and it is committed to provide the best solutions in terms of safety, reliability and operational continuity.

Loss of a wire for multi-phase RCD

This case is worse than the previous one.

The probability of interruption of the “wrong” phase conductor and/or neutral conductor is much higher than the loss of the neutral conductor only. Voltage dependent RCDs cannot trip, while loads supplied by not interrupted conductors will work properly. The user cannot see any evidence of the problem. This situation is extremely deceptive!

Undervoltage of supply lines

According to the present standard, voltage dependent RCDs are required to work with a minimum voltage of 85% of the rated supply voltage.

Undervoltages can be caused by different reasons.

If the supply voltage falls to a value lower than the operating value of the voltage dependent RCD and greater than a dangerous level (50 V), the RCD will not trip but the risk of dangerous faults is present. Voltage independent RCDs work properly regardless of the actual supply voltage.

ADDITIONAL TOPICS:

Transient overvoltages (or power frequency overvoltages, see above, POP device)

This kind of overvoltage can damage voltage dependent RCDs.

Voltage independent RCDs do not have problems with transient overvoltages.

Are voltage dependent RCDs less subject to unwanted tripping?

Unwanted tripping of RCDs is a problem which is increasing all over the world for a lot of different reasons.

According to ABB's experience in countries where voltage dependent RCDs are common, this kind of RCD also has this problem. In product standards for RCD, tests against unwanted tripping are the same both for voltage dependent and voltage independent RCDs.

All the principal manufacturers have developed special voltage independent RCDs with extremely high immunity against unwanted tripping. In the ABB catalogue, these RCDs are called "APR" type. According to our long experience, APR RCDs can eliminate 99.9% of unwanted tripping! Unfortunately there is not a classification in IEC or EN standards for these RCDs (the only exception is in Austrian national standard: they are called "Type G").

Voltage dependent RCDs have a power dissipation even without any load (this is similar to "standby" power dissipation)

Even if this power dissipation seems to be very low, it is not negligible, especially if you have several voltage dependent RCDs in the installation. This is not in line with modern philosophy of energy saving which avoids any unnecessary power consumption.

- With a few exceptions, in countries where voltage dependent RCDs are commonly used, the earthing system of public distribution is TN. In TN systems, earth fault current is very high as a short circuit current. So, if for any reason an RCD does not trip, the earth fault current makes the overcurrent protection (MCB or fuse) trip. In TT and IT systems, the earth fault current is low and only RCDs can break it.
- In IEC 61008/9 product standard for RCDs, voltage dependent RCDs are not included. In fact IEC 61008/9 is composed by Part 1 (general requirements) and by two Parts 2: 2.1 (voltage independent RCDs), and 2.2 (voltage dependent RCDs). Part 2.2 does not exist as an EN standard. As Part 1 cannot be used without Part 2.1 or Part 2.2, only voltage independent RCDs are included in IEC 61008/9.

Residual current protective devices

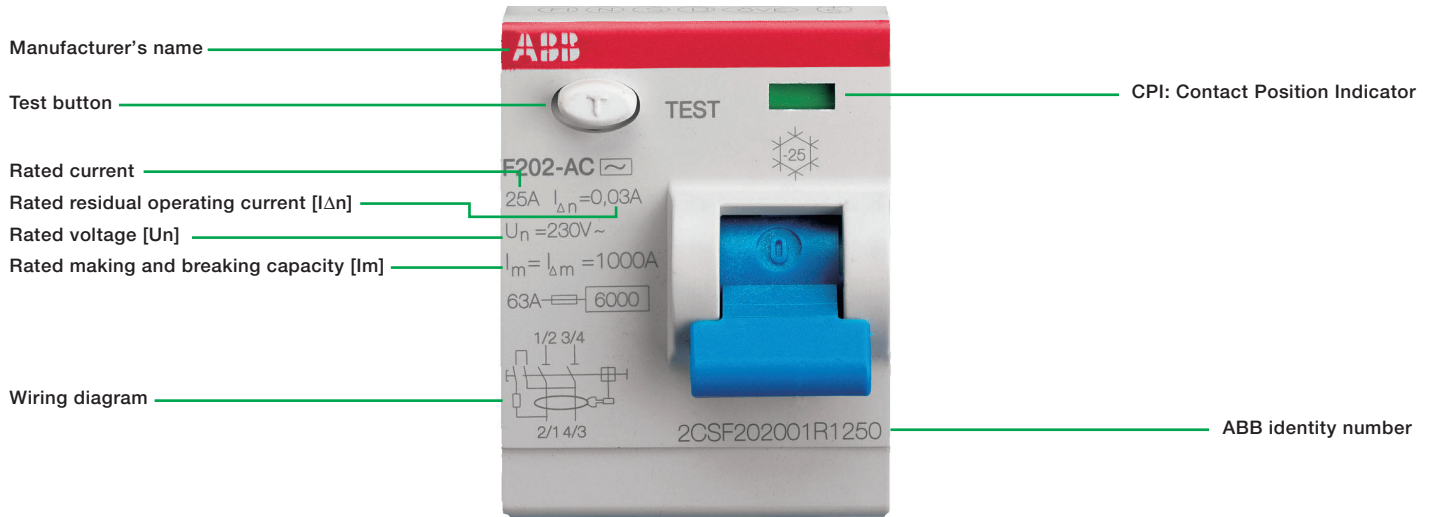
Marking on RCDs

3

Each RCCB must be marked with a lot of technical data. The typical features that must be marked on devices, according to the Standards, are:

- Rated operational voltage (U_e): the rated operational voltage of a RCCB is the value of the voltage, assigned by ABB, to which its performance is referred.
- Rated current (I_n): the value of current, assigned to the RCCB by ABB, which the RCCB can carry in uninterrupted duty.
- Rated residual operating current ($I_{\Delta n}$): the value of residual operating current assigned to the RCCB, at which the RCCB shall operate under specified conditions.
- Rated frequency: the rated frequency of a RCCB is the power frequency for which the RCCB is designed and to which the values of the other characteristics correspond.
- Rated making and breaking capacity (I_m): The r.m.s. value of the a.c. component of prospective current which a RCCB can make, carry and break under specified conditions.

An example of a RCCB: F202 AC 25/0,03



Residual current protective devices

Test button

To check if you have RCD protection in your consumer unit, look to see if there is a device with a pushbutton marked 'T' or 'Test'. This 'test' button is part of an RCD.

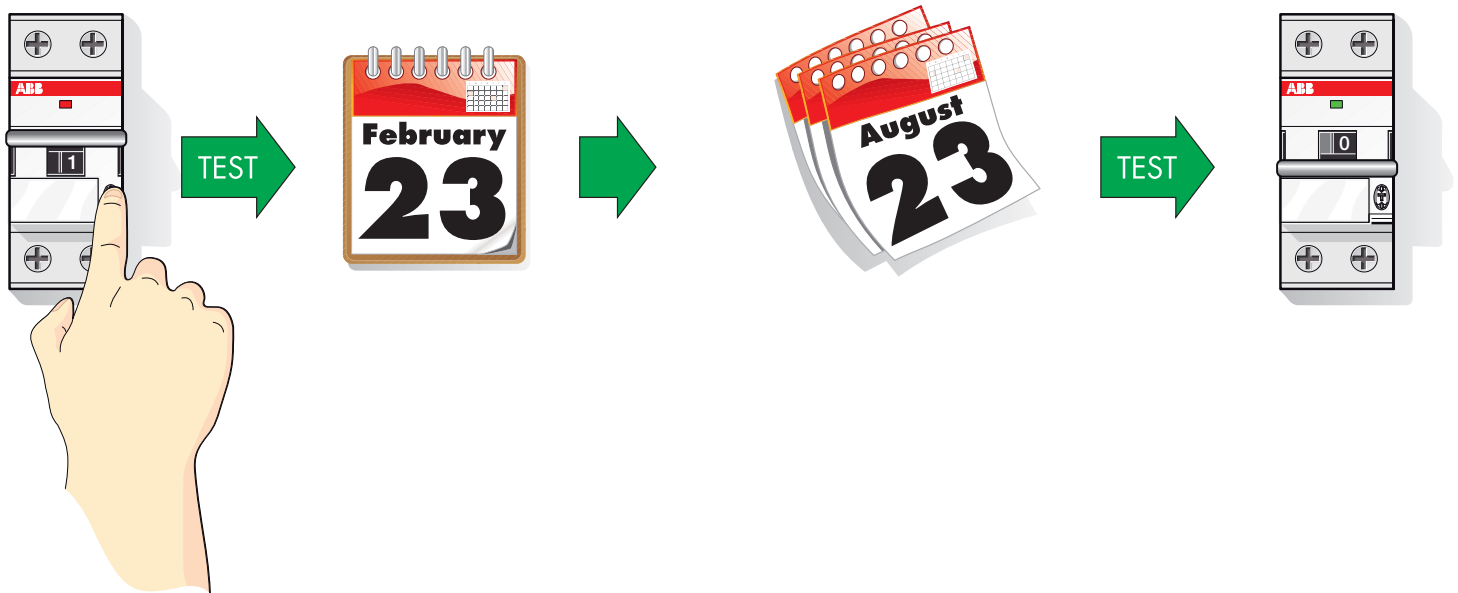
If you have an RCD, you should check that it is functioning properly by pushing the test button periodically. When tested, the RCD should switch off the power to the areas of the home it protects.

The RCDs in your consumer unit may not cover everything in your home, such as the lighting circuits, so it is a good idea to check - while the RCD is off - which sockets and lights are no longer working, showing that they are protected by that RCD.

Switch the RCD back on to restore the supply.

If your RCD does not switch off the electricity supply to the protected circuits when the test button is pressed, or if it does not reset, get advice from a registered electrician.

If you do not have RCD protection fitted in your consumer unit, it is strongly suggested to protect yourself by contacting an installer to ask for it because if you damage a hidden cable when fixing something to a wall, you won't be protected against electric shock unless you have an RCD in your consumer unit protecting that circuit.



Solutions for protection against earth fault currents

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Solutions for protection against earth fault currents

ABB's range

4

In most electrical systems, reliable and safe protection is implemented by combining the protection functions against overcurrent with those against earth faults, together with an effective earthing arrangement.

This choice, aside from protection against indirect contact, also provides reliable and timely protection against earth faults of small value where prevention from fire risks is absolutely necessary.

The proper choice of protection devices must provide for tripping selectivity against earth faults as well as that against overcurrents.

In order to fulfil the requirements for adequate protection against earth faults, ABB SACE has designed the following product categories:

- RCBOs (residual current operated circuit-breakers with integral overcurrent protection) DS201-DS202C series with rated current from 6 A up to 40 A;
- RCCBs (residual current circuit-breakers) F200 type, with rated current from 16 A to 125 A.
- RCBOs (residual current operated circuit-breakers with integral overcurrent protection) DS200 with rated current from 6A up to 63A;
- RCD blocks (residual current blocks) DDA 200 type to be coupled with type S200 thermal magnetic circuit-breakers with rated current from 0.5 A to 63 A;
- RCD blocks (residual current blocks) DDA 800 type to be coupled with type S800B, S800N and S800S thermal magnetic circuit-breakers with rated current up to 100 A. These blocks are available in two sizes: 63 A and 100 A;

	$I_{\Delta n}$ [A]	DDA200	DDA800
S200	0.5÷63	■	-
S800	6÷100	-	■

- The RD DIN rail series are residual current relays with an external toroidal transformer can detect leakage currents and it is possible to set selectivity and intervention time.
- The ELR series are front panel residual current relays. ELR allows monitoring and protection of the low voltage distribution network through the use of toroidal transformers.
- Electronic RCBOs series DS271, DSN201. In only one module width, these DIN rail residual current circuit-breakers with overcurrent protection offer a technologically advanced and comprehensive range with outstanding features, sizes, tripping characteristics and accessories.

RCBOs: DS201-D202C series

To meet the demand for devices capable of realising complete protection of modern plant circuits, ABB expands the offering of its System pro *M* compact® with new residual current circuit-breakers with overcurrent protection, both available in two modules DS201 (1 phase + neutral) and DS202C (2 phases).

The DS201 series replaces the current range of 1P+N RCBOs and combines protection against overcurrent and earth fault currents in a single device. The range is available in three versions: DS201 L (with 4.5 kA breaking capacity), DS201 (with 6 kA breaking capacity) and DS201 M (with 10 kA breaking capacity), in compliance with the IEC 61009 standard.

The DS202C series combines protection against earth-fault current and overcurrent in a single device, guaranteeing high breaking capacities (6 kA with DS202C and 10 kA with DS202C M), in compliance with the IEC 61009 standard.



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Residual current circuit breakers with overcurrent protection

Standard	IEC 61009
Family name	DS201 - DS202C
Number of poles	1p+N, 2P
Rated current [A]	1, 2, 4, 6, 8, 10, 13, 16, 20, 25, 32, 40
Sensitivity [mA]	10, 30, 100, 300, 1000
Type	A, AC, APR
Breaking capacities I _{cn} [A]	4500 (DS201 L) 6000 (DS201 - DS202C) 10000 (DS201 M - DS202C M)
Tripping curves	B, C, K

RCCBs: F200 series

RCCBs F200 are suitable in many fields from residential to commercial.

They offer protection from indirect contact and, thanks to the availability of 10 and 30 mA sensitivities, they ensure additional protection against direct contact.

The availability of high rated currents (80, 100 and 125 A) also makes F200 RCCBs suitable for industrial applications.



RCCBs (residual current circuit breakers)

Standard	IEC 61008
Family name	F200
Number of poles	2P, 4P
Rated current [A]	16, 25, 40, 63, 80, 100, 125
Sensitivity [mA]	10, 30, 100, 300, 500
Type	A, AC, B, B+, APR (A), Selective (A, B, B+)
Special versions	400 Hz, 16 2/3 Hz, B PV

Solutions for protection against earth fault currents

ABB's range



4

RCBOs: DS200 series

RCBOs combine protection against both earth-fault currents and overloads or short-circuits in a single device. DS200 series are mainly used in commercial/industrial applications.

Residual current circuit breakers with overcurrent protection

Standard	IEC 61009
Family name	DS202 - DS203 - DS204
Number of poles	2P, 3P, 4P
Rated current [A]	6, 10, 13, 16, 20, 25, 32, 40, 50, 63
Sensitivity [mA]	30
Type	A, AC
Breaking capacities I _{cn} [A]	6000 (DS202 - DS203 - DS204) 10000 (DS202M - DS203M - DS204M)
Tripping curves	B, C, K



RCD blocks: DDA200 series

DDA200 blocks fit on the left-hand side of S200 MCBs allowing complete accessorisation for the MCB.

RCDs blocks

Standard	IEC/EN 61009 Annex G
Family name	DDA200
Number of poles	2P, 3P, 4P
Rated current [A]	25, 40, 63
Sensitivity [mA]	10, 30, 100, 300, 500, 1000, 2000
Type	A, AC, B, APR (A), Selective (A, B)
Special versions	AE (emergency stop), 110 V and 400 V (A and AC type)
To be used in conjunction with S200 MCBs (with equal or lower rated current)	

RCD blocks: DDA 800 series

For assembly with MCBs S800 B, S800 N and S800 S the DDA 800 RCD blocks are available in the following types: AC, A, A selective and A APR (RCD-blocks resistant to unwanted tripping).



RCDs blocks	
Standard	IEC 90947-2 Annex B
Family name	DDA800
Number of poles	2P, 3P, 4P
Rated current [A]	63, 100
Sensitivity [mA]	30, 300, 500, 1000
Type	A, AC, APR (A), Selective (A)
To be used in conjunction with S800 MCBs (with equal or lower rated current)	

Residual current relays: RD series

RD2 RESIDUAL CURRENT MONITORS

RD2 residual current relay with external toroidal transformer is able to detect leakage current. It is possible to set sensitivity and intervention time. According to the IEC 62020 Standard, this relay is "Type A".



Residual current relays with external toroids	
Standard	IEC 62020
Family name	RD2
Sensitivity	from 30 mA up to 2 A
Intervention time settings	from 0 s (instantaneous) up to 5 s
Features	Test push-button
	Reset push-button
	Green "ON" LED that signals power supply presence
	Red "TRIP" LED that signals relay operation
	1 output contact
Rated supply voltage	RD2: 230...400 V a.c.
	RD2-48: 48...150 V a.c./d.c.

Solutions for protection against earth fault currents

ABB's range



4

RD3 RESIDUAL CURRENT RELAY

RD3 provides residual current protection according to IEC/EN 60947-2 Annex-M.

They can be used in conjunction with all S200 automatic devices and Tmax range moulded case circuit breakers up to T5.

RD3 has two different output contacts in order to give indications about residual current status.

Residual current relays with external toroids

Standard	IEC 60947-2 Annex M
Family name	RD3
Sensitivity	from 30 mA up to 30 A
Intervention time settings	from 0 s (instantaneous) up to 10 s
Features	Test push-button Reset push-button Green "ON" LED that signals power supply presence Red "TRIP" LED that signals relay operation 2 output contacts
Rated supply voltage	RD3: 230...400 V a.c. RD3-48: 12...48 V a.c./d.c.

Three different products belong to the RD3 family

RD3	two output contacts, remote reset, removable terminals (plug-in)
RD3 M	like RD3 + pre-alarm setting + frequency filter
RD3 P	like RD3 M + IDn% LED bar + autoreset setting + no trip test function



Front panel residual current relays: ELR series

Front panel residual current relays are electronic devices used in combination with an external toroidal transformer. They are according to the protection standard IEC 60947-2 Annex-M.

Residual current relays with external toroids

		ELR48P	ELR72	ELR72P	ELR96	ELR96P	ELR96PF	ELR96PD
Operating voltage	[V]	24, 48, 110, 230 a.c./24, 48, 115 d.c.	24, 48, 110, 230 a.c./24, 48, 110 d.c.	24, 48, 110, 230 a.c./24, 48, 115 d.c.	24, 48, 230, 400 a.c./24, 48 d.c.	24, 48, 230, 400 a.c./24, 48 d.c.	110, 230, 400 a.c.	110, 230, 400 a.c.
Frequency filter		-	-	-	-	-	Yes	Yes
Type		A						
Sensitivity setting	[A]	from 0.03 to 30						
Tripping time setting Δt	[s]	from 0 to 5						
Contacts	[no.]	2	1	2	1	2	2	2
Contact capacity	[A]	5 (250 V a.c.)						
Dimensions	[mm]	48x48	72x722	72x72	96x96	96x96	96x96	96x96
Digital display		-	-	-	-	-	-	Yes
Standards		IEC 60947-2 Annex M						

Electronic RCBOs: DS271, DSN201 series

ABB offer an electronic 1P+N RCBO in one module width.

This product combines a voltage dependent residual current device and overcurrent protection in one module width. The contact configuration consists of a switched pole and a let-through (solid) neutral. The neutral is not sectioned. This product has functional earth wiring. Supply must be on the bottom side by means of a terminal (for the phase) and via cable for the neutral. Load side is on the top of the device.

The neutral supply cable is blue and the FE cable is white.

DS271

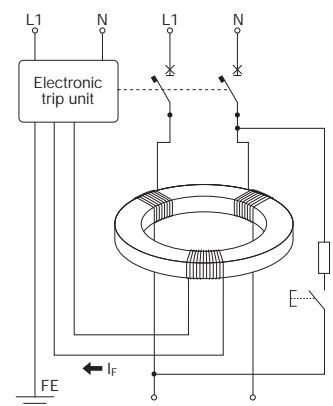
Residual current circuit breakers with overcurrent protection

Standard	IEC 61009, BSEN 61009-2-2
Family name	DS271
Number of poles	1P+N
Rated current [A]	6, 10, 16, 20, 25, 32, 40
Sensitivity [mA]	10, 30, 100, 300
Type	A, AC
Breaking capacities I _{cn} [A]	10000
Tripping curves	B, C

DSN201

Residual current circuit breakers with overcurrent protection

Standard	IEC 61009, AS/NZS 61009-1
Family name	DSN201
Number of poles	1P+N
Rated current I _n [A]	6...25
Sensitivity I _{Δn} [mA]	10, 30
Type	A, AC
Breaking capacities, to IEC IEC 61009-1 I _{cn} [A]	6000
Tripping curves	C



Solutions for protection against earth fault current

ABB RCDs with special versions



4

The increasing usage of power electronics embedded in earthed devices may generate leakage currents that include a significant direct current or high frequency component that may affect the reliability of standard type AC or type B residual current devices.

In order to get through this, type B residual current devices were introduced. They can assure higher protection levels with the maximum operational continuity under whatever working condition. For this reason, type B RCDs are considered universal devices because they provide protection against all the tripping waveforms listed in the Standards EN 62423

Type B RCDs are suitable for non-linear circuits that are able to generate leakages with high direct current (higher than 6 mA) and/or high frequency components. The main circuits that shall be considered responsible for such leakages are:

- Single-phase or poly-phase rectifiers
- Rectifiers with high levelling capacity
- Rectifiers with active correction of the power factor
- Continuous voltage generator with no separation from a.c. networks (es. pannelli fotovoltaici)
- inverter at variable frequency

The main loads that include the above mentioned circuits are:

- motor starters at variable frequency with three-phase supply (industrial machine, lifts and elevators,...)
- Photovoltaic plants
- UPS
- Recharging stations for electrical vehicles
- Frequency converter,
- Radiological machines (TAC, RMN,...)

RCDs against unwanted tripping

APR type RCDs fit all applications where it is necessary to ensure safety and continuity of supply while preventing unwanted tripping.

Tripping should be considered “unwanted” when the RCD trips without presence of an earth fault current or direct contact of a person with the live part.

Typical causes of unwanted RCD tripping could be:

- presence of leakage current with modest value but with high level of harmonics or high frequency;
- presence of transient impulsive currents (e.g. usually caused opening and closing of capacitive or inductive loads);
- overvoltages caused by lightning;
- transient impulsive currents added to permanent leakage currents already present (eg. caused by electronic devices).

According to IEC/TR 62350 (“Guidance for the correct use of residual current-operated protective devices (RCDs) for household and similar”), the recommended solutions are:

- “installation” solution: split the installation into several different circuits, each of them protected by an RCD
- “product” solution: select RCDs which are more resistant to unwanted tripping, like ABB APR type RCDs

APR is more than ten times more resistant to unwanted tripping than standard types (both AC and A).

Selective types are more resistant than APR types but they cannot be made with sensitivity less than 100mA! (no additional protection against direct contact).



	Instantaneous	APR	Selective
Resistance to unwanted tripping caused by overvoltage (operation or atmospheric)	250	3000	5000
Peak value for 8/20µs “pulse wave”			

Selective (type S) RCDs

Selective RCDs have a delayed tripping action and are installed upstream of other rapid residual current operated circuit-breakers to guarantee selectivity and limit the power out only to the portion of the system affected by a fault. The tripping time is not adjustable. It is set according to a predetermined time – current characteristic with an intrinsic delay for small currents, tending to disappear as the current grows.

IEC 61008 and 61009 establish the tripping times relative to the type of RCD and the $I_{\Delta n}$.

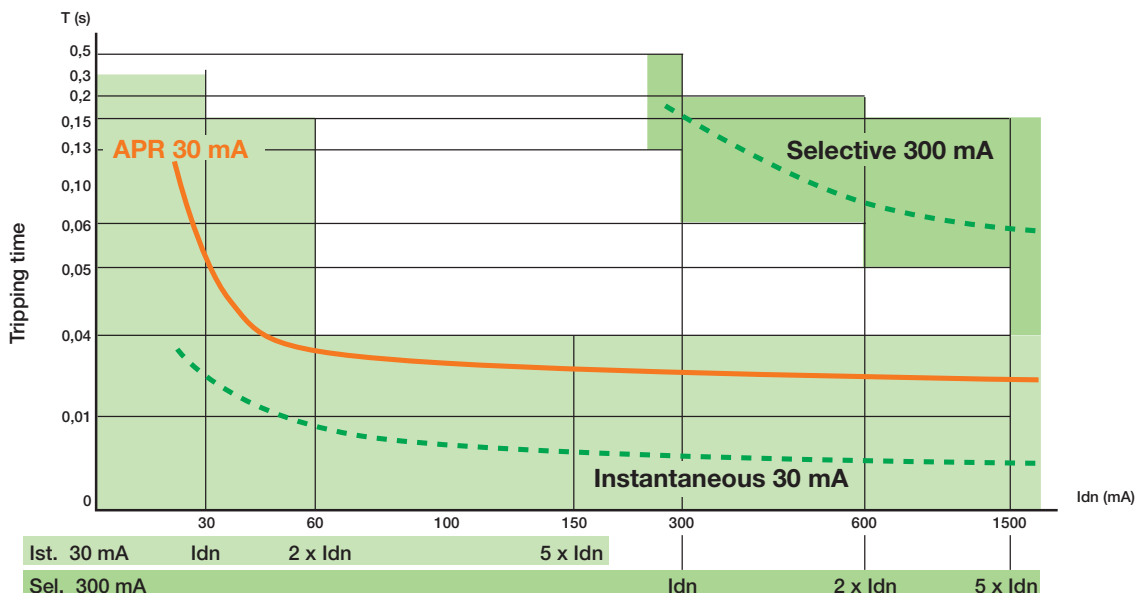
Type AC	I_n [A]	I_{Δ} [A]	Tripping times (s) x currents			
			$1 \times I_{\Delta}$	$1 \times I_{\Delta}$	$1 \times I_{\Delta}$	500 A
Generic	any	any	0.3	0.15	0.04	0.04
S (selective)	any	> 0.030	0.13-0.5	0.06-0.2	0.05-0.15	0.04-0.15

The indicated maximum tripping times are also valid for A type RCDs, but increasing the current values by a factor of 1.4 for RCDs with $I_{\Delta n} > 0.01$ A and of factor 2 for RCDs with $I_{\Delta n} \leq 0.01$

The range of ABB RCDs also includes APR (anti-disturbance) devices which trip according to the limit times allowed by the Standards for instantaneous RCDs. This function is due to the slight tripping delay (approx. 10 ms) relative to the standard instantaneous ones.

The graph shows the comparison of the qualitative tripping curves for:

- a 30 mA instantaneous RCD
- a 30 mA APR instantaneous RCD
- a 100 mA selective RCD (type S)



Solutions for protection against earth fault currents

ABB RCDs with special versions



4

RCD-blocks type AE

Emergency stop using DDA 200 AE series RCD-blocks

The AE series RCD-block combines the protection supplied by the RCBOs with a positive safety emergency stop function for remote tripping.

In the AE version, the DDA 200 AE series RCD-blocks are available.

Operating principle (patented)

Two additional primary circuits powered with the same voltage and equipped with the same resistance have been added to the transformer; under normal conditions the same current would flow through, but since they are wound by the same number of coils in opposite directions they cancel each other out and do not produce any flow.

One of these two windings acts as the remote control circuit: the emergency stop is obtained by interrupting the current flow in this circuit.

The positive safety is therefore obvious: an accidental breakage in the circuit is equivalent to operating an emergency control button.

Advantages

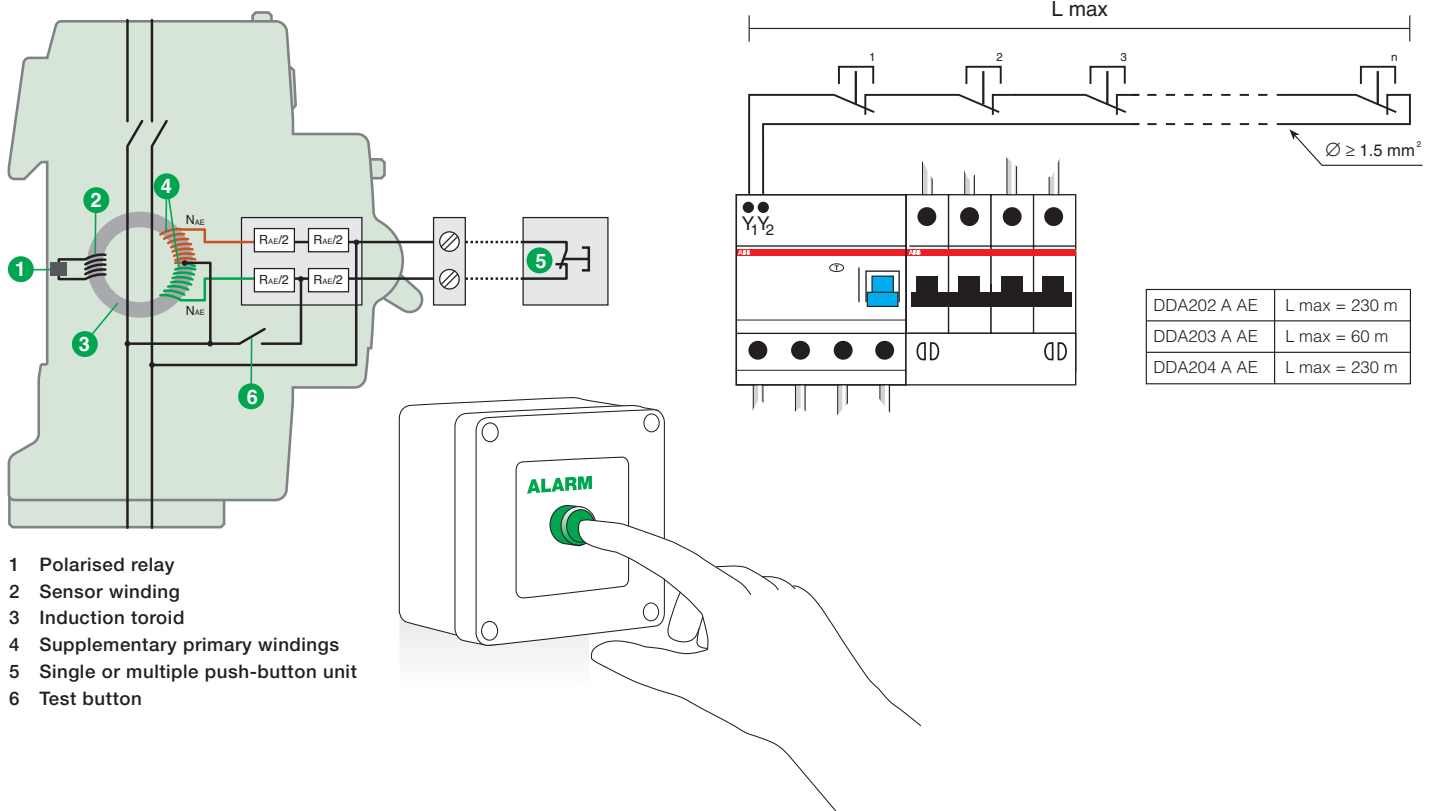
Compared with the devices which are normally used in emergency circuits, DDA 200 AE blocks have the following advantages:

- positive safety
- no unwanted tripping if there is a temporary reduction or interruption of the mains voltage
- efficient immediate operation even after long off-service periods of the installation

Use

Application of the DDA 200 AE blocks complies with the requirements of IEC 60364-8. They are therefore suitable, for example, for escalators, lifts, hoists, electrically operated gates, machine tools, car washes and conveyor belts.

No more than one DDA 200 AE can be controlled using the same control circuit. Each DDA 200 AE requires a dedicated control circuit.



RCDs for 50-400 Hz

At 400 Hz frequency, a standard F200 has an effective residual current value of more than 3 times its rated residual current; this is due to an increase of the magnetic reluctance of the toroidal transformer caused by an increasing frequency.

ABB offers the F200 400 Hz that can be used in networks up to 400 Hz (typical in some airport areas) while keeping its rated sensitivity.



RCDs with neutral on left side

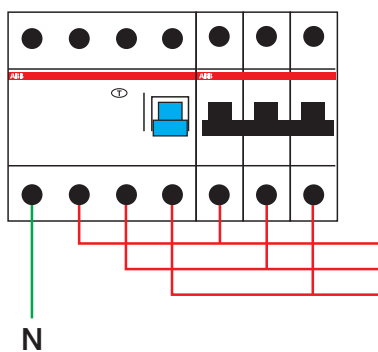
In case of a three-phase system without neutral with concatenate voltage between phases of 230 V or 400 V, ABB offers F204 with neutral on the left where it is sufficient to connect the 3 phases normally (supply to terminals 1/2 3/4 5/6 and load to terminals 2/1 4/3 6/5) to have a perfectly working RCD.

The test button circuit of these RCCBs is wired inside the device between terminal 3/4 and 5/6 and has been sized for an operating voltage between 195 V and 440 V.

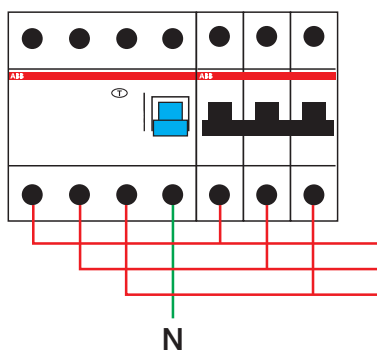
RCCBs, particularly in Germany, are normally placed at the left of the miniature circuit breakers but have the N-conductor on the right. This causes problems with regard to integrated busbar connection. RCCBs in conjunction with miniature circuit breakers therefore require a special busbar. In order to make it possible to use standard busbars whenever required, four-pole RCCBs with the N-conductor on the left are also available.

The habit of installing the RCCB on the left of the miniature circuit breakers and using standard busbar connections can thus be maintained.

Neutral on the left: standard busbar can be used



Neutral on the right: special busbar required



Solutions for protection against earth fault currents

ABB RCDs with special versions

RCD blocks with 110V and 400V

Special version of RCD blocks to assemble on site with S 200 series MCBs. Special version are available with protection against the effects of sinusoidal alternating and/or direct pulsating earth fault currents, protection against indirect contacts and additional protection against direct contacts (with $I_{\Delta n}=30$ mA).

DDA200 110 V is a particular RCD-block with voltage range for test button $U_t = 110-245$ V. RCD blocks work for naval applications where the IT system is typically used and the voltage between the phase and the neutral conductor is 115 - 125 V. DDA200 110 V ($U_t = 110-245$ V) are suitable for naval applications.

A special 400 V version is also available in the two-pole version for two-phase industrial systems where voltage between phases is 400 V.

Applications: naval, industrial.

RCDs 16 2/3Hz

F200 16 2/3 Hz are suitable for in distribution networks with frequency of 16 2/3 Hz: this kind of network was developed at the beginning of 20th century for electrical traction systems and is currently adopted in some European countries (e.g. Switzerland, Germany, Norway etc.)



Markings and approvals

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Markings and approvals

ABB RCDs

All ABB RCDs and their accessories comply with international product Standards IEC 61008, IEC 61009 and UL 1053.

Consequently they are tested according to the standard IEC 61543, for electromagnetic compatibility of RCDs for household and similar use.

They also conform to the following EC directives:

- Low Voltage Directive 2006/95/EC
- EMC Directive 2004/108/EC

The quality mark is an additional guarantee that the product is compliant with safety standards. This is issued by a third-party authority that authorises the marking on the product by issuing the necessary certificate. The approvals obtained must be carried on the certified product, clearly displayed with the technical features of the product.

The CE marking is a mark that must be affixed to certain types of products in order to verify the compliance to all Community directives.

The manufacturer has the responsibility to issue a self-certification, which states that the product has been assessed and satisfies all health, safety and environmental requirements of the Directives (European declaration of conformity).

5



● AMERICA

Country	Approval
Canada	CSA
United States	UL
Argentina	IRAM
Brazil	UCIEE

Naval approval

Country	Approval
United States	ABS

● ASIA OCEANIA

Country	Approval
Taiwan	BSMI
China	CCC
India	BIS-ISI
Singapore	PSB
Malaysia	SIRIM
Australia	OFT
New Zealand	OFT



At international level there are relevant differences between the laws that rule the approvals: there is the principle of territoriality of national marks, meaning the effects of registration of a trade mark extends only to the territory of the state which has granted it.

Generally speaking a company submits the range of product that needs to be approved to a recognized institution. The products withstand the tests foreseen by the Standards and, in case of positive result, they issue a CB certificate and the approval.

By the mean of the CB certificate other approval company can acknowledge the request of the manufacturer without carrying out additional tests. This is meant to quicken the release of further approval when a product has been already tested deeply. The duration of the CB certificate is 3 years.

Every Nation has its own certification authority and a quality mark.

The obtained markings must be reported on the product.

Below is a map with main markings around the world



● EUROPE	
Country	Approval
Austria	ÖVE
Belgium	CEBEC
Belarus	STB
Denmark	DEMKO
Finland	FIMKO
France	NF (LCIE)
Germany	VDE
UK	BSI
Italy	IMQ
Norway	NEMKO
Netherlands	KEMA-KEUR
Portugal	CERTIF
Russia	GOST_R
Spain	AENOR
Sweden	SEMKO
Switzerland	SEV
Ukraine	GOST_Uk

Naval approval	
Country	Approval
France	BV
Norway	DNV
Germany	GL
UK	LR
Italy	RINA
Russia	RMRS & RRR

Markings and approvals

ABB RCDs

ABB System pro M Compact RCDs also have many national and international approvals. Thanks to these approvals, the devices can be used without restriction as devices for the world market.

For RCCBs there will be two kinds of marking on the product: for European countries there will be a marking according to EN standards, while for the extra-European countries there will be a marking according to IEC standards. In fact IEC and EN standards have few differences. An example of such differences could be the rated voltage, which is 230/400 for EN and 240/415 for IEC.

All ABB SACE RCDs comply with the IEC 61008 and IEC 61009 Standards. In particular the paragraph “Verification of resistance to mechanical shock and impact” requires submitting RCDs to several mechanical shocks, during which the RCDs must not open.

Moreover, all RCCBs and RCD-blocks are immune to mechanically generated vibrations and to electromagnetic effects, in compliance with the IEC 60068-2-6 Standards. For these reasons, the major classification organisations (RINA, Lloyd’s Register of Shipping) consider ABB RCDs suitable for marine, offshore and industrial applications. Besides this, the test button of ABB’s RCDs also operate in low-voltage net applications (with 230V between two phases), so ABB does not need a dedicated range for naval and low-voltage applications, since the standard one can be used.

The naval approval authorities do not provide for affixing of marks either on product or on the box label.



Notes on installation and use

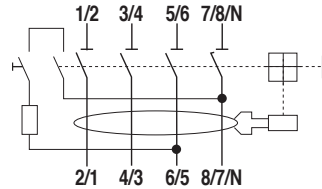
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Auto reclosing and remote control of RCDs	6/10

Notes on installation and use

Use of a 4P RCCB in a 3-phase circuit without neutral

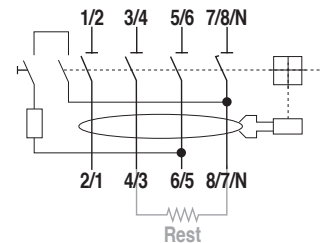
The test button circuit of these 4P F 200 RCCBs is wired inside the device between terminal 5/6 and 7/8/N as indicated below, and has been dimensioned for an operating voltage between 110 and 254 V (110 and 277 V according to UL 1053).



In case of installation in a 3-phase circuit without neutral, if the concatenate voltage is between 110 and 254 V (277 V according to UL 1053) for the correct working of the test button there are two possible solutions:

- 1) To connect the 3-phase to the terminals 3/4 5/6 7/8/N and the terminals 4/3 6/5 8/7/N (supply and load side respectively)
- 2) To connect the 3-phase normally (supply to terminals 1/2 3/4 5/6 and load to terminals 2/1 4/3 6/5) and to bridge terminal 1/2 and 7/8/N in order to bring to the terminal 7/8/N the potential of the first phase. In this way the test button is supplied with the phases' concatenate voltage.

If the circuit is supplied with a concatenate voltage higher than 254 V, as in the typical case of 3-phase net with concatenate voltage of 400 V - or 480 V according to UL 1053 - (and voltage between phase and neutral of 230 V or 277 V according to UL 1053), it is not possible to use these connections because the circuit of the test button will be supplied at 400 V and could be damaged by this voltage.



$I\Delta n$	Rest [Ω]
0.03	3300
0.1	1000
0.3	330
0.5	200

In order to allow the correct operation of the test button also in 3-phase nets at 400 V - 480 V according to UL 1053 - (concatenate voltage) it is necessary to connect the phases normally (supply to terminals 1/2 3/4 5/6 and load to terminals 2/1 4/3 6/5) and to jump terminal 4/3 and 8/7/N by mean of an electric resistance as indicated above.

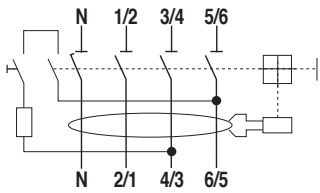
In this way, the test button circuit is fed at 400 V - 480 V according to UL 1053 - but for example in an RCCB with $I\Delta n=0.03$ A there will be the Rest=3.3 kOhm resistance in series to the test circuit resistance. Rest will cause a voltage drop that leaves a voltage less than 254 V in the test circuit - 277 V according to UL 1053. Rest resistance must have a power loss higher than 4 W.

In normal operation of the RCCB (test circuit opened) the Rest resistance is not powered, so it does not cause any power loss.

RCCBs with neutral pole on left side

The test button circuit of these RCCBs is wired inside the device between terminal 3/4 and 5/6 as indicated below, and it has been dimensioned for an operating voltage between 195 V and 440 V - 480 V.

In case of a three-phase system without neutral with concatenate voltage between phases of 230 V or 400 V - 277 V or 480 V - it is enough to connect the 3 phases normally (supply to terminals 1/2 3/4 5/6 and load to terminals 2/1 4/3 6/5) without any bridge.



Notes on installation and use

Coordination between SCPD and F200

If you are using an RCCB you must verify that the Short Circuit Protection Device (SCPD) protects it from the effects of high current that arise under short-circuit conditions.

The IEC 61008 provides some tests to verify the behaviour of RCCBs in short-circuit conditions. The tables below provide the maximum withstanding short-circuit current expressed in eff. kA for which the RCCBs are protected thanks to coordination with the SCPD installed upstream or downstream.

The tests are performed with SCPD with a rated current (thermal protection) less than or equal to the rated current of the associated RCCB.

F 202

	Single-phases 230-240 V circuit					
	25 A	40 A	63 A	80 A	100 A	125 A
SN201L/S201L Na	4.5	4.5				
SN201/S201 Na	6	6				
SN201M/S201M Na	10	10				
S202L	10	10				
S202	20	20	20			
S202M	25	25	25			
S202P	40	25	25			
S802N	36	36	36	36	36	36
S802S	50	50	50	50	50	50
Fuse 25 gG	100					
Fuse 40 gG	60	60				
Fuse 63 gG	20	20	20			
Fuse 100 gG	10	10	10	10	10	
Fuse 125 gG						10

F 202

	400-415 V circuits with isolated neutral (IT) under double faults					
	25 A	40 A	63 A	80 A	100 A	125 A
SN201N/SN201/SN201M	3	3				
S201L/S201L Na/S202L	4.5	4.5				
S201/S201 Na/S202	6	6	6			
S201M/S201M Na/S202M	10	10	10			
S201P/S201P Na/S202P	25	15	15			
S801N/S802N	20	20	20	20	20	20
S801S/S802S	25	25	25	25	25	25

F 204

	Three-phases circuits with neutral (y/D) 230-240 V/400-415 V*					
	25 A	40 A	63 A	80 A	100 A	125 A
SN201L/S201L/S201LNa*	4.5	4.5				
SN201/S201/S201Na*	6	6				
SN201M/S201M/S201MNa*	10	10				
S202L*	10	10				
S202*	20	20	20			
S202M*	25	25	25			
S202P*	40	25	25			
S802N*	36	36	36	36	36	36
S802S*	50	50	50	50	50	50
Fuse 25 gG	100					
Fuse 40 gG	60	60				
Fuse 63 gG	20	20	20			
Fuse 100 gG	10	10	10	10	10	
Fuse 125 gG						10

* The switches are considered between phase and neutral (230/240V)

F 204

	Three-phases circuits with neutral (y/D) 230-240 V/400-415 V					
	25 A	40 A	63 A	80 A	100 A	125 A
S203L/S204L	4.5	4.5				
S203/S204	6	6	6			
S203M/S204M	10	10	10			
S203P/S204P	25	15	15			
S803N/S804N	20	20	20	20	20	20
S803S/S804S	25	25	25	25	25	25
Fuse 25 gG	50					
Fuse 40 gG	30	30				
Fuse 63 gG	20	20	20			
Fuse 100 gG	10	10	10	10	10	
Fuse 125 gG						10

Notes on installation and use

Coordination between SCPD and F200

F 204

	Three-phases circuits with neutral (y/D) 133-138V/230-240V					
	25 A	40 A	63 A	80 A	100 A	125 A
SN201L	10	10				
SN201	15	15				
S201M	20	20				
S203L/S204L	10	10				
S203/S204	20	20	20			
S203M/S204M	25	25	25			
S203P/S204P	40	25	25			
S803N-S804N	36	36	36	36	36	36
S803S-S804S	50	50	50	50	50	50
Fuse 25 gG	100					
Fuse 40 gG	60	60				
Fuse 63 gG	20	20	20			
Fuse 100 gG	10	10	10	10	10	
Fuse 125 gG						10

Notes on installation and use

Selectivity using RCDs

RCDs raise similar issues to those surrounding the installation of MCBs, and in particular the need to reduce to a minimum the parts of the system which are out of order in the event of a fault.

For RCBOs the problem of selectivity in the case of short-circuit currents may be handled with the same specific criteria as for MCBs.

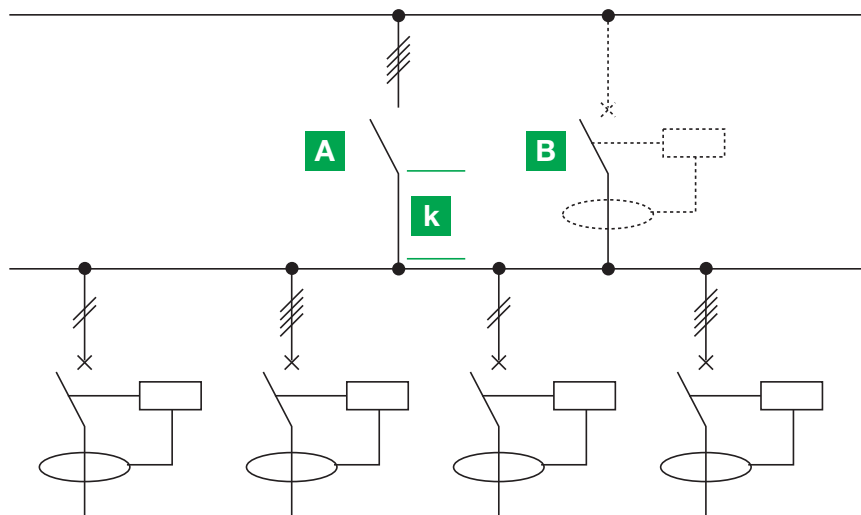
However, for correct residual current protection, the more important aspects are connected with tripping times. Protection against contact voltages is only effective if the maximum times indicated on the safety curve are not exceeded.

If an electrical system has user devices with earth leakage currents which exceed the normal values (e.g.: presence of capacitor input filters inserted between the device phase and earth cables) or if the system consists of many user devices, it is good practice to install various RCDs, on the main branches, with an upstream main residual current or non-residual current device instead of a single main RCD.

Horizontal selectivity

The non-residual current main circuit-breaker provides “horizontal selectivity”, preventing an earth fault at any point on the circuit or small leakages from causing unwanted main circuit-breaker tripping, which would put the entire system out of order.

However, in this way, section k of the circuit between the main circuit-breaker and the RCDs remains without “active” protection. Using a main RCD to protect it would lead to problems with “vertical selectivity”, which requires tripping of the various devices to be coordinated, so that service continuity and system safety are not compromised. In this case, selectivity may be amperometric (partial) or chronometric (total).



Vertical selectivity

Vertical selectivity may also be established for residual current tripping, bearing in mind that in working back from system peripheral branches to the main electrical panels, the risk of unskilled persons coming into contact with dangerous parts is significantly reduced.

Notes on installation and use

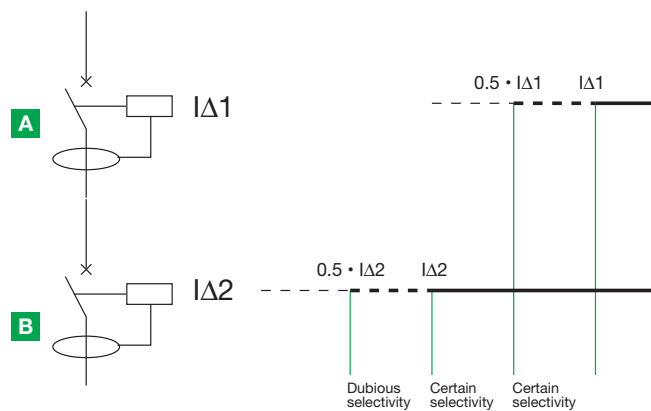
Selectivity using RCDs

Amperometric (partial) selectivity

Selectivity may be created by placing low-sensitivity RCDs upstream and higher-sensitivity RCDs downstream.

An essential condition which must be satisfied in order to achieve selective co-ordination is that the $I_{\Delta 1}$ value of the breaker upstream (main breaker) is more than double the $I_{\Delta 2}$ value of the breaker downstream. The operative rule to obtain amperometric (partial) selectivity is $I_{\Delta n}$ of the upstream breaker = $3 \times I_{\Delta n}$ of the downstream breaker (e. g.: F 204, A type, 300 mA upstream; F 202, A type, 100 mA downstream).

In this case, selectivity is partial and only the downstream breaker trips for earth fault currents $I_{\Delta 2} < I_{\Delta m} < 0.5 \cdot I_{\Delta 1}$.



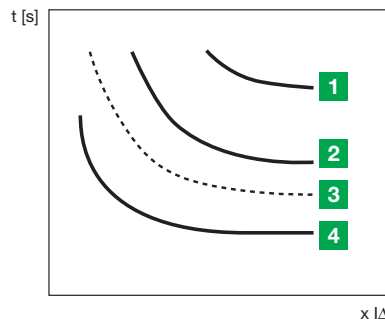
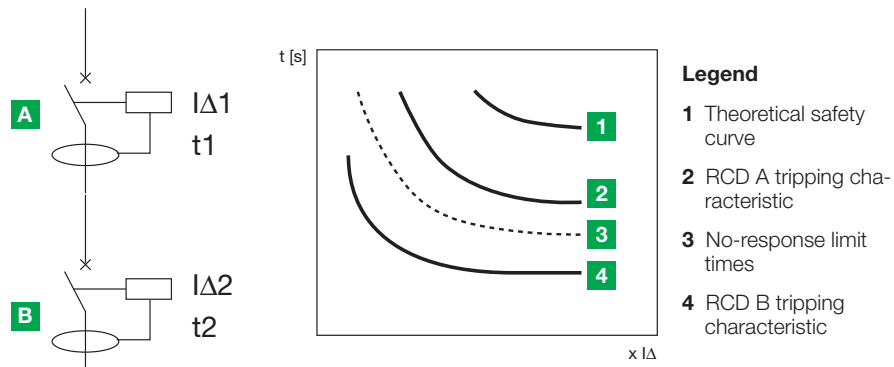
Chronometric (total) selectivity

To achieve total selectivity, delayed or selective RCDs must be installed.

The tripping times of the two devices connected in series must be coordinated so that the total interruption time t_2 of the downstream breaker is less than the upstream breaker's no-response limit time t_1 , for any current value. In this way, the downstream breaker completes its opening before the upstream one.

To completely guarantee total selectivity, the I_{Δ} value of the upstream device must also be more than double that of the downstream device in accordance with IEC 64-8/563.3, comments. The operative rule to obtain amperometric (partial) selectivity is $I_{\Delta n}$ of the upstream breaker = $3 \times I_{\Delta n}$ of the downstream breaker (e. g.: F 204, S type, 300 mA upstream; F 202, A type, 100 mA downstream).

For safety reasons, the delayed tripping times of the upstream breaker must always be below the safety curve.



- Legend**
- 1 Theoretical safety curve
 - 2 RCD A tripping characteristic
 - 3 No-response limit times
 - 4 RCD B tripping characteristic

Table of RCD selectivity

		Upstream I Δ n [mA]	10	30	100	300	300	500	500	1000	1000
Downstream I Δ n [mA]			inst	inst	inst	inst	S	inst	S	inst	S
10	inst			■	■	■	■	■	■	■	■
30	inst				■	■	■	■	■	■	■
100	inst					■	■	■	■	■	■
300	inst									■	■
300	S									■	■
500	inst										
500	S										
1000	inst										
1000	S										

inst=instantaneous S=selective ■=amperometric (partial) selectivity ■=chronometric (total) selectivity

The tripping time on RCDs is not adjustable. It is set according to a predetermined time – current characteristic with an intrinsic delay for small currents, tending to disappear as the current grows.

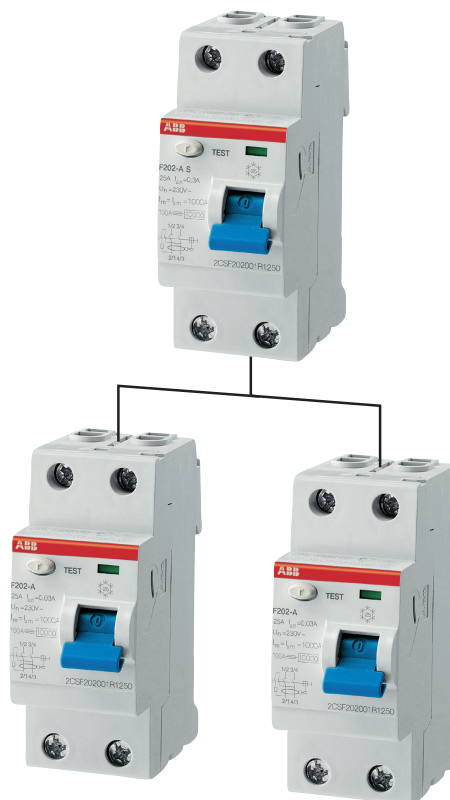
IEC 61008 and 61009 establish the tripping times relative to the type of RCD and the I Δ n (see the table):

Type AC	I _n [A]	I Δ n [A]	Tripping time [s] x current			
			1xI Δ	1xI Δ	1xI Δ	500 A
Generic	any	any	0.3	0.15	0.04	0.04
S (selective)	any	> 0.03	0.13-0.5	0.06-0.2	0.05-0.15	0.04-0.15

Example:

Downstream F200 A type 30mA
 Upstream F200 A S type 300mA
 Fault = 300 mA

F200 A type 30mA will open between 0 and 0.04s
 F200 A Selective type 300 mA stays closed up to 0.13s
 100% Selectivity because 0.13s is greater than 0.04s



Notes on installation and use

Auto reclosing and remote control of RCDs



Locations where remote controlled mechanisms are favoured include 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.

The use of a remote controlled mechanism allows the user direct and immediate access to the installation even in remote or hard to access locations. Fast reconnection to the supply following a fault scenario, in particular, saves considerable time and costs.

F2C-ARI auto reclosing device

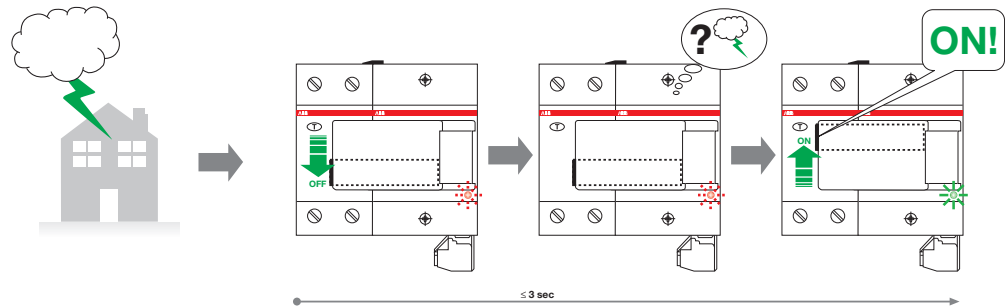
The F2C-ARI is suitable for switchboards located in difficult to access areas, in case of unmanned stations and in general where a high level of service availability is required (public lighting, traffic and signalling control, mobile phone stations...).

The F2C-ARI performs automatic re-closing of the associated RCCBs and, in addition, the remote control (open-close). This unit is suitable for F200 series up to 100 A both 2P and 4P. This device ensures personal and system safety in case of faults and improves reliability and continuity of service in case of unwanted tripping.

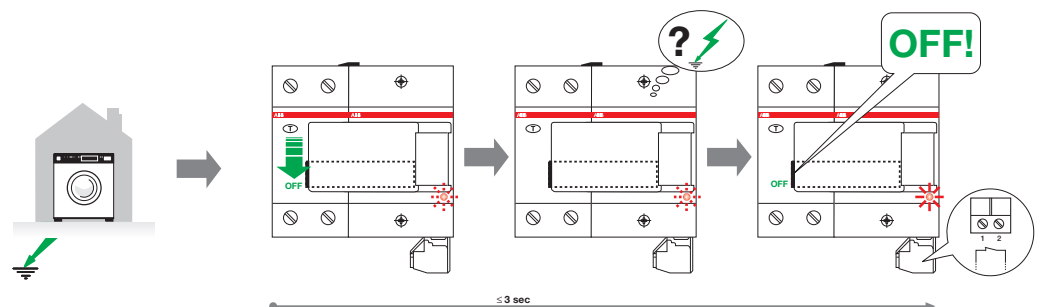
F2C-ARH auto reclosing device

The F2C-ARH is an autoreclosing device suitable for F202 30 mA and 100 mA usually used in household applications. Unlike the F2C-ARI auto-reclosing unit, it does not require a separate low voltage power supply, but can be supplied by the associated RCCBs (2-pole RCCBs up to 63 A – 30 mA and 100 mA) at the 230 V a.c. rated voltage.

Another feature that makes the product perfect for home applications is an internal control unit that checks there are no insulation faults in the system before allowing the RCCB to reclose. This ensures that re-closing occurs only in case of unwanted tripping of the RCCB (i.e. over-voltages induced by electrical storms) and it guarantees continuity of power supply.



When the RCCB trips in presence of an insulation fault, the auto-reclosing device does not allow re-closing.



Motor operating device F2C-CM

With the range of motor operating devices it is possible to open and close F200 series RCCBs up to 100 A by remote control. The motor operating device has two integrated contacts:

- One 1NO+1NC auxiliary change-over contact which indicates the position of the associated RCCB's contacts.
- One 1NO+1NC signal change-over contact which indicates that the associated RCCB has tripped.



Choosing the correct differential protection

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Selection of RCDs

General rules

The selection of the most appropriate RCD protection depends on the following criteria:

- protection task in the installation
- rated residual current $I_{\Delta n}$
- type of residual current/characteristic of load
- type of RCD (AC/A/F/B)
- resistivity against unwanted tripping/selectivity requirements
- standard type/type S/short-time delayed type
- RCD product types
- RCCBs, RCBOs, RCUs, CBRs, MRCDs

For each step we'll provide a scheme that can support the user everytime he has to choose an RCD that suits a given requirement or application.

Step 1 | Rated residual current $I_{\Delta n}$

Protection against electric shock		Protection against thermal effects
Fault protection - $I_{\Delta n}$ according to IEC/HD 60364-4-41, cl. 411	Additional protection - $I_{\Delta n} \leq 30\text{mA}$ IEC/HD 60364-4-41, cl. 411.3.3	For locations with risks of fire due to the nature of processed or stored materials - $I_{\Delta n} \leq 300\text{ mA}$ for low impedance faults IEC/HD 60364-4-42, cl. 422.3.9
<ul style="list-style-type: none"> - Z_s (TN system) - R_A (TT system) - typ. 100 mA /300 mA / 500 mA 		<ul style="list-style-type: none"> - $I_{\Delta n} \leq 30\text{mA}$ for earth faults with significant impedance like for panel heating systems

Step 2 | Type of residual current

Type AC	Type A	Type F	Type B
For alternating sinusoidal residual current, suddenly applied or smoothly increasing. May be not allowed in some countries	As type AC + Residual pulsating dc current, suddenly applied or smoothly increasing + Residual pulsating dc current superimposed on smooth dc current $\leq 6\text{mA}$	As type A + Composite residual currents, suddenly applied or slowly rising, intended for circuits supplied between L and N or L and earthed middle conductor; residual pulsating dc current superimposed on smooth dc current $\leq 10\text{mA}$	As type F + - residual sinusoidal ac currents up to 1 kHz - residual ac currents superimposed on a smooth dc current - residual pulsating dc currents superimposed on a smooth dc current - residual pulsating rectified dc current which results from two or more phases - residual smooth dc currents whether suddenly applied or slowly increased independent of polarity.

Step 3 | Operational continuity

Istantaneous		Selective	
Operational continuity	Responsive protection	Operational continuity	Responsive protection
APR	Standard RCD	S	B S

Step 4 | Product types



RCCB	RCBO	BLOCKS	MRCD
For household and similar installations			
For industrial installations			
Residual current protective device without integral overcurrent protection	Residual current protective device with integral overcurrent protection	Residual current unit to be assembled to an assigned overcurrent protective device forming a RCBO	Modular residual current device

Choosing the correct differential protection

Unwanted tripping of RCDs



Unwanted tripping of RCDs can represent a side-effect because it affects the operational continuity. It could also be wrongly considered a quality problem of the device.

Typical causes of unwanted RCD tripping could be:

- presence of leakage current with modest value but with high level of harmonics or high frequency
- presence of transient impulsive currents (e.g. usually caused by opening and closing of capacitive or inductive loads);
- overvoltages caused by lightning
- transient impulsive currents added to permanent leakage currents already present (eg. caused by electronic devices)

What are the possible solutions?

According to IEC 62350 (Guidance for the correct use of residual current-operated protective devices (RCDs) for household and similar) the recommended solutions are:

- “installation” solution: split the installation into several different circuits, each of them protected by an RCD
- “product” solution: select RCDs which are more resistant to unwanted tripping

The F200 type APR is ten times more resistant to unwanted tripping than standard ones (both AC and A). Selective types are more resistant than APR types but they cannot be made with sensitivity less than 100mA! (no additional protection against direct contact!!)

ABB classifies APR types as instantaneous. The F200 APR has higher resistance to unwanted tripping than standard models. APR are made only with sensitivity of 30mA because:

- they can be used to protect people against direct (additional to insulation) and indirect contact: complete protection and continuity of supply
- if higher sensitivities (> 30mA) are requested, ABB already offers selective types that guarantee higher resistance to unwanted tripping

APR types suit all applications where it is necessary to ensure safety and continuity of supply while preventing unwanted tripping.

Typical examples of this can be found in these situations:

- Environments subjected to overvoltage due to lightning
- Simultaneous switching on of fluorescent lamps with electronic ballasts
- Simultaneous switching of IT apparatus (computers or electronic devices)
- Devices with capacitors which connect phases to the earth installed in long circuits
- Switching on of motor softstarter/speed variator.

Types B RCDs are inherently APR devices and therefore they can be used in case of unwanted trippings as well. Compared with APR devices, type B can assure operational continuity even in case of low ratings (30 mA) and in case of high frequency leakages.

Choosing the correct differential protection

Earth fault currents with smooth DC

In order to detect wave forms of earth fault currents similar to smooth direct (ripple free) or with high frequency components, the type B RCDs have been introduced. Type B RCDs are not mentioned in the reference standards for RCDs, IEC 61008-1 and IEC 61009-1. These kinds of devices are included in the IEC 60755 technical report (general requirements for residual current operated protective devices), in section 4.2.10.3, where all the additional types of residual currents which a B type RCD is able to detect are specified. Besides this, International Standard IEC 62423 ed.2 has been published, specifying the additional requirements for type B RCDs. This Standard can only be used together with IEC 61008-1 (for RCCBs) and IEC 61009-1 (for RCD-blocks and RCBOs), meaning that type B RCDs must comply with all requirements of IEC 61008/9. The Standard includes:

- definitions,
- requirements (they must be able to detect earth fault currents up to 1000 Hz),
- tests, in addition to the tests of IEC 61008/9.

Type B RCDs suit all cases where it is possible to have smooth direct earth fault currents or high harmonic distortion, and type A devices are not able to guarantee the adequate level of protection. Typical examples are:

- Three-phase a.c./d.c. converters where, in absence of double insulation, insulation defects or earth faults can occur in the d.c. part of the circuit (downstream the rectifier).
- Three-phase UPS where, in absence of double insulation, insulation defects or earth faults can occur in the d.c. part of the circuit (downstream the rectifier).
- Electro-medical devices where a.c./d.c converters inside the instruments are often used.
- Three-phase Frequency Converters where the earth fault current can have very high frequency components or elevated harmonic distortion.
- In photovoltaic installations

For example, in PV installations a dangerous situation can occur in case of internal insulation breakdown between inverter DC and AC; in this case, some DC voltage could pass through the network. In the case of earth fault currents or indirect contact on the network (AC side), type A (sensitive to alternating and/or pulsating current with DC component) or type AC (sensitive only to alternating current) RCDs are not able to detect the d.c. fault current. Inverters with no separation between the AC side and the DC side require a type B RCD on the AC-side: IEC 60364-7 art. 712.413.1.1.1.2 “Where an electrical installation includes a PV power supply system without at least simple separation between the AC side and the DC side, an RCD installed to provide fault protection by automatic disconnection of supply should be type B. If the PV inverter by construction is not able to feed D.C. fault current into the electrical installation a B-type RCD is not mandatory”.

F202 B, F204 B

Main technical specifications	F202 B, F204 B
Rated operating current [A]	25, 40, 63, 80, 125
Rated operating voltage [V a.c.]	230...400
Rated current sensitivity [mA]	30, 100, 300, 500
Number of poles	2, 4
Type	B, B S (selective version)
Standard	IEC 61008 IEC 62423 (for instantaneous version) DIN VDE 0664 pt. 100 (for selective version)

DDA202 B, DDA203 B, DDA204 B

Main technical specifications	RCD-blocks DDA202 B, DDA203 B, DDA204 B
Rated operating current [A]	up to 63
Rated operating voltage [V a.c.]	230...400
Rated current sensitivity [mA]	30, 300
Number of poles	2, 3, 4
Type	B, B S (selective version)
Standard	IEC 61009 Annex G IEC 60755



Choosing the correct differential protection

Where do we use residual current relays?

Residual current relays are electronic devices for residual current monitoring and residual current protection according to annex M of IEC 60947-2.

IEC 60947-2 is the standard of “Low-voltage switchgear and controlgear – Part 2: Circuit-breakers”. Devices according to this standard are intended for use by skilled people. In fact, residual current relays use the circuit breaker as a switch device after detecting a fault current by means of the external toroidal transformer.

Therefore, the reference standard explains the possibility of using residual current relays in typically industrial contexts, where continuity of service is often critical and may be guaranteed by the selectivity.

Generally, the residual current relays with external toroidal transformer are used for upstream protection. Downstream, electromechanical RCDs (F200 for example) may be used for the protection of the single terminal lines. It is important that the main switch is the last to trip after a fault. A well-designed system ensures that only the part of the circuit affected by the fault should be placed out of service.

By setting the delay (adjustable on the front of the relay), it is possible to guarantee that the first RCD to trip is the nearest to the fault.

In addition, it is possible to set the sensitivity $I_{\Delta n}$. This is very useful especially in those complex environments where it is difficult to plan which users will be connected to the lines to be protected in the first phase of design.

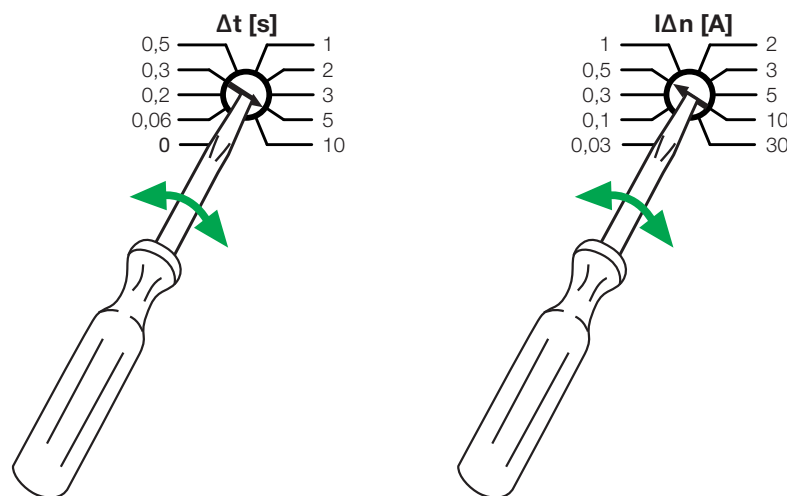


ABB leading RCD technology

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ABB leading RCD technology

ABB is a leader in power and automation technologies that enable utility and industry customers to improve performance while lowering environmental impact.

The ABB Group of companies operates in around 100 countries and employs about 145,000 people.

Technology leadership, global presence, application knowledge and local expertise are key factors in offering products, systems and services that enable ABB's customers to improve their businesses in terms of energy efficiency, reliability of networks and industrial productivity.

ABB Low Voltage Division: many solutions in low-voltage systems

ABB Low Voltage Division offers a wide range of products and systems for low voltage electrical distribution and automation in the residential, commercial and industrial sectors.

The product range also includes intelligent building control systems, also known as KNX systems, for home and building automation to improve comfort, energy efficiency and security.

Components and systems for charging electric vehicles complete the portfolio.

A significant part of these products are made in Italy, in highly specialised and automated production facilities; all sites have obtained ISO 9001 quality, Health and Safety OHSAS 18001 and ISO 14001 certificates.

Furthermore, the ABB Low Voltage Division, always focused on excellence, has implemented IRIS and SA8000 certifications in some of its factories: this is the standard of absolute impor-



tance to quality and corporate social responsibility. Local research and development, attentive to the most important aspects of technological innovation, responds quickly and often anticipates the needs of designers, systems integrators and installers operating in different sectors.

The ABB test laboratory, thanks to its high-tech equipment and the expertise of its specialists, ensures accurate testing and qualified certification of its products. A testimony to the high standards achieved: the Low Voltage laboratory Division in Vittuone (Milan, in Italy) was accredited and recognised as a ACAE LOVAG Registered Laboratory and was also authorised to apply the Supervised Manufacturer's Testing (SMT) procedure.



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