

Special Insert

Everything you wanted to know about  
Type B residual current circuit breakers  
but never dared to ask

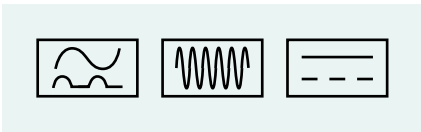
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Type AC or Type A RCDs, compliant with the Standards IEC/EN 61008 and IEC/EN 610091), are suitable for most types of household and similar applications. However, the increasing use of power electronics technologies in Consumer appliances with earth connection can result in leakage currents having waveforms with a high DC component and/or high frequency, in both fault and fault-free conditions. These currents, not intended for Type A or Type AC residual current circuit breakers, could affect their proper operation. It must be said that Type A RCDs, as a rule, are immune to the residual current overlap of a direct current up to 6 mA. In case of direct current leakage over 6 mA, the proper operation of Type A circuit breakers is not guaranteed.

Depending on the case, the Type A or Type AC residual current circuit breaker could therefore present the following drawbacks:

- desensitization of the residual current circuit breaker which may not trip properly in the event of a ground fault of equipment that generates currents with a high DC component or high frequency (failed tripping, delayed or excessive residual current values);
- desensitization of the residual current circuit breaker which may not trip properly in the event of a fault on another circuit powered from the same RCD (even if this fault current has a sinusoidal alternating shape);
- nuisance tripping with no fault.



1

Figure 1 - Marking of the Type B residual current circuit breakers

To solve these problems, Type B residual current circuit breakers were introduced in the 1990s, whose First Edition of the IEC 62423 product standard dates back to 2007 (and in more recent years, Type F RCDs were introduced, with intermediate characteristics between Type A and Type B RCDs). Pending an actual product standard for Type B residual current circuit breakers, one referred to the IEC 60755 Technical Report (General Requirements for Residual Current Operated Protective Devices), which contains the general characteristics of RCDs, including those for Type B.

With the issuance in 2013 of the Second Edition of the Standard IEC EN/62423 (Type F and B RCDs with and without integral overcurrent protection for household and similar installations), derived with a few minor changes from the corresponding Second Edition of the international Standard IEC 62423, the regulatory evolution of Type B RCDs for household and similar use came to a conclusion. This Second Edition contains some small changes in the requirements for Type B circuit breakers. In addition, it introduces the bipolar Type B RCDs and the Type F RCDs previously not contemplated by the standard.

Type B RCDs that comply with the latest edition of IEC/EN 62423 can be identified by the marking of Figure 1, whose graphic representation recalls the various residual current forms 't' for which the Type B circuit breaker is designed.

The Standard IEC/EN 62423 must be used in conjunction with the Standard IEC/EN 61008 or the Standard IEC/EN 61009 as it contains only the requirements and tests in addition to those laid down in the cited standards for Type A RCDs. To these standards, only for industrial applications, must be added the Standard IEC/EN 60947-2.






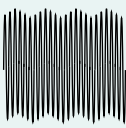




<sup>1)</sup> The Standard IEC/EN 61008 covers "pure" RCDs; the IEC/EN 61009 covers RCDs with integral overcurrent protection, including those obtained by adding a residual current block to an overcurrent circuit breaker.

Residual current waveforms for Type B residual current circuit breakers

The new edition of IEC/EN 62423 further enriches the set of residual current waveforms with which the Type B circuit breakers must be tested. The vast number of waveforms contemplated - which include various unidirectional forms, direct current without ripple, high-frequency currents and different combinations of these - allows it to be said that a Type B RCD guarantees proper tripping with every possible fault current, no matter how strange and complex the device that generated it. Therefore, the attribute “universal” by which the RCD type B<sup>2)</sup> is sometimes denoted is fully justified.

The test residual current waveforms now contemplated for Type B circuit breakers are<sup>3)</sup>:

- sinusoidal alternating current at rated frequency;
- pulsating unidirectional current, with or without phase angle delay;
- unidirectional current generated by two or three-phase rectifiers;
- sinusoidal alternating current up to a frequency of 1 kHz;
- direct current without ripple
- current obtained by overlapping direct current on alternating current;
- current obtained by overlapping direct current on pulsating unidirectional current;
- current obtained by the overlap of several frequencies.

	Residual current form	Tripping current limit values
alternating		0.5...1.0 IΔn
unidirectional pulsating		0.35...1.4 IΔn
unidirectional pulsating with phase angle delay		Cutting angle 90°: from 0.25 to 1.4 IΔn  Cutting angle 135°: from 0.11 to 1.4 IΔn
alternating overlapped on direct		max. 1.4 IΔn + 0.4 IΔn DC
unidirectional pulsating overlapped on direct		max. 1.4 IΔn + 0.4 IΔn DC
multi-frequency		from 0.5 to 1.4 IΔn
two-phase rectified		from 0.5 to 2.0 IΔn
three-phase rectified		
direct without ripple		
alternating up to 1 kHz		Current frequency 150 Hz from 0.5 to 2.4 IΔn  Current frequency 400 Hz from 0.5 to 6 IΔn  Current frequency 1000 Hz from 0.5 to 14 IΔn

2

Figure 2 - Tripping waveforms for all Type B

<sup>2)</sup> This terminology should not mislead: Type B RCDs are intended for use on AC voltage mains networks (non-sinusoidal waveforms are those of residual current). RCDs for DC mains networks are being studied (the so-called “Type DC” circuit breakers).

<sup>3)</sup> See also the article “Residual current protection devices” on Day by DIN 2|14 and the ABB Technical Guide “Protection against ground faults with residual current circuit breakers”.

The tests on RCDs are performed with both polarities, positive and negative, with the residual current applied both slowly and suddenly. Different tripping and non-tripping values are contemplated for the various waveforms, expressed as a multiple of the rated tripping residual current  $I_{\Delta n}$ , which is always referred to the AC mains frequency. The limit values of the tripping residual current take into account the different types of hazard for people of the various waveforms, and, at the same time, allow for an increase in service continuity while reducing the risk of nuisance tripping in the absence of fault (noise is filtered).

For example, a Type B RCD with  $I_{\Delta n} = 30 \text{ mA}$ , when direct residual current without ripple is applied, has a maximum tripping threshold of up to  $60 \text{ mA}$  to take into account the lesser danger of DC current. For the same reason, for a  $400 \text{ Hz}$  frequency residual current, the maximum tripping value allowed is  $180 \text{ mA}$

### Application of Type B RCDs

Type B RCDs are suitable for non-linear circuits capable of generating ground fault current with a high direct component (more than  $6 \text{ mA}^{(4)}$ ) and/or high frequency; the main ones are shown in Table 1.

Table 1 - Power circuits that require Type B residual current breakers

	Non-linear circuit	Fault waveform
1		
2		
3		
4		
5		
6		
7		

<sup>4)</sup> Type A RCDs are suitable to detect pulsating residual currents that, for a period of at least  $8.33 \text{ ms}$  in each  $20 \text{ ms}$  period of the mains frequency (equal to  $150^\circ$  electrical degrees at  $50 \text{ Hz}$ ), take on a null value or one not greater than  $6 \text{ mA}$ .

These are essentially:

- rectifiers, in general three-phase or two-phase (cases 1, 2, 3);
- half-wave rectifiers with high smoothing capacity (4);
- rectifiers with active power factor correction (PFC) (5);
- direct voltage generators permanently connected without galvanic separation to alternating current networks (e.g. solar panels) (6);
- variable frequency drives (7).

- static transfer systems (STS) and uninterruptible power systems (UPS) (see Fig. 3);
- charging systems for electric vehicles powered by alternating current (see Fig. 4<sup>6)</sup>);
- drives in direct current;
- frequency converters;
- medical diagnostic imaging equipment (CAT, MRI, etc.);

and others.

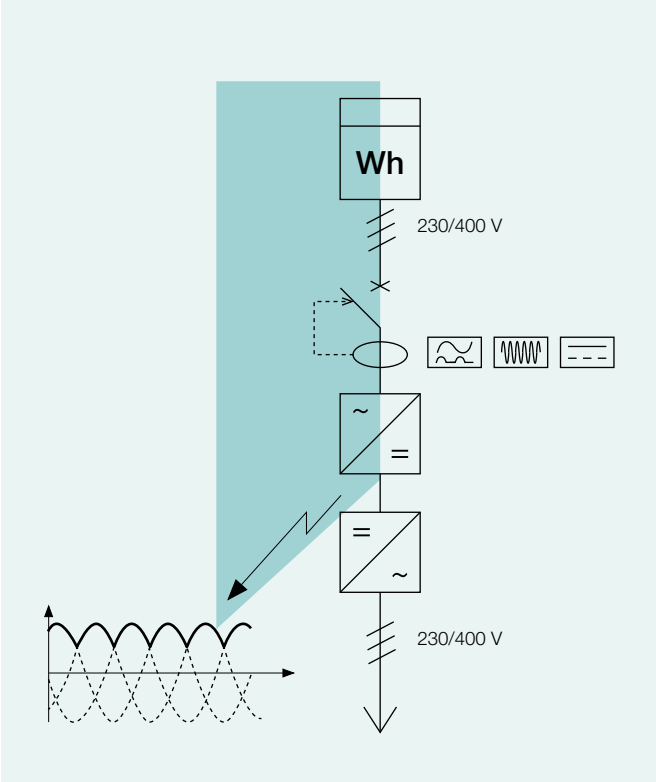
The main types of equipment that contain these circuit configurations are:

- variable frequency motor drives with three-phase power supply (industrial machinery, elevators, etc.) (see fig. 5);
- photovoltaic plants (fig. 6<sup>5)</sup>);

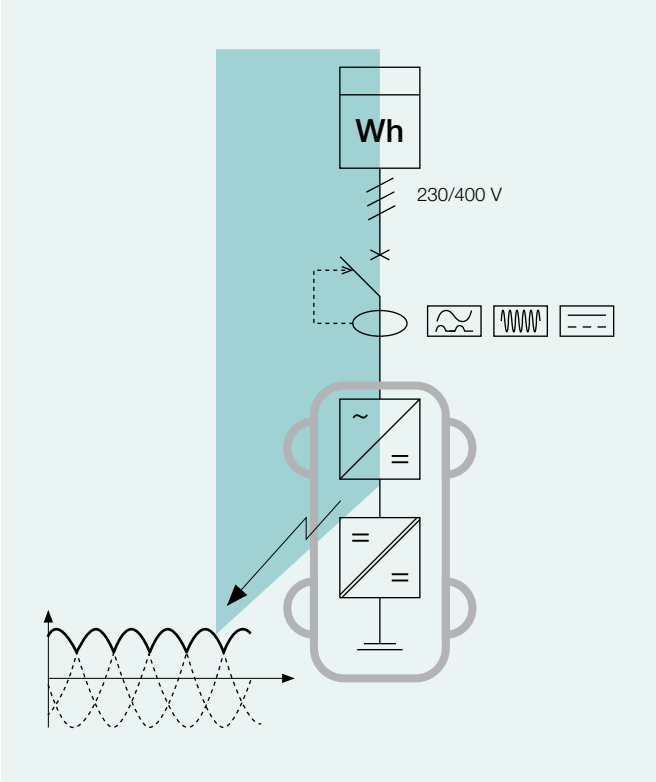
Please note that the most typical applications of Type B RCDs are three-phase, but also single-phase applications are not excluded, especially those with higher power.

Figure 3 - The Type B residual current circuit breaker with use of UPS devices

Figure 4 - The Type B residual current circuit breaker for charging electric vehicles



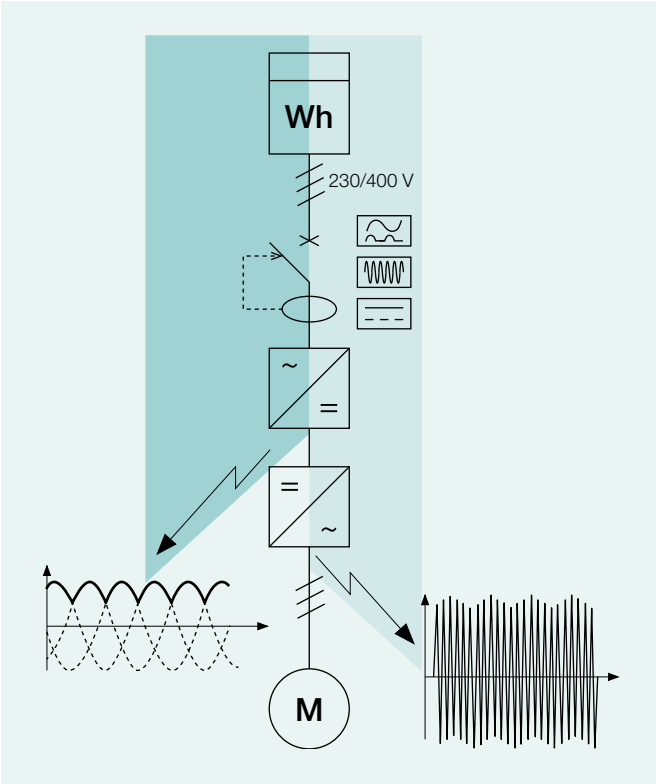
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<sup>5)</sup> In case of ground fault on the direct current side, the RCD located downstream of the inverter would be passed through, based on the characteristics of the inverter, by a non-alternating current, containing a high direct component and high frequency. See the ABB Technical Application Paper N° 10 "Photovoltaic Plants".

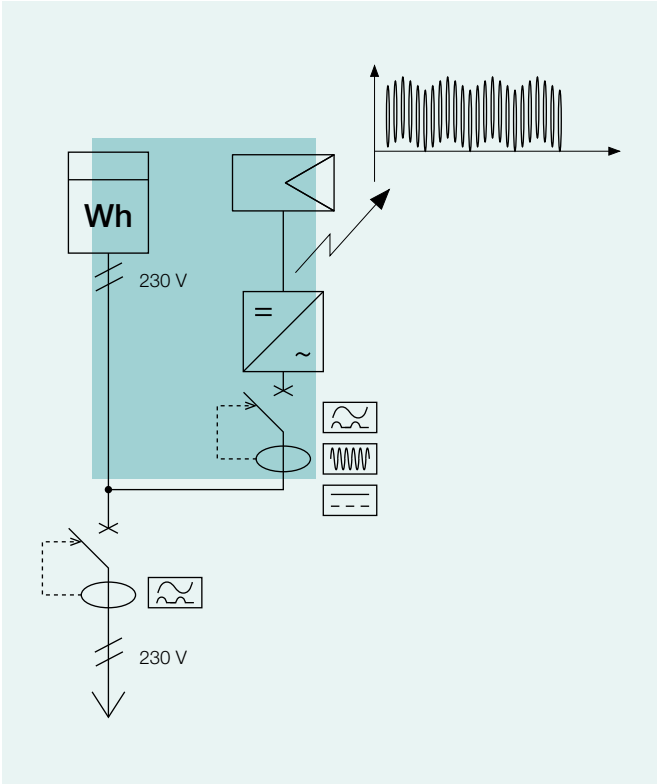
<sup>6)</sup> See "Power supply for electric vehicles" in Day by DIN 2|12 and Day by DIN 2|13.



5

Figure 5 - Application to motors powered by variable frequency

Figure 6 - PV systems without isolation transformer



6

### Immunity to nuisance tripping of Type B RCDs

For Type B RCDs, stringent tests of immunity to nuisance tripping were added in addition to those already provided for Type A RCDs. These tests are<sup>7)</sup>:

- normalized surge current withstand 8/20  $\mu$ s up to the value of 3000 A (Fig. 7);
- insensitivity to residual currents of duration up to 10 ms of amplitude up to 10  $I_{\Delta n}$  (Fig. 8).

With these properties, Type B RCDs turn out to be RCDs with high immunity to nuisance tripping caused by grid surges, electronic loads and EMC filters. Therefore, Type B circuit breakers are the ideal solution for all “difficult” loads, not only from the point of view of protection, but also in terms of service continuity.

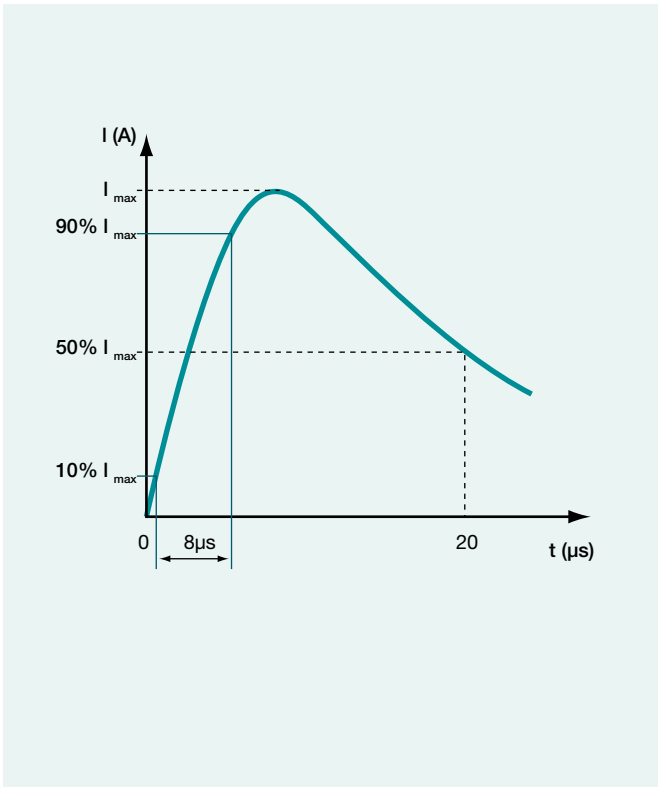
### Where regulations require Type B RCDs

For photovoltaic systems - in the case of systems without at least a simple separation between the AC side and the DC side - if the converter is not exempt by construction design from injecting direct fault currents into the electrical system, one must install a Type B RCD on the AC side (see IEC 60364 Art. 712.413.1.1.1.2).

In group 1 and group 2 rooms for medical use, only Type A or Type B RCDs must be used, according to the type of possible fault current (see IEC 60364 Art. 710.413.1.3).

For STSs and UPSs, if their design contemplates the possibility of ground fault current with direct current components, their installation instructions must state that the building’s residual current circuit breakers must be Type B for the UPSs and the three-phase STSs, and Type A for the single-phase STSs (see IEC/EN 62040-1 Art. 4.7.12 and IEC/EN 62310-1 Art. 4.1.10).

<sup>7)</sup> This is essentially the same type of test passed by ABB’s Type A APR series RCDs, which feature high resistance to nuisance tripping. See “Continuity of supply” in Day by DIN 1|12.



7

As for the charging of electric vehicles, where the charging station is equipped with a socket-outlet or vehicle connector complying with the IEC 62196 series, one must take protection measures against DC fault current, for example Type B RCDs (see IEC 60364 Art. 722.531.2.101)<sup>8)</sup>.

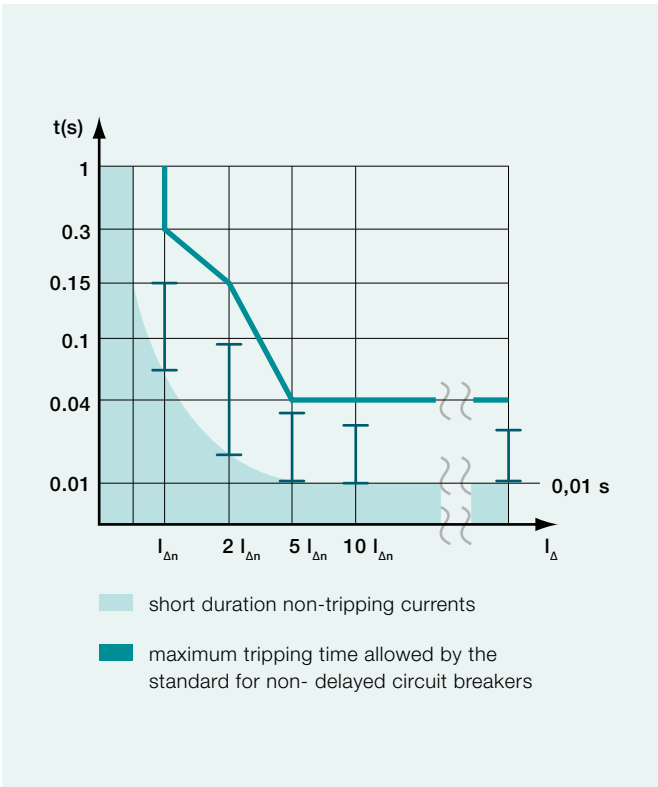
More generally, as to the correct choice of the residual current circuit breaker for power electronics equipment not included in the previous cases, see IEC 62103/EN 50178 (Electronic equipment for use in power installations), according to which (Article 5.2.11.2):

- mobile electronic equipment with rated input power  $\leq 4$  kVA must always be designed to be compatible with Type A RCDs;
- mobile electronic equipment with rated input power  $> 4$  kVA or fixed at any power, which are not compatible with Type A RCDs, must be provided with a warning on the device and in the operating manual to require the use of a Type B RCD or another protection method (e.g. isolation transformer).

### How does a Type B RCD work?

Type B residual current circuit breakers manufactured according to the Standard IEC/EN 62423 are equipped with two ferromagnetic toroids in series: one is intended to detect alternating and pulsating residual currents, the other is for direct currents. All live conductors pass through both toroids (phases and neutral) so as to form a primary winding of a transformer on which the residual current circulates.

The first toroid works in electro-mechanical mode like in a conventional Type A or Type AC circuit breaker: a residual current oscillating at the mains frequency generates by electromagnetic induction a voltage across the secondary winding, which, if it reaches a preset threshold value, causes the release of a demagnetization actuator that acts on the opening mechanism of the contacts.



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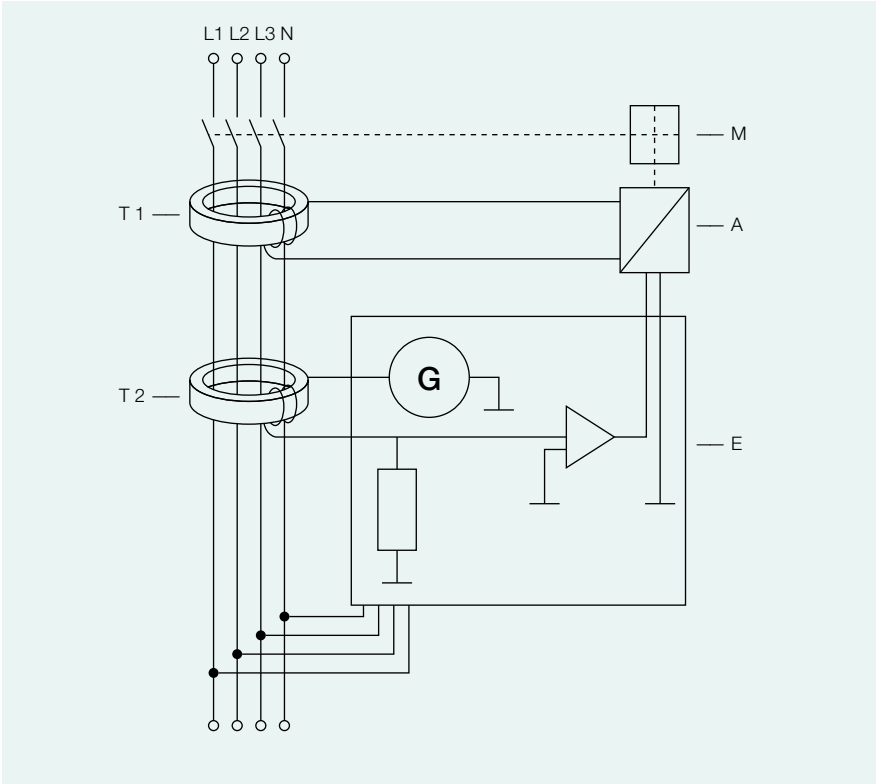
Figure 7 - Surge current  
8/20  $\mu$ s

Figure 8 - Insensitivity to short  
duration residual currents

<sup>8)</sup> Protection device against DC fault current can either be provided by EV charging station or be part of the upstream installations.



T1 - Toroid Core for Detection of AC Sinusoidal and Pulsating DC residual current  
 T2 - Toroid Core for detecting pure DC residual Current  
 M - Mechanical Trip Unit  
 A - Actuator  
 E - Electronics for tripping in case of pure DC leakage Current



9

Figure 9 - Schematic diagram of a Type B circuit breaker

Figure 10 - Examples of the proper installation of a Type B circuit breaker

Figure 11 - Example of the improper installation of a Type B circuit

The second toroid is used by taking advantage of the magnetic saturation of the ferromagnetic material. To its secondary winding is permanently applied an alternating voltage that magnetizes the material. An electronic circuit is capable of detecting the inductance across the secondary winding. The appearance of a direct residual current brings the material to saturation and, consequently, changes its magnetic permeability. This variation, suitably processed, is the signal that determines the release actuator command.

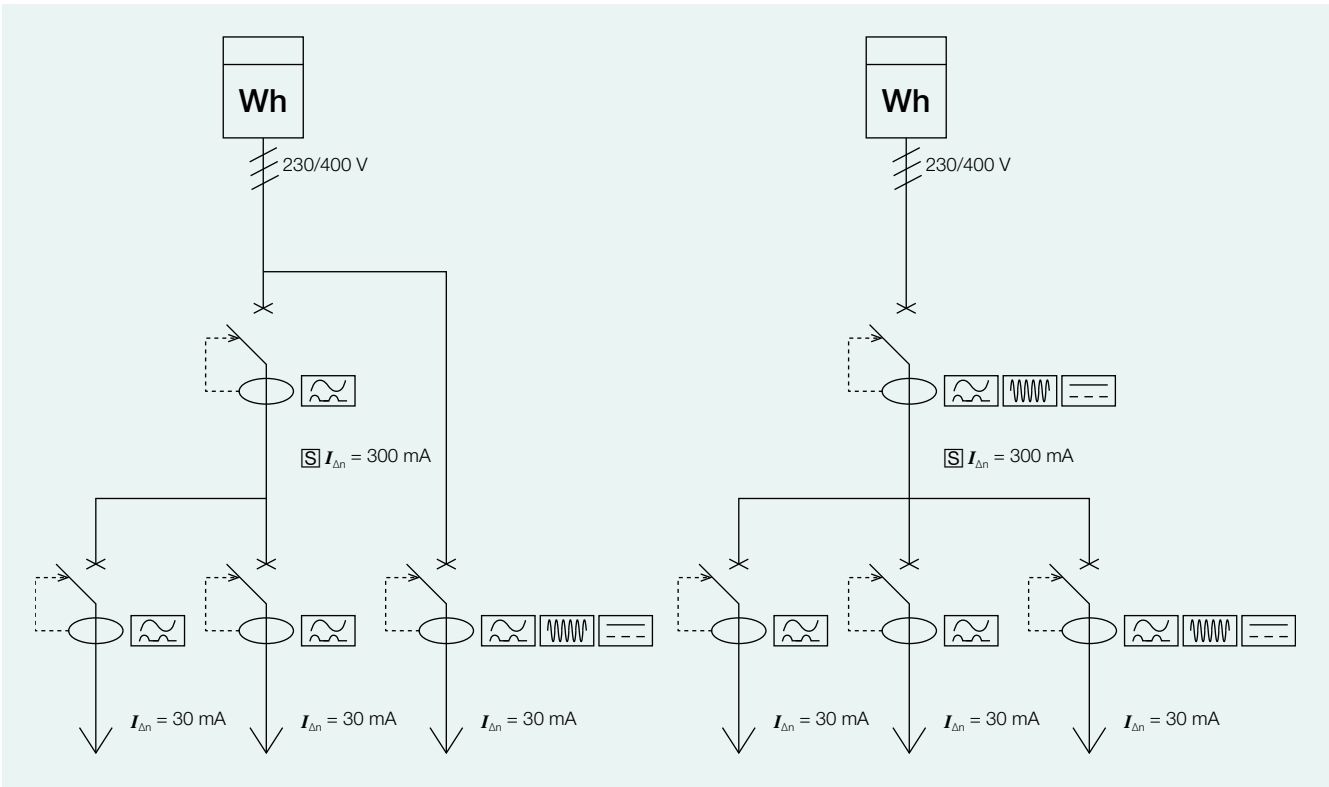
As required by the currently applicable European standards, the operation as a Type A RCD, i.e. the detection of faults with alternating or pulsating waveform, is guaranteed even in the total absence of voltage between the active conductors (phases and neutral). The operation as Type B, however, requires the presence of a minimum voltage on at least any two active conductors.

Proper installation of Type B RCDs

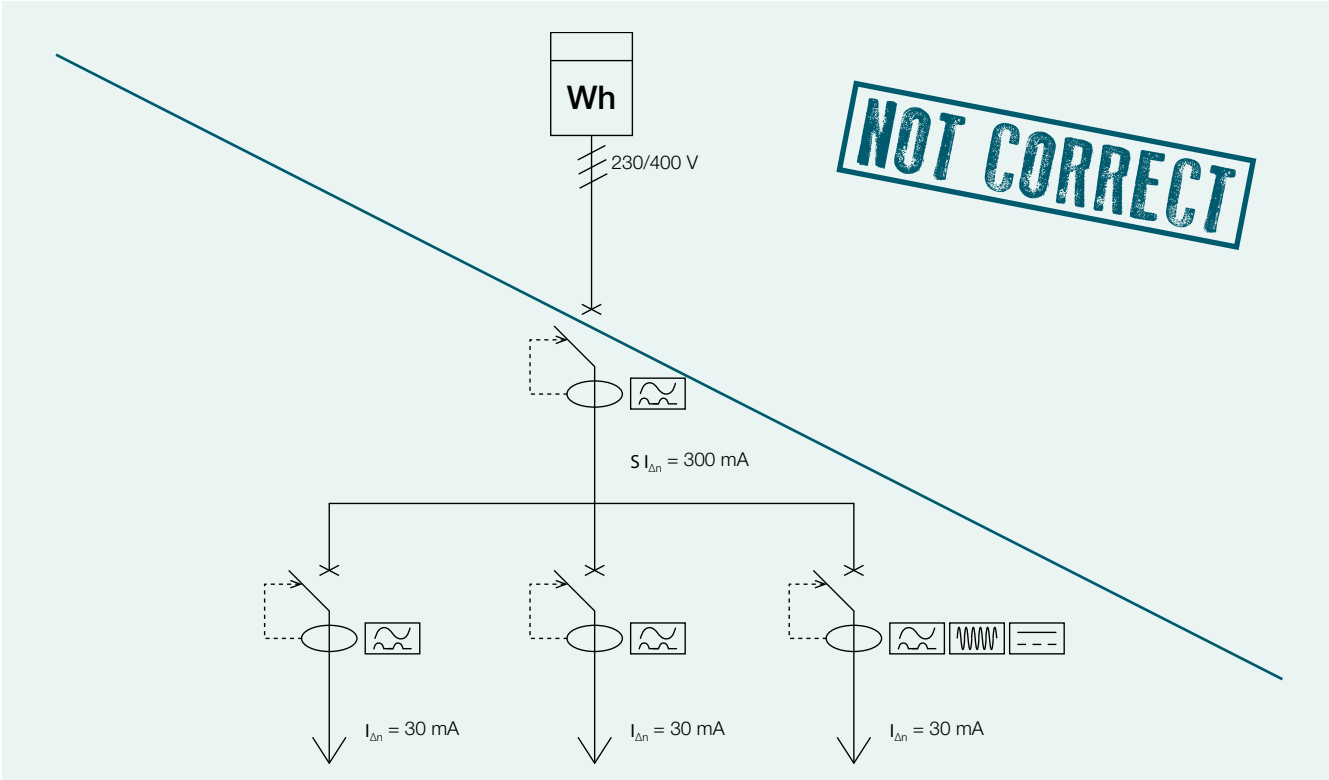
Since Type B residual current circuit breakers are used in the presence of loads that are able to generate also earth current with DC component, when designing the electrical system it is necessary for any other RCD installed upstream of a Type B RCD, passed through by the same fault current, also be of Type B<sup>9)</sup>. Any direct leakage could impair the proper operation of the upstream Type AC, A or F residual current circuit breakers, which are not suitable in the case of direct residual currents. In fact, even if the Type B RCD protects against direct fault currents, the tripping value (for example 60 mA for a circuit breaker with  $I_{\Delta n} = 30\text{ mA}$ ) is high enough to compromise the regular operation of another non-Type B RCD. It is therefore necessary to derive the power supply of the Type B RCD upstream of any non-Type B RCDs, or, if an upstream RCD is required, choose a Type B also for this one.

<sup>9)</sup> See the Standard IEC 62103/EN 50178 "Electronic equipment for use in power installations", Art. 5.3.2.3.





10



11

**Protection against indirect contact (fault protection) at high frequencies**

The maximum tripping values for Type B RCDs with  $I_{\Delta n}$  not exceeding 30 mA, for the purposes of additional protection against direct contacts, are below the limit curve of the ventricular fibrillation threshold established in Publication IEC/TS 60479 also in the case of direct or high-frequency current.

To provide fault protection (protection against indirect contact in TT systems, the circuit breaker must be coordinated with the resistance of the grounding system with the customary ratio:

$$R_E \cdot I_{\Delta n} \leq 50 \text{ V}$$

With this coordination ratio the protection against indirect contact is automatically checked in the case of direct current faults, since the permissible limit contact voltage in direct current is 120 V, which corresponds to 50 V in alternating current.

In the case of high-frequency faults, however, a permissible limit contact voltage has not yet been established at the regulatory level. Although the risks for the human body decrease as the frequency increases, until the standards have set these values, the Standard IEC/EN 62423 recommends as a precautionary measure to maintain unchanged the value of 50 V also at higher frequencies. To do this, it is necessary to take into account the actual tripping value of a possible fault frequency. For example, in the case of a type B circuit breaker whose tripping characteristic is that shown in Figure 12, at 1000 Hz tripping is guaranteed with a residual current of 300 mA (lower than the regulatory limit of 420 mA). Therefore, if the consuming equipment can generate a fault current at 1000 Hz, the ground resistance must satisfy the ratio

$$R_E \cdot 0,3 \text{ A} \leq 50 \text{ V}$$

i.e.

$$R_E \leq 166 \text{ }\Omega$$



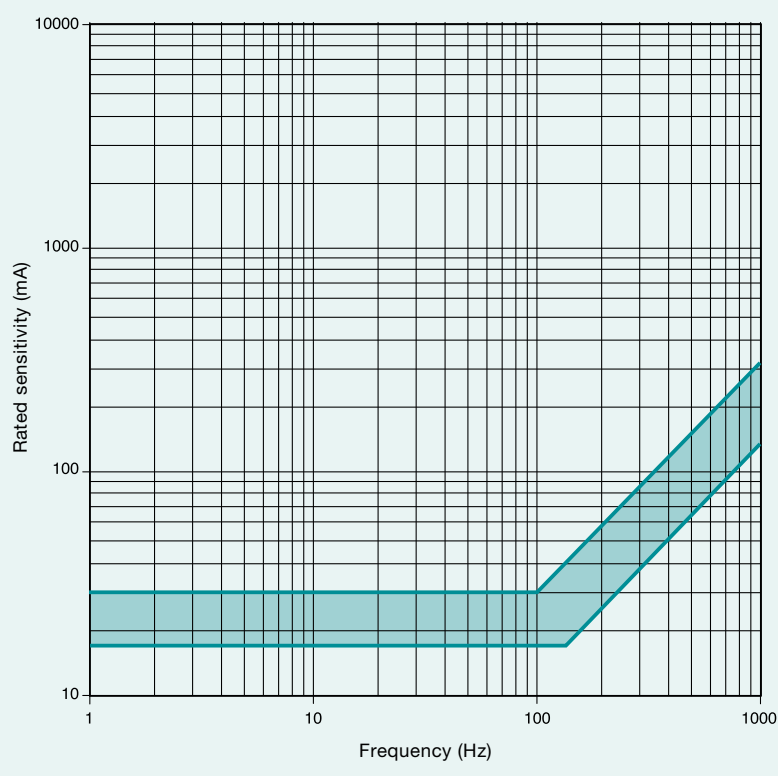
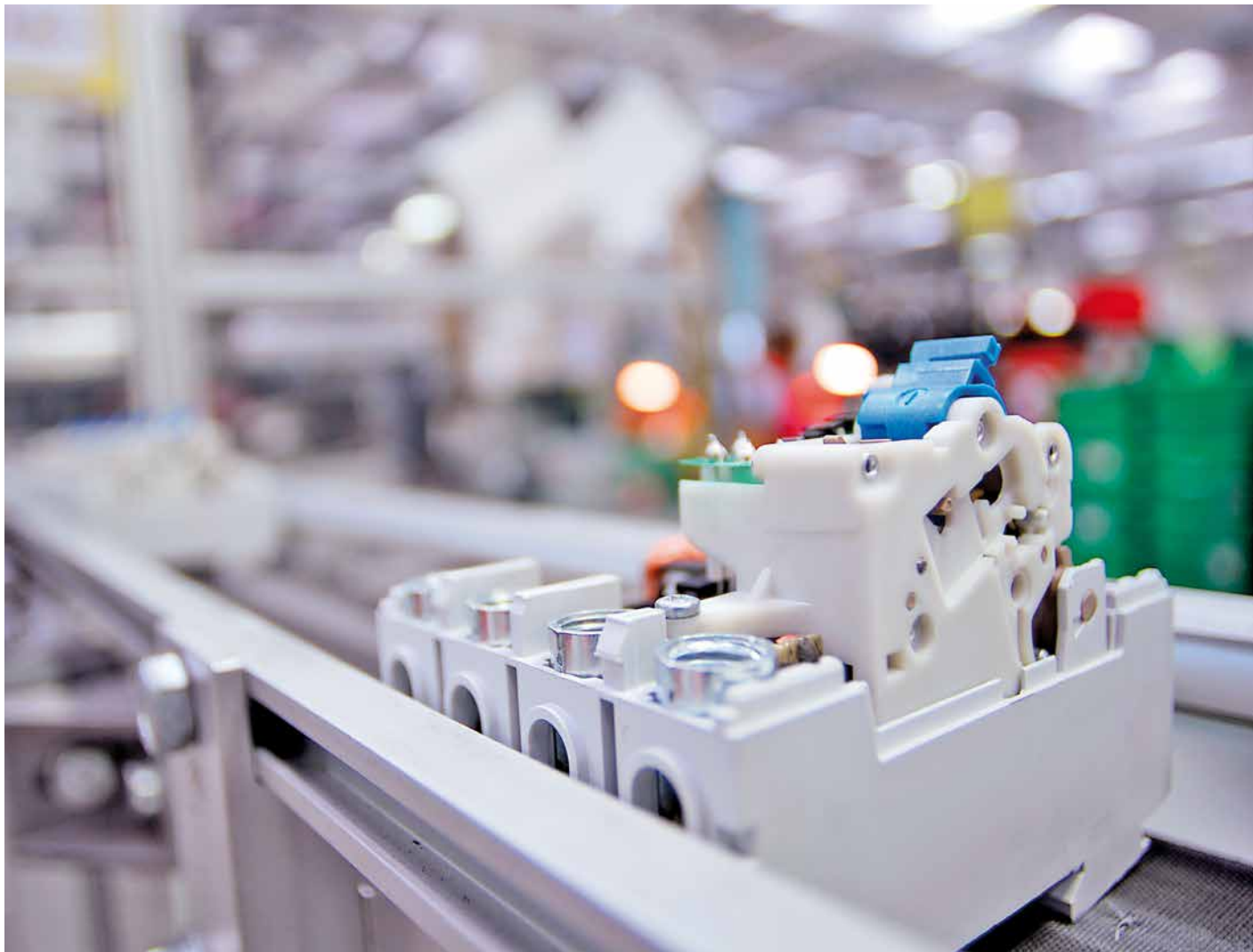


Figure 12 - Tripping curve in the frequency of a given circuit breaker



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