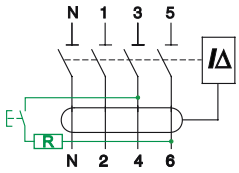
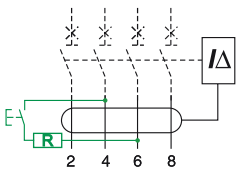
Earth leakage protection
Routine operating checks

Residual current devices are vital for the safety of people.
That is why:
■ the electrical installation operation and maintenance standards require these protection devices to be tested at regular intervals,
■ the product standards IEC 61008 and IEC 61009 require such devices to be fitted with a test button (marked "T") on the front panel.
The user can therefore check and be certain that the device is working correctly.

The test button provides reliable information about how the device is working: tripping as soon as the button is pressed guarantees that the protection is working properly. If the device fails to trip, it must be examined to determine the cause of this malfunction.



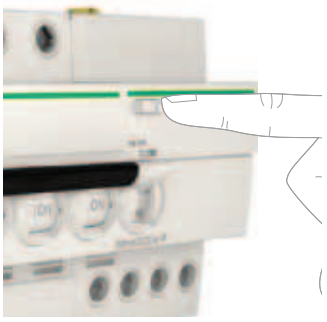
Example iID



Example Vigi iC60

Test frequency
The residual current devices must be tested as frequently as required by the installation regulations and/or the safety regulations currently in force.
In the absence of any regulations, Schneider Electric recommends the test to be carried out:
■ after initial connection and any subsequent reconnection,
■ every years, for devices recently installed in good environmental conditions (no dust, corrosion, humidity, etc.),
■ every 3 months, for devices that have been in use for seven years or more in good environmental conditions,
■ every months, for devices used in corrosive or harsh environmental conditions or highly exposed to lightning strikes.

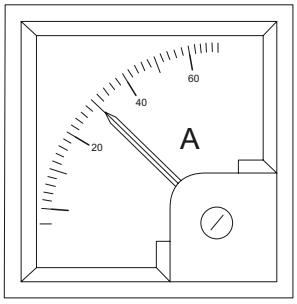
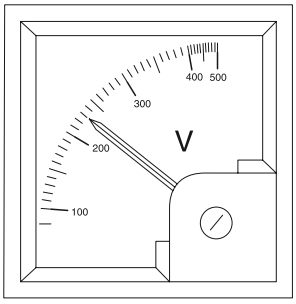
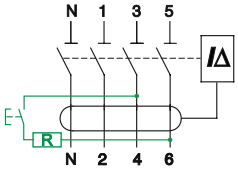
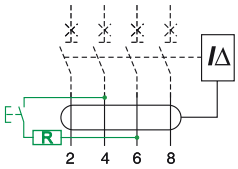
Procedure

The residual current device is powered on and the loads are connected.	**Briefly** press the test button marked "T" on the front panel. ⚠ Pressing the test button too long can seriously damage the device.	The residual current device should trip instantly. If it fails to trip, the additional checks described below should be performed.	When the test is finished, put the residual current device back into service.
			

Earth leakage protection
Routine operating checks

Failure to trip during the test

Failure to trip during the test is often due to a cause that is external to the residual current device.
The table below shows the possible causes, the additional checks and tests to be carried out and the corrective actions to be taken, depending on the results.
After a corrective action has been performed, repeat the test until a correct result is obtained.

Cause of the malfunction			
Network frequency	**Network voltage**	**Connection (three-pole or four-pole device)**	**Load leakage currents**
Additional test			
Check that the network frequency is the same as the frequency read on the device.	Check that the mains voltage is the same as that indicated on the front face of the device.	Measure the voltage between terminals: ■ 3 and 6 for iID ■ 4 and 6 for Vigi iC60. This voltage must be between 85 % and 110 % of the voltage indicated on the device.	Disconnect the loads and press the test button again.
		 iID  Vigi iC60	
Incorrect test result			
If the network frequency is different, the button test is not significant.	■ If the voltage measured is less than 85 % of that indicated on the device, the test button may not work, although the protection device will continue to function. ■ If the voltage measured is more than 110 % of the voltage indicated on the device there is a risk that the device will be destroyed.	The incorrect voltage may be due to a connection error (e.g. phase/neutral inversion/missing phase, etc.). The Acti 9 three-pole and four-pole residual current devices cannot be used on single-phase circuits. The Acti 9 four-pole residual current devices can be used normally on three-phase circuits without neutral.	If the device trips, the earth leakage protection is working correctly.
Corrective actions			
The device must be checked by an external device (see below).	**If the voltage measured is different from the rated voltage of the mains, look for the problem on the power supply or on the downstream circuits (lines, loads):** **■ if the rated voltage of the mains is lower than that indicated on the device it must be replaced by a device with a suitable rated voltage the next time it is shut down** **■ if the rated voltage of the mains is higher than the voltage indicated on the device it must immediately be replaced by a device with a suitable rated voltage.**	**Modify the connection to obtain the rated voltage (phase-phase) between terminals.**	**Measure the permanent leakage current of each load.** **■ in the event of abnormal load leakage, correct the insulation fault.** **■ otherwise, separate the circuits to reduce the permanent leakage currents seen by each residual current device.**

If none of the additional tests indicate a fault, the residual current device is faulty. Checking with an external device (see below) will show whether or not it has to be replaced urgently.

Test result	Positive	Negative
Diagnosis		
	■ the earth leakage protection device is working properly ■ the test circuit is faulty	Earth leakage protection is not working
Corrective actions		
	The residual current device must be replaced quickly (as soon as it is no longer being used).	**The residual current device must be replaced immediately**

Earth leakage protection
Routine operating checks

Some tertiary and industrial installation safety regulations require residual current devices to be checked with a specific device.

Checking with a specific test device
For the tests performed to be valid, these devices must comply with IEC 61557-6.

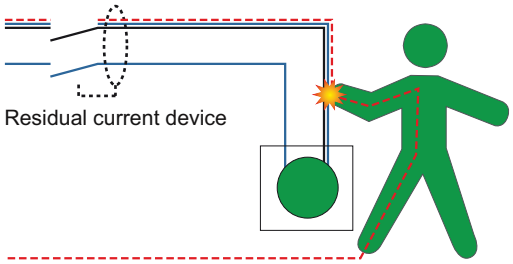
These devices are used to check:
- the operating voltage
- the tripping threshold (according to the sensitivity IΔn) of the residual current device
- the tripping times at IΔn, 2 x IΔn, 5 x IΔn, etc. The normal values are shown on pages CT6-1 and CT6-4.

With an IT earthing system (isolated neutral), a first insulation fault should be created artificially to allow a fault current to circulate during the tests.

Procedure
- Disconnect the fixed and mobile loads (if the residual current device protects the power outlets).
- Connect the test device to the downstream terminals of the residual current device or to a downstream power outlet.

Earth leakage protection
Response time of high-sensitivity residual current devices 30 mA

All the high-sensitivity residual current devices (30 mA) in the Acti 9 range conform to the IEC/EN 61008 and IEC/EN 61009 standards. The response times defined by these standards guarantee their effectiveness in protecting people against direct contacts.



Response time

The response time of a residual current device is the time between the appearance of a dangerous leakage current and circuit power down.

Types AC, A, *Si*

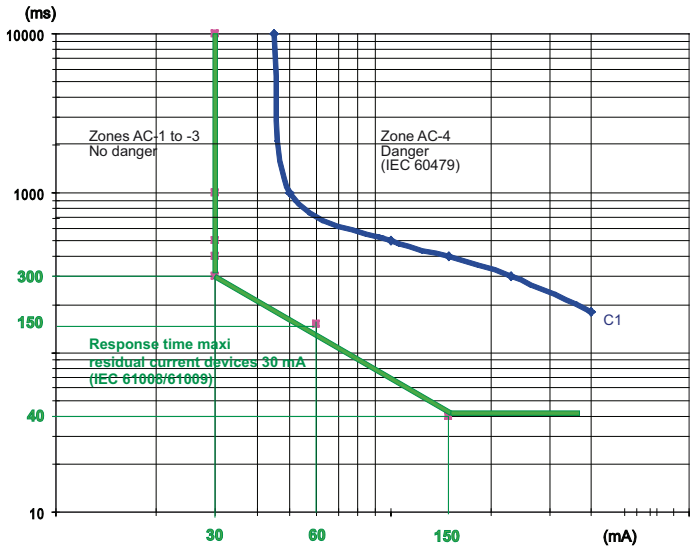
Fault current (mA)		Maximum response time (ms)
I∆n/2	15 mA	No tripping
I∆n	30 mA	300 ms
2 x I∆n	60 mA	150 ms
5 x I∆n	150 mA	40 ms

Type B, DC leakage current

Fault current (mA)		Maximum response time (ms)
I∆n/2	15 mA	No tripping
2 x I∆n	60 mA	300 ms
4 x I∆n	120 mA	150 ms
10 x I∆n	300 mA	40 ms

These response times conform to the specifications of the IEC/EN 61008, IEC/EN 61009 and IEC/EN 62423 (DC leakage current) standards.

They guarantee protection of people against direct contacts for the following reasons :
- when a person comes into direct contact with a live conductor, the current passes directly through the human body,
- this current, with the same magnitude, is detected by the residual current device.



- The IEC 60479 technical report studies the sensitivity of the human body to the electric current. Curve c1 defines for each current value the maximum time before the current causes injury to a person.
- Superimposing the two curves shows that the above response times protects the users.

Measuring the response time

If the user wishes to check the response time of his residual current devices, he should follow a specific procedure to:
- establish a leakage current of calibrated magnitude,
- measure the exact response time.

Procedure

The measuring instruments must conform to **IEC**/EN 61557-6.
Carry out the operations in the following order according to the safety instructions:
- disconnect the loads,
- install the measuring instrument downstream of the residual current device to be tested (for example on a power outlet),
- perform the measurement.

Earth leakage protection
Response time of medium-sensitivity residual current devices 100 mA...1000 mA

Response time of iC60 Vigi and iID residual current devices
The medium-sensitivity residual current devices (100…1000 mA) in the Acti 9 range conform to IEC/EN 61008, IEC/EN 61009 and IEC/EN 62423 (DC leakage current):
- their response time guarantees personal protection against indirect contacts and fire risks,
- in the case of selective versions (S), a "non-tripping time" guarantees discrimination with the residual current devices installed downstream.

Types AC, A, *Si*

Instantaneous residual current devices

Residual current device		Sensitivity (IΔn) 100 mA	300 mA	500 mA	
Fault current (mA)	IΔn/2	50	150	250	No tripping
					Max. response time
	IΔn	100	300	500	300 ms
	2 x IΔn	200	600	1000	150 ms
	5 x IΔn	500	1500	2500	40 ms
	500 A				40 ms

Selective (S) and time-delayed (R) residual current devices

Residual current device		Sensitivity (IΔn) 100 mA	300 mA	500 mA	1000 mA	Type Selective (S)		Time-delayed (R)	
Fault current (mA)	IΔn/2	50	150	250	500	No tripping		No tripping	
						Non-tripping time	Response time	Non-tripping time	Response time
	IΔn	100	300	500	1000	130 ms	500 ms	300 ms	1000 ms
	2 x IΔn	200	600	1000	2000	60 ms	200 ms	150 ms	500 ms
	5 x IΔn	500	1500	2500	5000	50 ms	150 ms	150 ms	300 ms
	500 A					40 ms	150 ms	150 ms	300 ms

Type B, DC leakage current

Instantaneous residual current devices

Residual current device		Sensitivity (IΔn) 300 mA	500 mA	
Fault current (mA)	IΔn/2	150	250	No tripping
				Max. response time
	2 x IΔn	600	1000	300 ms
	4 x IΔn	1200	2000	150 ms
	10 x IΔn	3000	5000	40 ms
	5 A...200 A			40 ms

Selective (S) residual current devices

Residual current device		Sensitivity (IΔn) 300 mA		
Fault current (mA)	IΔn/2	150	No tripping	
			Non-tripping time	Response time
	2 x IΔn	600	130 ms	500 ms
	4 x IΔn	1200	60 ms	200 ms
	10 x IΔn	3000	50 ms	150 ms
	5 A...200 A		40 ms	150 ms

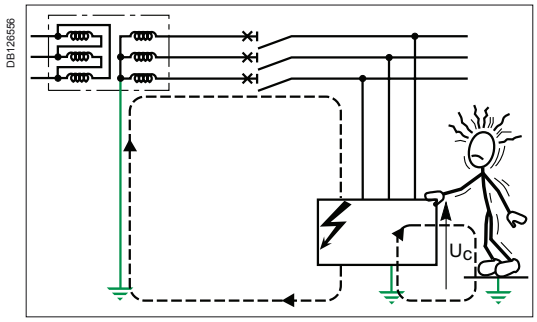
Definitions

Response time
Time between the appearance of a hazardous leakage current and circuit power down.

Non-tripping time
For selective and time-delayed devices, the non-tripping time is the time between the appearance of a hazardous leakage current and the device tripping.
If the leakage current disappears before this time, the device does not trip.
This fast disappearance of the leakage current can be due to:
- the transient nature of the fault (e.g. the current generated by a switching surge),
- the interruption of the fault current by another faster residual current device situated downstream.

Selective and time-delayed devices therefore afford the user:
- better immunity against nuisance tripping,
- total discrimination between residual current devices.

Earth leakage protection
Response time of medium-sensitivity residual current devices 100 mA...1000 mA



Protection against indirect contacts

The response times of residual current devices guarantee personal protection against indirect contacts, in conformance with the requirements of the installation standards (IEC 60364 or equivalent).

Indirect contacts

A person who comes into contact with an accidentally live frame caused by an insulation fault experiences an indirect contact: the contact voltage Uc creates a current that passes through the human body.

Maximum breaking time

The maximum breaking time required by the installation standards, in the event of an insulation fault, depends on:

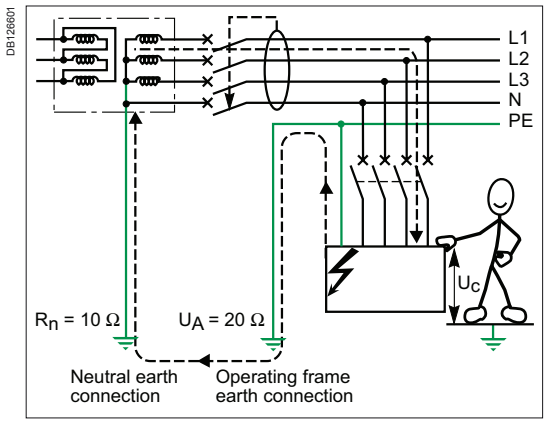
- the network voltage,
- the earthing system.

Maximum breaking time for terminating circuits (ms)

Earthing system	Network phase/neutral voltage			
	50...120V	120...230V	230...400V	> 400 V
TN or IT	800	400	200	100
TT	300	200	70	40

Note: a breaking time of no more than 5 s is permitted for distribution circuits to ensure discrimination with the devices installed on the terminating circuits.
This time should be reduced to the essential minimum.

These times are based on the maximum prospective values of the contact voltage Uc and on the contact times authorised by technical report IEC 60479.



Example

On a three-phase phase/neutral voltage network Uo = 230 V in a TT system:

- the resistance of the neutral earth connection Rn is 10 Ω,
- the resistance of the operating frame earth connection RA is 100 Ω.

In the event of an insulation fault, the leakage current Id is equal to: Uo/ (RA + Rn) i.e. 230 V/110 Ω = 2.1 A.
The contact voltage Uc is therefore Id x RA i.e. 2.1 A x 100 Ω = 210 V.

Protection sensitivity

The residual current device must trip as soon as the leakage current corresponds to a hazardous situation, i.e. a contact voltage of 50 V (in a dry atmosphere).
Hence, IΔn = 50 V / RA, i.e. 50 V/100 Ω = 500 mA.

Maximum breaking time

For a 230 V phase/neutral voltage network in a TT system, the IEC 60364 standard requires a maximum breaking time of 200 ms.
For the 2.1 A leakage current:

- □ an instantaneous residual current device with a sensitivity of 300 mA will power down the circuit in less than 40 ms,
- □ an instantaneous residual current device with a sensitivity of 500 mA will power down the circuit in less than 60 ms.

Note: For well-designed and regularly maintained electrical installations, the resistance of the operating frame earth connection can be less than 100 Ω.

Use of the time-delayed residual current devices

In accordance with the breaking times required by the installation standards (above), the selective and time-delayed residual current devices can be used in the following cases:

Circuit	Network voltage (phase/neutral)	Residual current device		
		Instantaneous I	Selective S	Time-delayed R
Terminating circuit	≤ 230 V	■	■	(1)
	> 230 V	■		
Sub-distribution or general		■	■	■

(1) Only in a TN system for a phase/neutral voltage < 120 V.

Earth leakage protection

Response time of medium-sensitivity residual current devices 100 mA...1000 mA

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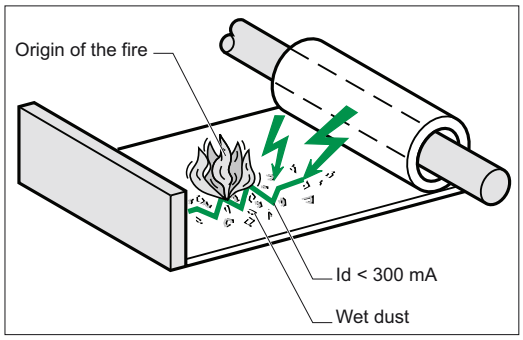

Protection against fire hazards

Most fires of electrical origin are caused by the creation and propagation of electric arcs in building materials, in the presence of moisture, dust, pollution, etc.
These arcs appear and develop due to the wear and tear or ageing of the insulating materials. The fire risk occurs when the leakage currents reach a few hundred milliamps for a few seconds.
For fault currents of this magnitude, residual current devices with a sensitivity of 300 or 500 mA trip in less than a second, whether they be instantaneous, selective or time-delayed.

The response times of residual current devices with a sensitivity of 300 mA guarantee protection against fires generated by leakage currents

IEC 60364-4-42 (subclause 422.3.10) states that it is mandatory to install a residual current device with a sensitivity less than or equal to 500 mA:
- on premises with a risk of explosion (BE3),
- on premises with a risk of fire (BE2),
- in agricultural and horticultural buildings,
- for circuits supplying fair, exhibition and entertainment equipment,
- on temporary outdoor leisure facilities.

In certain countries, the installation rules and/or local safety regulations require a sensitivity of 300 mA.

Earth leakage protection

Response time of medium-sensitivity residual current devices 100 mA...1000 mA

Discrimination of residual current devices

The non-tripping times of type (S) and (R) residual current devices ensure discrimination with the residual current devices located downstream.

Combination rules

To ensure discrimination between two cascading residual current devices, the following two conditions must be met simultaneously:

- the sensitivity of the upstream device must be at least 3 times the sensitivity of the downstream residual current device,
- the upstream residual current device must be one of the following types:
  - Selective (S) if the downstream residual current device is instantaneous,
  - Time-delayed (R) if the downstream residual current device is selective (S).

The figure below shows how compliance with these rules provides discrimination on three levels: whatever the value of the fault current, it will be interrupted by the device situated immediately upstream of the fault and only by this device.

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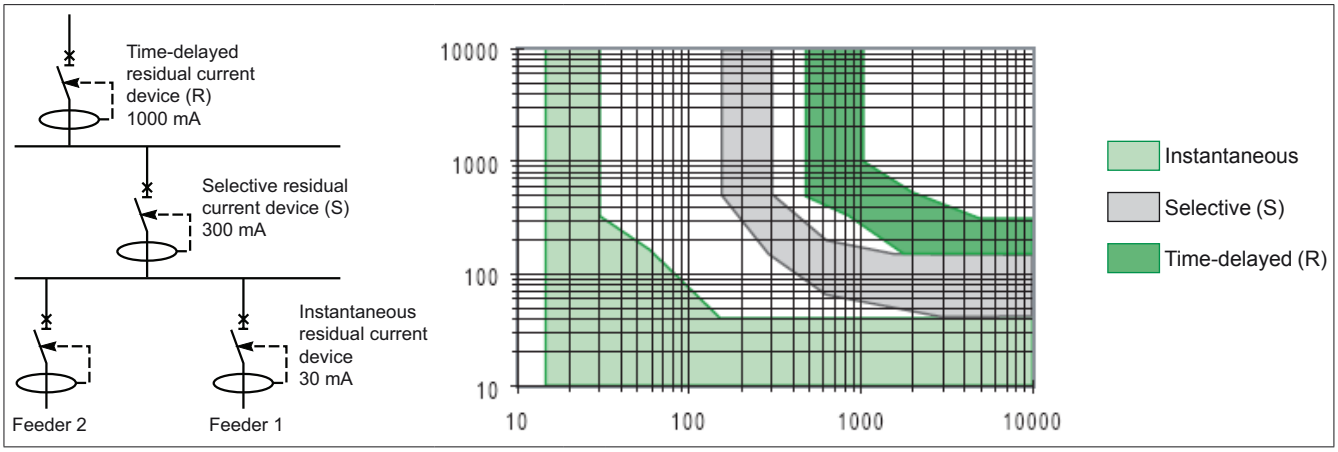


Example:

In the above diagram for a fault current of 1000 mA:

- if the fault occurs downstream of the 30 mA residual current device, the latter will interrupt the current in less than 40 ms, whereas type S and R devices "wait" for 80 ms and 200 ms respectively. Therefore, neither of the two devices trips,
- if the fault occurs downstream of the type S residual current device, the latter will interrupt the current in less than 175 ms, whereas the type R device "wait" for 200 ms and therefore does not trip.

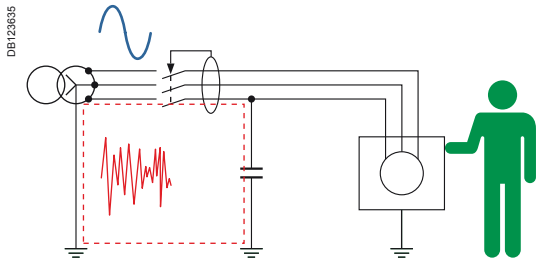
If these cascading combination rules are complied with, the level of continuity of service provided to the user depends on the way in which the "horizontal discrimination" is implemented: the terminal feeders must be divided into as many circuits as necessary, each protected by a residual current device.

Electrical and electromagnetic interference

Operation of earth leakage protection devices

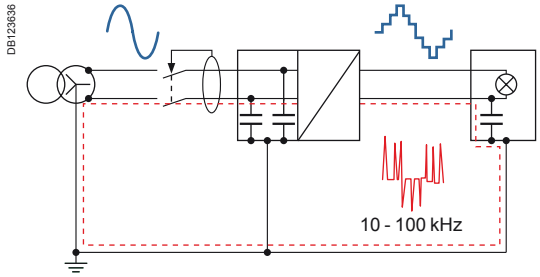
Some types of electrical and electromagnetic interference caused by the network or its environment may affect the operation of earth leakage protection devices and result in:
■ **Nuisance tripping** (tripping in a non-dangerous situation). Such tripping is often repetitive, which is highly detrimental to satisfying the user's energy requirements.
■ **Risk of non-tripping** in dangerous situations. This risk must be carefully analysed, because it affects people's safety. The standards define three categories of earth leakage protection devices according to their ability to control these types of situation.

■ The risk of interference must be taken into account when selecting earth leakage protection devices (see module CA902000), according to the loads supplied and the environment.
■ The explanations given below specify the main types of interference, their origin and how Schneider Electric's earth leakage protection devices respond, according to their type.



Nuisance tripping

This type of tripping is caused by the combination of two factors:
■ A transient or continuous high-frequency voltage that is superimposed on the normal network voltage (50 Hz).
■ The presence of capacitors between the electrical network and the earth (or frames). As these capacitors are exposed to a high-frequency voltage, a current which can trip an earth leakage protection device flows to earth.
The causes, duration and frequency spectra of such interference, which is often difficult to identify, can vary greatly, as shown in the examples below.



High-frequency harmonics

The current absorbed by non-linear loads such as IT equipment power supplies, frequency converters, variable speed drive motor controls, electronic ballast lights, etc. includes high-order harmonics.
If the natural capacitances of the protected circuit are significant (between the cables and earth, or between the live parts of the devices and their frames), earth leakage protection devices may be tripped, although no danger is present.
This risk of nuisance tripping is all the more likely to occur when a large number of identical loads are supplied in parallel and protected by the same earth leakage protection device.

Low-frequency continuous leakage currents

These leakage currents are mainly generated by the filtering capacitors in the power supply stage of electronic devices. Depending on the number of devices protected by the same earth leakage protection device, these leakage currents may:
■ Increase the risk of tripping in the event of high-frequency interference.
■ Cause frequent tripping

To guarantee satisfactory operation, these continuous leakage currents must not exceed 25% of the sensitivity (IΔn) of the earth leakage protection device, by limiting the number of "interfering" loads protected by the same earth leakage protection device.
■ If more accurate data is unavailable, the leakage current can be estimated on the following basis, for a 230 V, 50 Hz network:
□ heating floor: 1 mA / kW,
□ fax, printer: 1 mA,
□ PC, workstation: 2 mA,
□ photocopier: 1.5 mA.

If long cables are installed downstream of the earth leakage protection devices, it may be necessary to take the natural capacitance formed by the cable/earth pair into account (order of magnitude: at 230 V, approximately 1.5 mA for 100 m).