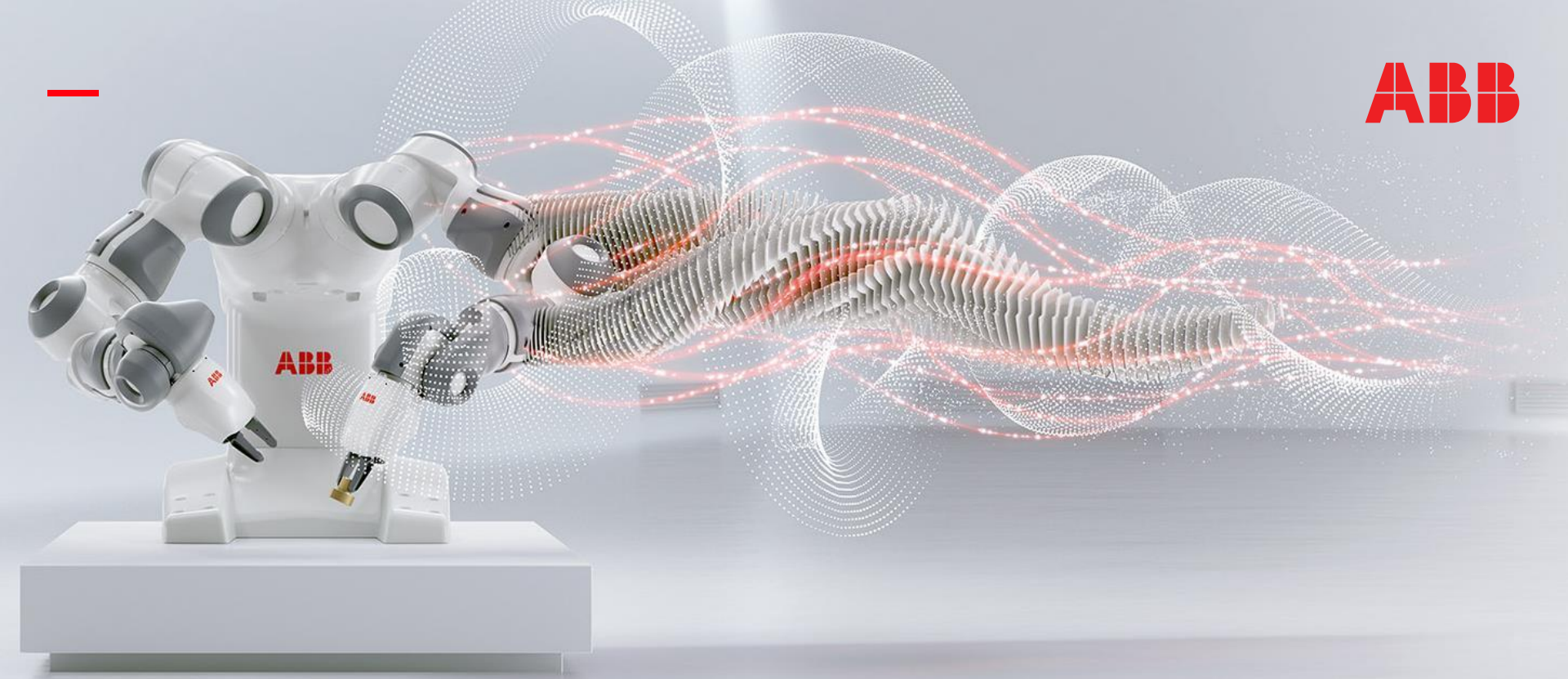

RAYMONDKOH / 21ST MARCH 2017

Extra Safety Campaign

SS 97 Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – General rules

Residual Current Devices
Reference Standard to IEC 60479-1

IEC/TS 60479
- Effects of current
on human beings and livestock

Part 1: general aspects
Part 2: special aspects
Part 3: effects of currents passing through the body of livestock
Part 4: effects of lightning strokes on human beings and livestock
Part 5: touch voltage threshold values for physiological effects


IEC

IEC/TS 60479-1

Edition 4.0 2005-07

TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

BASIC SAFETY PUBLICATION
PUBLICATION FONDAMENTALE DE SÉCURITÉ

Effects of current on human beings and livestock –
Part 1: General aspects

Effets du courant sur l'homme et les animaux domestiques –
Partie 1: Aspects généraux

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Reference Standard to IEC 60479-1
Introduction

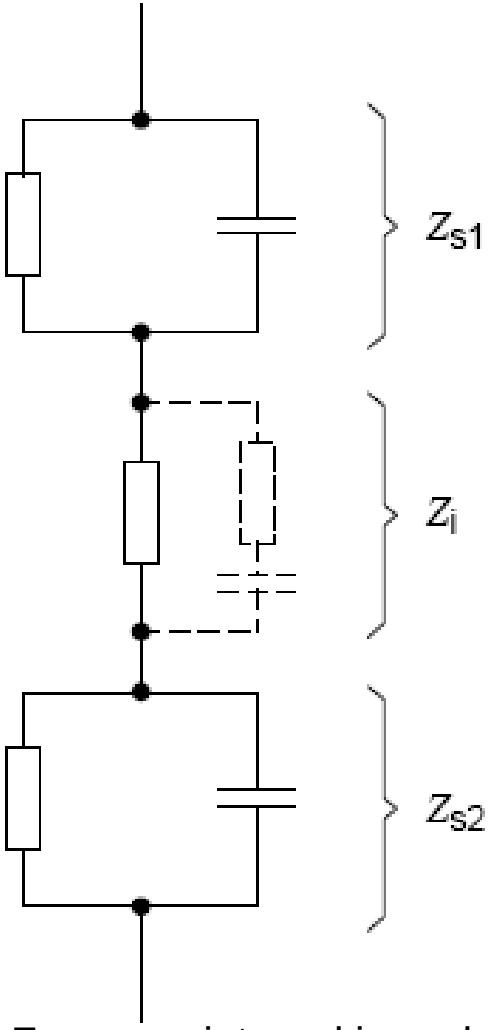
The hazards of electric shock

The danger depends mainly on the magnitude and duration of the current flow.

The human body can be considered an impedance.

This value of impedance depends on many factors.





Z_i	internal impedance
Z_{s1}, Z_{s2}	impedances of the skin
Z_T	total impedance

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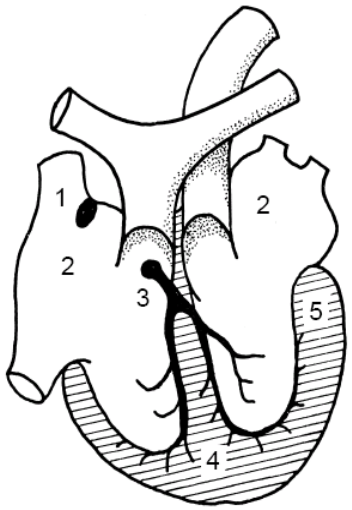
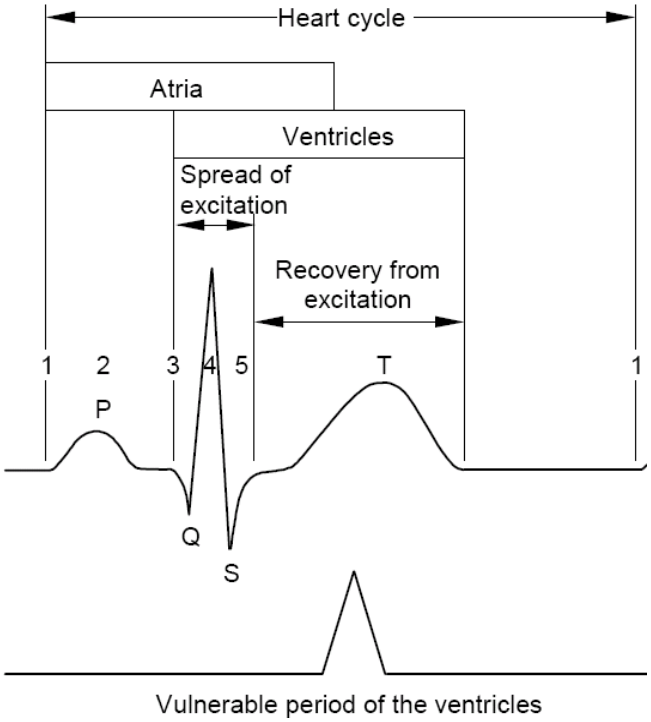
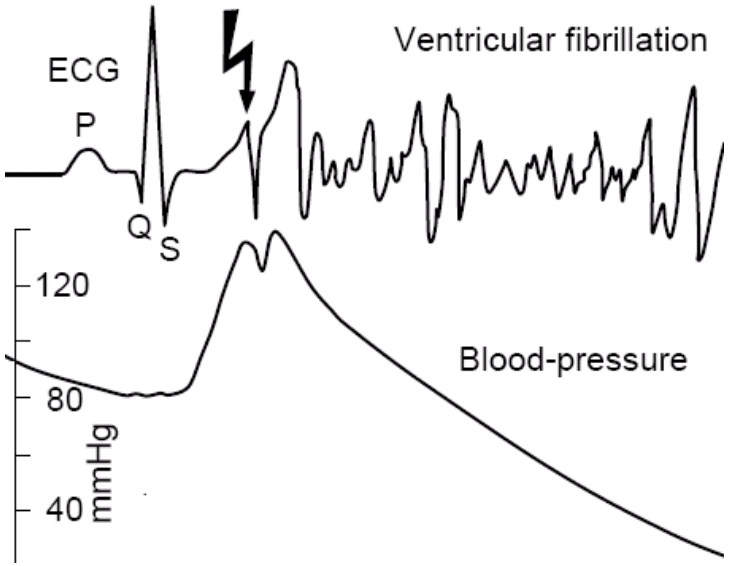
Reference Standard to IEC 60479-1
Effect of Current on Human Body







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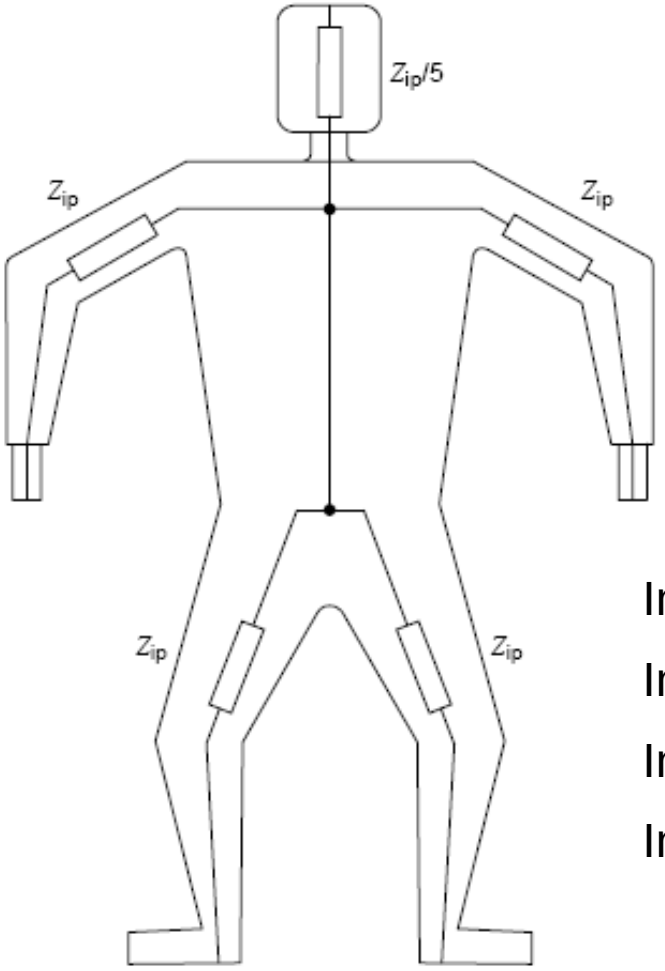
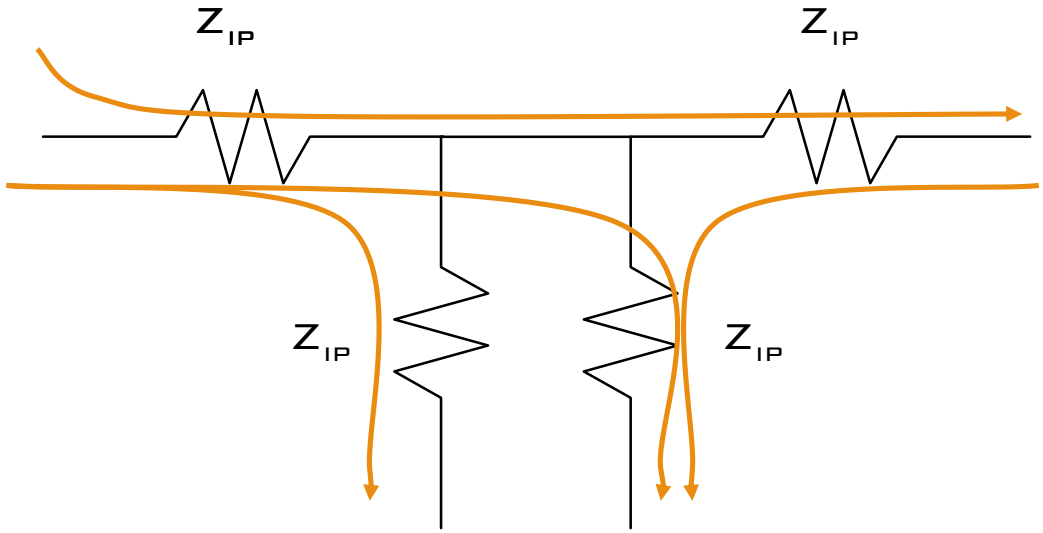
Reference Standard to IEC 60479-1
The Impedance of human Body

- The human body





Impedance hand to hand is 2 Z_{ip}

Impedance hand to foot is 2 Z_{ip}

Impedance from one hand to both feet is 3/2 Z_{ip}

Impedance from both hands to both feet is Z_{ip}

Working with 2 hands and standing posture

z_{IP} = internal partial impedance of one extremity

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Reference Standard to IEC 60479-1
Value of Total Impedances

Touch voltage V	Values for the total body impedances Z_T (Ω) that are not exceeded for		
	5 % of the population	50 % of the population	95 % of the population
25	1 750	3 250	6 100
50	1 375	2 500	4 600
75	1 125	2 000	3 600
100	990	1 725	3 125
125	900	1 550	2 675
150	850	1 400	2 350
175	825	1 325	2 175
200	800	1 275	2 050
225	775	1 225	1 900
400	700	950	1 275
500	625	850	1 150
700	575	775	1 050
1 000	575	775	1 050
Asymptotic value	575	775	1 050

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Reference Standard to IEC 60479-3
Value Of Total Cow Body Impedances

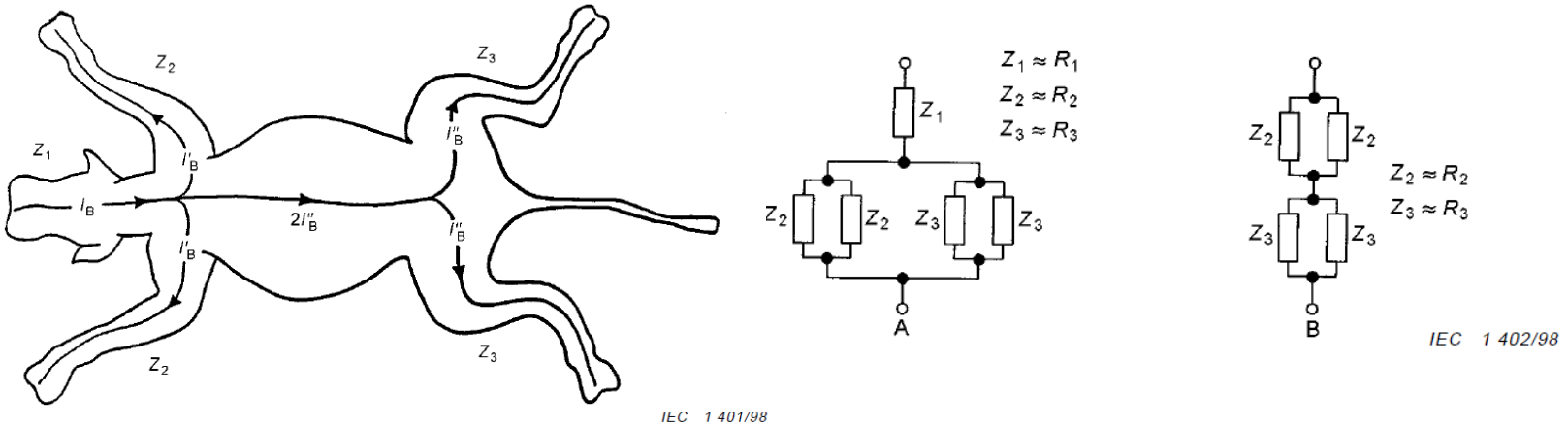

Figure 1 – Current flow and impedances of the relevant parts of the body of a cow for current path from the nose to the legs

Table 2 – Total body impedances Z_T for a.c. 50/60 Hz for cattle for touch voltages up to 230 V

Current path	Values for total body impedance (Ω) that are not exceeded for a percentage of the population		
	5 %	50 %	95 %
Nose to four legs	220	300	425
Forelegs to hindlegs	600	850	1 250
NOTE – The values are rounded off from statistical analysis of 80 cattle measured.			

Reference Standard to IEC 60479-1
Value Human Body Impedances Under Other Conditions

Table A.1 – Total body impedances Z_T, electrodes type A for dry condition and deviation factors F_D (5 % and 95 %)

Condition	Total body impedances Z_T (Ω) / deviation factors F_D		
	5 %	50 %	95 %
Dry	1 750 / 0,54	3 250	6 100 / 1,88

Table A.3 – Total body impedances Z_T for dry, water-wet and saltwater-wet conditions and deviation factors F_D (5 % and 95 %)

Condition	Total body impedances Z_T (Ω) / deviation factors F_D		
	5 %	50 %	95 %
Dry	80 400 / 0,48	169 000	355 500 / 2,10
Water-wet	39 700 / 0,54	73 400	135 600 / 1,85
Saltwater-wet	5 400 / 0,74	7 300	9 875 / 1,35

To 2.8% of original impedance

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Residual Current Devices
Use of RCDs against Indirect Contacts

- The RCDs and the insulation faults

The RCDs trip in presence of an earth fault current that they detects.

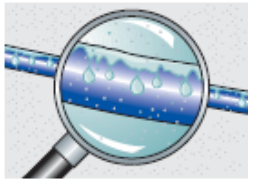
The presence of a fault current is generated for:



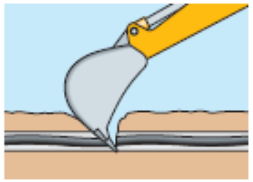
- insulation breaking;



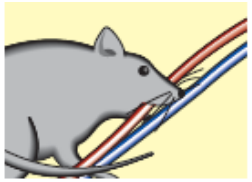
- time decay of dielectric properties;



- presence of humidity;



- mechanical breaking (excavator or rodent action).



Residual Current Devices
Products and Reference Standards







Residual Current Devices (RCDs)

Residual Current Circuit-Breakers for use by uninstructed people:

- **IEC 61008-1 :2000-09, SS97**
  - **Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs)**
- **IEC 61009-1 :2000-09, SS480**
  - **Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)**

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Residual Current Devices
Products and Reference Standards



Residual Current Devices (RCDs)

Residual Current Circuit-Breakers for use by uninstructed people:

- IEC 61009-1, Annex G:
  - **Additional requirements and tests for RCBOs consisting of a circuit-breaker and a residual current unit designed for assembly on site.**



- IEC 62423:
  - **Type B Residual Current Operated Circuit-Breakers with or without overcurrent protection fot household and similar uses.**

Residual Current Devices
Products and Reference Standards



Residual Current Devices (RCDs)

Devices mainly intended for the protection of installations or equipment against earth fault currents:

- IEC 60947-2 Annex B:
- Low Voltage Breakers- **Circuit-breakers incorporating residual current protection (CBRs)**



- IEC 60947-2 Annex M:
- Low Voltage Breakers-**Modular residual current devices (without integral current breaking device) (MRCDs)**
- **Earth Leakage Relay- ELR**



Residual Current Devices
Classification

Residual Current Devices (RCDs)

■ Main functional classifications of RCDs, based on Reference standards IEC 61008/9 & SS97/SS480 in Singapore are:

- According to the method of operation
- According to the behaviour in presence of d.c. components
- According to the time-delay (in presence of a residual current)



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Residual Current Devices
Selection of RCCB/ELCB

Number of Pole	:	2, 3?, 4,
Rated Current I_n	:	16A, 25A, 40A, 63A,…
Rated Sensitivity $I_{\Delta n}$	:	10mA, 30mA, 100mA
Frequency	:	50Hz, 400Hz
Type	:	AC, A, B, S, AP-R
Standard	:	IEC 61008, SS97
Technology/Design	:	Voltage independent volt. dependent/electronic

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Residual Current Devices
Selection of RCBO/ELMCB

Number of Pole	:	1+NA, 2, 3, 3+NA, 4,……
Rated Current I_n	:	16A, 25A, 40A, 63A,…
Tripping Curve	:	B, C, D, K, Z
Breaking capacity	:	6kA, 10kA,……
Rated Sensitivity $I_{\Delta n}$	:	10mA, 30mA, 100mA
Type	:	AC, A, B, S, AP-R
Standard	:	IEC 61009, SS480
Technology/Design	:	Voltage independent Volt. dependent/electronic

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Residual Current Devices
Internal Design of Residual Current Devices

VI RCDs: F200 internal lay-out



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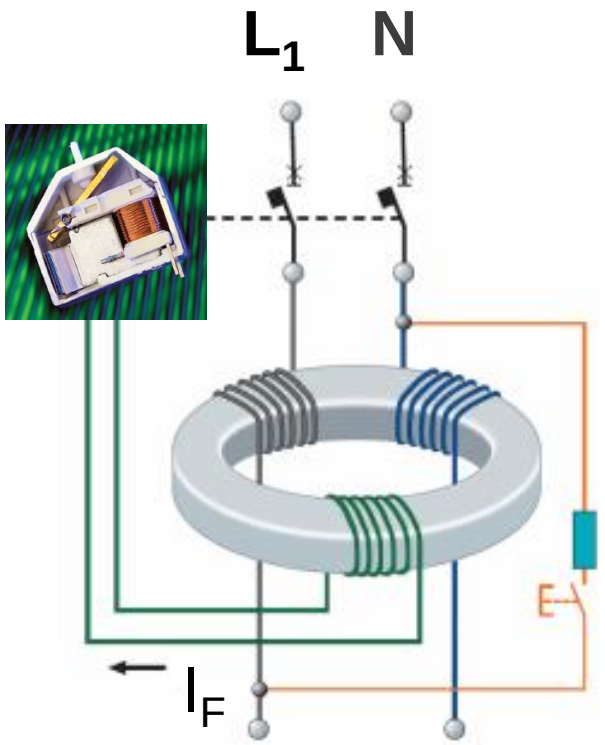
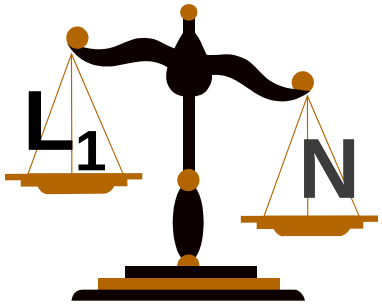
Residual Current Devices
Classification According to Method of Operation

According to the **method of operation**

- Voltage **In**dependent RCDs, also named “electromechanical”, provide protection against earth fault using the residual current to cause the tripping, by mean of an electromagnetic relay as actuator.





The tripping energy is directly supplied by the fault current. This supply mode is considered by most specialists as the most reliable. In many countries and particularly in Europe, this category of RCD is recommended for domestic and similar installations.

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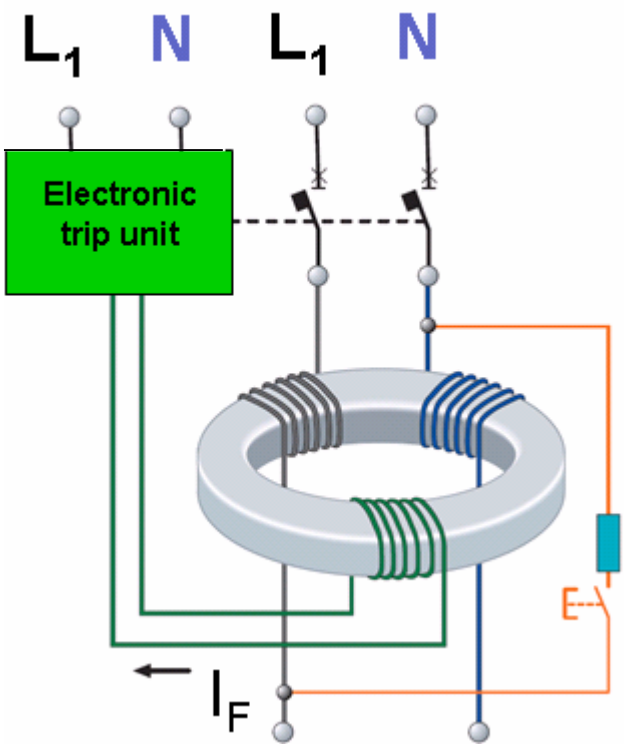
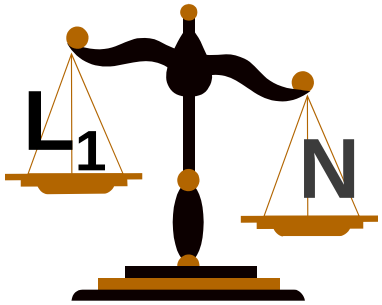
Residual Current Devices
Classification According to Method of Operation

According to the **method of operation**

- Voltage dependent RCDs, also named “electronic”, provide protection against earth fault comparing the residual current level to a predetermined threshold in an electronic circuit as actuator.





The tripping energy requires a source of energy that is independent from the fault current. These devices can therefore only cause tripping if this auxiliary energy source (usually the monitored circuit) is available when the fault current appears.

Residual Current Devices
Classification According to Type of Waveform Detection

According to the **behaviour in presence of d.c. components**

RCDs responding to SS97 / SS480 & IEC 61008/9 are classified in two types according to the capability to detect residual current with the overlapping of d.c. components:

- **Type AC** RCDs:
  - A RCD for which tripping is ensured for residual sinusoidal alternating current, whether suddenly applied or slowly rising.
  - In short, Type AC sensitive to alternating current only

- **Type A** RCDs:
  - A RCD for which tripping is ensured for residual sinusoidal alternating currents and residual pulsating direct currents, whether suddenly applied or slowly rising.

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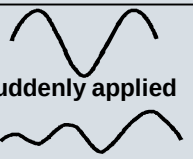
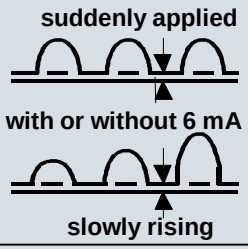
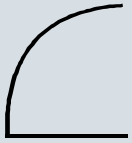
Residual Current Devices
Classification According to Type of Waveform Detection

According to the **behaviour in presence of d.c. components**

According to IEC 60755, a further type of RCD, able to detect even smooth d.c. currents, generated by rectifying circuits, is recognized:

	Form of residual current	Correct functioning of residual current devices		
		Type		
		AC	A	B
Sinusoidal		+	+	+
Pulsating			+	+
Smooth d.c.				+

Type B RCDs 

➡ **Universal current sensitive**

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Residual Current Devices
Classification According to Time-Delay

According to the **time-delay (in presence of residual current)**

- RCDs responding to SS97 & IEC 61008 are classified in two types according to the break time they intervene in presence of residual current in specified conditions:
  - RCDs without time-delay: **type for general use**;



  - RCDs with time-delay: **type S for selectivity**.
    - RCDs specially designed to attain a predetermined value of limiting non-actuating time, corresponding to a given value of residual current

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Residual Current Devices
Tripping Time Requirement

Type G (general) and type S (Selective) of IEC 61008 have a tripping time

Table 1 – Standard values of break time and non-actuating time

Type	I_n A	$I_{\Delta n}$ A	Standard values of break time (s) and non-actuating time (s) at a residual current (I_Δ) equal to: $I_{\Delta n}$	$2\ I_{\Delta n}$	$5\ I_{\Delta n}$ [a]	5 A, 10 A 20 A, 50 A, 100 A, 200 A [b], 500 A	
General	Any value	≤ 0.030 *	0.1	0.1	0.04	0.04	Maximum break times
		> 0.030	0.3	0.15	0.04	0.04	Maximum break times
S	≥ 25	> 0.030	0.5	0.2	0.15	0.15	Maximum break times
			0.13	0.06	0.05	0.04	Minimum non-actuating times

* the maximum break times of the RCCB of the general type with $I_{\Delta n} \leq 0.030$ A is drawn to comply with the safety requirements of SS CP 5 and other statutory requirements.

[a] For RCCBs of the general type with $I_{\Delta n} \leq 0.030$ A, 0.25 A may be used as an alternative to $5\ I_{\Delta n}$

[b] The tests at 5 A, 10 A, 20 A, 50 A, 100 A and 200 A are only made during the verification of the correct operation as mentioned in 9.9.2.4

Not for standards

For IΔn at 30mA and lower, the tripping time requirement in SS97 is 100ms for 1xIΔn & 2xIΔn

Residual Current Devices

Time-current zones of the effects of alternating current on the human body

Table 11 – Time/current zones for a.c. 15 Hz to 100 Hz for hand to feet pathway – Summary of zones of Figure 20

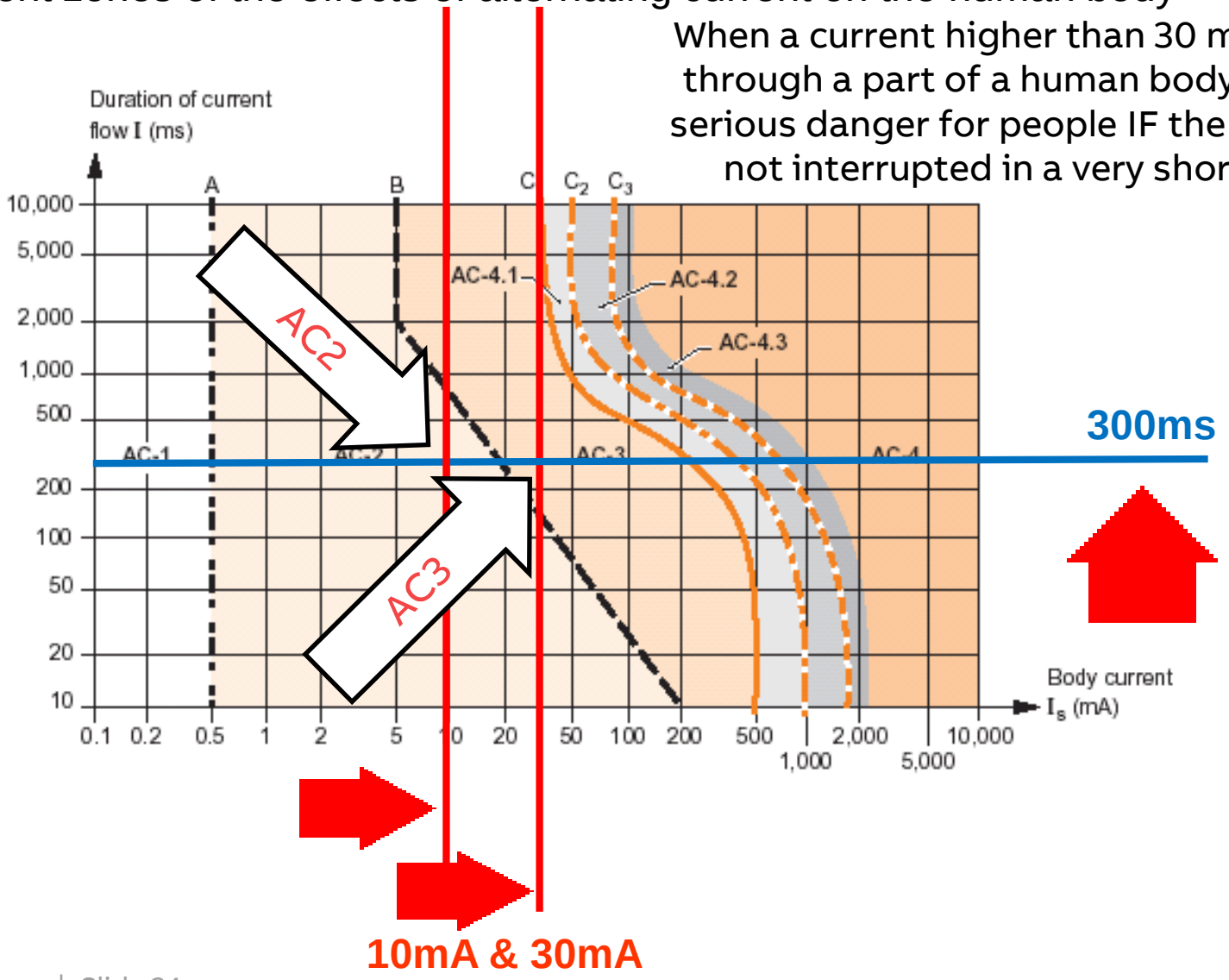
Zones	Boundaries	Physiological effects
AC-1	Up to 0,5 mA curve a	Perception possible but usually no 'startled' reaction
AC-2	0,5 mA up to curve b	Perception and involuntary muscular contractions likely but usually no harmful electrical physiological effects
AC-3	Curve b and above	Strong involuntary muscular contractions. Difficulty in breathing. Reversible disturbances of heart function. Immobilization may occur. Effects increasing with current magnitude. Usually no organic damage to be expected
AC-4 [1)]	Above curve c_1	Patho-physiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time
	c_1-c_2	AC-4.1 Probability of ventricular fibrillation increasing up to about 5 %
	c_2-c_3	AC-4.2 Probability of ventricular fibrillation up to about 50 %
	Beyond curve c_3	AC-4.3 Probability of ventricular fibrillation above 50 %

[1)] For durations of current flow below 200 ms, ventricular fibrillation is only initiated within the vulnerable period if the relevant thresholds are surpassed. As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path left hand to feet. For other current paths, the heart current factor has to be considered.

Residual Current Devices
IEC 61008 Tripping Time Requirement

Time-current zones of the effects of alternating current on the human body

When a current higher than 30 mA passes through a part of a human body, there is serious danger for people IF the current is not interrupted in a very short time.



Residual Current Devices
SS97 Tripping Time Requirement

Time-current zones of the effects of alternating current on the human body

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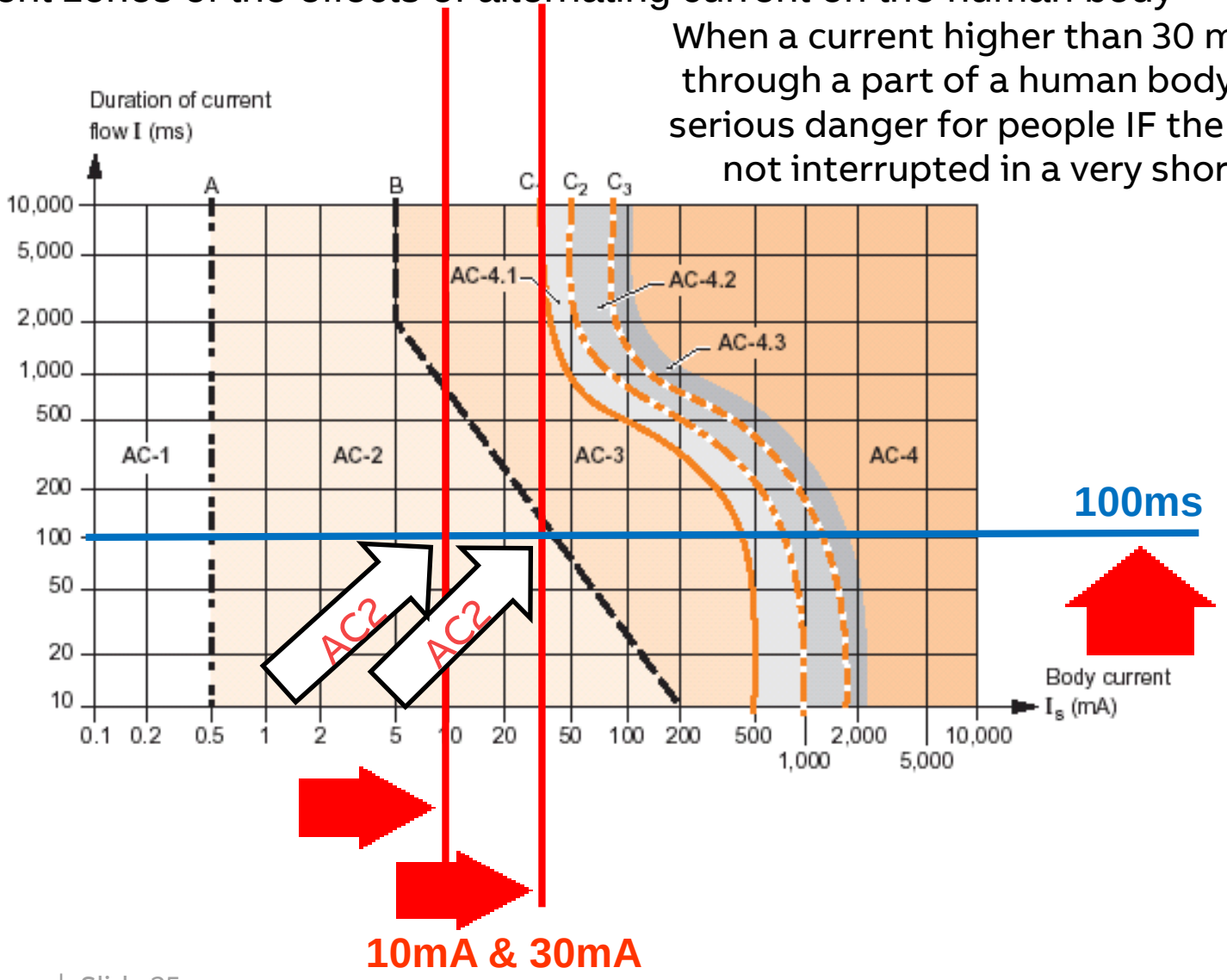

Residual Current Devices

Time-current zones of the effects of alternating current on the human body

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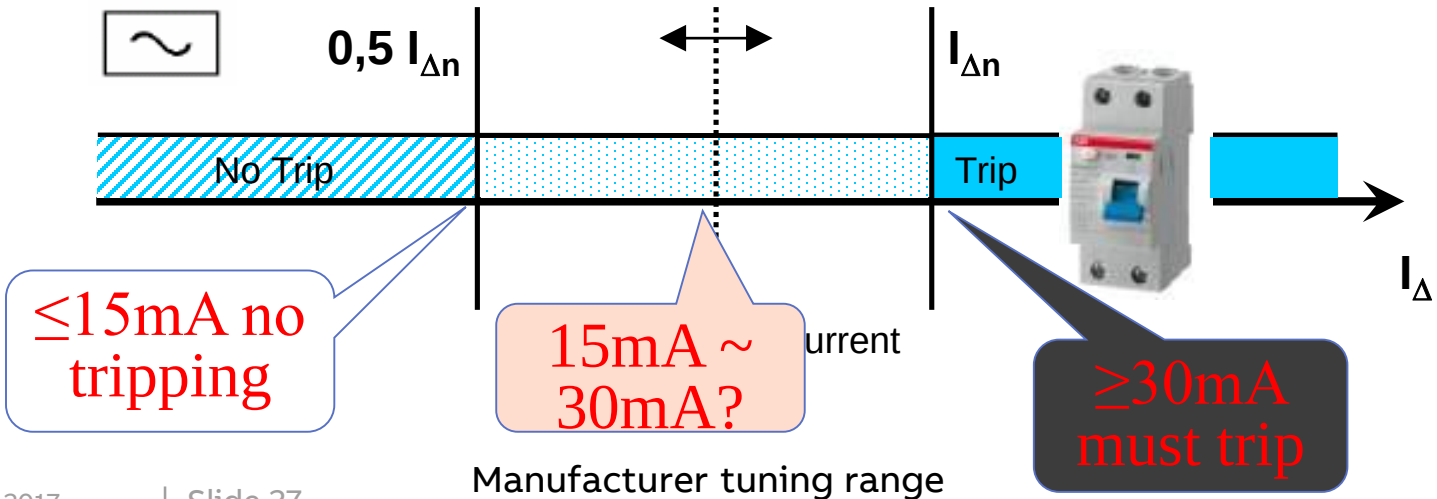
AC-4 [1)]	Above curve c_1	Patho-physiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time
	c_1-c_2	AC-4.1 Probability of ventricular fibrillation increasing up to about 5 %
	c_2-c_3	AC-4.2 Probability of ventricular fibrillation up to about 50 %
	Beyond curve c_3	AC-4.3 Probability of ventricular fibrillation above 50 %

[1)] For durations of current flow below 200 ms, ventricular fibrillation is only initiated within the vulnerable period if the relevant thresholds are surpassed. As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path left hand to feet. For other current paths, the heart current factor has to be considered.

Residual Current Devices
Intervention Characteristics

Residual operating current limits

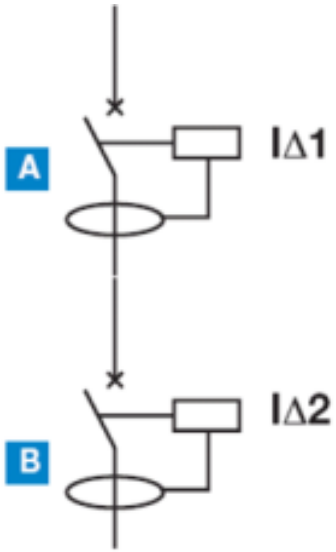
- In IEC 61008 & in SS97 require that RCDs must intervene in presence of a residual current within defined current limit:
  - **Residual operating current ($I_{\Delta n}$)**
    - Value of residual current which causes the RCD to operate under specified conditions
  - **Residual non-operating current ($I_{\Delta n0}$)**
    - Value of residual current (=0.5 $I_{\Delta n}$) at and below which the RCD doesn't operate under specified conditions.



Residual Current Devices
Selectivity

Selectivity

- Installation of an RCD upstream of another RCD is often referred to as discrimination although the word “selectivity” is sometimes used.
- The normal purpose of such discrimination is to ensure that a residual current on a sub circuit causes only the RCD protecting the sub circuit to trip and does not cause the upstream RCD to trip unless the fault is sustained beyond a certain time.



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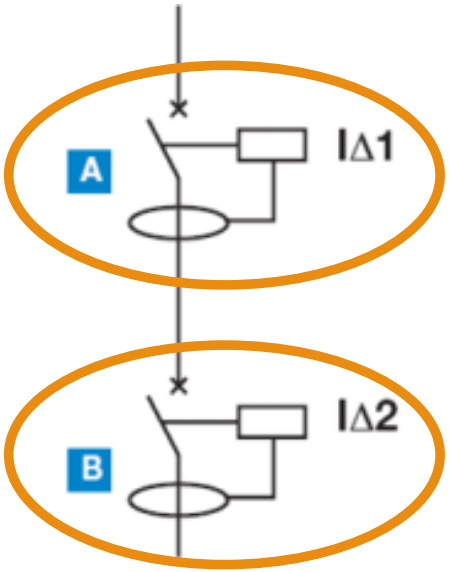
Residual Current Devices
Coordination for RCD

Selectivity

is a type of coordination of two, or more, protective devices in series.

Selectivity is done between one residual current device on the supply side and one residual current device, or more than one, on the load side.

A is the supply side (or upstream) RCD



B is the load side (or downstream) RCD

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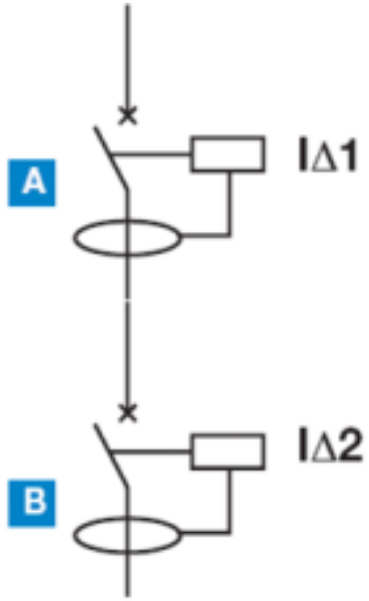
Residual Current Devices
Selectivity and Coordination for RCD

The normal purpose of selectivity is to ensure that an earth leakage current

causes only the RCD protecting the downstream circuit to trip

and does not cause the tripping of the upstream one.



Two types of RCD selectivity exist:

- amperometric selectivity
- chronometric selectivity

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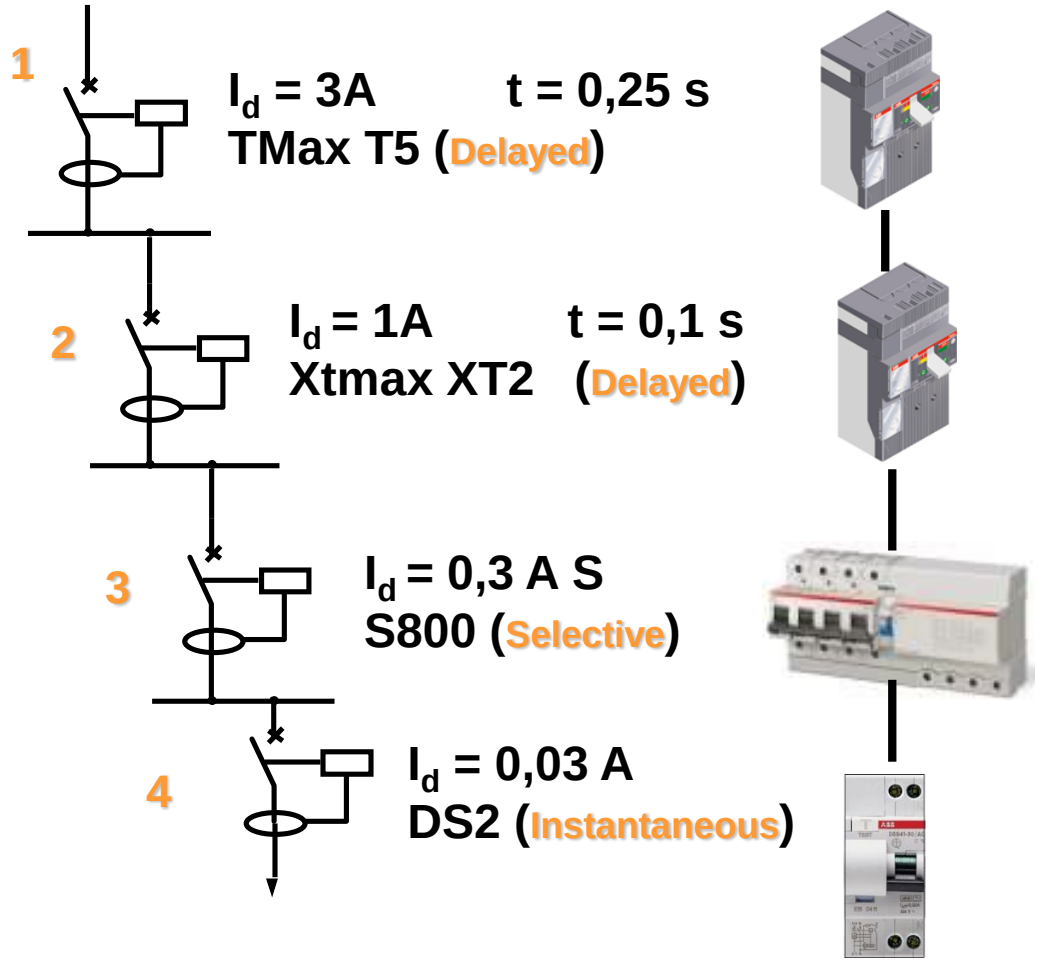
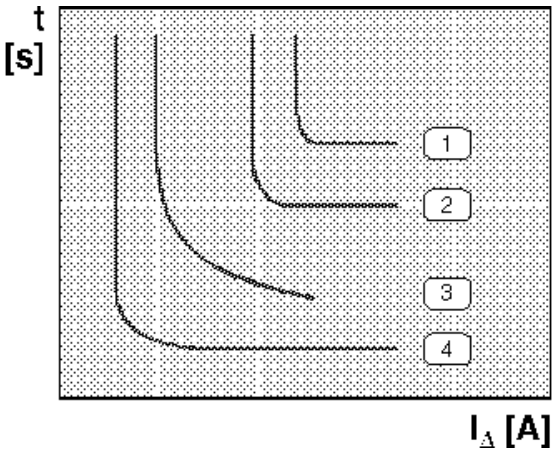
Residual Current Devices
Selectivity and Coordination for RCD

Chronometric Selectivity

- Example in industrial applications



4 level of residual current selectivity



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Residual Current Devices
Selectivity and Coordination for RCD

Amperometric selectivity

is strictly based on the residual current values;

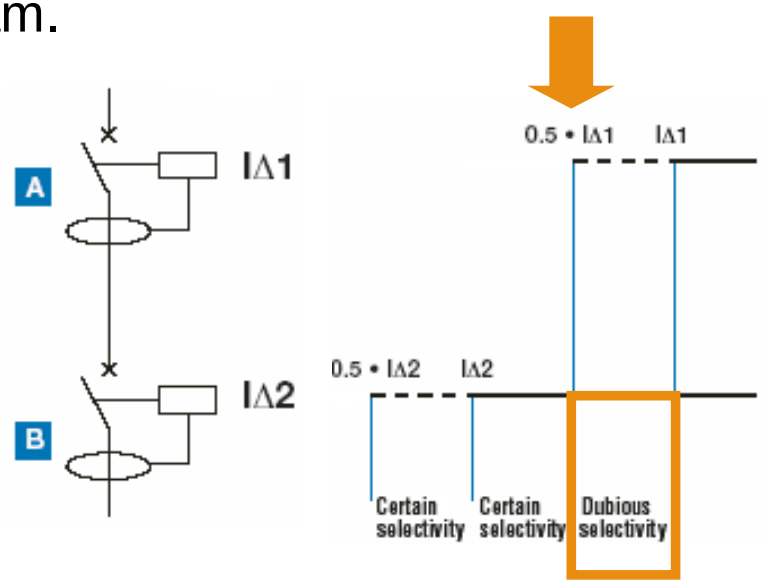
may be created by placing low-sensitivity RCDs upstream and higher-sensitivity RCDs downstream.

The operative rule to obtain an amperometric selectivity is

$I_{\Delta 1} = 3 \times I_{\Delta 2}$

F 202, 30mA upstream;

F 202, 10mA downstream.

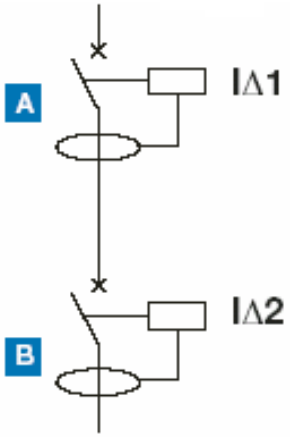


Amperometric selectivity is a partial selectivity

Residual Current Devices
Amperometric Selectivity for Final Distribution

F 202, 100mA upstream;

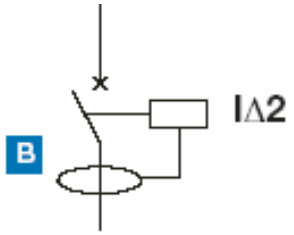
F 202, 30mA downstream.



X 4

● ● ● ● ● ●

$I_{\Delta no} = 15$ mA



Amperometric selectivity is a partial selectivity!!

Residual Current Devices
Other Critical Considerations

Table 11 – Time/current zones for a.c. 15 Hz to 100 Hz for hand to feet pathway – Summary of zones of Figure 20

Zones	Boundaries	Physiological effects
AC-1	Up to 0,5 mA curve a	Perception possible but usually no 'startled' reaction
AC-2	0,5 mA up to curve b	Perception and involuntary muscular contractions likely but usually no harmful electrical physiological effects
AC-3	Curve b and above	Strong involuntary muscular contractions. Difficulty in breathing. Reversible disturbances of heart function. Immobilization may occur. Effects increasing with current magnitude. Usually no organic damage to be expected
AC-4 [1)]	Above curve c_1	Patho-physiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time
	c_1-c_2	AC-4.1 Probability of ventricular fibrillation increasing up to about 5 %
	c_2-c_3	AC-4.2 Probability of ventricular fibrillation up to about 50 %
	Beyond curve c_3	AC-4.3 Probability of ventricular fibrillation above 50 %

[1)] For durations of current flow below 200 ms, ventricular fibrillation is only initiated within the vulnerable period if the relevant thresholds are surpassed. As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path left hand to feet. For other current paths, the heart current factor has to be considered.

