Part 4 Protection Safety

2018 18th Edition (BLUE BOOK) BS7671

Part 4 Protection for Safety

Chapter 41 – Protection against Electric Shock

Chapter 42 – Protection against Thermal Effects

Chapter 43 – Protection against Overcurrent

Chapter 44 – Protection against Voltage variations

Part 4 Protection for Safety

Chapter 41 – Protection against Electric Shock

411 – Automatic disconnection

412 - Class II equipment

413 – Electrical Separation part 1

414 – Separated Extra Low Voltage (SELV)

415 – Additional Protection (RCD, MPB)

416 - Barriers and Enclosures

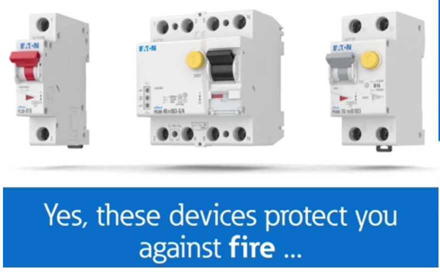
417 - Obstacles and placing out of reach

418 - Non conducting location

Part 4 Protection for Safety

Methods of reducing the likelihood of electric shock

1. Limit the **current flow to a person**
2. Limit the *<u>current flow through a person</u>*
3. Limit the **<u>duration of shock</u>**



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Part 4 - Protection Safety

Part 4 Protection for Safety

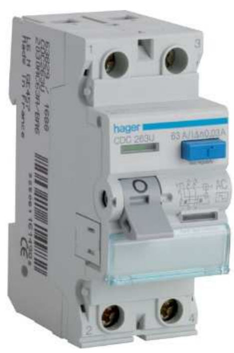
1. Limit the current flow to a person (Basic Protection)

- Insulation (416)
- Class II equipment (412)
- Barriers and Enclosures (416.2)
- Non conducting location (418.1) restricted to trained personnel
- Obstacles and placing out of reach (417)
- Electrical Separation (413, 418.3)

Part 4 Protection for Safety

2. Limit the current flow through a person (Basic and Fault protection)

- SELV (414)
- PELV (414)
- FELV (411.7)
- RLV (411.8)
- Protective Bonding (415.2)
- Earth free protective ‘earth’ bonding zone (418.2) “…intended to prevent the appearance of a dangerous touch voltage”



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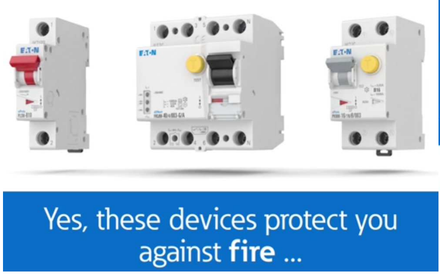
3. Limit the duration of shock (Fault Protection)

- Automatic Disconnection of Supply (RCDs, OPDs not shock protection) (411)
- RCDs in TT systems (411.5)



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Part 4 Protection for Safety

Certain Conditions apply for Automatic protection (ADS) 411.4.4

1. Under fault conditions the supply must be disconnected from a circuit within the time stated – Table 41.1
2. Have an Earth Fault Loop Impedance below or equal to Uo/Ia – Tables 41.2, and 41.3
3. This has changed to: $U_0 \times C_{min} / I_a$

Part 4 Protection for Safety

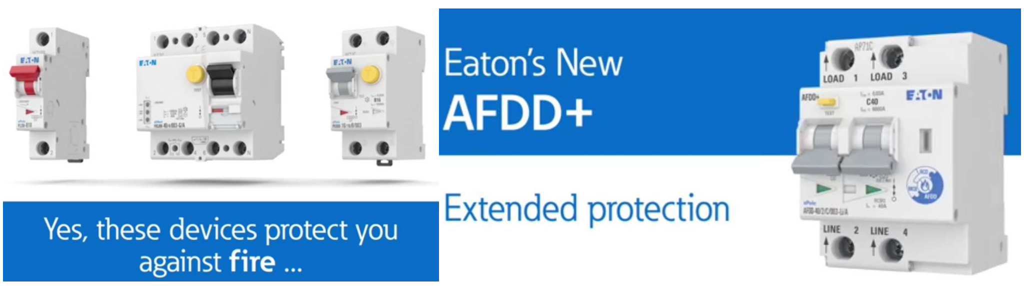
From the BS7671 DPC 17th Edition Amendment 3

Adjusts for a lower European supply voltage 230V – 220V

Changes in supply voltages at sub-station transformers

Part 4 Protection for Safety Examples:

1. If the nominal voltage is 230V and allowing for future variations in the supply voltage what will be the maximum Zs for a power circuit protected by a B16A MCB ? 2.73Ω
2. By calculation show the minimum fault current to give instantaneous disconnection for a C40A at the adjusted nominal voltage and hence find the maximum Zs for the breaker.
3. What other calculation should be taken into consideration when comparing the measured value with the calculated Zs value? nominal voltage



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Part 4 Protection for Safety

411 shock protection

Automatic disconnection under fault conditions Instantaneous disconnection

assumes 5 x In for a type ‘B’ MCB

$$Z_S \text{ max} = U_0 / (5 \times In)$$

Assumed touch voltage (RHS of table 41.3)…

Type	Amd 2	Amd 3	Time(s)	Zs
B	46/In	43.7/In	0.1 - 5	Max
C	23/In	21.9/In	0.1 - 5	Max
D	11.5/In	10.9/In	0.1 - 3	Max
D	N/A	21.9/In	5	Max

Part 4 Protection for Safety

The functioning of the symbols with regard to calculating Zs

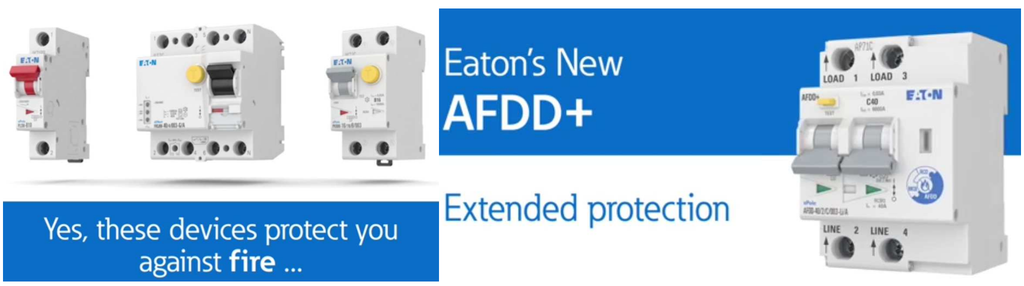
The functioning of the symbols with regard to calculating Zs

Part 4 Protection for Safety

Max Zs for fuses to BS88-2,-3,-6,-1361

Part 4 Protection for Safety

412 Protection by double or reinforced insulation



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Part 4 Protection for Safety

414 Protection through Extra Low Voltages

Band 1 voltages: <50Vac, 120Vdc

Band 2 Voltages: >50Vac < 1000Vac, >120Vdc < 1500Vdc

Part 4 Protection for Safety

Chapter 41 – Protection against Electric Shock

Fault Protection (Indirect Contact)

Part 4 Protection for Safety

416 – 417 Basic Protection (Direct Contact)

Basic Insulation of Live Parts 416.1

Barriers or Enclosures - 416.2

Obstacles, Placing out of Reach – 417.2, 417.3

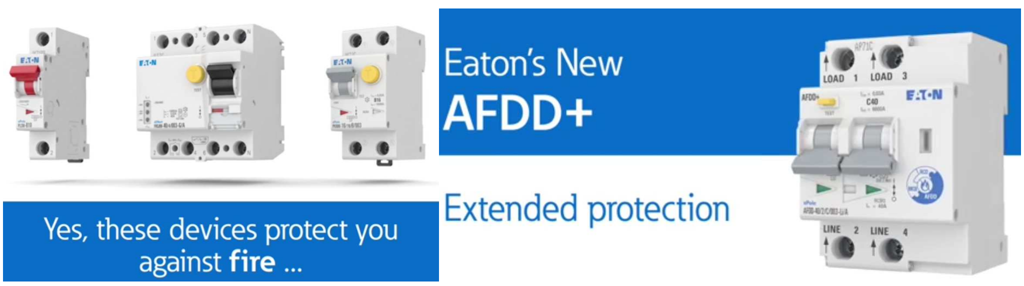
Class II Equipment - 412

Part 4 Protection for Safety

418 Basic Protection where supervised by a skilled or instructed person

1. Non-conducting Location (418.1) (No earth contact at sockets)
2. Earth Free local equipotential bonding (418.2)
3. (Faradays Cage)
4. Obstacles (417.2) – Not strictly recognized see (729)
5. Placing out of Reach (417.3) - Not strictly recognized
6. Electrical separation from more than one item of electrical equipment (418.3)

(common neutrals in IT systems)



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Part 4 Protection for Safety

411 Fault Protection (Indirect Contact)

1. Automatic Disconnection (ADS)

2. SELV, PELV, FELV

The use of:

1. RCDs

2. Class II equipment Are additional measures added to ADS and ELV

Part 4 Protection for Safety

Why is RCD protection used for ordinary persons?

(Electricity is the same in the USA as in Europe!)

Part 4 Protection for Safety

Part 4 Protection for Safety

Additional Protection 411.3.3 30mA RCDs to be used on Socket outlets

Where:

1. All Socket outlets < 32A

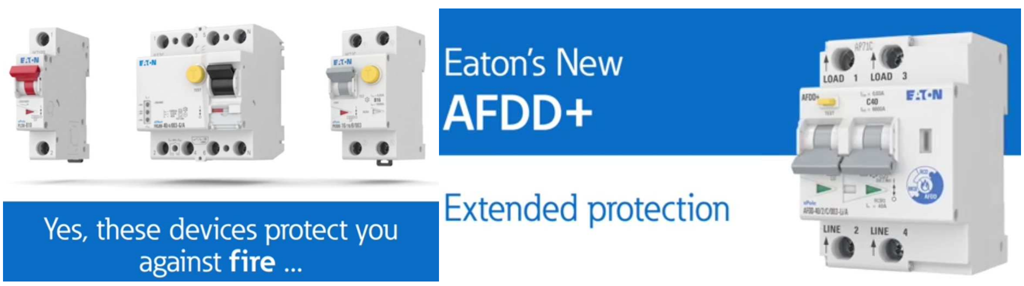
2. Mobile equipment used outside < 32A

Exceptions permitted to 1. above:

1. Amendment 3 now discounts ‘under the supervision of a competent person’

2. Identified and labelled for a specific item of equipment (freezers, fire alarm, sprinklers)

3. Documented Risk assessment justifying no RCD



Part 4 Protection for Safety - Shock Protection for Special Locations

410.1 – Additional Protection - RCDs, Supplementary Protective Bonding

410.2 – SELV, PELV

410.3 – Electrical Separation (one item of equipment)

410.4 – Class II Equipment

Now becomes a general requirement for all socket outlets unless specifically specified and underwritten by a technically skilled person

411.3.3 Additional Protection for ADS in accordance with 415

Two methods are used:

415.1 Protection by Residual Current Devices

415.1.1 max value = 30mA, At 5 IΔN < 40ms

415.1.2 Not recognized as a sole means of protection

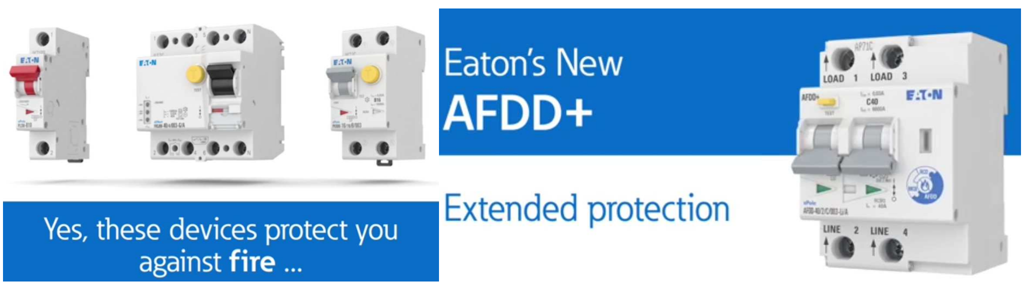
415.2 Supplementary Bonding

415.2.1 Supplementary Bonding to localised and generalized zones

To include local cross-bonding to all extraneous and exposed conductive parts with structural elements and metallic service pipes

415.2.2 Where doubt exists to the effectiveness of supplementary bonding then it should be tested against

R ≤ 50 / Ia for AC systems and **R ≤ 120V / Ia** for DC systems



Part 4 Protection for Safety

The use of Supplementary bonding (415.2.2)

Where doubt exists regarding the effectiveness of extraneous conductive parts having the same potential then…

$$\text{AC Systems}: R \leq \frac{50V}{I_a} \qquad \text{DC Systems}: R \leq \frac{120V}{I_a}$$

Where protection is given by a RCD then…

$$R = \frac{50}{30 \times 10^{-3}} = 1.67k\Omega$$

Where protection is given by a 20A type B MCB (EN 60898) or RCBO (61009-1) then…

$$I_a = \frac{218.5}{2.19} = 100A$$ <u>or Appendix 3 Fig 3A4 Page 325</u> $$R_2 = \frac{50}{100} = 0.5\Omega$$

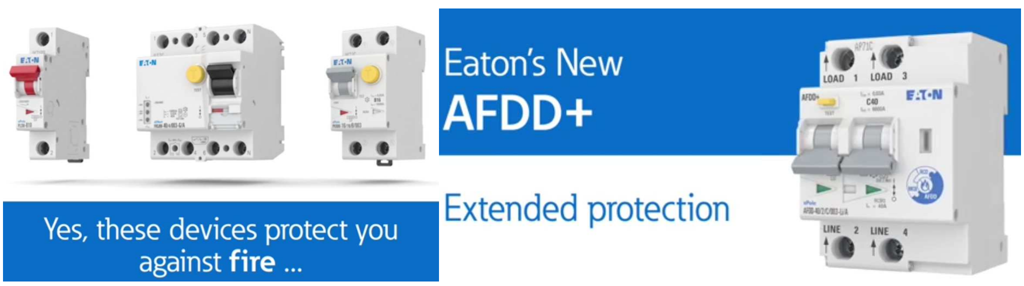
If the <u>impedance of the circuit (exposed conductive part) is < 0.5Ω</u> then the touch voltage on any simultaneously touchable metalwork for the time the fault is in operation will not rise above 50V

Stop the voltage potentials on exposed and extraneous conductive parts rising beyond the safety voltage - touch voltage – in fault conditions – 415.2

$$\text{AC Systems}: R \leq \frac{50V}{I_a} \qquad \text{DC Systems}: R \leq \frac{120V}{I_a}$$

Where R is the resistance between two simultaneously touchable exposed/extraneous metalwork

Use an RCD for additional protection to detect earth fault currents at 50V≥ Zs x IΔN - 415.1.1 (Where IΔN ≤ 30mA, t ≤ 40mS at 5IΔN)



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Protection Against Shock - BS7671 2008: Protection

Fault Protection using SELV or/and local additional supplementary bonding by controlling the current flowing through the body

Note 1: Disconnection times not required for shock, but for thermal effects

Part 4 Protection for Safety

- Protection provided by a Residual Current Device Following condition applies:
- Regulation 411.5.2:
  - Z_s = Earth fault loop impedance in Ohms; $I\Delta n$ = rated residual operating current in Amps
- Protection in TT systems.
  - The use of over current protective devices are not excluded although it is preferred to use a RCD with a disconnection time of not greater than 1 sec 411.3.2.4
- Regulation 411.5.3
  - R_A = sum of all the resistances of earth electrode and protective conductors connected to the exposed conductive parts;
- Regulation 411.5.4
  - I_a =the current causing automatic operation of the protective device

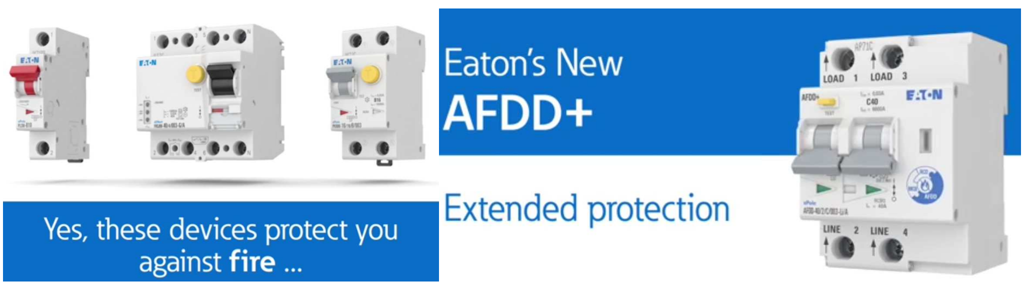
Fault protection using an RCD to BS EN 61008/9 by controlling the duration of current flowing through the body

You do not need an earth with RCD, but you do need an imbalance of current between the Line and Neutral

Protection against shock and Fire

The use of and terminology of IT systems are more prevalent in the 17th edition (411.6.1)

What is an IT system? High impedance to earth or no connection



Part 4 Protection for Safety - Basic and fault protection in IT systems

IT systems – Insulation Monitoring Devices IMDs **(411.6.3)**

What is needed? IMD / Main Switch. Gear / Dist. Board RCBO / Final Circuits /

Limiting Impedance / Supply Source / Supply Electrode

Single fault condition must behave like a TN system and disconnect within the times stated in 41.1

IT system of protection $V_{poc(V2)} = V_S \times (R2 / R1 + R2 + R3) = 4.5V$

Where **R3 is fixed by the distributor around 50,000 Ohms**

R2 is the resistance of the earth path across a human body (1.0 kOhms)

and **R1 is the resistance of the phase conductor (1.0 Ohm)**

The Max voltage across body to the source = (Voltage drop sits outside EQBZ)

Basic and Fault protection

Methods of protection IT systems

High impedance to earth means that the majority of the volt drop under fault conditions is outside of the equipotential bonding zone of the installation

(Earth to phase monitoring device < 50kΩ causes an alarm to sound IEC 60364)

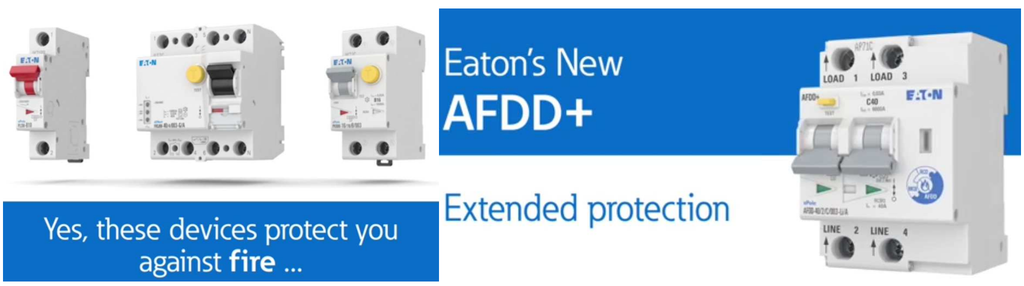
Suitable Protective Devices 411.6.3

1. **I**nsulation **M**onitoring **D**evice (**IMD**)
2. **R**esidual **C**urrent **M**onitoring Device (**RCM**)
3. Insulation Fault Location System
4. **O**vercurrent **P**rotective **D**evice (**OPD**)
5. **R**esidual **C**urrent **D**evice (**RCD**)

PELV and IT systems

IT systems and earth monitoring equipment

The earth conductor is not separated with PELV but monitored



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<u>Part 4 - Protection Safety</u>

Basic and Fault Protection

FELV Systems 411.7

Designed where SELV and PELV are not fulfilled (414)

Basic Protection 411.7.2

1. Insulation
2. Barriers and/or enclosures

Fault Protection 411.7.3

Exposed conductive parts shall be connected to the primary earthing system to provide Automatic disconnection in the event of a fault Methods of reducing voltage for a FELV system do not include

1. Autotransformers
2. Semiconductor devices
3. Potentiometers

Reduced Low Voltage Systems (RLV) 411.8

(Voltage range < 110V ac 55V to earth single phase, 63.5V ac to earth three phase)

Basic Protection

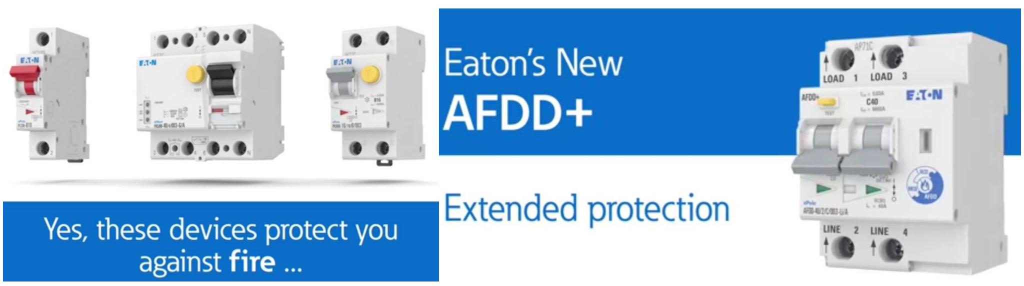
Insulation

Barriers and Enclosures

Fault Protection

Automatic Disconnection < 5secs by OPD or RCD

For RCDs: 50V ≥ $I\Delta N$ x Zs ($I\Delta N$ x Zs ≤ 50V) See Table 41.6



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Protection against Thermal effects 420.1

Scope: electrical installations and equipment with regard to measures for the protection of persons, livestock and property against:

(i) the harmful effects of heat or thermal radiation developed by electrical equipment

(ii) the ignition, combustion or degradation of materials

(iii) flames and smoke where a fire hazard could be propagated from an electrical installation to other nearby fire compartments, and

(iv) against safety services being cut off by the failure of electrical equipment.

NOTE 1: For protection against thermal effects and fire, statutory requirements may be applicable. Refer to Appendix 2.

421.1.201 Domestic Switchgear

assemblies including consumer units shall comply with BSEN61439-3:

(i) have their enclosure manufactured from non-combustible material, or

(ii) be enclosed in a cabinet or enclosure constructed of non-combustible material and complying with reg. 132.12

NOTE 1: Ferrous metal e.g. steel is deemed to be an example of a non-combustible material

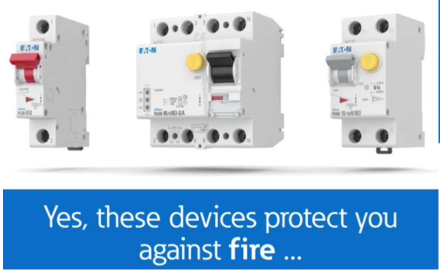
NOTE 2: implementation date is January 2016 but does not preclude compliance before this date

421.2 protection against hot surface temperatures

Mounted on a surface of low thermal conductance Be screened by low thermal materials Positioned to allow dissipation of heat

421.3 protection against arcs and sparks

Totally enclosed in arc resistant material Screened by arc resistant material Mounted to allow safe extinguishing of sparks in compliance with its standard



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<u>Part 4 - Protection Safety</u>

Protection against Thermal effects

422.3.200 Flexible cables shall be of the following construction:

(i) **Heavy duty type having a voltage rating of not less than 450/750 V**, or

(ii) suitably protected against mechanical damage. **422.3.201**

A heating appliance shall be fixed. **422.3.202**

A heat storage appliance shall be of a type which prevents the ignition of combustible dusts or fibres by the heat storing core.

422.3 and 422.4 Lamps and luminares must be positioned away from combustible structures and materials

< 100W = 0.5m

> 100W < 300W = 0.8m

> 300W < 500W = 1.0m

422.3.9 where MIMS, busbar, powertrack, are not used then:

TT,TN systems should be protected by <300mA RCD

Where overheating and fire are high use a <30mA RCD

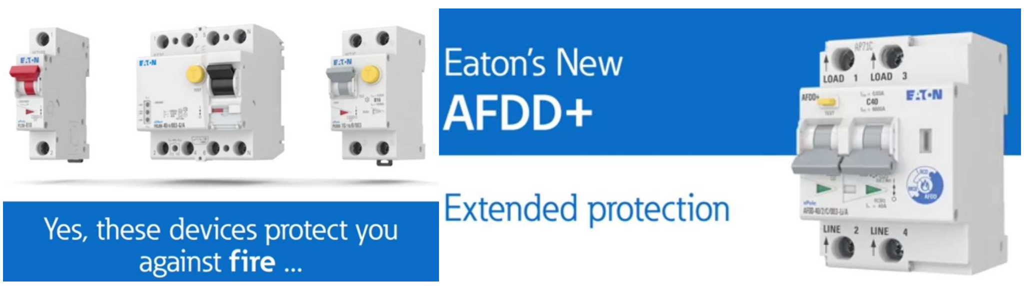
IT systems use IMD

423.1 Protection against burns

Protection against overheating - 424.1 Forced air heating systems

Forced air heating systems shall be such that their heating elements, other than those of central storage heaters, cannot be activated until the prescribed air flow has been established and are deactivated when the air flow is less than the prescribed value. In addition, they shall have two temperature limiting devices independent of each other which prevent permissible temperatures from being exceeded in air ducts.

<u>Supporting parts, frames and enclosures of heating elements shall be of non-combustible material. Note: comply with Building regs (CIBSE code H,C and M)</u>



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Part 4 - Protection Safety

Problem Currents

Examples:

Fault current (**434**)

Overload currents (***433***)

Overcurrents (***435***)

Short Circuit Current (**434**)

Earth Fault currents (***435***)

Shock Currents

Prospective Fault Current

Protective device's Operating current

Overcurrent Protective Devices

Types of Protective Devices (In) – 432.1, 433.3, 434.3

– **BS 3036 Rewireable** fuse links

– ***BS1361 Cartridge*** Fuse links

– ***BS 88 pt 2 & pt6 HRC or HBC*** Fuses

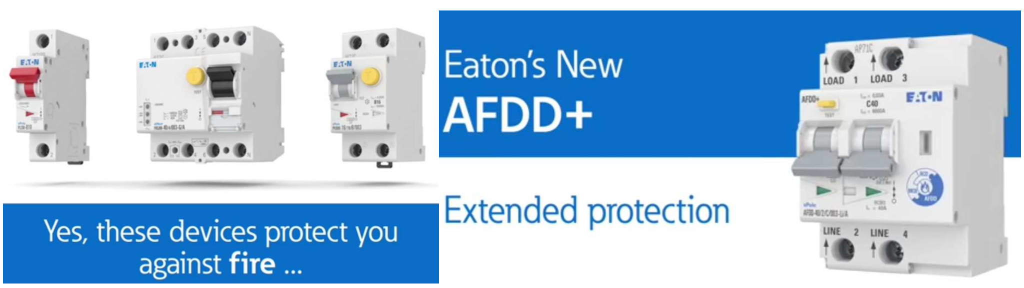
– BS 3871 MCBs - Miniature Circuit Breakers (old type)

- *No longer included in BS7671*

– **BS EN 60898** New type **MCB**

– ***BS-EN 60947-2 MCCB*** 10kA+

– ***BS EN 61009 RCBO*** Residual Current Breaker with overload protection



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<u>Part 4 - Protection Safety</u>

Overcurrent Protective Devices

Fusing Factor – 533.1.1.2 ii

Fusing Factor = Actual Fusing Current (I_2) / Rated Fusing Current (In)

Typical Fusing Factors for:

– BS88 Pt2 & Pt6 (HRC or HBC Fuses) = 1.25 - 1.75

<u>– BS3036 (rewireable fuse) = 2.0</u>

– BS1361/2 (Cartridge Fuse) = 1.3 - 1.5

– BS3871 / BS EN 60898 (Circuit Breaker) = 1.1 - 1.4

Appendix 3 Time current characteristics

Coordination of Protective Devices

Coordination of Protective Devices and Current Carrying Capacities of Conductors for overload and short circuit – 433.1.1, 435.1

$I_B \le I_n \le I_z$

I_B = Amperage load

I_n = Protective Device e.g., Circuit Breaker or rewireable fuse size

I_z = Current rating for cable/wire

<u>I_2 = e.g., BS3036 (rewireable fuse) I_n x 2…fusing current of a device within conventional time</u>

(a) $I_B \le I_n$

∴ $I_B \le I_n \le I_z$

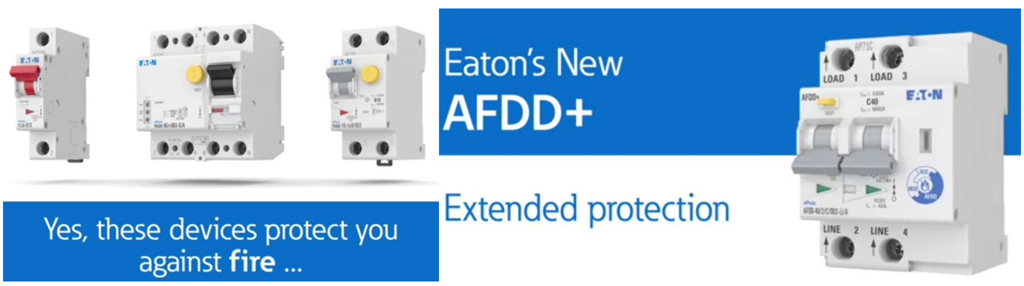
(b) $I_2 \le 1.45 \times I_z$ **>>Overload Conditions**

– Note: It is the tabulated current after taking external factors into consideration

– Compliance with 433.1.1 (i), (ii), (iii)

– HBC BS88pt2.1, pt6 HRC or HBC Fuses – BS1361 Cartridge Fuse

– Circuit Breaker to BS EN 60898 and BS EN 60947-2 – RCBO to BS EN 61009-1



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Part 4 - Protection Safety

Coordination of Protective Devices

I_z = current carrying capacity of the cable for continuous service.

To Comply with BS7671 using BS3036 – 433.1.1

In order to satisfy the terms in 433.1.1 (ii) then :

To satisfy the fact that rewirables have a fusing factor up to 2 times

Fusing Current = Fusing Factor x Fuse Rating

= $2 \times I_n$

The use of Semi-enclosed or re-wireable fuses to BS3036 is not recommended for untrained persons – 533.1.1

Fusing Current = Fusing Factor x Fuse Rating

$I_n \leq 0.725\, I_z$ = $2 \times I_n$

$I_2 = 2 \times I_n$ and $I_2 \leq 1.45\, I_z$

and $2 \times I_n \leq 1.45\, I_z$

$$\therefore\ I_n \leq \frac{1.45}{2} \times I_z \leq 0.725\, I_z$$

The tripping current rule $I_2 <= 1.45 I_z$

I_2 is the... $I_n \times 2$ fusing current of a device within conventional time

Iz = current carrying capacity of the cable for continuous service.

Fusing current factors are…

BS EN 60898 CB fusing factor = 1.45

For example, small MCB rated at 10A you would expect it carry safely 10A continuously. The I_2 current would be 1.45 times I_n in one hour so you would expect the device to carry up to 14.5A for no longer than an hour before operating

BS 3871 CB fusing factor = (old and discontinued) had 2 figures…

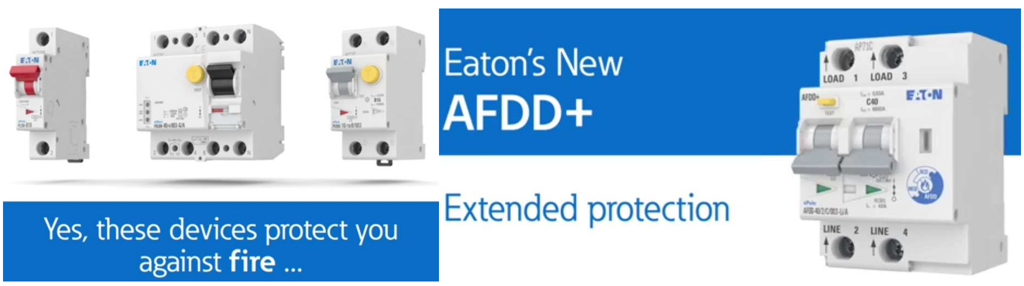
<=10A - 1.5In and >10A - 1.35In

BS 88 Fuse - fusing factor = 1.6

BS 1361 Fuse - fusing factor = 1.5

BS 1362 <= 13A - 1.9In

BS 3036 Fuse - fusing factor = 2.0



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Coordination of Protective Devices

I_2 is the ....I_n x 2 i.e., fusing current of a device within conventional time

MCBs to BS EN 60898 ≤ 63 A (In)
Non-Tripping current I1 = 1.13 In
Tripping current I_2 = 1.45 In (tripping time ≤ 1 hour)
MCBs to BS EN 60898 ≥ 63 A (In)
Non-Tripping current I1 = 1.13 In
Tripping current I_2 = 1.45 In (tripping time ≤ 2 hours)

BS 88 fuse <16 A (In)
Non-Fusing current I1 = 1.25 In for 1 hour
Fusing current I_2 = 1.6 In (fusing time ≤ 1 hour)
BS 88 fuse 16 A < In ≤ 63 A
Non-Fusing current I1 = 1.25 In for 1 hour
Fusing current I_2 = 1.6 In (fusing time ≤ 1 hour)

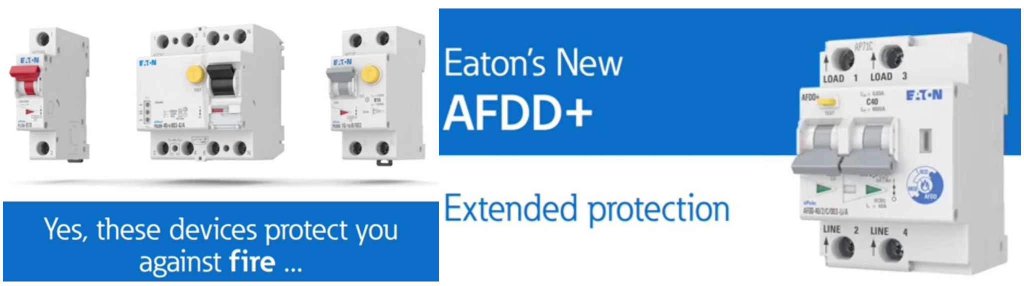
BS 88 fuse 63 A < In ≤ 160 A
Non-Fusing current I1 = 1.25 In for 2 hours
Fusing current I_2 = 1.6 In (fusing time ≤ 2 hours)

BS 88 fuse 160 A ≤ In ≤ 400 A
Non-Fusing current I1 = 1.25 In for 3 hours
Fusing current I_2 = 1.6 In (fusing time ≤ 3 hours)
BS 88 fuse 160 A ≤ In ≤ 400 A
Non-Fusing current I1 = 1.25 In for 3 hours
Fusing current I_2 = 1.6 In (fusing time ≤ 3 hours)

BS 88 fuse 400 A < In
Non-Fusing current I1 = 1.25 In for 4 hours
Fusing current I_2 = 1.6 In (fusing time ≤ 4 hours)

BS 1361 fuse 5 A < In ≤ 45 A
Fusing current I_2 = 1.5 In (fusing time ≤ 4 hours)

BS 1361 fuse 60 A < In ≤ 100A
Fusing current I_2 = 1.5 In (fusing time ≤ 4 hours)



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Coordination of Protective Devices

Energy Let through (434)

– All electromechanical devices have a maximum breaking capacity

– Maximum amount of energy that the component will allow through without exploding or disintegrating

– General Equation

$$E = I^2t \quad \textit{where} \quad P = \frac{E \ \textit{joules}}{t \ \textit{seconds}}$$

– Note: The Resistance of the conductor can be regarded as negligible (but not zero) for the short time period and very high fault currents

Short Circuit Protection

$$t = \frac{S^2k^2}{I^2}$$

Regulation 434.5.2 States that:

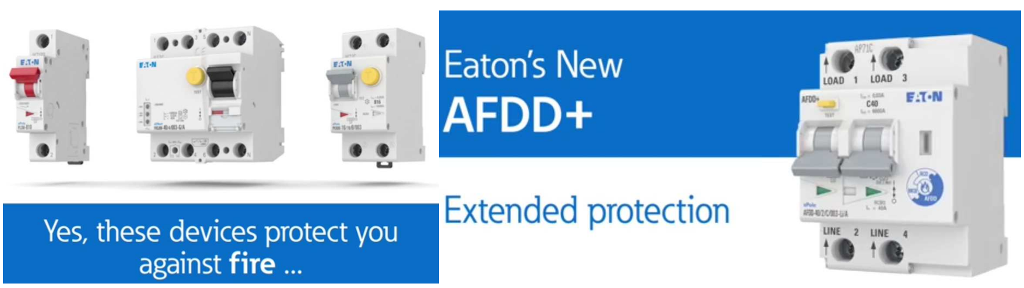
The regulation is satisfied if the time for disconnection is equal to or less than:

The fault current must be cleared before the time given in the above equation Note: for short circuits between live conductors and for earth fault currents

$$543.1.1 \qquad S = \frac{\sqrt{I^2 x\ t}}{k}$$

434.5.2 and 543.1.1 states that for the time that the earth fault exists the Live conductors and/or CPC must be able to dissipate the heat generated without damage to the other cables

So as long as : $S^2k^2 \geq I^2t$ Then the thermal characteristics of the cable are protected from the energy let through of the protective device The size of the cpc usually works out to be much smaller than anticipated, if regulation 543.1.4 is applicable then this must be sized up according to Table 54.7



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Part 4 - Protection Safety

Applying Circuit Design 2

Operating Characteristics of Protective Devices

Energy Let Through (Heat) 434.5.2

MCB Breaking Capacities

MCB to BS3871 Obsolete from 2001 (blue)

Circuit Breakers BS EN 60898 / BS EN 61009

Electromagnetic stress proportional to (I^2) peak current

Electromagnetic stress (I^2) let through by one cycle of AC current

Fuse Link Cut-Out

Discrimination of OPD

435.2 Discrimination of Protective Devices

– I^2 characteristics of HBC fuses

– Rated Current plotted against Amperes squared

Ferraz Shawmut BS88 cartridge fuses

I^2t Characteristics

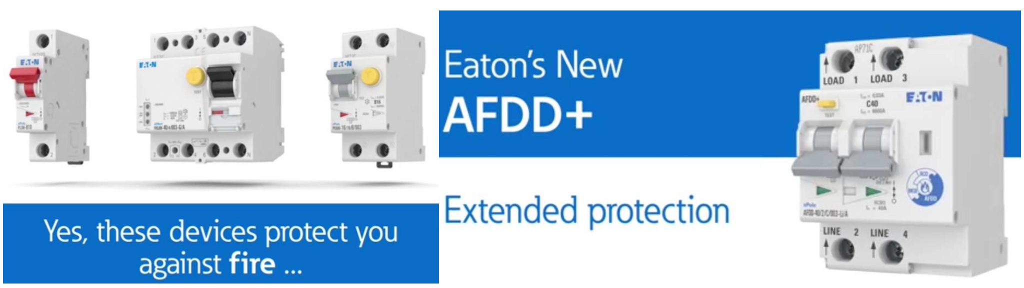
Ampere Fuse rating

Discrimination achieved when downstream fuse when downstream fuse is ½ the size of the size of the upstream OPD

Protection against Fault Currents

Discrimination of Protective Devices - 434.1 to 434.5.3

Discrimination of devices must take place to reduce danger and inconvenience 314.1 and 2 If fuse ‘Z’ blows then fuse ‘Y’ should be of such size that it can withstand the energy let through without disconnecting



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Part 4 - Protection Safety

Coordination of OPD

The example, shows the superimposed characteristics of a **5 A semi-enclosed fuse** and a **10 A miniature circuit breaker** which we shall assume are connected in series.

*If a fault current of 50 A flows, **the fuse will operate in 0.56 s** whilst the **circuit breaker would take 24 s** to open. Clearly the **fuse will operate first** and the devices have discriminated.*

However, if the **fault current is 180 A**, the **circuit breaker will open in 0.016 s**, well before the **fuse would operate, which would take 0.12 s**. In this case, **there has been no discrimination.**

Graph A shows discrimination from instantaneous disconnection of the **16A MCB** from the **32A fuse** at 180A

Graph B shows poor discrimination between **16A MCB** and **25A fuse** starting at 100A+ in an overload condition but none for short circuit

Protection against Overcurrents

Positioning of Device – 433.2 and 434

• Where a conductors diameter reduces along the line of a cable run a method of protection is required for that part of the cable which has a reduced cross sectional area 434.1.1

– Examples of reduced cable conductors are:

• Fused spur on a ring final circuit

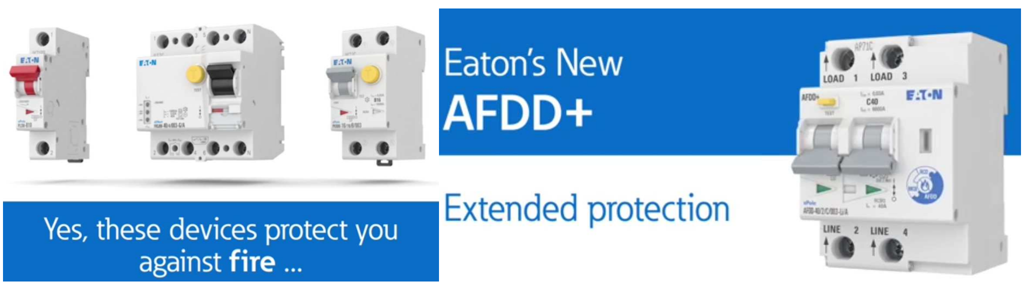
• Installation method changed (overhead to underground)

• Type of cable has changed (PVC in conduit to MIMS)

• Ambient change in temperature (Boiler house to outside)

– Rules for termination between reduction in current carrying capacity and Protective Device 434.2.1

1. Not Exceed 3m in length
2. Be erected to minimise risk of fault current
3. Be erected to minimise fire and danger to persons



Part 4 - Protection Safety

Protection against Overcurrent

Omission of protective devices for safety reasons 433.3.3 Used where unexpected disconnection would cause a dangerous situation

1. The exciter circuit of a rotating machine
2. The supply circuit of a lifting magnet
3. The secondary circuit of a current transformer
4. A circuit supplying a fire extinguishing device
5. A circuit supplying a safety circuit (fire or gas alarm)
6. A circuit supplying medical equipment in IT systems

Voltage and Electromagnetic disturbances

441 Overvoltages due to HV and LV faults

HV faults to earth at the substation 442.2

Loss of supply neutral on LV systems 442.3

Line to Neutral Short Circuit in LV systems 442.5

Accidental earthing of a line conductor to earth in IT systems 442.4

Stress Voltages created by HV currents circulating around exposed conductive parts producing an electromagnetic effect thus producing a secondary fault voltage (stress voltage U1 and U2)

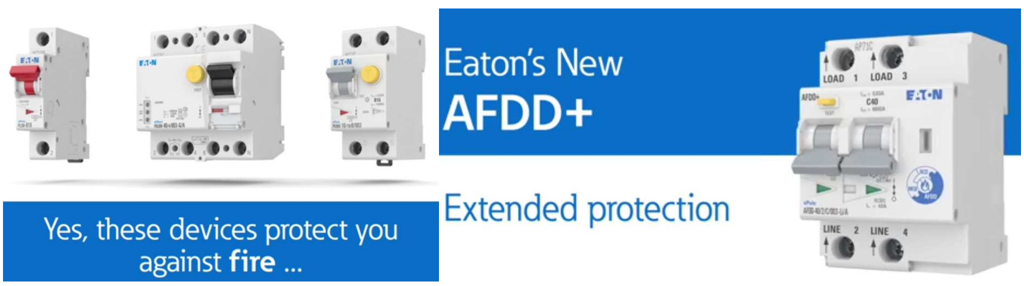
Fig 44.1 - Representative diagram for connections to Earth in the substation and the LV installation and the overvoltages occuring in case of faults.

442.1 rules for designers and installers of substations Quality of system earth Maximum level of earth fault current Resistance of earthing arrangements

442.2.1 The size of calculated Fault voltages from table 44.1 must not exceed a dangerous level across exposed conductive parts and earth.

442.2 HV fault voltages (U1 and U2 as specified in table 44.1) appearing across LV installations should not exceed the values given in table 44.2

443 Overvoltage requirements



Electromagnetic Disturbances

444.1 electromagnetic disturbances caused by fast changes in current in power cables can affect auxilliary circuits See Appendix 1: BS 6701, 50310,50174, 610000-5-2

444.4.1 typical sources of interference are: Inductive loads, electric motors, fluorescent lights, welding machines, rectifiers, choppers, VSDs, lifts, transformers, transformers, switchgear, large power distribution busbars

444.4.2.1 measures for protection (i) Bypass conductors for screen control cables (ii) Surge protective devices (SPDs) (iii) reduce cable loop areas (keep power cables and earthing conductors together (iv) Keep power and signal cables separate (v) Equipotential bonding networks

Problem Voltages

445 Undervoltages

445.1.1 Suitable precautions shall be taken to provide protection when the voltage dips or is reduced see 552.1.3

445.1.5 No automatic restarting of rotating machinery (Note: see external classifications appendix 5)