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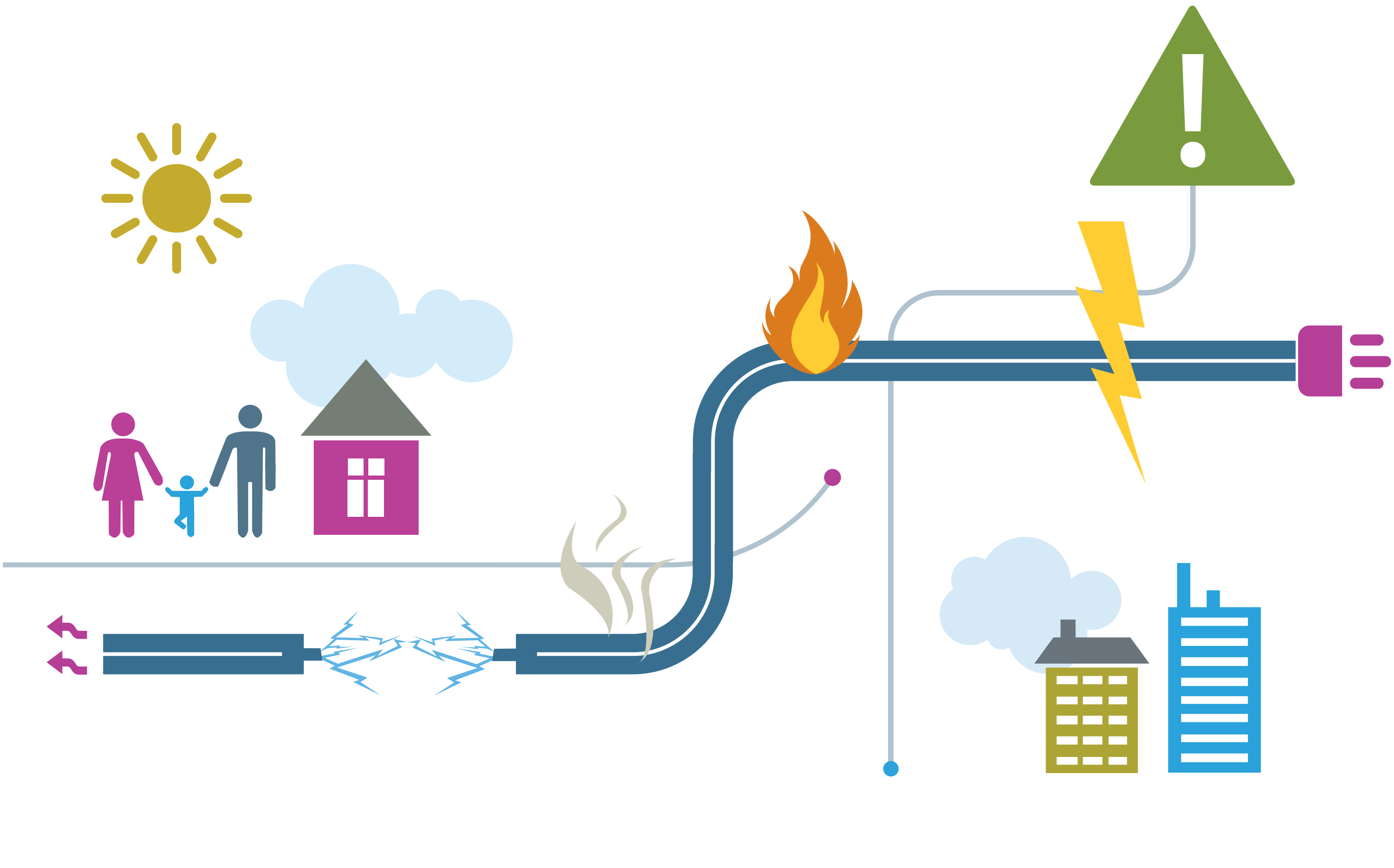
GUIDE TO ARC FAULT DETECTION DEVICES (AFDD)



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ABOUT BEAMA

BEAMA is the long established and respected trade association for the electrotechnical sector. The association has a strong track record in the development and implementation of standards to promote safety and product performance for the benefit of manufacturers and their customers.

This Guide provides guidance on Arc Fault Detection Devices (AFDDs) and their application in electrical installations.

This Guide has been produced by BEAMA's Building Electrical Systems Portfolio which comprises of major UK manufacturing companies operating under the guidance and authority of BEAMA, supported by specialist central services for guidance on European Single Market, Quality Assurance, Legal and Health & Safety matters.

Details of other BEAMA Guides can be found on the BEAMA website www.beama.org.uk

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1
INTRODUCTION

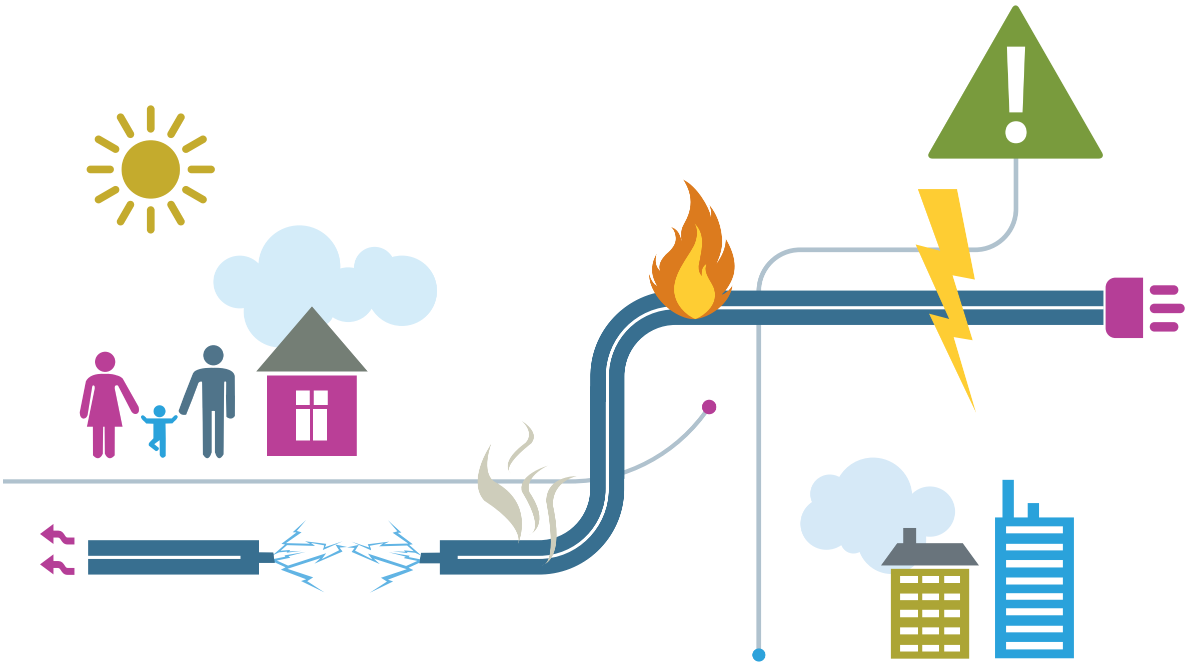
UK fire statistics identify that electrical fires are still unacceptably high. Use of overcurrent and residual current protection has vastly reduced the risk and consequence of electrical fires.

However, due to their characteristics, electric arcs in cables and connections cannot be detected by fuses, circuit breakers (e.g. MCBs, MCCBs) or by Residual Current Devices (RCDs), such electrical arcing can cause fires. Modern technology makes it possible to detect dangerous arcs and thus to protect installations. More specifically, an arc fault detection device (AFDD) disconnects the circuit's electricity supply when it detects the presence of dangerous electrical arcs, thus preventing the outbreak of fire.

The installation of AFDDs is recommended[1] for final circuits in:

- premises with sleeping accommodation,
- buildings depending on their particular characteristics (risks of fire) due to processed or stored materials (e.g. barns, wood-working shops, stores for combustible materials, etc.),
- buildings constructed of combustible materials (e.g. wood),
- locations with irreplaceable objects (e.g. museums, libraries, art galleries, etc.).

This guide considers Arc Fault Detection Devices (AFDD) according to BS EN 62606 and their application within installations.



1 Context from IEC 60364-4-42 Edition 3, HD 60364-4-42 A1:2015

2
TERMINOLOGY AND DEFINITIONS

Arc	Luminous discharge of electricity across an insulating medium, usually accompanied by the partial volatilization of the electrodes.
Parallel arc fault	Arc fault where the arc current is flowing between active conductors in parallel with the load of the circuit.
Series arc fault	Arc fault where the current is flowing through the load(s) of the final circuit protected by an AFDD.
AFDD	Arc Fault Detection Device – device intended to mitigate the effects of arcing faults by disconnecting the circuit when an arc fault is detected.
AFD unit	Part of the AFDD ensuring the function of detection and discrimination of dangerous earth, parallel and series arc faults and initiating the operation of the device to cause interruption of the current.
MCB	Miniature Circuit Breaker
MCCB	Moulded Case Circuit Breaker
RCD	Residual Current Device
RCCB	Residual Current Circuit Breaker without integral overcurrent protection
RCBO	Residual Current Circuit Breaker with integral overcurrent protection
Ring Final Circuit	A final circuit arranged in the form of a ring and connected to a single point of supply

3
OVERVIEW

Electrical fires continue to be a significant issue in UK installations. Electricity is a major cause of accidental fires in UK homes – over 20,000 electrical fires each year. Fire statistics[2] for 2011/12 identify that 89% of electrical fires are caused by electrical products, 11% (circa 2,200) of which are caused by faults within installations or by people not using installations properly.

More recent statistics[3] from 2013/14 attribute 12% of fires to electrical distribution (wiring, cabling, plugs). These statistics demonstrate that electrical fires occur and can cause injuries, deaths and damage or destroy significant amounts of property. Electrical fires can be a silent killer occurring in areas of the home that are hidden from view and early detection. The objective is to protect such circuits in a manner that will reduce the risk of it being a source of an electrical fire.

The use of circuit breakers, fuses and RCDs greatly reduces the risk of fire. BS 7671: 2008 Amd 3: 2015 introduced further requirements to minimise the spread of fire that may occur within a consumer unit[4].

ELECTRICAL FIRES CAN BE A SILENT KILLER OCCURRING IN AREAS OF THE HOME THAT ARE HIDDEN FROM VIEW AND EARLY DETECTION.

Basic protection:	Insulation of live parts (class II equipment, cable insulation, barriers or enclosures)
Fault protection:	Automatic disconnection of the power and the fault
Additional protection:	For example, RCD not exceeding 30 mA

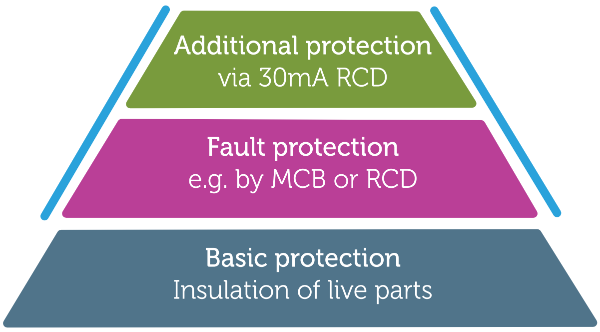


FIGURE 1 – EXISTING PROTECTION SCHEME

The above measures have made significant improvements in protection against the risk of fire. The use of AFDDs provide additional protection not offered by these measures as AFDDs are designed to detect low level hazardous arcing that circuit breakers, fuses and RCDs are not designed to detect. UK fire statistics for 2013/14 identify circa 12% of electrical fires start within the electrical distribution system of an installation (wiring, cables, plugs), AFDDs detect series and parallel arcs which can occur within these cables and connections.

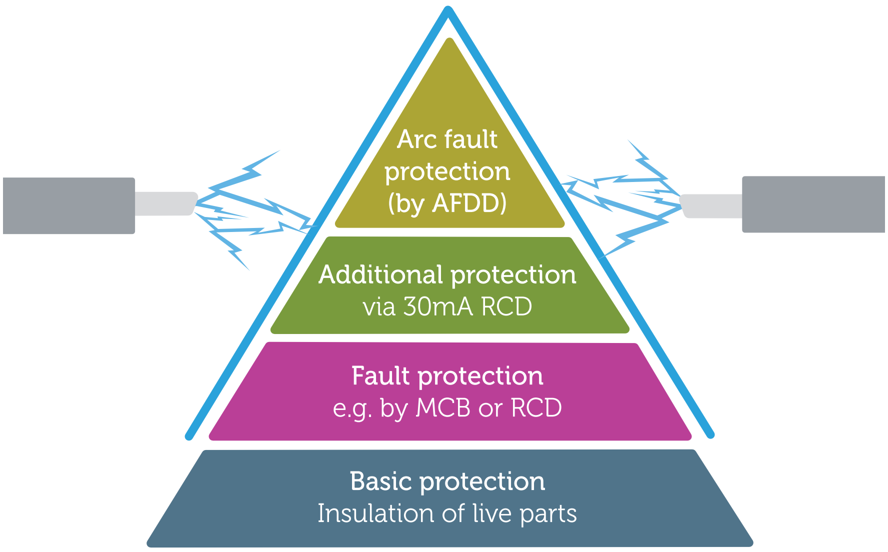
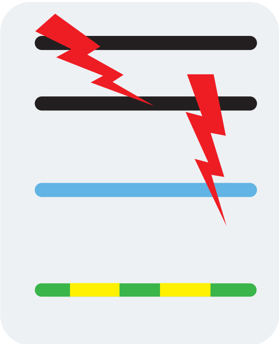


FIGURE 2 – ENHANCED PROTECTION, ADDING THE MISSING LINK

2 Source: *Department for Communities and Local Government, Fire Statistics 2011/12*
3 *Source: Department for Communities and Local Government, Fire Statistics 2013/14*
4 *See BEAMA Technical Bulletin on Enhanced Fire Safety available on the BEAMA website*

4
TYPES OF ELECTRICAL FAULT AND ASSOCIATED PROTECTION



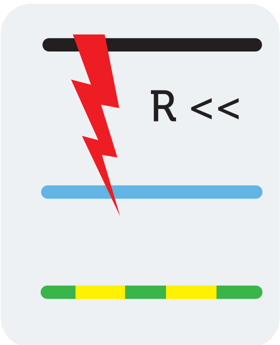
a) Overcurrent

- Short-term: no damage
- Long-term: thermal overload

Originates from:

- Insulation faults
- Connections between L-L, L-N

Protection is provided by circuit breakers, RCBOs or fuses.



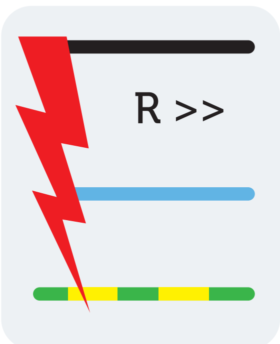
b) Short circuit current

- Fault current over a very low impedance
- High magnitude of fault current

Originates from:

- Mechanical damage, water ingress
- Connections between L-L, L-N

Protection is provided by circuit breakers, RCBOs or fuses.



c) Leakage Current

- Typically Earth leakage current
- Typically much smaller than nominal current, approximately 1-500 mA

Originates from:

- Insulation ageing
- Mechanical stress
- Dirt and dust
- Connections between L-PE

Protection is provided by RCCBs or RCBOs.

d) Series arc fault current

Originates from

- Damaged (e.g. crushed, broken, etc) cables
- Loose connections

Protection is provided by AFDDs.

e) Parallel arc fault current (L-N)

Originates from :

- Fault between L-N
- High impedance due to damaged insulation, fault current is too low to trip other protection devices

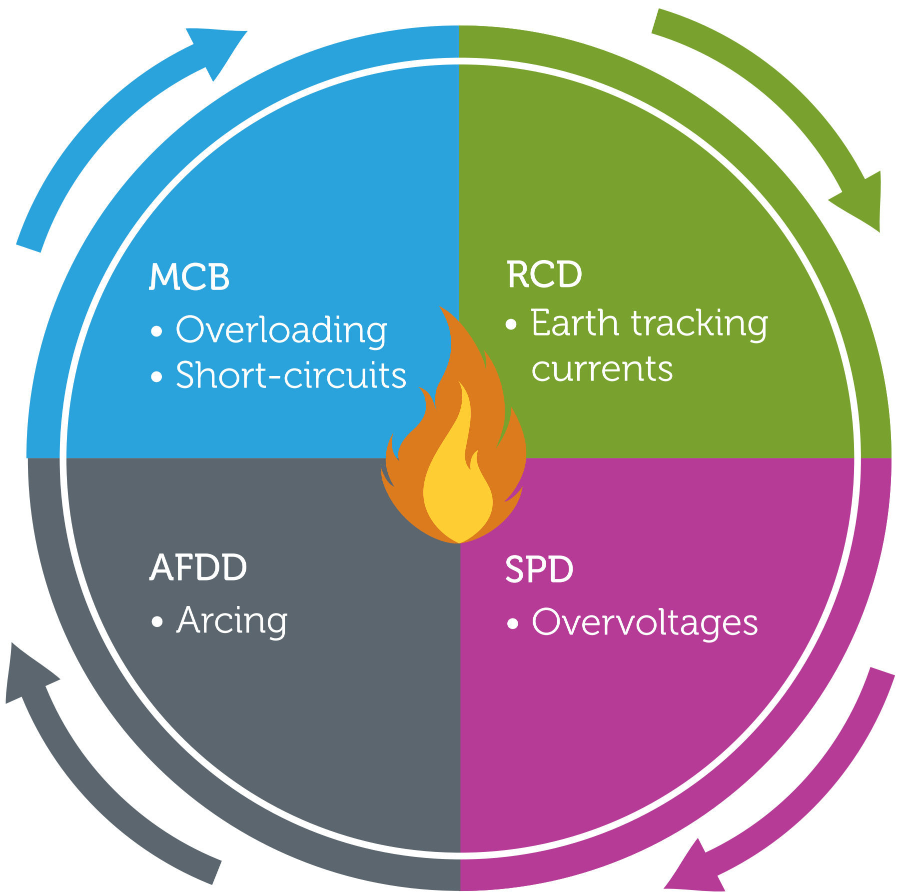
Protection is provided by AFDDs.

f) Parallel arc fault current (L-E)

Originates from :

- Fault between L-E
- High impedance due to damaged insulation, fault current is too low to operate circuit breakers or fuses

Protection is provided by RCDs and AFDDs.



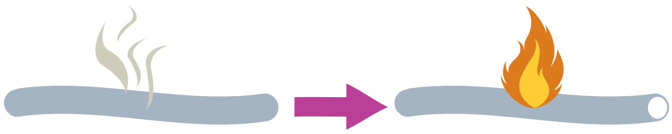
5
CAUSES OF SERIES AND PARALLEL ARC FAULTS

An arcing fault is an unintentional arcing condition in a circuit. Arcing creates high intensity heating at the point of the arc resulting in burning particles that may over time ignite surrounding material, such as wood or insulation. Repeated arcing can create carbon paths that are the foundation for continued arcing, generating even higher temperatures. The temperatures of these arcs can exceed 6,000 degrees Celsius.

Development of an arc fault

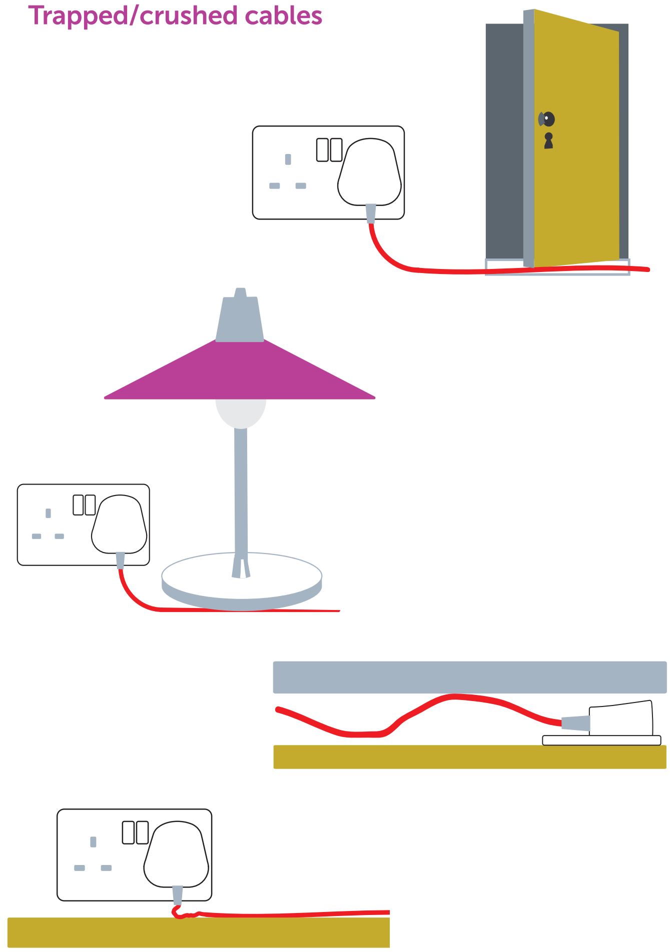
Arc faults are rarely instant and, depending on a wide number of factors, can take time to develop. The time for an arc fault to form is dependent on its root cause (external influences, ageing, etc.).

Arc faults can occur immediately or over a long period (hours, days, weeks, months, years). With the arc developing, temperatures up to 6000°C can be generated and thus the surrounding insulation starts to burn and eventually a fire develops. The illustrations below illustrate a developing arc fault.

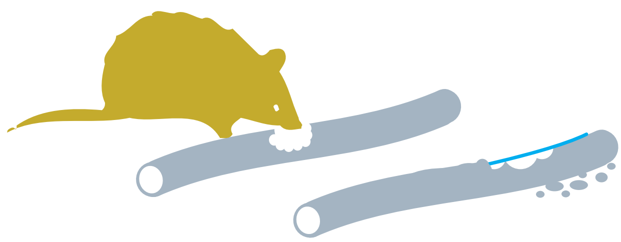


Arc faults can occur in many locations where electrical energy is present, with varied root causes, for example :

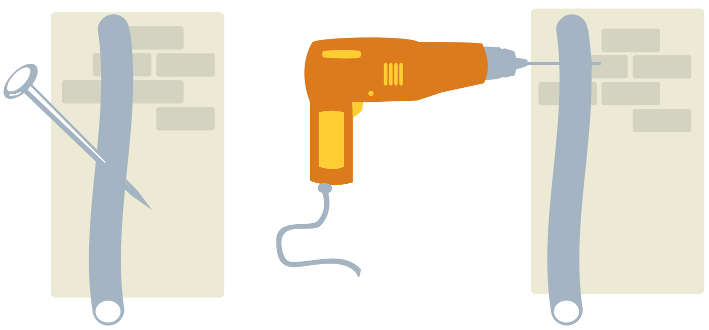
Trapped/crushed cables



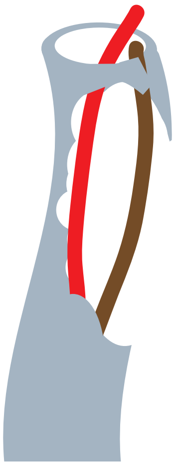
Rodent damage

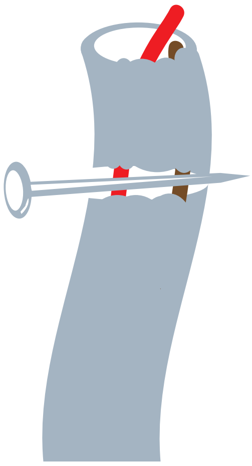


Pierced insulation

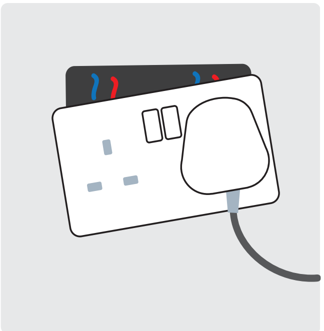


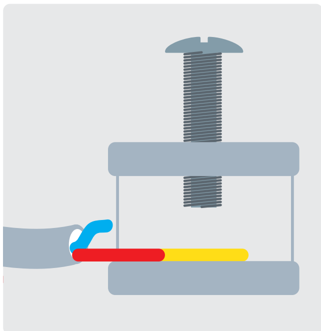
Damaged insulation





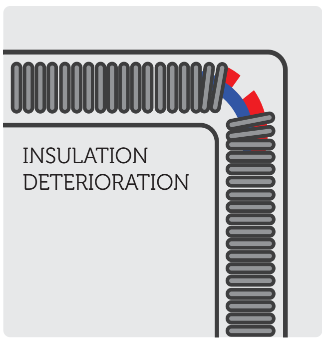
Loose terminations

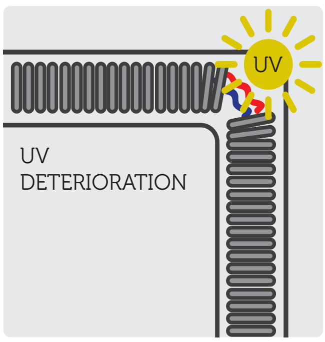


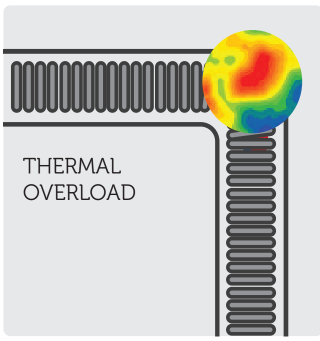


NOTE: AFDDs will detect arcing but not high resistance connections within loose terminations. AFDDs will not detect high resistance connections due to trapped insulation.

Deteriorating insulation







6
HOW AFDDs WORK

Unlike a circuit breaker which detects overloads and short circuit currents and RCDs which detect current imbalance, an AFDD utilises electronic technology to analyse the signature (waveform) of an arc to differentiate between normal arcing and arcing faults. Although AFDD manufacturers may employ different technologies to analyse arcs, the end result is the same, detecting parallel arcs (line to line, line to neutral and line to earth) and series arcs (arcing within one of the conductors). Upon detection of an arcing fault, the AFDD disconnects the final circuit from the supply.

AFDD manufacturers test for numerous possible operating conditions and design their devices to constantly monitor for arcing faults.

In electrical circuits there are numerous cases of normal arcs appearing that correspond to typical operation, such as:

- Arcs created by switches, contactors, impulse switches, and other control devices when contacts are opened;
- Arcs created by motors of the different electrical loads connected to the circuit (portable electrical tools, vacuum cleaner motor, etc.)

To differentiate between normal arcing and arcing faults, the parameters analysed are both numerous and varied, such as:

- The signature (waveform) of the arc.
- Duration of the arc (very short durations, for example, are characteristic of the normal operation of a switch).
- Irregularity of the arc (the arcs of motors, for example, are fairly regular and as such are not considered an arc fault).

AFDDs are designed and tested to not respond to arcing under normal operation of equipment such as vacuum cleaners, drills, dimmers, switch mode power supplies, fluorescent lamps, etc. In addition, they are designed and tested to continue to respond to arc faults whilst the aforementioned equipment is being operated.

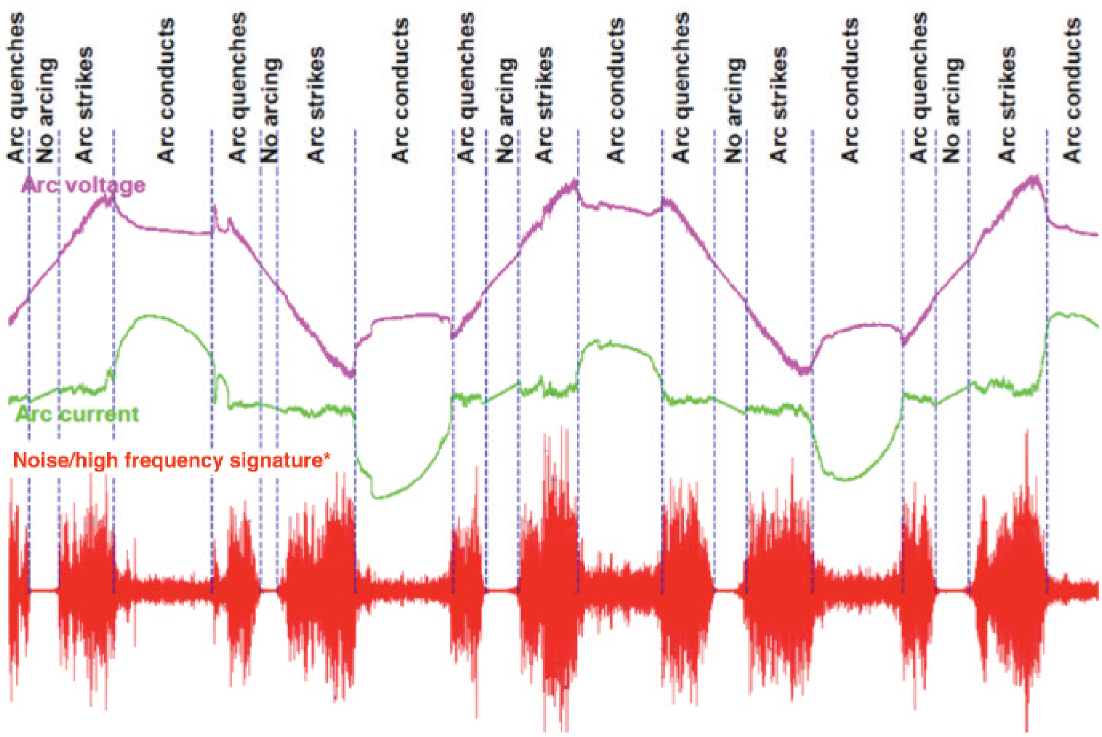


FIGURE 3 – TYPICAL SIGNATURE OF AN ELECTRIC ARC

*noise / high frequency signature exceeding 50Hz which can be kHz or MHz and which correspond to an electric arc fault.

7
SELECTION AND INSTALLATION OF AFDDs

7.1. AFDDs are selected based on:

7.1.1. Method of construction

a) AFDD as one single device,
comprising an AFD unit and opening means and intended to be connected in series with a suitable short circuit protective device declared by the manufacturer complying with one or more of the following standards BS EN 60898-1, BS EN 61009-1 or BS EN 60269 series.

b) AFDD as one single device,
comprising an AFD unit integrated in a protective device complying with one or more of the following standards BS EN 60898-1, BS EN 61008-1, BS EN 61009-1 or BS EN 62423.

c) AFDD comprising of an AFD unit (add-on module) and a declared protective device, intended to be assembled on site.

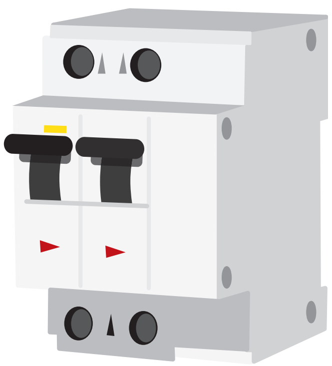


FIGURE 4 – AFDD INTEGRATED WITH AN RCBO (7.1.1 B)

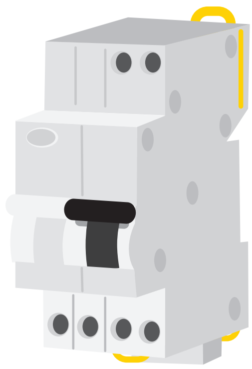


FIGURE 5 – AFDD INTEGRATED WITH AN MCB (7.1.1 B)

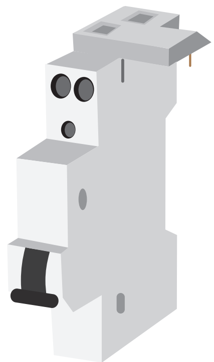


FIGURE 6 – AFDD ADD-ON MODULE (7.1.1 C)

7.1.2. Number of poles

a) Two pole
b) Three pole
c) Four pole

7.1.3. Voltage rating

a) 230V
b) 230/400V
c) 400V

7.1.4. Current rating

Between 6A and 63A, preferred values are 6 – 8 – 10 – 13 – 16 – 20 – 25 – 32 – 40 – 50 – 63 A.

7.1.5. Characteristics

a) Rated operational voltage (Un)
The rated operational voltage of an AFDD is the value of voltage, assigned by the manufacturer, to which its performance is referred.

b) Rated current (In)
The value of current, assigned to the AFDD by the manufacturer, which the AFDD can carry in uninterrupted duty.

c) Conditional short-circuit current (Inc)
Value of the a.c. component of a prospective current, which an AFDD, protected by a suitable short-circuit protective device in series can withstand under specified conditions of use and behaviour.

These three characteristics are marked on the AFDD.

7.2. Coordination

Where necessary, coordination of AFDDs with overcurrent protective devices is required.

7.2.1 Short-circuit coordination

BS EN 62606 prescribes tests that are intended to verify that the AFDD, protected by the declared protective device, is able to withstand, without damage, short-circuit currents up to its rated conditional short-circuit current (Inc). An AFDD with an integrated overcurrent protective device (7.1.1b) and 7.1.1c)) provides the necessary coordination. An AFDD not having an integrated short-circuit protective device (7.1.1a)) requires coordination in accordance with the manufacturer's instructions.

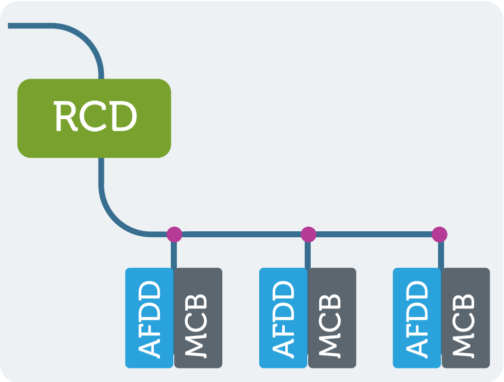
7.2.2 Selectivity coordination

7.2.2.1 Selectivity of an RCD supplying an AFDD integrated with an MCB

For a series arc fault or a parallel arc fault (L-N), the AFDD/MCB will operate without tripping the RCD thus selectivity is automatically achieved.

For a parallel arc fault (L-E), selectivity will be dependent on the characteristics and magnitude of the arc.

- Should the frequency and magnitude of the arc not correspond to the tripping characteristics of the RCD, then only the AFDD/MCB will trip.
- Should the frequency and magnitude of the arc correspond to the tripping characteristics of the RCD, then the RCD will trip and generally the AFDD/MCB will also trip.



7.2.2.2 Selectivity of an RCD supplying an AFDD integrated with an RCBO

For selectivity of an RCD with the AFDD element, 7.2.2.1 applies.

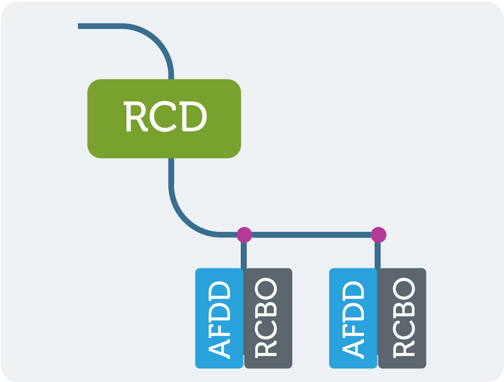
For selectivity of an RCD with the RCBO element, the following applies:

- the RCD is of selective type (type S or time delayed type with appropriate time delay setting), and
- the ratio of the rated residual current of the RCD to that of the RCBO is at least 3:1.

In case of RCDs with adjustable rated residual current and time delay, manufacturer instructions for selectivity should be followed.

NOTE 1: RCD type S is in accordance with BS EN 61008 series or BS EN 61009 series.

NOTE 2: A time-delay type RCD in accordance with BS EN 60947-2:2006, Annex B or Annex M will be marked with the symbol (Δt) followed by the limiting non-actuating time in ms or marked with an [S]



7.3. Installation of an AFDD

An AFDD shall be installed in accordance with the manufacturer's instructions.

7.4. Installation of an AFDD in assemblies

In low voltage assemblies to the BS EN 61439 series e.g. Consumer Units, Distribution Boards, incorporated devices, including AFDDs, shall only be those declared suitable according to the assembly manufacturer's instructions or literature.

8
AFDDs AND THE WIRING REGULATIONS

The IET Wiring Regulations, BS 7671, take account of the technical substance of agreements reached at CENELEC level in Harmonized Documents (HD). Where no CENELEC HD exists, IEC level documents are taken into account. IEC 60364-4-42 Edition 3 and HD 60364-4-42 A1:2015 recommend the use of AFDDs as follows:

It is recommended that special measures be taken to protect against the effects of arc faults in final circuits:

- in premises with sleeping accommodation;
- in locations with risks of fire due to the nature of processed or stored materials, i.e. BE2 locations, (e.g. barns, woodworking shops, stores of combustible materials);
- in locations with combustible constructional materials, i.e. CA2 locations (e.g. wooden buildings);
- in fire propagating structures, i.e. CB2 locations;
- in locations with endangering of irreplaceable goods.

In a.c. circuits, the use of arc fault detection devices (AFDD) in compliance with IEC 62606 will satisfy the above-mentioned recommendation.

If used, an AFDD shall be placed at the origin of the circuit to be protected.

The use of AFDDs does not obviate the need to apply one or more measures provided in other clauses in this standard.

In order to implement the technical intent of the HD, BS 7671 18th Edition will include requirements covering the use of AFDDs however the actual requirements and final wording will not be available until publication of the 18th Edition in July 2018.

9
AFDDs AND RING FINAL CIRCUITS

An AFDD will afford the necessary protection to a ring final circuit including to the equipment connected to the ring. It should be noted that a series arc in a leg of a ring final circuit (for example due to a break in the conductor or a loose connection) will not be of a sufficient magnitude to pose a fire hazard as a result of that arcing. In such an occurrence, the arcing will be minimal presenting a high resistance causing the load current to flow through the other leg of the ring final circuit and as such will not be detected by an AFDD.

10
TESTING AFDDs

AFDDs are provided with:

- a manual test button. When tested manually, the AFDD should trip. BEAMA recommends manual testing be performed every six months.

and/or

- an automatic test function that checks the arc detection circuit. The automatic test function consists of a test at switch-on and at intervals not exceeding at least once a day. During this automatic testing, the AFDD does not trip unless a malfunction is detected. In case a malfunction is detected the AFDD will trip and indicate a malfunction.

AFDDs integrated with an RCCB or RCBO will at least include a test button for the RCD element of the device.

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