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GUIDE TO ARC FAULT DETECTION DEVICES (AFDDs)

Third Edition – October 2019

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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 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. BEAMA's Building Electrical Systems Portfolio comprises of major UK manufacturing companies.

Details of other BEAMA Guides can be found on the BEAMA website
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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 (AFDDs) disconnects the circuit's electricity supply when it detects the presence of dangerous electrical arcs, thus preventing the outbreak of fire.

BS 7671:2018, the IET Wiring Regulations, recommend the use of AFDDs conforming to BS EN 62606 as a means of providing additional protection against fire caused by arc faults in AC final circuits. See Section 8.

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

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 with over 17,000 electrical fires each year. Fire statistics[1] for 2017/18 identify that almost 23 % of domestic electrical fires are caused by faulty appliances and leads.

The 2017/18 fire statistics[1] also 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.

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

Basic protection:	basic insulation of live parts or by barriers or enclosures
Fault protection:	by protective earthing, protective equipotential bonding and automatic disconnection in case of a fault
Additional protection:	for example, RCD not exceeding 30 mA

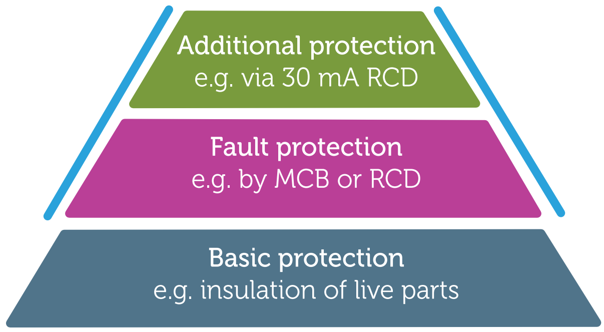

FIGURE 1 – EXISTING PROTECTION SCHEME

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 2017/18 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.

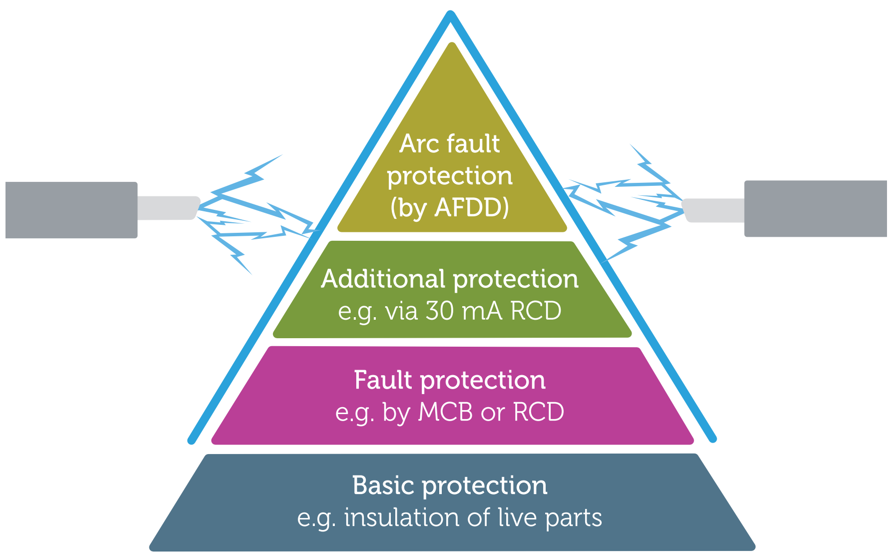

FIGURE 2 – ENHANCED PROTECTION, ADDING THE MISSING LINK

1 Source: *Department for Communities and Local Government, Fire Statistics 2017/18*
2 *See BEAMA Technical Bulletin on Enhanced Fire Safety available on the BEAMA website*

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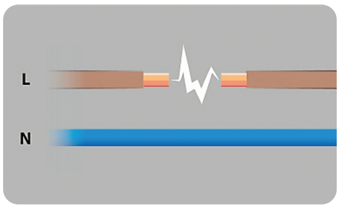
TYPES OF ARC FAULT



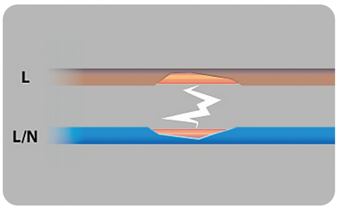
a) Series arc fault current

Originates from

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

A series arc is in series with a load and at a lower level than a parallel arc. The series arc fault characteristics result in the rms value of current and I^2t being too low to operate a fuse or MCB.

Protection is provided by AFDDs.



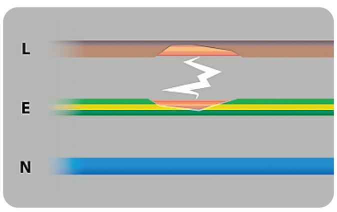
b) Parallel arc fault current (L-N)

Originates from :

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

Parallel arc fault characteristics (including short duration high peak currents) result in rms, I^2t, and peak time values that are generally too low to operate protective devices such as fuses or MCBs.

Protection is provided by AFDDs.

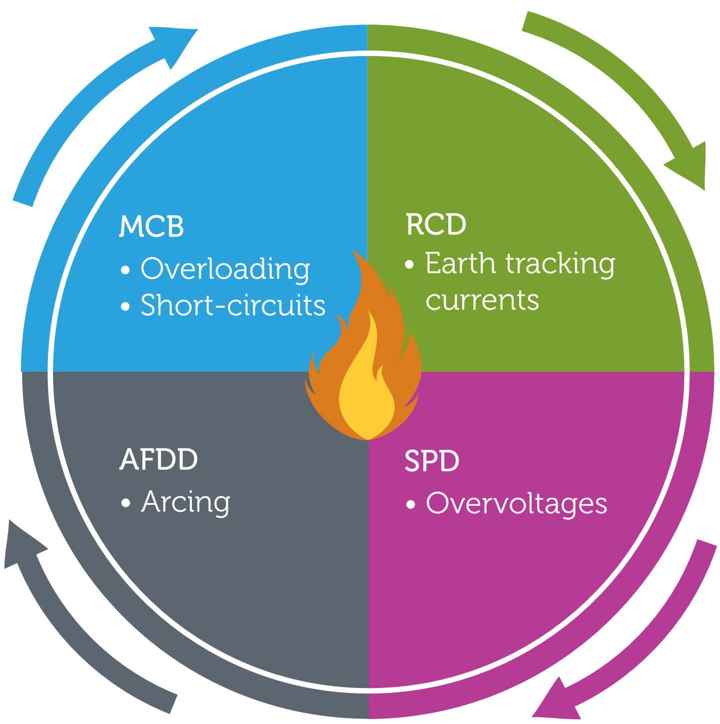


c) Parallel arc fault current (L-E)

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.



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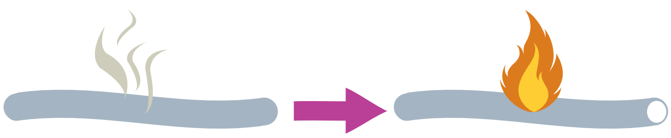
CAUSES OF SERIES AND PARALLEL ARC FAULTS

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. Repeated arcing can create carbon paths that are the foundation for continued arcing, generating even higher temperatures. The temperatures of these arcs can exceed 6000 °C.

Development of an arc fault

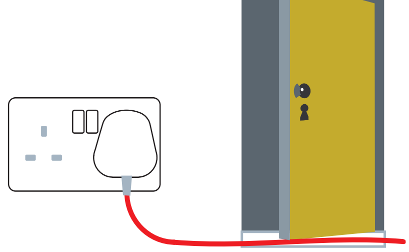
Arc faults are rarely instant and, depending on a wide number of factors, can take time to develop. The time for an arc fault to form is dependent on its root cause (external influences, ageing, etc.).

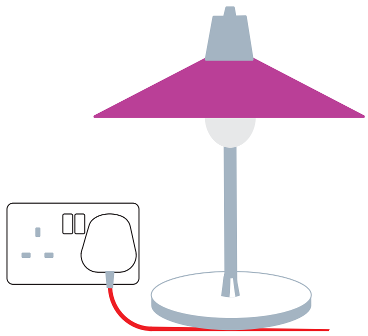
Arc faults can occur immediately or over a long period (hours, days, weeks, months, years). With the arc developing, temperatures up to 6000 °C can be generated and thus the surrounding insulation starts to burn and eventually a fire develops. The illustrations below illustrate a developing arc fault.

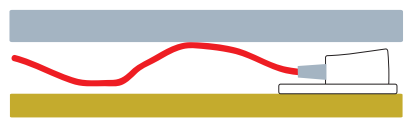


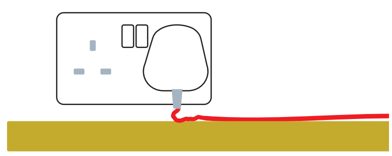
Arc faults can occur in many locations where electrical energy is present, with varied root causes, for example :

Trapped/crushed cables

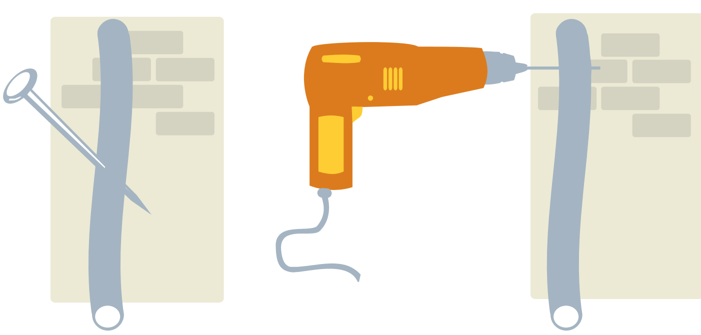




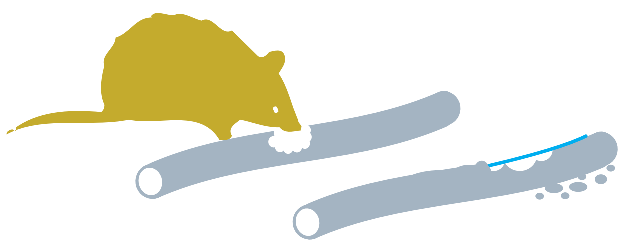




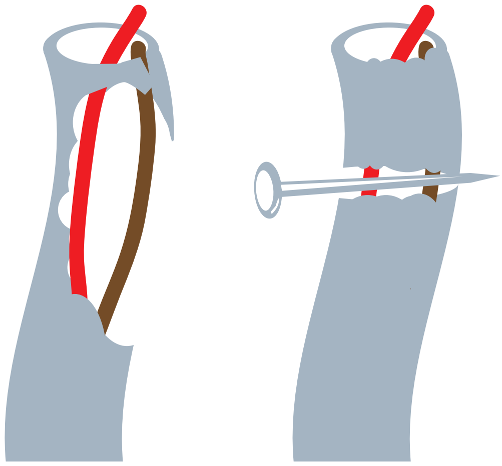
Pierced insulation



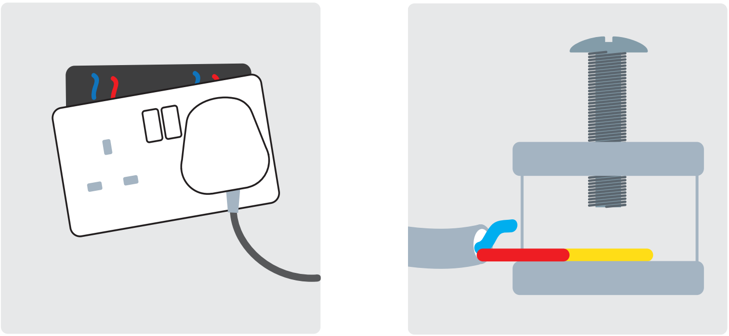
Rodent damage



Damaged insulation

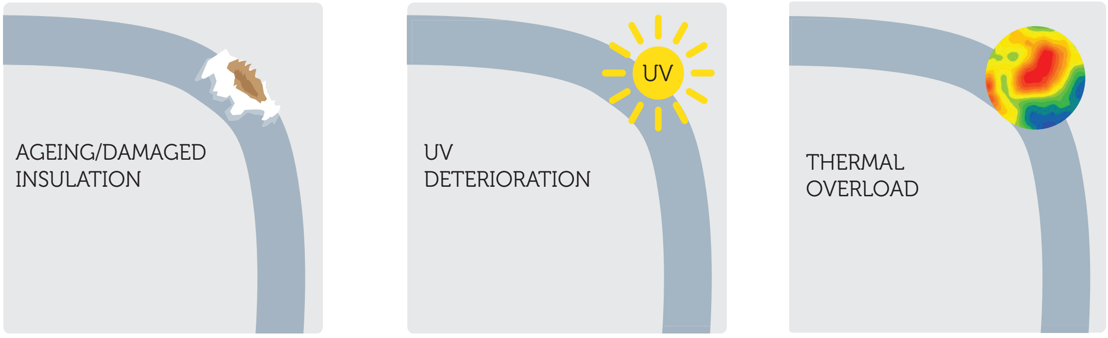


Loose terminations



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



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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.

https://vimeo.com/351569574

https://vimeo.com/351570442

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.

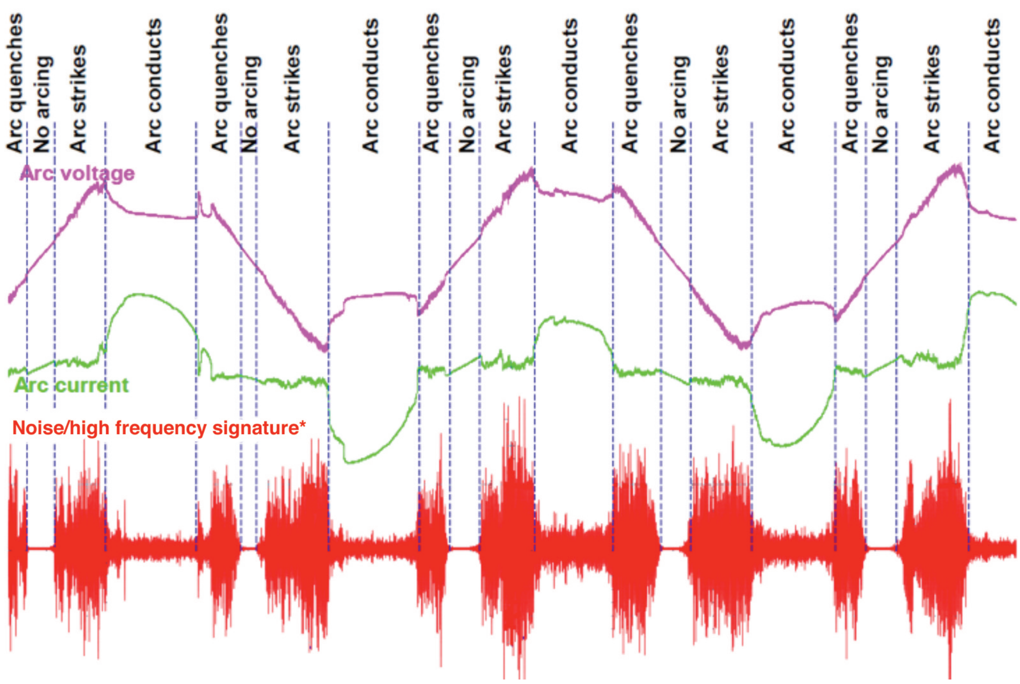


FIGURE 3 – TYPICAL SIGNATURE OF AN ELECTRIC ARC

*noise / high frequency signature exceeding 50 Hz 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.

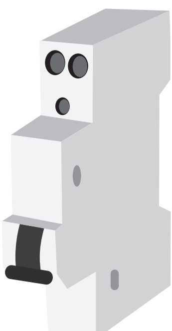


FIGURE 4 – STANDALONE AFDD (7.1.1 a)

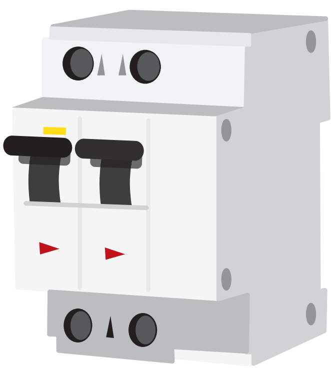


FIGURE 5 – AFDD INTEGRATED WITH AN RCBO (7.1.1 b)

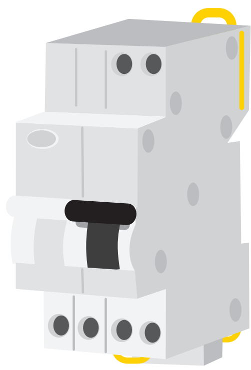


FIGURE 6 – AFDD INTEGRATED WITH AN MCB (7.1.1 b)

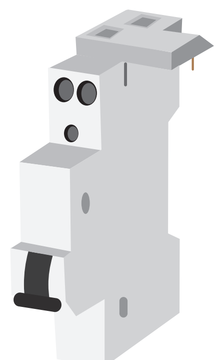


FIGURE 7 – AFDD ADD-ON MODULE (7.1.1 c)

7.1.2. Number of poles
a) Two pole
b) Three pole
c) Four pole

7.1.3. Voltage rating
a) 230 V
b) 230/400 V
c) 400 V

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

7.1.5. Characteristics
a) Rated operational voltage (U_n)
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 (I_n)
The value of current, assigned to the AFDD by the manufacturer, which the AFDD can carry in uninterrupted duty.

c) 'Rated conditional short-circuit current (I_{nc}) 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 (I_{nc}). An AFDD with an integrated overcurrent protective device (7.1.1 b) and 7.1.1 c)) provides the necessary coordination. An AFDD not having an integrated short-circuit protective device (7.1.1 a)) requires coordination in accordance with the manufacturer's instructions.

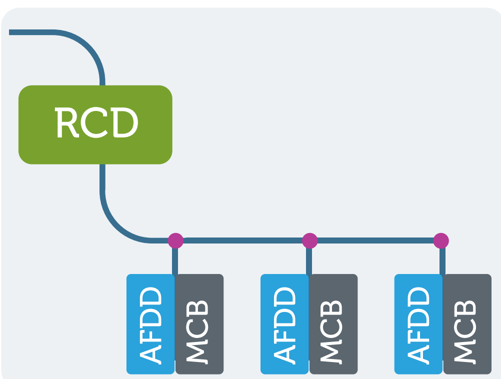
7.2.2 Selectivity coordination

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.

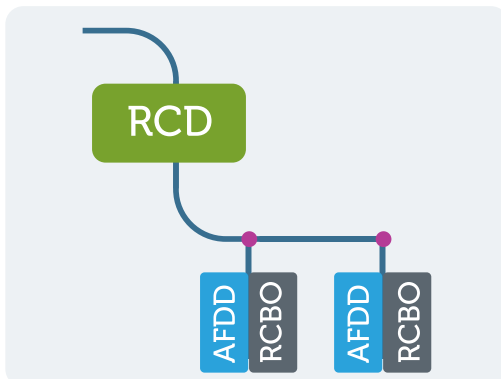
For selectivity of an RCD with the RCBO element, the following applies:

- 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: 2018 regulation 421.1.7 and 532.6 state the following:

421.1.7 Arc fault detection devices conforming to BS EN 62606 are recommended as a means of providing additional protection against fire caused by arc faults in AC final circuits.

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

NOTE: Examples of where such devices can be used include:

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

532.6 Arc fault detection devices (AFDDs)

Where specified, arc fault detection devices shall be installed:

(i) at the origin of the final circuits to be protected, and

(ii) in AC single-phase circuits not exceeding 230 V.

AFDDs shall comply with BS EN 62606. Coordination of AFDDs with overcurrent protective devices, if necessary, shall take account of the manufacturer's instructions.

Furthermore for medical locations, regulation 710.421.1.201 states:
In Medical locations of Group 1 and 2 Arc Fault Detection Devices (AFDDs) are not required to be installed. In medical locations of Group 0 Arc Fault Detection Devices (AFDDs) shall be used subject to a risk assessment.

9
AFDDs AND RING FINAL CIRCUITS

In ring final circuits, an AFDD will afford the following protection:

1. Parallel arcing faults within the ring final circuit (see Note 1)
2. Parallel and series arcing faults in spurs off a ring final circuit
3. Parallel and series arcing faults in cables and equipment connected to the ring final circuit.

NOTE 1: In the event of a break in a leg of a ring final circuit, the load current will flow through the resulting radial circuits therefore, the risk of fire hazard due to series arcing is negligible.

10
TESTING AFDDs

AFDDs are provided with:

- a manual test button. When tested manually, the AFDD should trip. For AFDDs without an automatic test function, BEAMA recommends pressing the test button 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.

For AFDDs with both a test button and automatic test function, manufacturer's instructions shall be followed with respect to test button operation.

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

BEAMA recommends disconnecting AFDDs during fixed installation insulation resistance testing at 500 V DC. If this is not practical, the DC voltage can be reduced to 250 V but specific manufacturer's guidance shall be followed.

11 FREQUENTLY ASKED QUESTIONS

Q.1 Will an AFDD trip on any kind of arcing?

No, the AFDD is designed to differentiate between what is known as dangerous arcing and arcing associated with normal operation of equipment.

Dangerous arcing is when a continuous (long duration) arc is established creating sufficient energy to cause ignition; e.g. ignition of cable insulation.

A long duration arc is one that exceeds the maximum break times (known as trip time) stated in BS EN 62606 (see Q2).

Arcing associated with normal operation e.g. switching, motor brushes, is short duration arcing – sometimes referred to as 'sparking'.

Q.2 What is the trip time of an AFDD?

The trip time of an AFDD is dependent on the arcing current. For increasing levels of arc current the trip time decreases. BS EN 62606 Table 1 lists the following maximum break (trip) times :

Test arc current (r.m.s. values)	2,5 A	5 A	10 A	16 A	32 A	63 A
Maximum break time	1 s	0,5 s	0,25 s	0,15 s	0,12 s	0,12 s

Q.3 When required for additional fire protection, RCDs shall be a rated residual operating current not exceeding 300 mA. Why is the minimum AFDD tripping current of 2.5 A so much greater than 300 mA?

300 mA (0.3 A) equates to: 230 V x 0.3 A = 69 W which is related to leakage current and not arc current. RCDs do not detect the specific waveform / signature associated with a stable electric arc. The AFDD tripping time at 2.5 A relates to approximately 100 W and can be explained as follows: The break (tripping) time in BS EN 62606 for AFDDs, is derived from the energy to ignite a cable by degrading the insulation with contact arcing and glowing. The minimum energy value of 100 J with an arc voltage of 40 V was established for the tripping characteristic for series arcing. The total break time tB is therefore derived as follows:

$$t_B = \frac{100\ J}{40\ V \quad I_{arc}} = \frac{2.5\ A\ s}{I_{arc}} \quad \text{for } I_{arc} \leq 20\ A \text{ and } t_B = 0.12s \quad \text{for } I_{arc} > 20\ A$$

100 W for 1 s equates to 100 J, so the AFDD can promptly interrupt the current and limit the duration of combustion of the cable, thus significantly reducing the risk of the fire spreading. AFDDs detect the specific waveform / signature associated with a stable electric arc.

Q.4 Will an AFDD trip if I create an arc manually?

It is very difficult to manually create an arc of sufficient current magnitude and duration to trip an AFDD. See section 6 above.

Intermittent touching of conductors together will create numerous short duration arcs (sparks), these arcs (sparks) do not create sufficient arcing current and time duration to trip an AFDD.

Q.5 Under what conditions would could a high resistance connection develop with arcing and an AFDD detecting the arc?

At an electrical connection which clamps on the conductor insulation or which is incorrectly torqued, excessive ohmic heating may occur without sustained arcing and therefore an AFDD would not operate. However, if the connection subsequently deteriorates as a result of the heating, sustained arcing can occur that will operate the AFDD.

A high resistance connection can undergo progressive deterioration e.g. high resistance creates localized heating, heating increases oxidation and creep, the connection becomes less tight, which can result in carbonization and sustained arc tracking which will operate the AFDD.

Q.6 Do AFDDs work on low load-current circuits?

For series arc faults below 2.5 A an AFDD according to BS EN 62606 is not required to trip. However, this does not negate the need for an AFDD as the risk of a parallel arc fault greater than 2.5 A is very probable, irrespective of the low current load.

Q.7 Why is a 2.5 A or higher arc fault considered dangerous when it is known that currents below 2.5 A can cause ignition?

2.5 A is the arc current and not the circuit current. An arc current below 2.5 A does not dissipate enough power to cause ignition. In a high resistance electrical connection, the circuit current below 2.5 A could cause ignition but this is not an arcing current.

Q.8 Why was 2.5 A selected as the lowest test arc current?

Based on the probability of cable insulation ignition, values of arc current less than 2.5 A presented a lower risk.

Q.9 Is 'sleeping accommodation' defined in BS 7671?

BS 7671 does not define sleeping accommodation however, publication DLCG Fire Safety-risk assessment/sleeping accommodation identifies many types of sleeping accommodation.

This publication is not applicable to domestic premises however this does not mean that domestic sleeping accommodation is not covered by BS7671 regulation 421.1.7.

Q.10 Are AFDDs intended to protect more than one final circuit?

No. An AFDD should be placed at the origin of a single final circuit. This arrangement is prescribed in the AFDD product standard to minimise unwanted tripping.

Installation designs should meet the requirements of BS 7671. The fundamental principle in Regulation 314.1 is that every installation shall be divided into circuits, as necessary, to avoid danger and minimize inconvenience in the event of a fault and to reduce the possibility of unwanted tripping.

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