The P4 Combined Arc Fault Detection Device & RCBO (AFDD RCBO)

TECHNICAL GUIDE

SAFETY IS NOT A GAME

Contents

1

Introduction.

Electrical fires continue to be a significant issue within UK Installations. The Department for Communities and Local Government; Fire statistics 2017/18, identifies over 17,000 domestic fires within the UK, with approximately 12% starting within the electrical distribution system and up to 23% caused by faulty appliances and leads.

Since the 1980s, the use of MCBs to provide overcurrent protection and latterly RCDs to provide residual current protection have reduced the risk and consequences of these types of electrical fires.

In 2015, the Wiring Regulations BS7671 mandated that consumer units for domestic installations be manufactured from non-combustible material to minimise the spread of fire that may occur within a consumer unit, and more recently in 2018, introduced a requirement for installing Surge Protection Devices (SPD's), thus adding a further mode of protection against the effects of transient overvoltage faults.

The introduction of Arc Fault Detection Devices (AFDDs) now offers an even more advanced level of protection in an installation, capable of identifying low level hazardous arcing faults that MCBs, RCDs and SPDs are not designed to detect or protect against.

AFDDs mitigate against the risk of fire caused by faults within the whole electrical Installation, both within the fixed wiring and the cabling of equipment connected to it.

The Lewden P4 series Combined AFDD & RCBO provides the highest degree of protection, safeguarding final circuits against the effects of current and voltage overload, short circuit, residual current and arcing faults, all within a single compact device.

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What is an arcing fault?

An arcing fault is defined as a "dangerous unintentional arc" within an electrical circuit which has the intensity and duration to cause localised heating at the point of the arc.

This high intensity heating can result in localised burning that over time can generate temperatures exceeding 6000°C, sufficient to burn surrounding insulation and eventually allowing a fire to develop.

Depending upon the nature of the fault, an arcing fault may not develop immediately, only becoming established over a long period of time as carbonisation of the surrounding insulation material creates the conditions for the arc to develop.

3

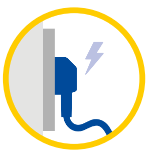
Potential causes of arcing faults.

Arcing faults can occur due to several reasons, ranging from poor installation or accidental damage to cabling and equipment, to deterioration of the cable over time due to external factors. These faults can occur within the fixed cabling installation, or on portable equipment connected to the fixed wiring installation.

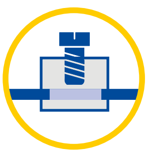
Electrical arcing faults may be caused by (but not limited to):

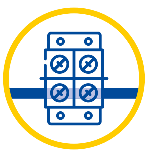
- Kinks or breaks in flexible appliance leads
- Conductor/insulation damage caused by drilling or construction work
- Incorrect wiring stripping
- Defective plugs and sockets
- Rodents chewing cables
- Damage to cable insulation (exposed or frayed wires)
- Dirty or worn electrical contacts
- Impurities such as corrosion or dust
- Appliance failure
- Poorly maintained electrical systems
- Trapped or Crushed Cables*
- Insulation deterioration due to:
  - o Incorrect bending radius of cables
  - o UV deterioration
  - o Thermal overload
- Loose terminations*

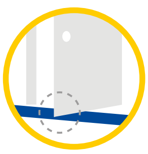
* **Note**: AFDD's will detect arcing but not high resistance connections, or trapped insulation.

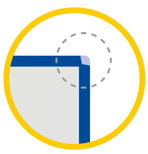

Defective wall plugs


Cable wear due to frequent use


Loose screwed connections


Incorrect wire stripping


Kink/break in the cable


Incorrect bending radii


Line damage resulting from drilling or construction work


Rodent bites

4

How an AFDD works in detecting dangerous arcing faults.

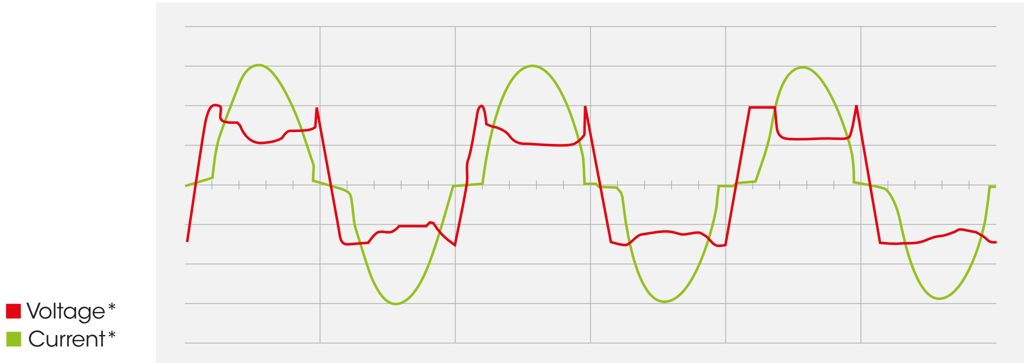
An AFDD uses microprocessor-based technology to continuously monitor the electrical circuit, identifying unintentional arcs caused by broken or damaged cables or poor connections. They can differentiate between "dangerous arcing" and "normal arcing" caused by switching events or operation of motor loads.

To achieve this, the AFDD analyses the duration and irregularity of the arc waveform itself. In this way, the AFDD can distinguish between dangerous arc faults and arcing caused by normal operation of equipment such as vacuum cleaners, drills, lighting dimmers etc.

Dangerous arcing consists of a long duration arc which becomes established and creates sufficient energy to cause localised ignition, whilst arcing associated with the normal operation of equipment is of much shorter duration and would not activate the AFDD.

Typical arc voltage and current waveforms

The simplified diagram below shows how arc faults can distort the voltage and current waveforms as the arc develops within the installation.



*High frequency arc pattern removed for clarity.

Arcing in the circuit distorts the normal AC sinusoidal wave shape. Shouldering of the current waveform is caused by the striking and extinguishing of individual arcs occurring as the waveform passes through the zero-crossing point. The voltage arc across the spark gap is distorted due to the change in impedance created by the arcing fault.

An AFDD is designed to identify these wave distortions and high frequency noise by waveform type, magnitude, and duration, as an arc fault. Upon detection, the P4 AFDD automatically disconnects both live conductors of the faulty circuit, providing total isolation.

BS EN62606 encompasses a wide range of tests designed to ensure that the AFDD does not trip when subjected to 'normal' arcs created by equipment such as vacuum cleaners, drills, lighting dimmers etc, (Immunity Testing). Furthermore, the standard also ensures that the AFDD can detect the presence of dangerous arc faults whilst any normal arcing created by this equipment is also present (Masking Testing).

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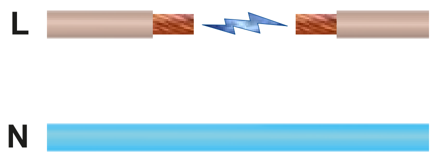
Series and parallel arcing faults.

Arcing Faults can be classified as *'Series'* or *'Parallel'*.
In general, series arc faults are localised, and fault current is limited by the connected load, thus remaining within the current rating of upstream overload protective devices.

Due to the arcing current being in series with the load series, arc fault currents are significantly lower than those which can be generated by parallel arc faults.

Parallel arc faults will significantly increase the circuit current, but due to the inherent high impedance, may not reach the short circuit current value which would cause operation of an upstream overcurrent protection device.



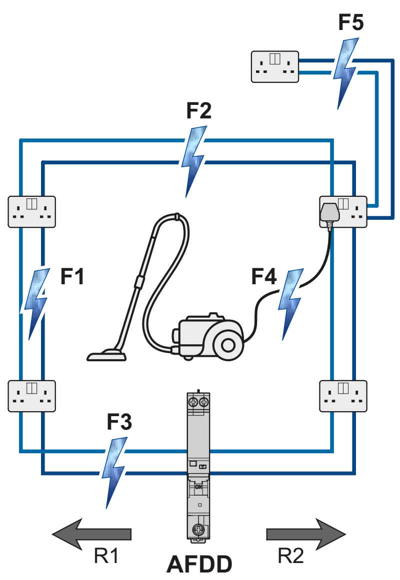
Series Arc Faults

A series arc occurs within a single conductor in line with the load. Series arc faults typically originate from damaged cables or loose connections and will have an rms current value and I2t too low to operate an MCB.

This type of fault cannot be detected by RCDs as there is no leakage current that flows through the ground conductor PE.

AFDDs will detect series arc faults in radial circuits and spurs derived from ring final circuits, as well as in cables of equipment connected to ring final circuits or radial circuits.

Note that AFDDs are not designed to trip due to series arc fault currents where the load current in the faulty circuit is below 2.5A (As specified within EN62606).



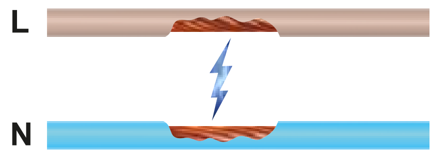
Series Arc Faults in Ring Final Circuits

In the event of a series arcing fault at F1, within a ring final circuit, the load current will flow through the resulting "radial" circuits (R1 & R2). This will significantly reduce the risk of a series arc developing at the break fault point (F1), and therefore reduce the risk of fire hazard.

However, the AFDD will continue to provide protection for parallel arc faults (F2 & F3) within the resultant "Radial" circuits, and protection against both series and parallel arc faults within cables of equipment connected to the final circuit (F4), or within spurs taken off the Ring final circuit (F5).

Note: An MCB or RCD/RCBO would not detect a series arc fault at F1 as described above.

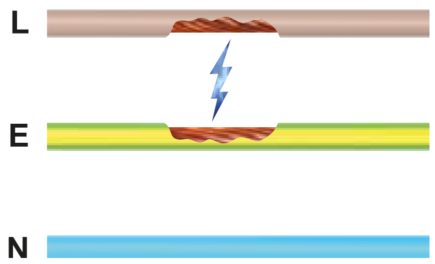
Parallel Arc Faults



Line to Neutral Parallel Arc Faults (L_N), can occur due to damaged insulation between phase and neutral conductors.

This manifests itself as a high impedance, and therefore generally produces arc fault currents with an rms value and I2t too low to operate an MCB.

This type of arc fault is not detected by RCDs as there is no leakage current that flows through the ground conductor PE.
Protection is provided by AFDDs.



Line to Earth Parallel Arc Faults (L-E), occur due to damaged insulation between phase and earth conductors.

Often appearing as high impedance faults, the resulting fault currents and I2t can be too low to operate an MCB, however, dependent upon the level of fault current (> 0.5 In) L-E parallel arc faults can be detected by RCDs.

AFDDs will detect Parallel Arcing Faults within final ring circuits and radial circuits as well as in cables of equipment connected to Ring or radial circuits.

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Effective areas of protective devices depending upon fault position & fault type.

The Table below identifies the key types of faults that can occur within electrical installations, and the corresponding devices that provide adequate protection.

Fault Between	Short Circuit	Overload	Residual Current	Serial Arc	Parallel Arc
L-N	MCB / RCBO	MCB / RCBO	-	AFDD	AFDD
L-PE	MCB / RCBO	MCB / RCBO	RCD / RCBO	-	RCD / RCBO / AFDD

Due to some arcing faults generating fault currents outside of the detection parameters of MCBs and RCDs, these devices cannot alone provide full protection on the installation wiring or the equipment cabling.

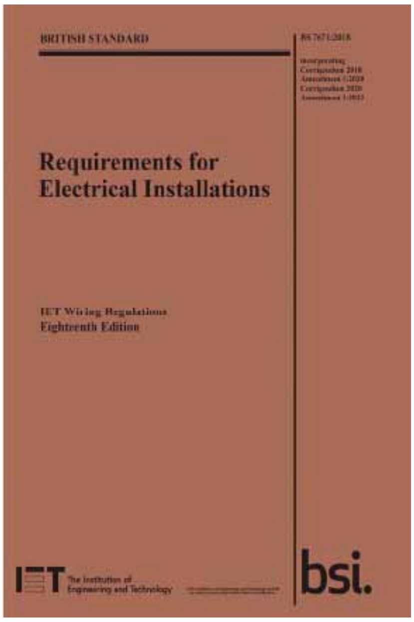
AFDDs provide the additional protection required to detect arcing faults, and as can be seen from the table, combining AFDD & RCBO devices offers the ultimate protection for distribution circuits against the effects of overcurrent, residual current, and series & parallel arcing faults.

7

BS7671 Wiring Regulations Requirements.

The Wiring Regulations BS7671 provides for several levels of protection against fire within electrical installations, ranging from the implementation of basic protection, by defining wiring practices, insulation of live parts, and the inclusion of barriers and enclosures, to the use of fault protection devices such as MCB's and RCDs, and more recently the requirement to install Surge Protection within designated areas.

In addition, there are 2 main areas within BS7671 which relate specifically to the installation of AFDD's:



Section 421
protection against fire caused by electrical equipment

Regulation 421.1.7

Arc fault detection devices conforming to EN62606 shall be provided for single phase AC final circuits supplying socket outlets with rated current not exceeding 32A in:

- Higher risk residential buildings (over six storeys or >18M height, whichever is reached first)
- Houses of multiple occupancy
- Purpose built student accommodation
- Care homes

For all other premises, the use of AFDDs is recommended for single phase AC final circuits supplying socket outlets not exceeding 32A.

Section 532
devices for protection agaibnst the risk of fire

532.6 Arc fault detection devices

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 230V

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

Whilst clause 532.6 is unchanged, in Amendment 2, Regulation 421.1.7 has been redrafted and it is now a requirement in certain premises, to protect AC single phase final circuits with AFDD's, in final circuits supplying socket-outlets with a rated current not exceeding 32A.

For all other premises, the new regulation "recommends" fitting of AFDD's on all final circuits supplying socket-outlets with a rated current ≤32A.

(**Note**: Guidance has been added to BS7671, based upon "rules for the structure and defining of UK Standards" published by BSI Standards.

Where the term '**recommendation**' in its verbal form is "**should**".

Further information scan the QR code to view the complete Lewden Amendment 2 Guide.

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The Lewden P4 series combined AFDD & RCBO.

The Lewden P4 series combined AFDD & RCBO offers the ultimate protection for 230V distribution circuits against the effects of:

1. Overcurrent faults (Overload and Short circuit)
2. Residual current faults (30mA type A)
3. Series & Parallel arcing faults
4. Prolonged overvoltage faults

They are designed for integration within the Lewden range of distribution boards and are fully interchangeable with the Lewden range of 6kA single module MCBs and RCBOs.

Available in current ratings of 6-40A, incorporated within a single module width.

The device combines a microprocessor based AFDD with a 1P+ Switched Neutral RCBO, incorporating a 30mA class A RCD and a 6kA MCB, and is suitable for use on TN-S, TN-C-S & TT network systems.

The switched Neutral pole makes the device suitable as a means of double pole isolation, and is particularly appropriate for installations within TT Earthing Systems where it is necessary to disconnect all live conductors to achieve safe isolation of individual circuits (BS7671:2018 Regulation 462).

Lewden AFDD RCBOs are suitable for use 230V 50Hz supplies. They are not designed for use on DC networks.

Applicable Standards

EN62606
General requirements for arc fault detection devices

EN61009-1
Residual current operated circuit breakers with integral overcurrent protection for household and similar uses.

UK CA | CE

The Electrical Equipment (Safety) Regulations 2016
The Low Voltage Directive 2014/35/EU

Intertek

To ensure commitment to safety and quality, the Lewden P4 Series Combined AFDD & RCBO has been independently laboratory tested and certified by Intertek, and bears the European safety 'S Mark'.

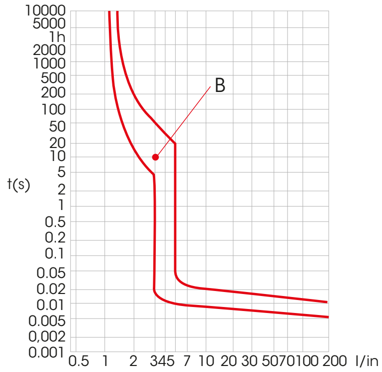
The S mark is a voluntary certification scheme demonstrating that the product continually meets all relevant technical safety requirements, verified by regular inspections of the manufacturing facility by Intertek.

9

Performance characteristics & fault identification.

Following an electrical fault in the load circuit the P4 device will trip. Upon re-closing, the LED will flash in sequence to signify the reason for the last break of circuit.

LED Status	Description
Constantly lit	Power On - Device active
1 flash per second for 10 seconds *	Series or Parallel Arcing fault
2 flash per second for 10 seconds *	Overvoltage fault >275V
5 flashes per second ongoing *	AFDD Self Test fault



Tripping caused due to an Overcurrent fault

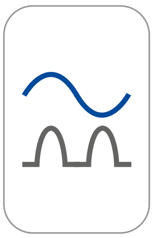
The P4 features the bi-metallic and magnetic tripping elements of a B curve MCB, designed to detect thermal overload and short circuit faults up to 6kA, with an energy limiting class 3.

B Curve MCB's respond to fault currents between 3 to 5 times the rated current of the device. This makes them ideal for use in residential applications where appliances have low level inrush currents.

The Graph below details the Time/current tripping characteristics for a B curve MCB.

Tripping caused due to a Residual current fault

The P4 incorporates a 30mA Class A RCD, designed to detect both AC and pulsating DC fault currents up to 6mA as identified within BS7671 531.3.3(i) & (ii) and detailed in the table below.



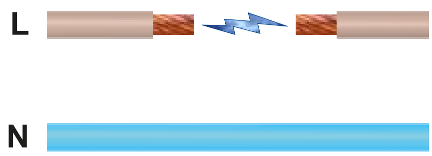
Class	Residual Current Protection level
A	Provides protection against AC earth fault currents and pulsating DC currents, whether suddenly applied or slowly increasing. Tripping is achieved for residual pulsating DC currents superimposed on a smooth DC current up to 6mA.
	Particularly suited to single phase loads featuring electronic components. e.g. Lighting controls and LED drivers, induction hobs, power supplies for class II equipment, multimedia equipment, inverters etc. Type A devices are also suitable for type AC RCD applications such as immersion heaters, tungsten and halogen lighting, ovens, showers etc.

Following an overcurrent or residual current fault, it will not be possible to reclose the device if the fault remains present in the load circuit. The fault needs to be identified and repaired before the circuit can be re-energised. The standard fault-finding procedure for overcurrent and residual current faults should be adopted.

If the fault is no longer present in the circuit, the device can be re-closed, and the LED will be constantly illuminated.

Tripping caused due to series/parallel arc fault

The P4 is designed to operate under series and parallel arc fault conditions in accordance with the requirements of IEC BS EN62606. Tripping time is dependent upon the waveform magnitude and duration of the arcing current.

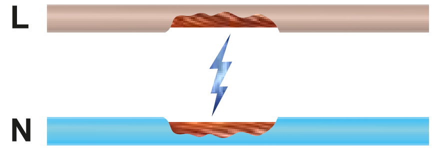


If arcing occurs in series with the load, arc fault currents are significantly lower than those which can be generated by parallel arc faults.

Where low current arcing exists up to 63A, the standard defines the maximum tripping time for AFDDs, with the trip time reducing as the current increases.

The table below details the tripping times for the Lewden P4 range up to the maximum rated device (40A).

Series Arc Fault	
Load Current (A)	Maximum Trip Time (s)
2.5	1
5	0.5
10	0.25
16	0.15
32	0.12
40	0.12



For higher arc fault current values, (normally caused by parallel arcing), BS EN 62606 does not specify maximum tripping times based upon the magnitude of the arcing current but indicates the maximum number of half-wave cycles affected by the arc in 0.5 seconds.

This is due to the nature of the arcing pattern, where parallel arc faults can occur more sporadically and may not affect all cycles of the waveform.

Therefore, as can be seen from the Parallel Arc Fault table, the AFDD detects the number of half-waveforms affected by the arc over a 0.5 second period.

Parallel Arc Fault	
Test Current (A)	Max permitted No of arcing half waves within 0.5s (N)
75	12
100	10
150	8
200	8
300	8
500	8

If tripping was caused due to either a series or parallel arc fault within the load circuit, the LED will indicate the condition by flashing once per second for the first 10 seconds after the device is re-closed.

If the fault is still present upon re-closing the device, it will subsequently trip again. The time taken to trip will be dependent upon the type of fault, magnitude, and duration.

If the initial cause of the fault has since been removed, the LED will revert to constant illumination immediately after the flashing sequence has ended.

Tripping caused due to overvoltage detection

Installations can be subjected to overvoltage faults lasting from several seconds to several minutes. This can lead to premature failure of fragile electronic components and break down of insulation properties, potentially creating a fire risk.

On installations where single phase circuits are derived from a three-phase incoming supply, loss of the supply neutral conductor can increase line voltage on single phase circuits from 230V up to 400V.

The P4 series monitors line voltage and will disconnect the load circuit when line voltage exceeds 275V (230V + 20%).

The Table below shows how as the magnitude of the overvoltage increases, the maximum and minimum operation times decreases.

Overvoltage Fault Condition				
Line Voltage (AC)	275V	300V	350V	400V
Maximum tripping time (s)	10	3	0.75	0.2
Minimum non actuation time (s)	3	1	0.25	0.1

If tripping was caused due to an overvoltage condition, the LED will indicate the fault by flashing twice per second for the first 10 seconds after the device is re-closed.

If the fault is still present on re-closing, the device will trip again. The time taken to trip will be dependent upon the magnitude of the overvoltage.

If the fault is due to an overvoltage and the fault is still present, identify if this could be caused by any equipment connected to the installation. Where the overvoltage is present upon the incoming supply, contact the DNO immediately.

Tripping due to self-test failure

The AFDD element of the device incorporates a self-check function, which is performed on initial closing of the device and then every hour subsequently. The device will trip within 5 seconds following a self-check failure.

Upon re-closing the device, the condition is indicated by the LED flashing 5 times per second for as long as the device remains energised.

In the event of a self-check failure, contact Lewden for further assistance.

10 On-site Testing.

After completion of the installation, it is essential that it is tested by a qualified electrician in accordance with the latest edition of the IET Wiring Regulations for Electrical /installations (BS7671).

The P4 is an electronic voltage dependent device designed to operate from a 230/240V 50/60Hz supply, with tolerance +10% / -15%.

The device may not function within specified parameters where the supply voltage falls below the minimum tolerance threshold.

Insulation Resistance Test

Insulation resistance testing between live conductors (L-N) must be performed on the load side of the device with both conductors disconnected.

RCD Trip Time Test

RCD trip time testing must be conducted using a calibrated RCD tester, with healthy battery condition. BS7671 stipulates a minimum testing requirement to verify tripping times when subjected to sinusoidal AC residual current faults. Testing is performed with the tester set to the 'AC' test function, with a fault current of 1x In or higher.

Further testing may be conducted to verify tripping times on higher AC residual current test current or with the device subjected to pulsating DC residual current faults, however this is not a specific requirement of BS7671.

Pulsating DC testing must be conducted with the tester set to the 'A' test function.

(Test instrument manufacturer's instructions should be referenced to establish the correct procedure for testing Type A devices).

Residual Current Test Parameter			Result
AC setting	0.5xIΔn		RCBO will not trip
	1.0xIΔn	0 & 180°	RCBO must trip within 300ms
	5.0xIΔn	0 & 180°	RCBO must trip within 40ms
A setting	1.4xIΔn		RCBO must trip within 300ms
	350mA		RCBO must trip within 40ms

Note: BS EN 61009-1 does not include a 0.5x In test for a Type A RCBO.

The P4 features a Test button (T) which tests the mechanical and electrical functionality of the residual current function only.

Depressing the button momentarily will cause the device to trip immediately. This test must be repeated throughout the installation life of the device, at intervals defined within BS7671.

11

Frequently asked questions.

Q1. Are AFDD's intended to protect more than one final circuit

NO. An AFDD should be placed at the origin of each final circuit to be protected, as recommended by the Wiring Regulations BS7671.

Q2 Will an AFDD trip on any type of arcing?

NO. AFDD's are designed to differentiate between dangerous arcing caused by faults within the final circuit and arcing caused by the normal operation of equipment. Arcing associated with the normal operation of equipment is often referred to as "sparking".

AFDD's are designed to identify low current serial arcing as well as high current parallel arcing faults.

Q3. What is the trip time of an AFDD

Arcing faults are rarely instant and depend upon a number of factors, and can take a time to develop. The time taken to trip an AFDD will depend upon the type of arcing fault and the level of the arcing current. Dangerous arcing requires a long duration arc to establish cresting sufficient energy to cause an ignition.

Q4. How can I be sure that the AFDD will not be affected by arcing which is caused naturally by equipment within the installation?

BS EN62606 stipulates a series of tests designed to ensure not only that the AFDD does not trip when subjected to "normal" arcing created by load equipment when used under normal operating conditions (Immunity Tests), but also ensuring that the AFDD is able to detect the presence of a dangerous arcing fault whilst simultaneously subjected to normal arcing created by any load equipment in operation on the circuit (Masking Testing).

Q5. Will an AFDD trip if I manually create an arc

It is difficult to manually create an arc of sufficient magnitude, duration and waveform to trip an AFDD.

Q6. Can a high resistance connection be detected by an AFDD

In a high resistance connection, created either by a conductor clamped incorrectly onto the insulation, or by insufficient tightening torque, the

AFDD will not be able to detect the initial high resistance which may occur, however, this connection may produce localised heating, which over time can create local carbonisation and sustained arcing which can be detected by the AFDD

Q7. Can an AFDD work on ring final circuits?

Yes. In ring final circuits, the AFDD will detect parallel arc faults on both the ring circuit and in cables of equipment connected to the ring final circuit.

It will also detect Parallel and series arcing faults in cable spurs connected to a final ring circuit, and in flexible cables of equipment connected to the spur.

If a fault occurs in a ring, which would normally manifest as a series arc fault, such as a break in a leg of the ring, the load current will flow through the resulting "radial" circuit caused by breaking the ring. Therefore, with no current flowing through the damaged part of the ring, the risk of fire hazard due to series arcing at the fault is negligible.

Q8. Can an arc be established if conductors have a large gap between them?

Paschen's Law dictates that arc development is related to the voltage and distance between two contacts. To create a stable arc, requires a gas filled spark gap to develop between the two contacts, and that at 230Vac rms, the typical spark gap would be no wider than 7.5μm.

Whilst this suggests that in the instance where the gap is larger than 7.5μm, it is not possible to create an electric arc, it has been found that when an insulated conductor has been damaged, localised heat within the insulation generated at the point of damage carbonises the insulation and causes ionisation which lowers the voltage at which dielectric breakdown can occur, creating the conditions for arcing to appear across the conductors via the carbonised insulation.

Q9. Why was 2.5A selected as the lowest test arc current?

As detailed in Section 9, the trip time of an AFDD is dependent upon the magnitude of the arcing current. BS EN 62606 outlines disconnection times derived from the energy required to ignite a cable by degradation of the insulation when subjected to contact arcing.

For low current (Series) arc faults, BS EN62606 defines a maximum break time of 1 second for a minimum energy value of 100J, which is the equivalent to 100W for 1 second, with an arc voltage of 40V.

This equates to an rms arcing current of 2.5A for 1 second, and is designed to ensure that the AFDD interrupts the circuit; limiting the duration of the cable combustion and therefore significantly reducing the risk of local ignition.

Q10. Can I retrofit an AFDD into an existing consumer unit?

The P4 AFDD/RCBO is compatible and interchangeable with any Lewden 6kA devices (MCB's and RCBO's, and can be installed into the Lewden PRO consumer unit ranges as well as the Lewden TPN Distribution board if it has been converted to use 6kA devices.

Q11. Testing the P4 AFDD/RCBO?

The AFDD element of the P4 device incorporates a self-check function in accordance with BS EN62606, which is performed upon each time the device is switched on and then every hour subsequently. The device will indicate If there is an internal fault by flashing the LED as detailed in Section 10 (Fault Identification).

The RCD element of the P4 device has a Test button, which tests the functionality of the RCD in accordance with BS EN 61009-1 and BS7671.

Ongoing testing of the RCD element of the device should be undertaken as per the latest requirements of BS7671.

Q12. How do I carry out final circuit cabling Insulation Resistance testing?

Due to the design of the AFDD and its internals electronics, insulation resistance testing must be carried out with the final circuit cables disconnected on the load side of the device, as detailed in Regulation 643.3.3 of the Wiring Regulations (BS7671).

This outlines the requirements for insulation resistance testing on final circuit cabling, stating that where connected equipment is likely to influence the measurement or result of the test, or to be damaged, the test shall be applied prior to the connection of such equipment.

Notes

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LEWDEN LTD
Unit 4, Bradbury Drive,
Springwood Industrial Estate,
Braintree
Essex
CM7 2SD

Tel.: +44 (0) 1376 336 200
sales@lewden.co.uk

www.lewden.com

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