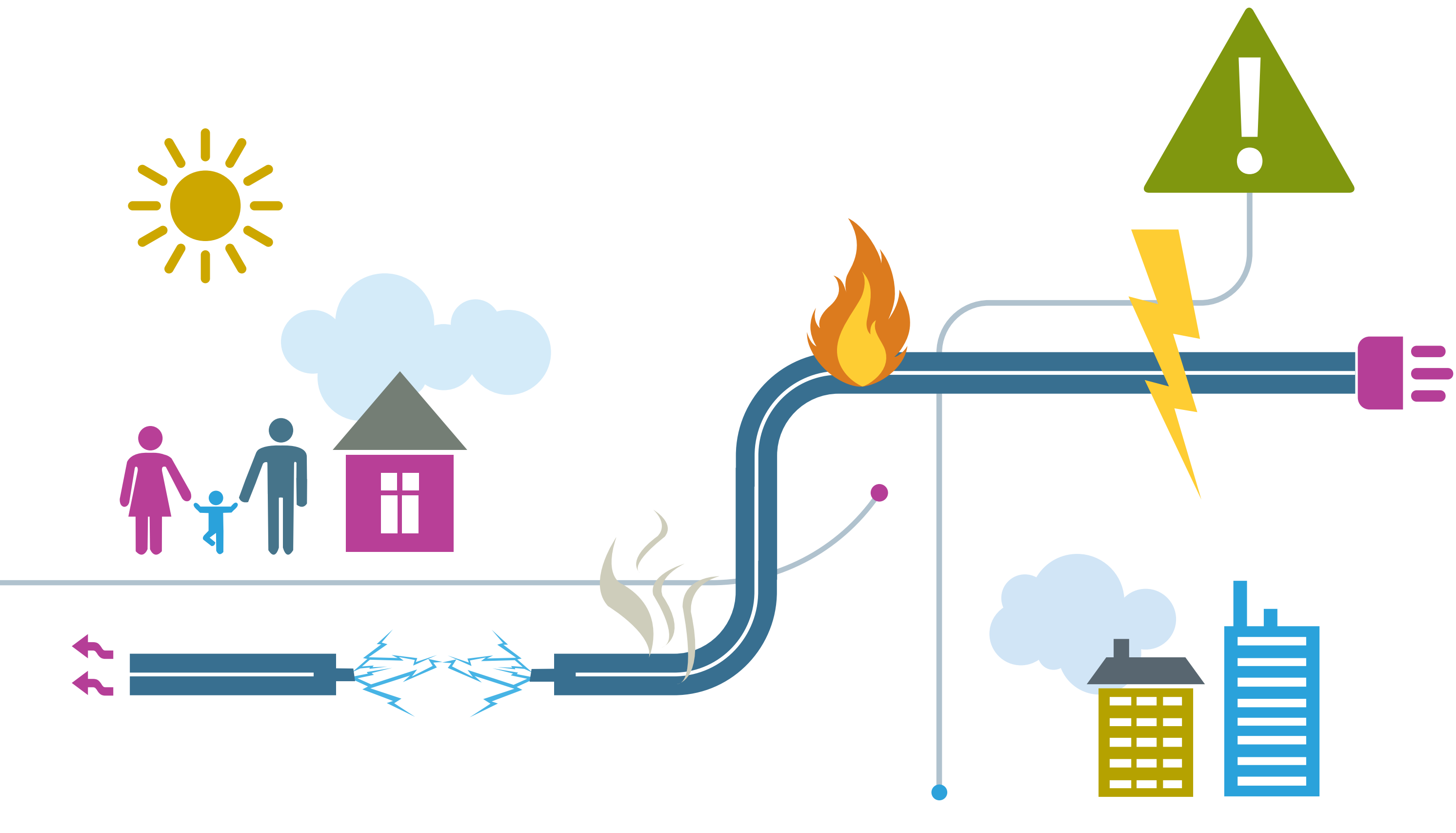
The trade association for energy infrastructure & systems

TECHNICAL BULLETIN

AFDDs PERFORMANCE WITH XLPE / LSOH CABLE



February 2025

ABOUT BEAMA

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

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

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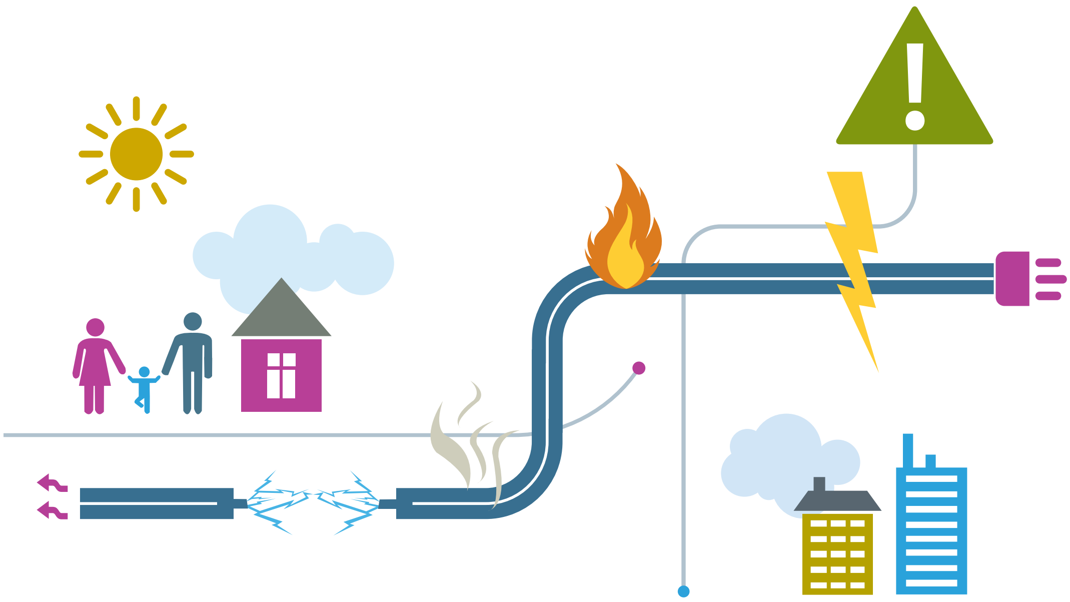

1. Introduction

Two false statements are being made in relation to arc fault detection devices (AFDDs) and cross-linked polyethylene insulated (XLPE) cable i.e.:

1. AFDDs require carbon (produced by the charring of) PVC/PVC cable to detect arc faults and do not work when used with XLPE cable.
2. XLPE cable does not char under any arc fault conditions therefore, AFDDs can be omitted.

The terms "char" and "carbon" both relate to forms of carbon produced by materials under heat, but they differ in their composition and context.

The objective of this bulletin is to provide independent test evidence that demonstrates these two statements to be incorrect.

2. Independent testing

RINA Tech UK were employed to test the performance of AFDDs and RCBOs in response to electrical arc faults using BASEC approved, PVC, and XLPE insulated / Low Smoke, Zero Halogen sheathed (LSOH) cable. LSOH and some similar abbreviations are registered trademarks, also commonly described as LSHF, LSZH, OHLS.

The test method applied, used a cable conductor break to repeatedly make and break the electrical connection to cause series electrical arcing. This test method intentionally avoided any pre-ageing or special preparation of the cable samples, other than a conductor break, so as not to duplicate the laboratory test method to the product standard and focus on the cable performance. The AFDDs used in the tests all conformed to BS EN 62606.

3. Summary of test results

Appendix 1 details the complete test reports therefore, in summary:

a. Three different models of AFDD were tested, and each of the models tripped in response to series arcing which occurred between the broken cable conductors.

b. Three different models of RCBO were also tested, and none tripped in response to series arcing. Occasional flames were observed to briefly cause ignition of the XLPE / LS0H and PVC cables.

c. With respect to the RCBOs not tripping, there was significantly more extensive charring of the XLPE / LS0H and PVC cables in comparison with the AFDD tested samples which tripped.

4. Conclusions from the tests

The test results validate that:

a. It is possible for XLPE / LS0H cable to char under arc fault conditions.

b. AFDDs will function correctly when used with XLPE / LS0H cable.

c. The cable insulation types tested, had no bearing on the performance of the AFDDs. The cable code for the BS 7211 XPLE cable used would generally be 6242B and for the PVC/PVC BS 6004 6242Y.

5. Benefits of XLPE / LSOH cable

While PVC remains a popular material for cable insulation, it may be necessary to use XLPE cross-linked, thermosetting, insulated cables.

The main reasons XLPE insulation is used includes better fire performance and is tougher, with a greater barrier to abrasion, moisture, and mechanical stress, allowing the cable to survive in harsh environments. LSOH sheath reduces toxic smoke emissions.

APPENDIX 1

Complete RINA Tech UK test reports

BEAMA

AFDD 2.5sqmm Twin and Earth Conductor Break Testing at 20A

Performance of arc fault detection and RCBO devices in response to cable conductor breaks

Report No. 2025 - 0075 Rev. 1 – January 2025

Project No. P0044491

Rev.	1
Description	Final Issue
Prepared by	Nick Aitken
Checked by	Joe Stubbs
Approved by	Ben Hickman
Date	30 January 2025

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Note on report approval

The persons identified above have signed off each stage of this report in accordance with RINA's BMS/QA procedure.

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Issue and Revision Record

Rev.	Description	Prepared by	Checked by	Approved by	Date
0	Draft Issue	Nick Aitken	Joe Stubbs	Ben Hickman	17 January 2025
1	Final Issue	Nick Aitken	Joe Stubbs	Ben Hickman	30 January 2025

EXECUTIVE SUMMARY

RINA has carried out testing to establish how Arc Fault Detection Devices (AFDDs) and Residual Current Circuit Breakers with Overcurrent Protection (RCBOs) behave in response to cable conductor breaks in 2.5mm^2 cross sectional area BS6004 and BS7211 twin and earth cable supplying resistive loads at 20A, where cable movement causes intermittent connection of the broken conductors with the possibility of electrical arcing. Each of the AFDDs and RCBOs was tested using BASEC approved PVC (cable code 6242Y) and XLPE / LS0H (cable code 6242BH) insulated cable.

The purpose of this testing was to compare the performance of the AFDDs at detecting and interrupting arc faults in the damaged cables, and to assess the severity of damage which occurs to the two insulation types when the circuit under test is being protected by an AFDD or by an RCBO.

Three models of AFDD were tested, and each of the models tripped in response to arcing which occurred between the broken cable conductors, where arcing was sustained for a sufficient period (at least 3 mains cycles). The conductor break was on the Line conductor. A new length of twin and earth cable was prepared for each of the devices under test. There was negligible charring of the external sheath of the cables.

All three models of AFDD were successful at isolating arc faults in twin and earth cable which had suffered a conductor break, at currents of 20A.

Three models of RCBO were also tested, and none of the models tripped in response to arcing. The conductor break was on the Line conductor. A new length of twin and earth cable was prepared for each of the devices under test. Arcs continued to occur at the cable conductor breaks until the conductor had been sufficiently eroded that electrical connection was not made by manipulating the cable. Occasional flames observed when arcing was sustained for sufficient time to briefly cause ignition of the XLPE / LS0H and the PVC insulation. Because arcing occurred for a longer duration and the magnitude of the arcing could be greater, there was significantly more extensive charring of the external sheath of the XLPE / LS0H and PVC cables in the vicinity of the arc faults, in comparison with the AFDD tested samples.

The cable insulation type had no bearing on the performance of the AFDDs or the RCBOs, and the cable insulation type had no bearing on the extent of damage which was caused during persistent arc faults in RCBO protected circuits.

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1 TEST RESULTS

1.1 Test setup

The test setup is shown below in Figure 1-1.

Voltage was measured between the Line and Neutral output from the device under test, using an isolated differential voltage probe. Current was measured using a clip-on current probe which was attached at the Line cable output from the device under test. The current probe frequency response was from 0Hz (i.e. DC), to 100kHz. Voltage and current waveforms were monitored and recorded using a 400MHz oscilloscope, which was configured to capture 10 seconds of data at a sample rate of 100k samples / second (i.e. the same rate as the maximum frequency response of the current probe).

The devices under test were mounted in a standard consumer unit, which was purchased from Screwfix.

The twin and earth cable which was used for the test was purchased from Screwfix. Both cable types were BASEC approved. The specific details of equipment can be found using the following website links.

Consumer unit: - https://www.screwfix.com/p/crabtree-starbreaker-15-module-13-way-part-populated-main-switch-consumer-unit/4812p

PVC insulated twin and earth cable: - https://www.screwfix.com/p/prysmian-6242y-grey-2-5mm-twin-earth-cable-50m-drum/83956

XLPE / LS0H insulated twin and earth cable: - https://www.screwfix.com/p/prysmian-6242bh-white-2-5mm-lszh-twin-earth-cable-100m-drum/74493

The loads which the twin and earth cables were supplying were resistive.

To prepare the cable for the tests the outer insulation of the twin and earth cable was cut, and wire cutters were then used to snip the Line conductor.

A new length of conductor was prepared for each test.

The test was carried out by energising the circuit, and manipulating the cable conductor break by a few millimetres, to repeatedly make and break electrical connection and cause electrical arcing.

Testing was continued until an electrical arc of sufficient duration had caused the AFDD to trip. RCBOs (which did not trip during testing) were tested until the conductor had been eroded by arc damage such than an electrical connection could no longer be created.

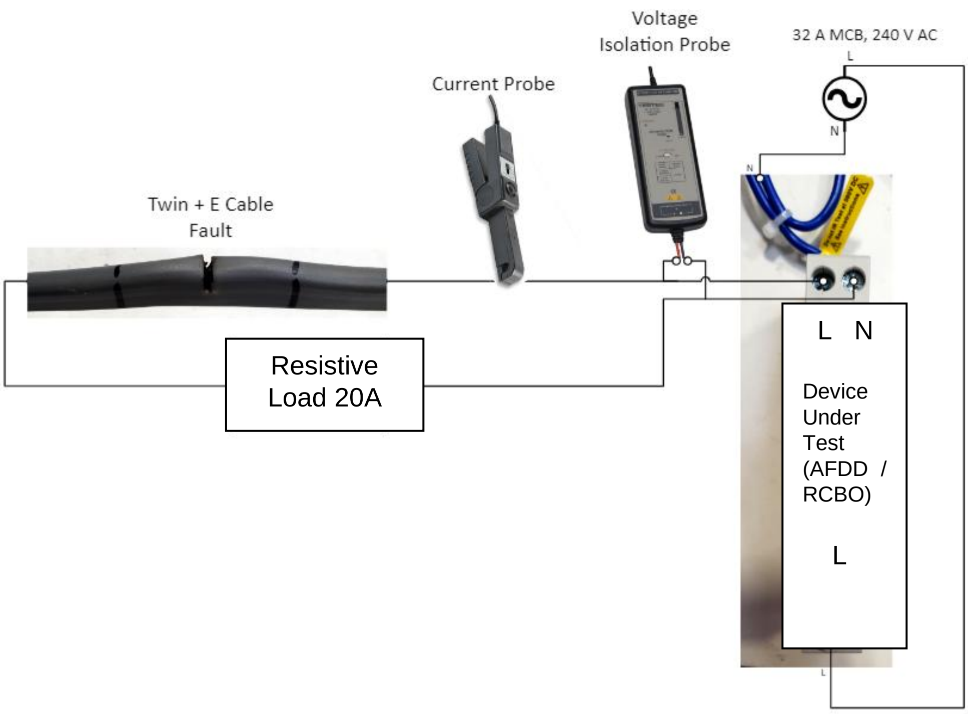

Figure 1-1: Switched socket overload test setup

1.2 Test results

A summary of the test results is shown in Table 1-1.

Table 1-1: Cable conductor break AFDD and RCBO protection performance

Sample ID	Device type	Cable insulation	Conductor Break Location	Arc current (A)	Result	Trip time in response to sustained arc
ABDX012	AFDD	PVC and XLPE	Line	20	Tripped	<0.5s
ABDX015	AFDD	PVC and XLPE	Line	20	Tripped	<0.5s
ABDX017	AFDD	PVC and XLPE	Line	20	Tripped	<0.5s
ABDX001	RCBO	PVC and XLPE	Line	20	No-trip	N/A
ABDX006	RCBO	PVC and XLPE	Line	20	No-trip	N/A
ABDX007	RCBO	PVC and XLPE	Line	20	No-trip	N/A

Table 1-2 shows a side-by-side comparison of the condition of the PVC and XLPE / LS0H insulated cables at the conclusion of each test. The left-hand side column shows cables which were protected with AFDDs and the right-hand side column shows cables which were protected with RCBOs.

Table 1-2: Condition of XLPE and PVC Insulated Cable Following Arc Testing

AFDD	RCBO
 ABDX012 PVC	 ABDX001 PVC
 ABDX012 XLPE	 ABDX001 XLPE

AFDD	RCBO
 ABDX015 PVC	 ABDX006 PVC
 ABDX015 XLPE	 ABDX006 XLPE

AFDD	RCBO
 ABDX017 PVC	 ABDX007 PVC
 ABDX017 XLPE	 ABDX007 XLPE

An example image during testing is shown below, along with an example current waveform at the point at which the AFDDs tripped, and an example current waveform during prolonged arcing when RCBOs did not trip.

Figure 1-2 shows an arc flash event during testing of PVC cable in an RCBO protected circuit, and Figure 1-3 shows the associated current waveform during that event. Based on assessment of the response of AFDDs to this current waveform, all three models of AFDD would be expected to trip.

Figure 1-2: ABDX007 RCBO Prolonged Arcing - PVC cable

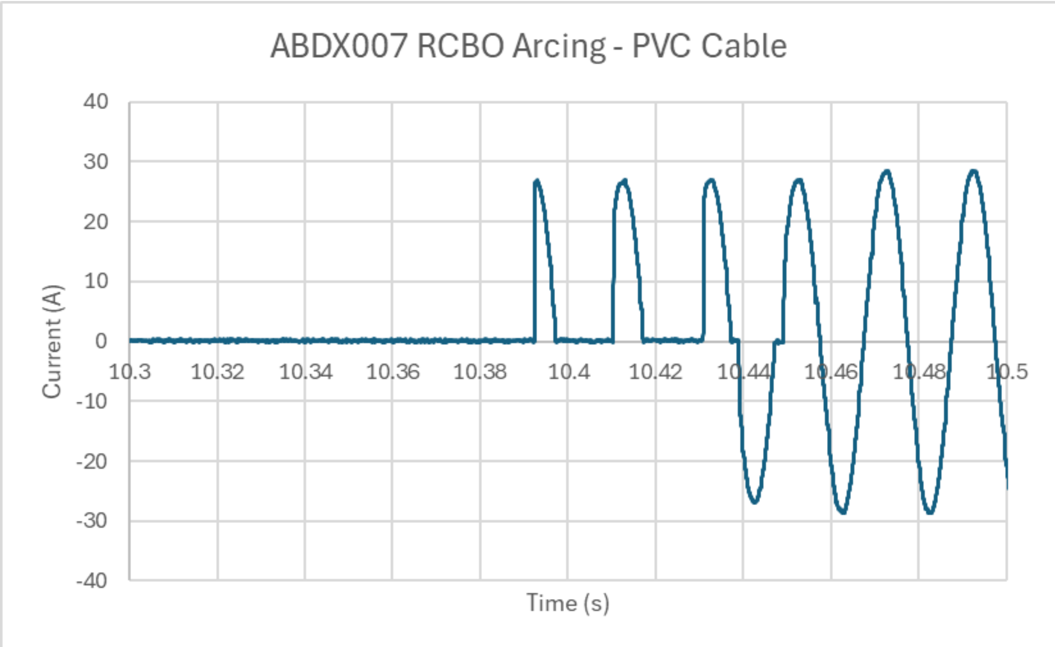

Figure 1-3: ABDX007 RCBO Current Waveform During Arc

Figure 1-4 shows an example current waveform from an AFDD trip event in response to arcing at a conductor break in XLPE / LS0H insulated cable. The arrows in Figure 1-4 indicate current waveform distortions which were detected by the AFDD leading to an arc fault induced trip.

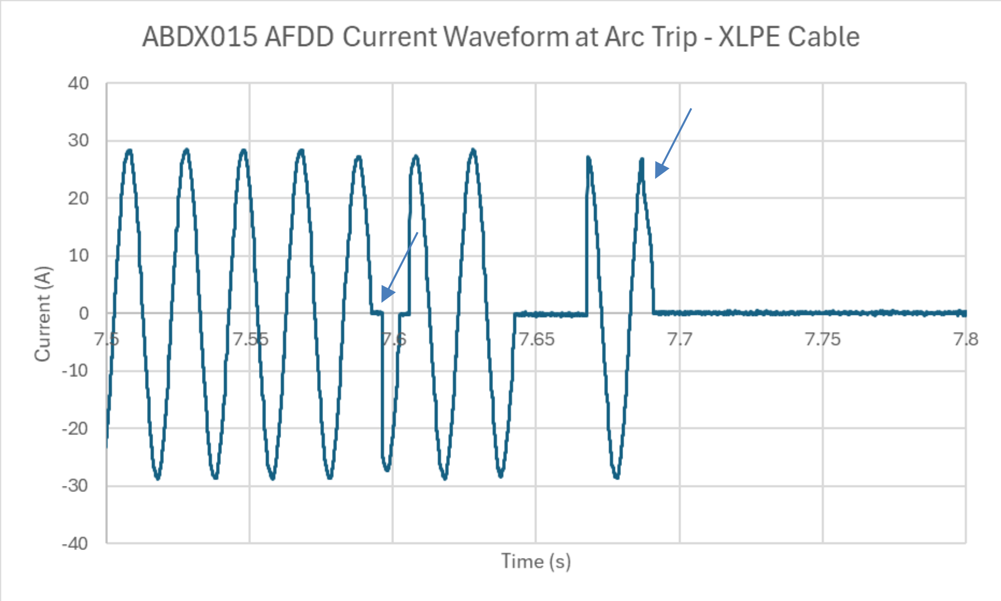

Figure 1-4: ABDX015 AFDD Current Waveform at Arc Trip

2 DISCUSSION AND CONCLUSIONS

The three models of AFDD which were tested all tripped in response to arcing at an intermittent break in the Line conductor of PVC and XLPE / LS0H insulated twin and earth cable, at currents of 20A. There was negligible evidence of charring of the external sheath of the XLPE / LS0H and PVC cables, apart from the PVC insulated cable tested with AFDD device ABDX017.

The three models of RCBO which were tested did not trip in response to series arcs at currents of 20A and arcing continued to occur when the cables were manipulated, until the conductor had been sufficiently eroded by arc damage such that electrical contact (and therefore arcing) no longer occurred during cable manipulation. There was extensive charring of the external sheath of the XLPE / LS0H and PVC cables in the vicinity of the arc faults.

The cable insulation type had no bearing on the performance of the AFDDs or the RCBOs, and the cable insulation type had no bearing on the extent of damage which was caused during persistent arc faults in RCBO protected circuits.

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BEAMA

AFDD 4sqmm Twin and Earth Conductor Break Testing at 32A

Performance of arc fault detection and RCBO devices in response to cable conductor breaks

Report No. 2025 - 0076 Rev. 1 – January 2025

Project No. P0044491

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EXECUTIVE SUMMARY

RINA has carried out testing to establish how Arc Fault Detection Devices (AFDDs) and Residual Current Circuit Breakers with Overcurrent Protection (RCBOs) behave in response to cable conductor breaks in 4mm^2 cross sectional area twin and earth cable supplying resistive loads at 32A, where cable movement causes intermittent connection of the broken conductors with the possibility of electrical arcing. Each of the AFDDs and RCBOs was tested using BASEC approved PVC (cable code 6242Y) and XLPE / LS0H (cable code 6242BH) insulated cable.

The purpose of this testing was to compare the performance of the AFDDs at detecting and interrupting arc faults in the damaged cables, and to assess the severity of damage which occurs to the two insulation types when the circuit under test is being protected by an AFDD or by an RCBO.

Three models of AFDD were tested, and each of the models tripped in response to arcing which occurred between the broken cable conductors, where arcing was sustained for a sufficient period (at least 3 mains cycles). The conductor break was on the Line conductor. A new length of twin and earth cable was prepared for each of the devices under test. There was negligible charring of the external sheath of the cables.

All three models of AFDD were successful at isolating arc faults in twin and earth cable which had suffered a conductor break, at currents of 32A.

The three models of RCBO which were tested did not trip in response to currents of 32A and arcing continued to occur when the cables were manipulated, until the conductor had been sufficiently eroded by arc damage such that electrical contact (and therefore arcing) no longer occurred during cable manipulation. Because arcing occurred for a longer duration and the magnitude of the arcing could be greater, there was significantly more extensive charring of the external sheath of the XLPE / LS0H and PVC cables in the vicinity of the arc faults, in comparison with the AFDD tested samples. The PVC and XLPE / LS0H insulated cables occasionally exhibited burning with flames for brief periods after an arc event, and arc flashes occasionally occurred which extended for several centimetres from the site of the arc.

The cable insulation type had no bearing on the performance of the AFDDs or the RCBOs, and the cable insulation type had no bearing on the extent of damage which was caused during persistent arc faults in RCBO protected circuits.

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Consumer unit: - https://www.screwfix.com/p/crabtree-starbreaker-15-module-13-way-part-populated-main-switch-consumer-unit/4812p

PVC insulated twin and earth cable: - https://www.screwfix.com/p/prysmian-6242y-grey-4mm-twin-earth-cable-25m-coil/25819

XLPE / LS0H insulated twin and earth cable: - https://www.cef.co.uk/catalogue/products/2326371-h6242b-4mm-lsf-twin-and-earth-cable-white-50m-drum

The loads which the twin and earth cables were supplying were resistive.

To prepare the cable for the tests the outer insulation of the twin and earth cable was cut, and wire cutters were then used to snip the Line conductor or the Neutral conductor.

A new length of conductor was prepared for each test.

The test was carried out by energising the circuit, and manipulating the cable conductor break by a few millimetres, to repeatedly make and break electrical connection and cause electrical arcing.

Testing was continued until an electrical arc of sufficient duration had caused the AFDD to trip. RCBOs (which did not trip during testing) were tested until the conductor had been eroded by arc damage such than an electrical connection could no longer be created.

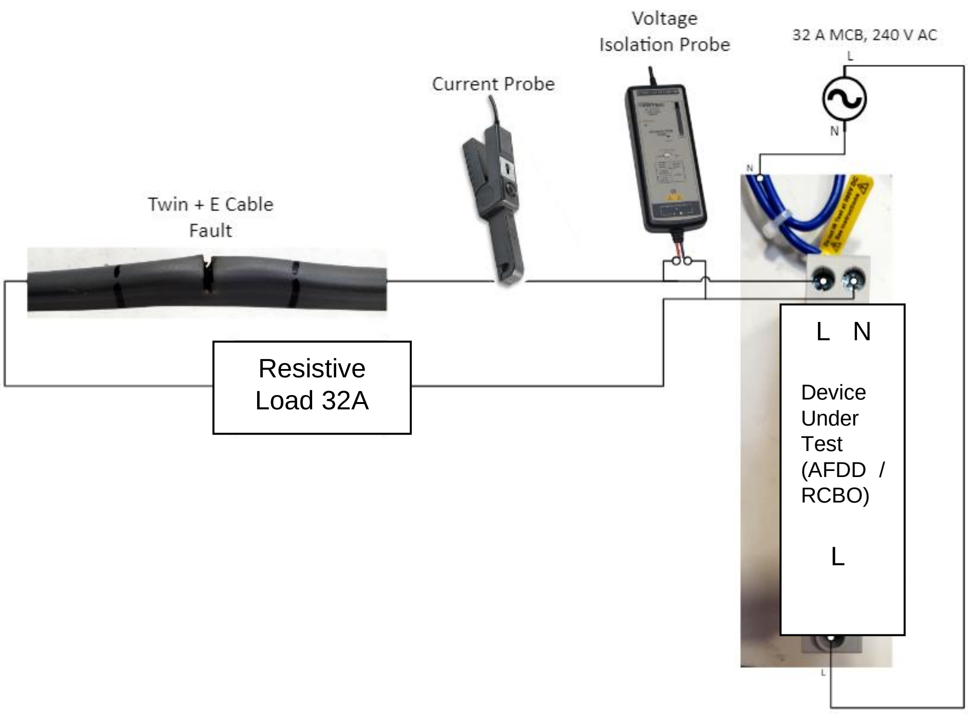

Figure 1-1: Switched socket overload test setup

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Sample ID	Device type	Cable insulation	Conductor Break Location	Arc current (A)	Result	Trip time in response to sustained arc
ABDX012	AFDD	PVC and XLPE	Line	32	Tripped	<0.5s
ABDX015	AFDD	PVC and XLPE	Line	32	Tripped	<0.5s
ABDX017	AFDD	PVC and XLPE	Line	32	Tripped	<0.5s
ABDX001	RCBO	PVC and XLPE	Line	32	No-trip	N/A
ABDX006	RCBO	PVC and XLPE	Line	32	No-trip	N/A
ABDX007	RCBO	PVC and XLPE	Line	32	No-trip	N/A

Table 1-2 shows a side-by-side comparison of the condition of the PVC and XLPE / LS0H insulated cables at the conclusion of each test. The left-hand side column shows cables which were protected with AFDDs, and the right-hand side column shows cables which were protected with RCBOs.

Table 1-2: Condition of XLPE and PVC Insulated Cable Following Arc Testing

Cable Protected by AFDD	Cable Protected by RCBO
 ABDX012 PVC	 ABDX001 PVC
 ABDX012 XLPE	 ABDX001 XLPE

Cable Protected by AFDD	Cable Protected by RCBO
 ABDX015 PVC	 ABDX006 PVC
 ABDX015 XLPE	 ABDX006 XLPE

Cable Protected by AFDD	Cable Protected by RCBO
 ABDX017 PVC	 ABDX007 PVC
 ABDX017 XLPE	 ABDX007 XLPE

A selection of images from during testing are shown below, along with an example current waveform at the point at which the AFDDs tripped, and an example current waveform during prolonged arcing when RCBOs did not trip.

Figure 1-2 shows burning of PVC cable insulation following an arc event. The burning continued for 2~3 seconds before self-extinguishing.

Figure 1-2: ABDX007 (RCBO) PVC Insulation Cable Insulation Flames Following Prolonged Arc

Figure 1-3 shows an arc flash event during testing of XLPE / LS0H insulated cable, with the arc flash extending for several centimetres from the cable conductor fault location.

Figure 1-3: ABDX007 (RCBO) XLPE Insulation Cable During Arc Event

Figure 1-4 shows the current waveform associated with the arc flash shown in Figure 1-3. Based on testing of three models of AFDD, all AFDDs would be expected to trip in response to the current waveform shown in Figure 1-4.

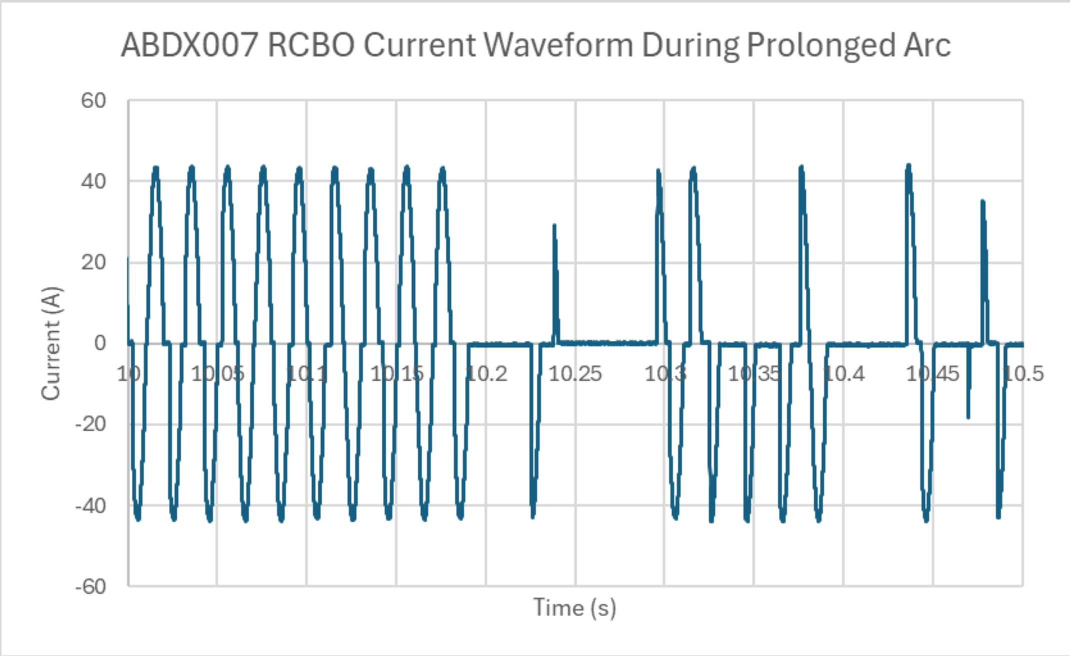

Figure 1-4: ABDX007 RCBO Current Waveform During Prolonged Arc of XLPE cable

Figure 1-5 shows the current waveform at the point where AFDD ABDX012 tripped. The arrow in Figure 1-5 indicates a current distortion at the 0V crossing point where the arc briefly extinguishes. The AFDDs detect this current distortion and trip in response to between 3 and 5 cycles of this current waveform characteristic.

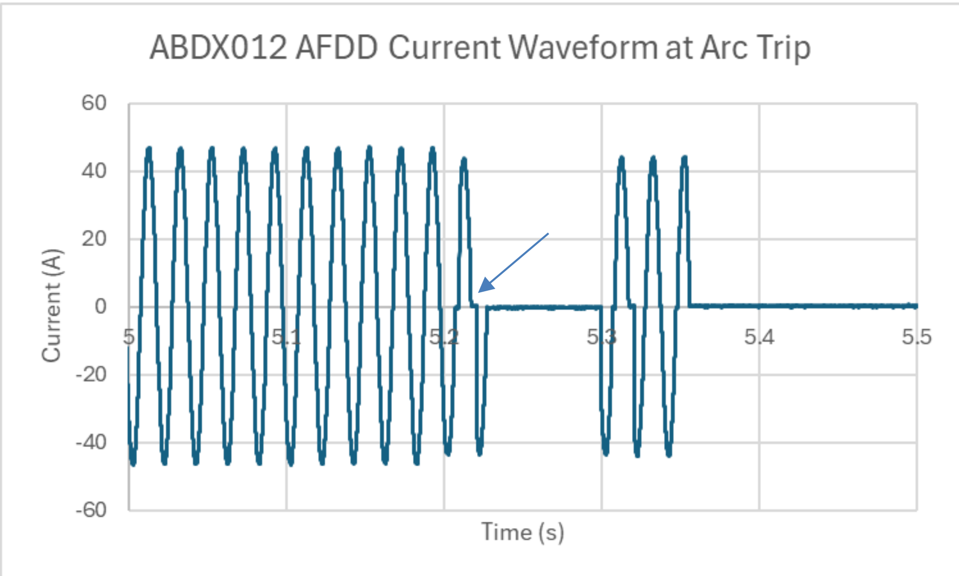

Figure 1-5: ABDX012 AFDD Current Waveform During Trip in Response to Arc – XLPE cable

2 DISCUSSION AND CONCLUSIONS

The three models of AFDD which were tested all tripped in response to arcing at an intermittent break in the Line conductor of PVC and XLPE / LS0H insulated twin and earth cable, at currents of 32A. There was negligible evidence of charring of the external sheath of the XLPE and PVC cables.

The three models of RCBO which were tested did not trip in response to series arcs at currents of 32A and arcing continued to occur when the cables were manipulated, until the conductor had been sufficiently eroded by arc damage such that electrical contact (and therefore arcing) no longer occurred during cable manipulation. There was significantly more extensive charring of the external sheath of the XLPE and PVC cables in the vicinity of the arc faults, in comparison with the AFDD tested samples. The PVC and XLPE / LS0H insulated cables occasionally exhibited burning with flames for brief periods after an arc event, and arc flashes occasionally occurred which extended for several centimetres from the site of the arc.

The cable insulation type had no bearing on the performance of the AFDDs or the RCBOs, and the cable insulation type had no bearing on the extent of damage which was caused during persistent arc faults in RCBO protected circuits.

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