Failure Modes, Effects and Diagnostic Analysis

Project:
Surge protective devices BLITZDUCTOR® BXT

Customer:

DEHN + SÖHNE GmbH + Co. KG.
Neumarkt
Germany

Contract No.: DEHN 09/04-20
Report No.: DEHN 09/04-20 R001
Version V5, Revision R0; June 2016
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Management summary

This report summarizes the results of the hardware assessment carried out on the surge protective devices BLITZDUCTOR® BXT in the versions listed in the drawings referenced in section 2.4.1. Table 1 gives an overview of the different configurations that belong to the considered surge protective devices BLITZDUCTOR® BXT.

The hardware assessment consists of a Failure Modes, Effects and Diagnostics Analysis (FMEDA). A FMEDA is one of the steps taken to achieve functional safety assessment of a device per IEC 61508. From the FMEDA, failure rates are determined and consequently the Safe Failure Fraction (SFF) is calculated for the device. For full assessment purposes all requirements of IEC 61508 must be considered.

Table 1: Configuration overview BLITZDUCTOR® BXT

BXT ML4 B 180	4-pole lightning current arrester module with LifeCheck monitoring function. For use in connection with downstream surge arresters -type2P1 or combined lightning current and surge arresters with a lower or equal voltage level; max. continuous operating voltage U_C: 130 VAC / 180 VDC
BXT ML4 BE 5	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 4 single lines with common reference potential as well as unbalanced interfaces; max. continuous operating voltage U_C: 4.2 VAC / 6 VDC
BXT ML4 BE 12	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 4 single lines with common reference potential as well as unbalanced interfaces; max. continuous operating voltage U_C: 10.6 VAC / 15 VDC
BXT ML4 BE 24	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 4 single lines with common reference potential as well as unbalanced interfaces; max. continuous operating voltage U_C: 23.3 VAC / 33 VDC
BXT ML4 BE 36	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 4 single lines with common reference potential as well as unbalanced interfaces; max. continuous operating voltage U_C: 31 VAC / 45 VDC
BXT ML4 BE 48	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 4 single lines with common reference potential as well as unbalanced interfaces; max. continuous operating voltage U_C: 38.1 VAC / 54 VDC
BXT ML4 BE 60	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 4 single lines with common reference potential as well as unbalanced interfaces; max. continuous operating voltage U_C: 49.5 VAC / 70 VDC
BXT ML4 BE 180	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 4 single lines with common reference potential as well as unbalanced interfaces; max. continuous operating voltage U_C: 127 VAC / 180 VDC
BXT ML4 BD 5	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 pairs of balanced interfaces with electrical isolation; max. continuous operating voltage U_C: 4.2 VAC / 6 VDC
BXT ML4 BD 12	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 pairs of balanced interfaces with electrical isolation; max. continuous operating voltage U_C: 10.6 VAC / 15 VDC

BXT ML4 BD 24	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 pairs of balanced interfaces with electrical isolation; max. continuous operating voltage U_C: 23.3 VAC / 33 VDC
BXT ML4 BD 48	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 pairs of balanced interfaces with electrical isolation; max. continuous operating voltage U_C: 38.1 VAC / 54 VDC
BXT ML4 BD 60	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 pairs of balanced interfaces with electrical isolation; max. continuous operating voltage U_C: 49.5 VAC / 70 VDC
BXT ML4 BD 180	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 pairs of balanced interfaces with electrical isolation; max. continuous operating voltage U_C: 127 VAC / 180 VDC
BXT ML4 BC 5	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting max. 4 earth-potential-free single lines with common reference potential; max. continuous operating voltage U_C: 4.2 VAC / 6 VDC
BXT ML4 BC 24	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting max. 4 earth-potential-free single lines with common reference potential; max. continuous operating voltage U_C: 23.3 VAC / 33 VDC
BXT ML4 BE C 12	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 pairs of balanced interfaces with protective diode circuit at the input, current loops (TTY) and opto-coupler inputs; max. continuous operating voltage U_C: 10.6 VAC / 15 VDC
BXT ML4 BE C 24	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 pairs of balanced interfaces with protective diode circuit at the input, current loops (TTY) and opto-coupler inputs; max. continuous operating voltage U_C: 23.3 VAC / 33 VDC
BXT ML4 BE HF 5	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 4 single lines with common reference potential as well as high-frequency transmissions without electrical isolation; max. continuous operating voltage U_C: 4.2 VAC / 6 VDC
BXT ML4 BD HF 5	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 pairs in high-frequency bus systems or video transmission systems; max. continuous operating voltage U_C: 4.2 VAC / 6 VDC
BXT ML4 BD HF 24	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 pairs in high-frequency bus systems or video transmission systems; max. continuous operating voltage U_C: 23.3 VAC / 33 VDC
BXT ML4 MY 250	Surge arrester module with LifeCheck monitoring function for protecting 4 lines of stranded signal interfaces up to 250 VAC; max. continuous operating voltage U_C: 250 VAC / 320 VDC
BXTU ML4 BD 0-180	Combined SPD module with actiVsense and LifeCheck technology for protecting 2 pairs of balanced interfaces which are galvanically isolated. Can be used for all voltages in the range from 0 to 180V. Automatically detects the operating voltage of the wanted signal and optimally adjusts the voltage protection level to the currently applied signal voltage.
BXT ML4 BD EX 24	Surge arrester module with LifeCheck function for protecting 2 pairs in intrinsically safe circuits and bus systems; max. continuous operating voltage U_C: 23 VAC / 33 VDC

BXT ML4 BC EX 24	Surge arrester module with LifeCheck function for protecting up to 4 earth-potential-free single lines with common reference potential in intrinsically safe circuits; max. continuous operating voltage U_C: 23 VAC / 33 VDC
BXT ML2 B 180	2-pole lightning current arrester module with LifeCheck monitoring function and shield earthing for use in nearly all applications. For use in connection with downstream surge arresters type 2P1 or combined lightning current and surge arresters with a lower or equal voltage level; max. continuous operating voltage U_C: 127 VAC / 180 VDC
BXT ML2 BE S 5	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 single lines with common reference potential as well as unbalanced interfaces, available with direct or indirect shield earthing; max. continuous operating voltage U_C: 4.2 VAC / 6 VDC
BXT ML2 BE S 12	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 single lines with common reference potential as well as unbalanced interfaces, available with direct or indirect shield earthing; max. continuous operating voltage U_C: 10.6 VAC / 15 VDC
BXT ML2 BE S 24	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 single lines with common reference potential as well as unbalanced interfaces, available with direct or indirect shield earthing; max. continuous operating voltage U_C: 23.3 VAC / 33 VDC
BXT ML2 BE S 36	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 single lines with common reference potential as well as unbalanced interfaces, available with direct or indirect shield earthing; max. continuous operating voltage U_C: 31 VAC / 45 VDC
BXT ML2 BE S 48	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 2 single lines with common reference potential as well as unbalanced interfaces, available with direct or indirect shield earthing; max. continuous operating voltage U_C: 38.1 VAC / 54 VDC
BXT ML2 BD S 5	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 1 pair of balanced interfaces with electrical isolation, available with direct or indirect shield earthing; max. continuous operating voltage U_C: 4.2 VAC / 6 VDC
BXT ML2 BD S 12	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 1 pair of balanced interfaces with electrical isolation, available with direct or indirect shield earthing; max. continuous operating voltage U_C: 10.6 VAC / 15 VDC
BXT ML2 BD S 24	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 1 pair of balanced interfaces with electrical isolation, available with direct or indirect shield earthing; max. continuous operating voltage U_C: 23.3 VAC / 33 VDC
BXT ML2 BD S 48	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 1 pair of balanced interfaces with electrical isolation, available with direct or indirect shield earthing; max. continuous operating voltage U_C: 38.1 VAC / 54 VDC
BXT ML2 BD 180	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 1 pair of balanced interfaces with electrical isolation; max. continuous operating voltage U_C: 127 VAC / 180 VDC
BXT ML2 BE HFS 5	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 1 pair in high-frequency transmissions without electrical isolation; available with direct or indirect shield earthing; max. continuous operating voltage U_C: 4.2 VAC / 6 VDC
BXT ML2 BD HFS 5	Combined lightning current and surge arrester module with LifeCheck monitoring function for protecting 1 pair in high-frequency bus systems or video transmission systems, available with direct or indirect shield earthing; max. continuous operating voltage U_C: 4.2 VAC / 6 VDC

BXT ML2 BD DL S 15	LifeCheck-equipped combined SPD module for protecting 1 pair of balanced and galvanically isolated interfaces, which particularly fulfils the requirements of Dupline buses, direct or indirect shield earthing; max. continuous operating voltage U_C: 12 VAC / 17 VDC
BXTU ML2 BD S 0-180	Combined SPD module with actiVsense and LifeCheck technology for protecting 1 pair of balanced interfaces which are galvanically isolated. Direct or indirect shield earthing. For all voltages in the range from 0 to 180V. Automatically detects the operating voltage of the wanted signal and optimally adapts the voltage protection level to the signal voltage currently applied.
BXT ML2 BD HF EX 6	Surge arrester module with LifeCheck monitoring for protecting 1 pair of balanced, high frequency bus systems in intrinsically safe circuits; max. continuous operating voltage U_C: 4.2 VAC / 6 VDC
BXT ML2 BD S EX 24	Surge arrester module with LifeCheck monitoring for protecting 1 pair of balanced lines in intrinsically safe measuring circuits and bus systems; max. continuous operating voltage U_C: 23.3 VAC / 33 VDC
BXT ML2 MY E 110	Surge arrester module with LifeCheck monitoring for protecting 1 pair of signal lines; max. continuous operating voltage line-line U_C: 120 VAC / 170 VDC max. continuous operating voltage line-PG U_C: 60 VAC / 85 VDC
BXT ML2 MY 250	Surge arrester module with LifeCheck monitoring for protecting 1 pair of signal lines; max. continuous operating voltage line-line U_C: 500 VAC / 620 VDC max. continuous operating voltage line-PG U_C: 250 VAC / 320 VDC
BXT M2 BD E EX 24	Surge arrester module without LifeCheck monitoring for protecting 1 pair of intrinsically safe measuring circuits and bus systems; max. continuous operating voltage U_C: 25.4 VAC / 36 VDC
BXT M2 BD S EX 24	Surge arrester module without LifeCheck monitoring for protecting 1 pair of intrinsically safe measuring circuits and bus systems; max. continuous operating voltage U_C: 25.4 VAC / 36 VDC
BXT ML4 MY 110	Surge arrester module with LifeCheck monitoring for protecting 2 pairs of signal lines; max. continuous operating voltage line-line U_C: 120 VAC / 170 VDC max. continuous operating voltage line-PG U_C: 60 VAC / 85 VDC
BXT ML4 BPD 24	Surge arrester module with LifeCheck feature for protecting two pairs in 24 VDC systems. Can also be used to protect earthed negative poles. Integrated PTC resistors allow to reliably reset the arrester after the system circuit has been affected by short-circuit currents up to 40 A.
BXT M2 BD HC5A 24 BXT M2 BD HC5A 24 CN	Space-saving combined arrester module for protecting one pair in 24 VDC systems of floating balanced interfaces. Module is adapted to the controller of motor-driven actuators with starting and operating currents up to 5 A.

For safety applications only the described configurations were considered. All other possible variants or electronics are not covered by this report.

Surge protective devices are not considered to be elements according to IEC 61508-4 section 3.4.5 as they are not performing one or more element safety functions. Therefore, there is no need to calculate a SFF (Safe Failure Fraction). Only the interference on a safety functions needs to be considered. This interference is expressed in a contribution to the overall PFD$_{AVG}$ / PFH.

The failure rates used in this analysis are from the *exida* Electrical & Mechanical Component Reliability Handbook for Profile 1.

The following tables show how the above stated requirements are fulfilled under worst-case assumptions.

Table 2: BXT ML2 B 180 and BXT ML4 B 180 – Failure rates [1]

Failure category	*exida* Profile 1	
	Analysis 1 [2]	**Analysis 2 [3]**
Failure category	**Failure rates (in FIT)**	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	3	3
Fail Dangerous Detected (λ_{DD})	0	1
Fail Dangerous Undetected (λ_{DU})	3	2

No effect	18	18
No part	1	1

Total failure rate (safety function)	**6 FIT**	**6 FIT**

MTBF	**4698 years**	**4698 years**

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[1] It is assumed that complete practical fault insertion tests can demonstrate the correctness of the failure effects assumed during the FMEDA.

[2] Analysis 1 represents a worst-case analysis.

[3] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 3: BXT ML2(4) BD *, BXT ML2 BD DL S 15, BXT ML2 BD S * – Failure rates

Failure category	*exida* Profile 1	
	Analysis 1 [4]	Analysis 2 [5]
	Failure rates (in FIT)	Failure rates (in FIT)
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	3	3
Fail Dangerous Detected (λ_{DD})	0	4
Fail Dangerous Undetected (λ_{DU})	6	2

No effect	18	18
No part	1	1

Total failure rate (safety function)	9 FIT	9 FIT

MTBF	4182 years	4182 years

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[4] Analysis 1 represents a worst-case analysis.

[5] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 4: BXT ML2 BD HF EX 6 – Failure rates

Failure category	*exida* Profile 1	
	Analysis 1 [6]	**Analysis 2** [7]
	Failure rates (in FIT)	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	2	2
Fail Dangerous Detected (λ_{DD})	0	1
Fail Dangerous Undetected (λ_{DU})	16	15

No effect	26	26
No part	21	21

Total failure rate (safety function)	**18 FIT**	**18 FIT**

MTBF	**1770 years**	**1770 years**

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[6] Analysis 1 represents a worst-case analysis.

[7] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 5: BXT ML2 BD HFS 5, BXT ML4 BD HF * – Failure rates

	exida Profile 1	
	Analysis 1 [8]	**Analysis 2** [9]
Failure category	**Failure rates (in FIT)**	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	3	3
Fail Dangerous Detected (λ_{DD})	0	4
Fail Dangerous Undetected (λ_{DU})	14	10

No effect	26	26
No part	1	1

Total failure rate (safety function)	**17 FIT**	**17 FIT**

MTBF	**2636 years**	**2636 years**

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[8] Analysis 1 represents a worst-case analysis.

[9] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 6: BXT ML2 BE HFS 5, BXT ML4 BE HF 5 – Failure rates

	exida Profile 1	
	Analysis 1 [10]	**Analysis 2** [11]
Failure category	**Failure rates (in FIT)**	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	3	3
Fail Dangerous Detected (λ_{DD})	0	8
Fail Dangerous Undetected (λ_{DU})	18	10

No effect	30	30
No part	1	1

Total failure rate (safety function)	**21 FIT**	**21 FIT**

MTBF	**2225 years**	**2225 years**

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[10] Analysis 1 represents a worst-case analysis.

[11] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 7: BXT ML2 BE S *, BXT ML4 BE *, BXT ML4 BC * – Failure rates

	exida Profile 1	
	Analysis 1 [12]	**Analysis 2** [13]
Failure category	**Failure rates (in FIT)**	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	3	3
Fail Dangerous Detected (λ_{DD})	0	7
Fail Dangerous Undetected (λ_{DU})	9	2

No effect	18	18
No part	1	1

Total failure rate (safety function)	**12 FIT**	**12 FIT**

MTBF	**3768 years**	**3768 years**

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[12] Analysis 1 represents a worst-case analysis.

[13] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 8: BXT ML4 BC EX 24 – Failure rates

| | exida Profile 1 | |
	Analysis 1 [14]	Analysis 2 [15]
Failure category	**Failure rates (in FIT)**	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	3	3
Fail Dangerous Detected (λ_{DD})	0	8
Fail Dangerous Undetected (λ_{DU})	11	3

No effect	36	36
No part	1	1

Total failure rate (safety function)	**14 FIT**	**14 FIT**

MTBF	**2269 years**	**2269 years**

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[14] Analysis 1 represents a worst-case analysis.

[15] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 9: BXT ML4 BD EX 24, BXT M2 BD E EX 24, BXT M(L)2 BD S EX 24 – Failure rates

	exida Profile 1	
	Analysis 1 [16]	**Analysis 2** [17]
Failure category	**Failure rates (in FIT)**	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	3	3
Fail Dangerous Detected (λ_{DD})	0	6
Fail Dangerous Undetected (λ_{DU})	10	4

No effect	54	54
No part	1	1

Total failure rate (safety function)	**13 FIT**	**13 FIT**

MTBF	**1696 years**	**1696 years**

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[16] Analysis 1 represents a worst-case analysis.

[17] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 10: BXT ML4 BE C *** – Failure rates

	exida Profile 1	
	Analysis 1 [18]	**Analysis 2** [19]
Failure category	**Failure rates (in FIT)**	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	4	4
Fail Dangerous Detected (λ_{DD})	0	9
Fail Dangerous Undetected (λ_{DU})	12	3

No effect	19	19
No part	1	1

Total failure rate (safety function)	**16 FIT**	**16 FIT**

MTBF	**3252 years**	**3252 years**

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[18] Analysis 1 represents a worst-case analysis.

[19] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 11: BXT ML2(4) MY 250, BXT ML2(4) MY E 110 – Failure rates

	exida Profile 1	
	Analysis 1 [20]	**Analysis 2 [21]**
Failure category	**Failure rates (in FIT)**	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	2	2
Fail Dangerous Detected (λ_{DD})	0	0.4
Fail Dangerous Undetected (λ_{DU})	10	9.6

No effect	18	18
No part	1	1

Total failure rate (safety function)	**12 FIT**	**12 FIT**

MTBF	**3743 years**	**3743 years**

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[20] Analysis 1 represents a worst-case analysis.

[21] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 12: BXTU ML2 BD S 0-180 and BXTU ML4 BD 0-180 – Failure rates

	exida Profile 1	
	Analysis 1 [22]	**Analysis 2 [23]**
Failure category	**Failure rates (in FIT)**	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	2	2
Fail Dangerous Detected (λ_{DD})	0	7
Fail Dangerous Undetected (λ_{DU})	42	35

No effect	48	48
No part	20	20

Total failure rate (safety function)	**44 FIT**	**44 FIT**

MTBF	**1026 years**	**1026 years**

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[22] Analysis 1 represents a worst-case analysis.

[23] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 13: BXT ML4 BPD 24 – Failure rates

	exida Profile 1	
	Analysis 1 [24]	**Analysis 2** [25]
Failure category	**Failure rates (in FIT)**	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	8	8
Fail Dangerous Detected (λ_{DD})	0	4
Fail Dangerous Undetected (λ_{DU})	9	5

No effect	18	18
No part	1	1

Total failure rate (safety function)	**17 FIT**	**17 FIT**

MTBF	**3216 years**	**3216 years**

[24] Analysis 1 represents a worst-case analysis.

[25] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

Table 14: BXT M2 BD HC5A 24 (CN) – Failure rates

	exida Profile 1	
	Analysis 1 [26]	**Analysis 2** [27]
Failure category	**Failure rates (in FIT)**	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	0	0
Fail Safe Undetected (λ_{SU})	2	2
Fail Dangerous Detected (λ_{DD})	0	4
Fail Dangerous Undetected (λ_{DU})	11	7

No effect	55	55
No part	1	1

Total failure rate (safety function)	**13 FIT**	**13 FIT**

MTBF	**1686 years**	**1686 years**

The failure rates are valid for the useful life of the surge protective devices BLITZDUCTOR® BXT (see Appendix 2).

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[26] Analysis 1 represents a worst-case analysis.

[27] Analysis 2 represents an analysis with the assumption that line short circuits and short circuits to GND are detectable or do not have an effect.

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