Failure Modes, Effects and Diagnostic Analysis

Project:
Ground Monitoring Device 71**/5, 81**/5, 82**/5

Company:
R. STAHL Schaltgeräte GmbH
Waldenburg
Germany

Contract No.: STAHL 11/07-089
Report No.: STAHL 11/07-089 R022
Version V2, Revision R1; April 2016
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Management Summary

This report summarizes the results of the hardware assessment in the form of a Failure Modes, Effects, and Diagnostic Analysis (FMEDA) of the Ground Monitoring Device 71**/5, 81**/5, 82**/5 in the version listed in the drawings referenced in section 2.3.1.

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.

For safety applications only the described variant was considered. All other possible variants are not covered by this report.

The failure rates used in this analysis are from the *exida* Electrical & Mechanical Component Reliability Handbook for Profile 3. The analysis has been carried out with the basic failure rates from the Siemens standard SN 29500. However as the comparison between these two databases has shown that the differences are within an acceptable tolerance the failure rates of the *exida* database are listed.

The listed failure rates are valid for operating stress conditions of an industrial field environment similar to IEC 60654-1 class C (sheltered location) with an average temperature over a long period of time of 40°C. For a higher average temperature of 60°C, the failure rates should be multiplied with an experience based factor of 2.5. A similar multiplier should be used if frequent temperature fluctuation must be assumed.

These failure rates are valid for the useful lifetime of the Ground Monitoring Device 71**/5, 81**/5, 82**/5, see Appendix 2.

The failure rates listed in this report do not include failures due to wear-out of any components. They reflect random failures and include failures due to external events, such as unexpected use, see section 4.2.3.

A user of the Ground Monitoring Device 71**/5, 81**/5, 82**/5 can utilize these failure rates in a probabilistic model of a safety instrumented function (SIF) to determine suitability in part for safety instrumented system (SIS) usage in a particular safety integrity level (SIL). A full table of failure rates is presented in section 4.3.1 along with all assumptions.

The Ground Monitoring Device 71**/5, 81**/5, 82**/5 is classified as a Type A[1] element according to IEC 61508, having a hardware fault tolerance of 0. The failure rates according to IEC 61508:2010 for the Ground Monitoring Device 71**/5, 81**/5, 82**/5 are listed in the following table.

[1] Type A element: "Non-complex" element (all failure modes are well defined); for details see 7.4.4.1.2 of IEC 61508-2.

Table 1: Ground Monitoring Device 71/5, 81**/5, 82**/5, AC powered, according to IEC 61508:2010**

	exida Profile 3 [2]
Failure category	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	**8**
Fail Safe Undetected (λ_{SU})	**229**
Fail Dangerous Detected (λ_{DD})	**1**
Fail Dangerous Detected (λ_{dd})	1
Fail Annunciation Detected (λ_{AD})	0
Fail Dangerous Undetected (λ_{DU})	**87**

Fail Annunciation Undetected (λ_{AU})	24
No effect	139
No part	67

Total failure rate (safety function)	**325**
SFF [3]	**73%**

SIL AC [4]	**SIL2**

[2] For details see Appendix 3.

[3] The complete sensor subsystem will need to be evaluated to determine the overall Safe Failure Fraction. The number listed is for reference only.

[4] The SIL AC (architectural constraints) needs to be evaluated on subsystem level. See also previous footnote.

Table 2: Ground Monitoring Device 71/5, 81**/5, 82**/5, DC powered, according to IEC 61508:2010**

	exida Profile 3 [5]
Failure category	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	**8**
Fail Safe Undetected (λ_{SU})	**168**
Fail Dangerous Detected (λ_{DD})	**1**
Fail Dangerous Detected (λ_{dd})	1
Fail Annunciation Detected (λ_{AD})	0
Fail Dangerous Undetected (λ_{DU})	**87**

Fail Annunciation Undetected (λ_{AU})	24
No effect	122
No part	74

Total failure rate (safety function)	**264**
SFF [6]	**67%**

SIL AC [7]	**SIL2**

[5] For details see Appendix 3.

[6] The complete sensor subsystem will need to be evaluated to determine the overall Safe Failure Fraction. The number listed is for reference only.

[7] The SIL AC (architectural constraints) needs to be evaluated on subsystem level. See also previous footnote.

Table of Contents

1 Purpose and Scope

This document shall describe the results of the hardware assessment in the form of the Failure Modes, Effects and Diagnostic Analysis carried out on the Ground Monitoring Device 71**/5, 81**/5, 82**/5.

The FMEDA builds the basis for an evaluation whether the Ground Monitoring Device 71**/5, 81**/5, 82**/5 meets the average Probability of Failure on Demand (PFD_{AVG}) requirements and if applicable the architectural constraints / minimum hardware fault tolerance requirements per IEC 61508 / IEC 61511. It **does not** consider any calculations necessary for proving intrinsic safety.

2 Project Management

2.1 *exida*

exida is one of the world's leading product certification and knowledge companies specializing in automation system safety and availability with over 300 years of cumulative experience in functional safety. Founded by several of the world's top reliability and safety experts from assessment organizations and manufacturers, *exida* is a global company with offices around the world. *exida* offers training, coaching, project oriented consulting services, internet based safety engineering tools, detailed product assurance and certification analysis and a collection of on-line safety and reliability resources. *exida* maintains a comprehensive failure rate and failure mode database on process equipment.

2.2 Roles of the parties involved

R. STAHL Schaltgeräte GmbH	Manufacturer of the Ground Monitoring Device 71**/5, 81**/5, 82**/5.
exida	reviewed the FMEDA and issued this report.

R. STAHL Schaltgeräte GmbH contracted *exida* in December 2015 to review the FMEDA and update the report.

2.3 Standards and Literature used

The services delivered by *exida* were performed based on the following standards / literature.

[N1]	IEC 61508-2:2010	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems; 2nd edition
[N2]	Electrical Component Reliability Handbook, 3rd Edition, 2012	*exida* LLC, Electrical Component Reliability Handbook, Third Edition, 2012, ISBN 978-1-934977-04-0

Reference documents

2.3.1 Documentation provided by the customer

[D1]	8146624300_08_instruction.pdf	Instruction manual
[D2]	8125_5071_8146_5075_Datasheet V1R0.pdf	Data sheet Ground Monitoring Device 8125/5071 and 8146/5075
[D3]	GroundingSystems_General_en.pdf	General description of Grounding Systems
[D4]	81 462 19 01 0_10.pdf	Example assembly instruction of Ground Monitoring Device
[D5]	Schaltplan_Elektronik_V0R2.pdf	Circuit diagram of switching repeater Type 91 706 03 20 0, Index 05
[D6]	FMEDA V5 8125_a1-c2-21 V1_3.xls	FMEDA for Ground Monitoring Device 71**/5, 81**/5, 82**/5 (AC) of 04.04.2016
[D7]	FMEDA V5 8125_a1-c2-11 V1_1.xls	FMEDA for Ground Monitoring Device 71**/5, 81**/5, 82**/5 (DC) of 04.04.2016
[D8]	Useful lifetime 9170_x1.pdf	Useful lifetime analysis

2.3.2 Documentation generated by *exida*

[R1]	FMEDA V5 8125_10-12-21 V1.1.xls of 31.10.11
[R2]	STAHL 9170-x1 09-03-52 R019 V3R0.doc

3 Product Description

The Ground Monitoring Device 71**/5, 81**/5, 82**/5 is classified as a Type A element according to IEC 61508, having a hardware fault tolerance of 0.

It is used to ground objects and monitor the ground connection to prevent electrostatic discharge during loading and unloading of flammable liquids. The ground connection is indicated by signal lamps. The additional potential-free contact (see Figure 1) can be used to generate a System OFF signal to stop the loading or unloading. In case of good ground connection, the output is closed.

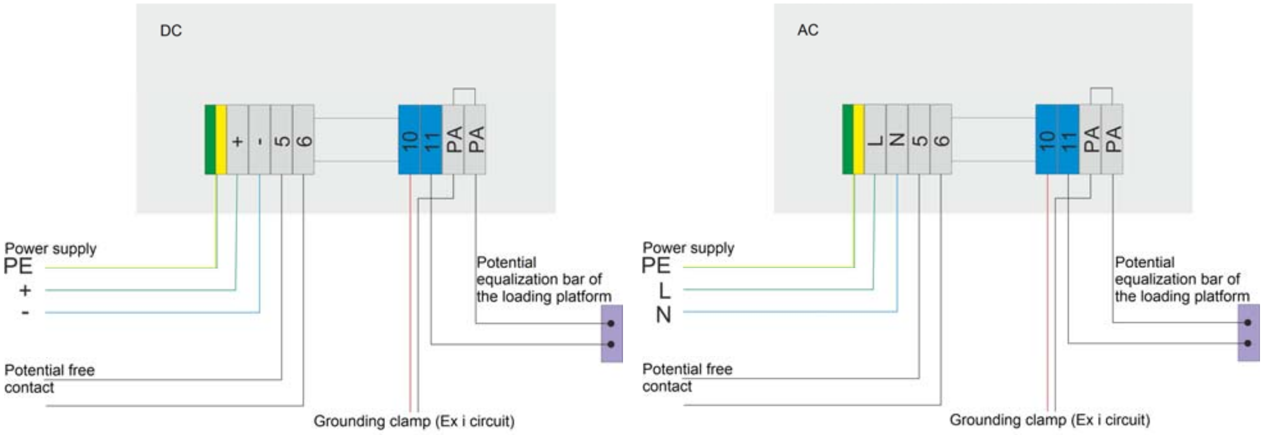


Figure 1: Connection scheme for the Ground Monitoring Device 71/5, 81**/5, 82**/5 DC version (left side) and AC version (right side)**

The Ground Monitoring Device 71**/5, 81**/5, 82**/5 is based on the switching repeater 9170 with additional hardware components in a special enclosure. The basic function is provided by the switching repeater 9170 circuit. The enclosures are needed to fulfill Ex requirements, which are not relevant for FMEDA. Due to different enclosures, the Ground Monitoring Device 71**/5, 81**/5, 82**/5 can be offered in a wide range of product numbers, but with the same electrical configuration. Depending on the supply concept, it can be supplied with DC or AC.

4 Failure Modes, Effects, and Diagnostic Analysis

The Failure Modes, Effects, and Diagnostic Analysis was performed by *exida*. The results are documented in [R1].

4.1 Description of the failure categories

In order to judge the failure behavior of the Ground Monitoring Device 71**/5, 81**/5, 82**/5, the following definitions for the failure of the device were considered.

Fail-Safe State	The fail-safe state is defined as the output being de-energized.
Fail Safe	A safe failure (S) is defined as a failure that plays a part in implementing the safety function that: a) results in the spurious operation of the safety function to put the output in open state b) increases the probability of the spurious operation of the safety function to put the output into a safe state or maintain a safe state.
Fail Dangerous	A dangerous failure (D) is defined as a failure that plays a part in implementing the safety function that: a) prevents a safety function from operating when required (demand mode) or causes a safety function to fail (continuous mode) such that the output is put into a hazardous or potentially hazardous state; or, b) decreases the probability that the safety function operates correctly when required.
Fail Dangerous Undetected	Failure that is dangerous and that is not being diagnosed by internal diagnostics.
Fail Dangerous Detected	Failure that is dangerous but is detected by internal diagnostics.
Annunciation	Failure that does not directly impact safety but does impact the ability to detect a future fault (such as a fault in a diagnostic circuit). Annunciation failures are divided into annunciation detected (AD) and annunciation undetected (AU) failures.
No effect	Failure mode of a component that plays a part in implementing the safety function but is neither a safe failure nor a dangerous failure.
No part	Component that plays no part in implementing the safety function but is part of the circuit diagram and is listed for completeness. When calculating the SFF this failure mode is not taken into account. It is also not part of the total failure rate.

4.2 Methodology – FMEDA, Failure Rates

4.2.1 FMEDA

A Failure Modes and Effects Analysis (FMEA) is a systematic way to identify and evaluate the effects of different component failure modes, to determine what could eliminate or reduce the chance of failure, and to document the system under consideration.

An FMEDA (Failure Mode Effect and Diagnostic Analysis) is an FMEA extension. It combines standard FMEA techniques with extensions to identify online diagnostics techniques and the failure modes relevant to safety instrumented system design. It is a technique recommended to generate failure rates for each important category (safe detected, safe undetected, dangerous detected, dangerous undetected, fail high, fail low) in the safety models. The format for the FMEDA is an extension of the standard FMEA format from MIL STD 1629A, Failure Modes and Effects Analysis.

4.2.2 Failure Rates

The failure rate data used by *exida* in this FMEDA are from the *exida* Electrical & Mechanical Component Reliability Handbook for Profile 3. The rates were chosen in a way that is appropriate for safety integrity level verification calculations. The rates were chosen to match operating stress conditions typical of an industrial field environment similar to *exida* Profile 3. It is expected that the actual number of field failures due to random events will be less than the number predicted by these failure rates.

For hardware assessment according to IEC 61508 only random equipment failures are of interest. It is assumed that the equipment has been properly selected for the application and is adequately commissioned such that early life failures (infant mortality) may be excluded from the analysis.

Failures caused by external events however should be considered as random failures. Examples of such failures are loss of power or physical abuse.

The assumption is also made that the equipment is maintained per the requirements of IEC 61508 or IEC 61511 and therefore a preventative maintenance program is in place to replace equipment before the end of its "useful life".

The user of these numbers is responsible for determining their applicability to any particular environment. Accurate plant specific data may be used for this purpose. If a user has data collected from a good proof test reporting system that indicates higher failure rates, the higher numbers shall be used. Some industrial plant sites have high levels of stress. Under those conditions the failure rate data is adjusted to a higher value to account for the specific conditions of the plant.

4.2.3 Assumptions

The following assumptions have been made during the Failure Modes, Effects, and Diagnostic Analysis of the Ground Monitoring Device 71**/5, 81**/5, 82**/5.

- Failure rates are constant, wear out mechanisms are not included.
- Propagation of failures is not relevant.
- The device is installed per manufacturer's instructions.
- Sufficient tests are performed prior to shipment to verify the absence of vendor and/or manufacturing defects that prevent proper operation of specified functionality to product specifications or cause operation different from the design analyzed.
- Complete practical fault insertion tests can demonstrate the correctness of the failure effects assumed during the FMEDAs.
- All devices are operated in the low demand mode of operation.
- External power supply failure rates are not included.
- The Mean Time To Restoration (MTTR) after a safe failure is 24 hours.
- For safety applications only the described variant is considered.
- Failures during parameterization are not considered.
- The time of a connected safety PLC to react on a dangerous detected failure and to bring the process to the safe state is identical to MTTR.
- Only one input and one output are part of the considered safety function.
- The relay output needs to be protected by a fuse which initiates at 60% of the rated current to avoid contact welding.
- Short circuit and lead breakage detection are activated during manufacturing process.

4.3 Results

For the calculation of the Safe Failure Fraction (SFF) the following has to be noted:

λ_{total} consists of the sum of all component failure rates. This means:

$\lambda_{total} = \lambda_{SD} + \lambda_{SU} + \lambda_{DD} + \lambda_{DU}$

$SFF = 1 - \lambda_{DU} / \lambda_{total}$

$DC_D = \lambda_{DD} / (\lambda_{DD} + \lambda_{DU})$

$MTBF = MTTF + MTTR = (1 / (\lambda_{total} + \lambda_{no\ part})) + 24\ h$

4.3.1 Ground Monitoring Device 71**/5, 81**/5, 82**/5

The FMEDA carried out on the Ground Monitoring Device 71**/5, 81**/5, 82**/5 leads under the assumptions described in section 4.2.3 and 4.3 to the following failure rates:

Table 3: Ground Monitoring Device 71/5, 81**/5, 82**/5, AC powered, according to IEC 61508:2010**

	exida Profile 3 [8]
Failure category	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	**8**
Fail Safe Undetected (λ_{SU})	**229**
Fail Dangerous Detected (λ_{DD})	**1**
Fail Dangerous Detected (λ_{dd})	1
Fail Annunciation Detected (λ_{AD})	0
Fail Dangerous Undetected (λ_{DU})	**87**
Fail Annunciation Undetected (λ_{AU})	24
No effect	139
No part	67
Total failure rate (safety function)	**325**
SFF [9]	**73%**
SIL AC [10]	**SIL2**

[8] For details see Appendix 3.

[9] The complete sensor subsystem will need to be evaluated to determine the overall Safe Failure Fraction. The number listed is for reference only.

[10] The SIL AC (architectural constraints) needs to be evaluated on subsystem level. See also previous footnote.

Table 4: Ground Monitoring Device 71/5, 81**/5, 82**/5, DC powered, according to IEC 61508:2010**

	exida Profile 3 [11]
Failure category	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	**8**
Fail Safe Undetected (λ_{SU})	**168**
Fail Dangerous Detected (λ_{DD})	**1**
Fail Dangerous Detected (λ_{dd})	1
Fail Annunciation Detected (λ_{AD})	0
Fail Dangerous Undetected (λ_{DU})	**87**
Fail Annunciation Undetected (λ_{AU})	24
No effect	122
No part	74
Total failure rate (safety function)	**264**
SFF [12]	**67%**
SIL AC [13]	**SIL2**

[11] For details see Appendix 3.

[12] The complete sensor subsystem will need to be evaluated to determine the overall Safe Failure Fraction. The number listed is for reference only.

[13] The SIL AC (architectural constraints) needs to be evaluated on subsystem level. See also previous footnote.

5 Using the FMEDA Results

The following section describes how to apply the results of the FMEDA. It is the responsibility of the Safety Instrumented Function designer to do calculations for the entire SIF. *exida* recommends the accurate Markov based exSILentia tool for this purpose.

The following results must be considered in combination with PFD_{AVG} values of other devices of a Safety Instrumented Function (SIF) in order to determine suitability for a specific Safety Integrity Level (SIL).

5.1 Example PFD_{AVG} calculation

An average Probability of Failure on Demand (PFD_{AVG}) calculation is performed for Ground Monitoring Device 71**/5, 81**/5, 82**/5 considering a proof test coverage of 99% (see Appendix 1.1) and a mission time of 10 years. The failure rate data used in this calculation are displayed in sections 3. The resulting PFD_{AVG} values for a variety of proof test intervals are displayed in Table 5.

For SIL2 applications, the PFD_{AVG} value needs to be < 1.00E-02.

Table 5: PFD_{AVG} values

	T[Proof] = 1 year	T[Proof] = 2 years	T[Proof] = 5 years
DC and AC version	PFD_{AVG} = 4.14E-04	PFD_{AVG} = 7.90E-04	PFD_{AVG} = 1.92E-03

This means that for a SIL2 application, the PFD_{AVG} for a 1-year Proof Test Interval is approximately equal to 4.14% of the allowed range.

Figure 2 shows the time dependent curve of PFD_{AVG}.

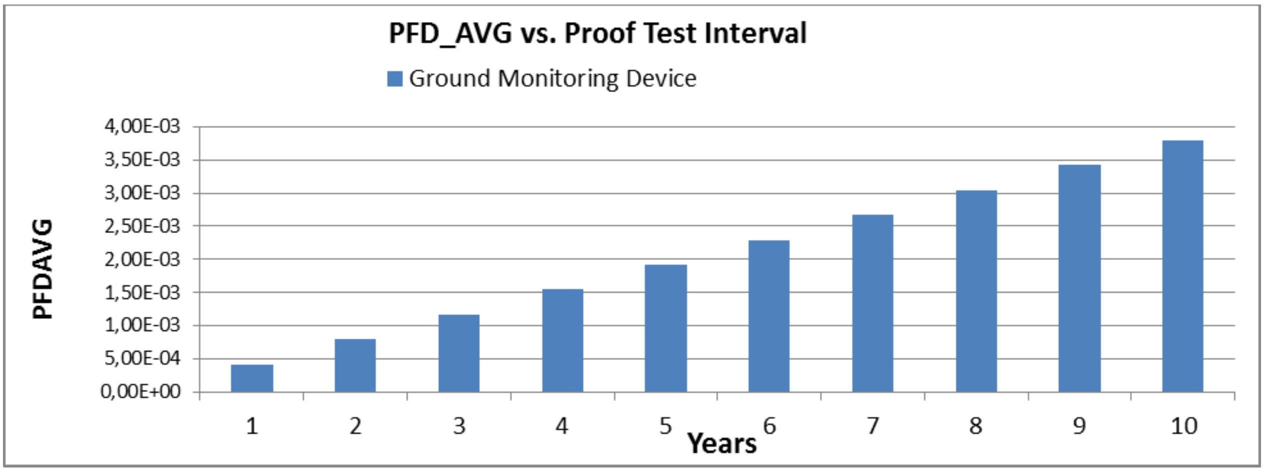


Figure 2: PFD_{AVG}(t)

6 Terms and Definitions

FIT	Failure In Time (1x10-9 failures per hour)
FMEDA	Failure Mode Effect and Diagnostic Analysis
HFT	Hardware Fault Tolerance
Low demand mode	Mode, where the frequency of demands for operation made on a safety-related system is no greater than twice the proof test frequency.
PFD_{AVG}	Average Probability of Failure on Demand
SFF	Safe Failure Fraction, summarizes the fraction of failures, which lead to a safe state and the fraction of failures which will be detected by diagnostic measures and lead to a defined safety action.
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System – Implementation of one or more Safety Instrumented Functions. A SIS is composed of any combination of sensor(s), logic solver(s), and final element(s).
Type A element	“Non-complex” element (all failure modes are well defined); for details see 7.4.4.1.2 of IEC 61508-2.

7 Status of the Document

7.1 Liability

exida prepares FMEDA reports based on methods advocated in International standards. Failure rates are obtained from a collection of industrial databases. *exida* accepts no liability whatsoever for the use of these numbers or for the correctness of the standards on which the general calculation methods are based.

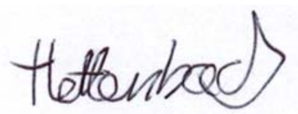
Due to future potential changes in the standards, best available information and best practices, the current FMEDA results presented in this report may not be fully consistent with results that would be presented for the identical product at some future time. As a leader in the functional safety market place, *exida* is actively involved in evolving best practices prior to official release of updated standards so that our reports effectively anticipate any known changes. In addition, most changes are anticipated to be incremental in nature and results reported within the previous three year period should be sufficient for current usage without significant question.

Most products also tend to undergo incremental changes over time. If an *exida* FMEDA has not been updated within the last three years and the exact results are critical to the SIL verification you may wish to contact the product vendor to verify the current validity of the results.

7.2 Releases

Version History:	V2R1:	April 26, 2016
	V2R0:	March 29, 2016
	V1R0:	November 04, 2011
	V0R1:	Initial draft; October 31, 2011
Author:	Jan Hettenbach	
Review:	V2R0:	A. Bagusch (R. STAHL Schaltgeräte GmbH), Jürgen Hochhaus (*exida*)
Release Status:	V2R1: Released to R. STAHL Schaltgeräte GmbH	

7.3 Release signatures



Dipl. -Ing. (Univ.) Jan Hettenbach	Dipl.-Ing. (FH) Jürgen Hochhaus

Appendix 1: Possibilities to reveal dangerous undetected faults during the proof test

According to section 7.4.5.2 f) of IEC 61508-2 proof tests shall be undertaken to reveal dangerous faults which are undetected by diagnostic tests.

This means that it is necessary to specify how dangerous undetected faults which have been noted during the FMEDA can be detected during proof testing.

Appendix 1 shall be considered when writing the safety manual as it contains important safety related information.

Appendix 1.1: Possible proof tests to detect dangerous undetected faults

A suggested proof test consists of the following steps, as described in Table 6. It is assumed that this test will detect 99% of possible dangerous failures.

Table 6: Steps for proof test

Step	Action
1.	Bypass the safety function and take appropriate action to avoid a false trip.
2.	Force the Ground Monitoring Device 71**/5, 81**/5, 82**/5 to go to the safe state and verify that the safe state is reached.
3.	Restore the loop to full operation.
4.	Remove the bypass from the safety PLC or otherwise restore normal operation.

Appendix 2: Impact of lifetime of critical components on the failure rate

According to section 7.4.9.5 of IEC 61508-2, a useful lifetime, based on experience, should be assumed.

Although a constant failure rate is assumed by the probabilistic estimation method (see section 4.2.3) this only applies provided that the useful lifetime[14] of components is not exceeded. Beyond their useful lifetime, the result of the probabilistic calculation method is meaningless, as the probability of failure significantly increases with time. The useful lifetime is highly dependent on the component itself and its operating conditions – temperature in particular (for example, electrolyte capacitors can be very sensitive).

This assumption of a constant failure rate is based on the bathtub curve. Therefore it is obvious that the PFD_{AVG} calculation is only valid for components which have this constant domain and that the validity of the calculation is limited to the useful lifetime of each component.

It is assumed that early failures are detected to a huge percentage during the installation period and therefore the assumption of a constant failure rate during the useful lifetime is valid.

Table 7 shows which components are contributing to the dangerous undetected failure rate and therefore to the PFD_{AVG} calculation and what their estimated useful lifetime is.

Table 7: Useful lifetime of components contributing to λ_{du}

Type	Name	Useful life
Relay	K81A, K81B, K82A, K82B	100.000 switching cycles
Opto-coupler - With bipolar output	O01A, O01B	More than 10 years

Assuming one demand per year for low demand mode applications and additional switching cycles during installation and proof testing, the relays do not have a real impact on the useful lifetime.

The useful lifetime analysis (see [D8]) which has been carried out by R. STAHL Schaltgeräte GmbH shows that the expected useful lifetime for all components with reduced useful lifetime is more than 10 years.

When plant experience indicates a shorter useful lifetime than indicated in this appendix, the number based on plant experience should be used.

[14] Useful lifetime is a reliability engineering term that describes the operational time interval where the failure rate of a device is relatively constant. It is not a term which covers product obsolescence, warranty, or other commercial issues.

Appendix 3: *exida* Environmental Profiles

Table 8 *exida* Environmental Profiles

exida Profile	1	2	3	4	5	6
Description (Electrical)	Cabinet mounted/ Climate Controlled	Low Power Field Mounted	General Field Mounted	Subsea	Offshore	N/A
		no self-heating	self-heating			
Description (Mechanical)	Cabinet mounted/ Climate Controlled	General Field Mounted	General Field Mounted	Subsea	Offshore	Process Wetted
IEC 60654-1 Profile	B2	C3	C3	N/A	C3	N/A
		also applicable for D1	also applicable for D1		also applicable for D1	
Average Ambient Temperature	30C	25C	25C	5C	25C	25C
Average Internal Temperature	60C	30C	45C	5C	45C	Process Fluid Temp.
Daily Temperature Excursion (pk-pk)	5C	25C	25C	0C	25C	N/A
Seasonal Temperature Excursion (winter average vs. summer average)	5C	40C	40C	2C	40C	N/A
Exposed to Elements/Weather Conditions	No	Yes	Yes	Yes	Yes	Yes
Humidity[15]	0-95% Non-Condensing	0-100% Condensing	0-100% Condensing	0-100% Condensing	0-100% Condensing	N/A
Shock[16]	10 g	15 g	15 g	15 g	15 g	N/A
Vibration[17]	2 g	3 g	3 g	3 g	3 g	N/A
Chemical Corrosion[18]	G2	G3	G3	G3	G3	Compatible Material
Surge[19]						
Line-Line	0.5 kV	0.5 kV	0.5 kV	0.5 kV	0.5 kV	N/A
Line-Ground	1 kV	1 kV	1 kV	1 kV	1 kV	
EMI Susceptibility[20]						
80MHz to 1.4 GHz	10V /m	10V /m	10V /m	10V /m	10V /m	N/A
1.4 GHz to 2.0 GHz	3V/m	3V/m	3V/m	3V/m	3V/m	
2.0Ghz to 2.7 GHz	1V/m	1V/m	1V/m	1V/m	1V/m	
ESD (Air)[21]	6kV	6kV	6kV	6kV	6kV	N/A

[15] Humidity rating per IEC 60068-2-3
[16] Shock rating per IEC 60068-2-6
[17] Vibration rating per IEC 60770-1
[18] Chemical Corrosion rating per ISA 71.04
[19] Surge rating per IEC 61000-4-5
[20] EMI Susceptibility rating per IEC 6100-4-3
[21] ESD (Air) rating per IEC 61000-4-2