

# **FMEA of Cable Failures within a Fire PSA**

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- Introduction
- Definition of Cable Failure Modes and Required Cable Data
- Methodology of the Cable FMEA
- Results
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# Past Activities (1)

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- Probabilistic studies for selected fire sequences in PWR
- Probabilistic study for fire in PWR-1300 (KONVOI)
- Several reviews of Fire PSA by GRS
- A systematic methodology for probabilistic fire risk analysis was developed by GRS
  - Analysis of fire ignition, fire propagation
  - Screening out of compartments, components and cables not relevant for the CDF
  - Adaptation of the basis PSA considering fire induced failures
  - Calculating the fire caused CDF by a newly developed fire analysis code

## Past Activities (2)

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- A Fire PSA was conducted for a BWR-69
  - For undisturbed full power state
  - Constrained to PSA level 1
- One result was that cable failures constitute the dominant contribution to fire CDF
- Due to limited information about cable types, structures, shielding, and laying conservative assumptions had to be taken about cable failure modes and their corresponding functional impact on the attached components

- Improving the current approach by the analysis of fire impact on electrical components
- Developing a methodology based on FMEA to assess fire related cable failures in a more realistic way
  - Determine which information about cables is necessary
  - Determine cable failure modes (e.g. from experiments) and their effects on the attached components
- Performing a pilot FMEA for all cables in a selected representative compartment of a NPP

# Determination of Necessary Cable Data

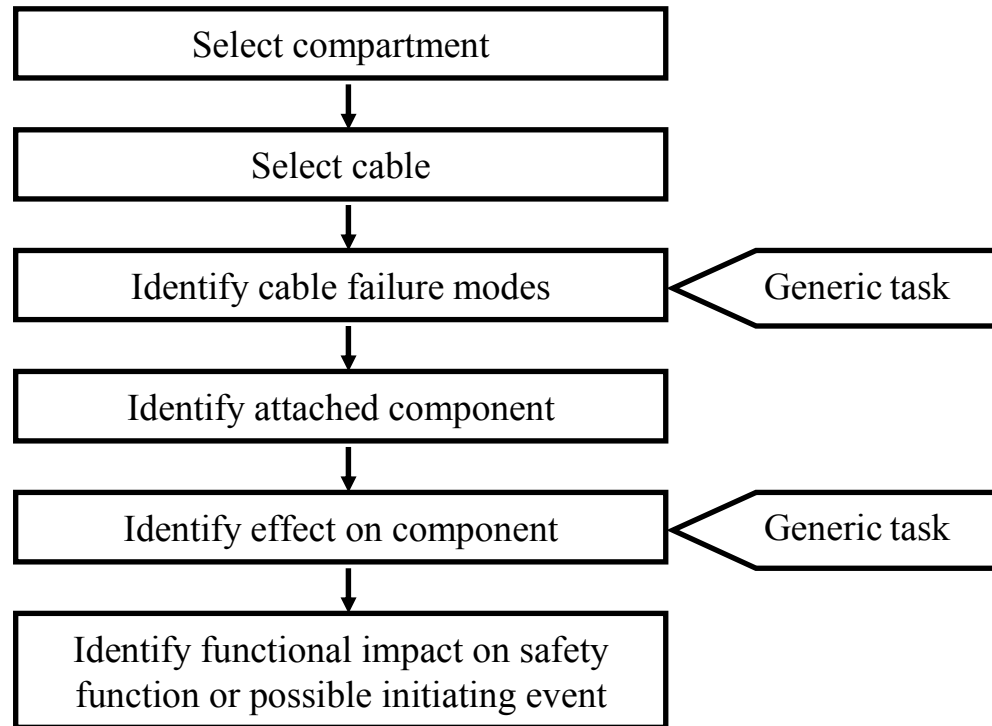
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- All cables within the NPP are recorded in a database
- The database includes information about:
  - Plant identification number of cable, code for cable function, description of cable type and voltage level
  - Description and plant identification number of the component supplied, controlled or monitored by the cable (“associated component”)
  - Plant identification numbers of the compartments passed through by the cable
  - Plant identification numbers of the components attached physically to the cable
  - Laying of the cable

- Failure criteria
  - Critical temperature in compartment depending on cable insulation material and cable function
  
- Failures types
  - Short to ground
  - Hot short
  - Interruption of cable
  - Multipolar short
  
- Experimental results for cable failures
  - Results from iBMB of Braunschweig University of Technology show, that conductor to conductor short occur first, later shorts conductor to tray

# Procedure for Performing the Cable FMEA

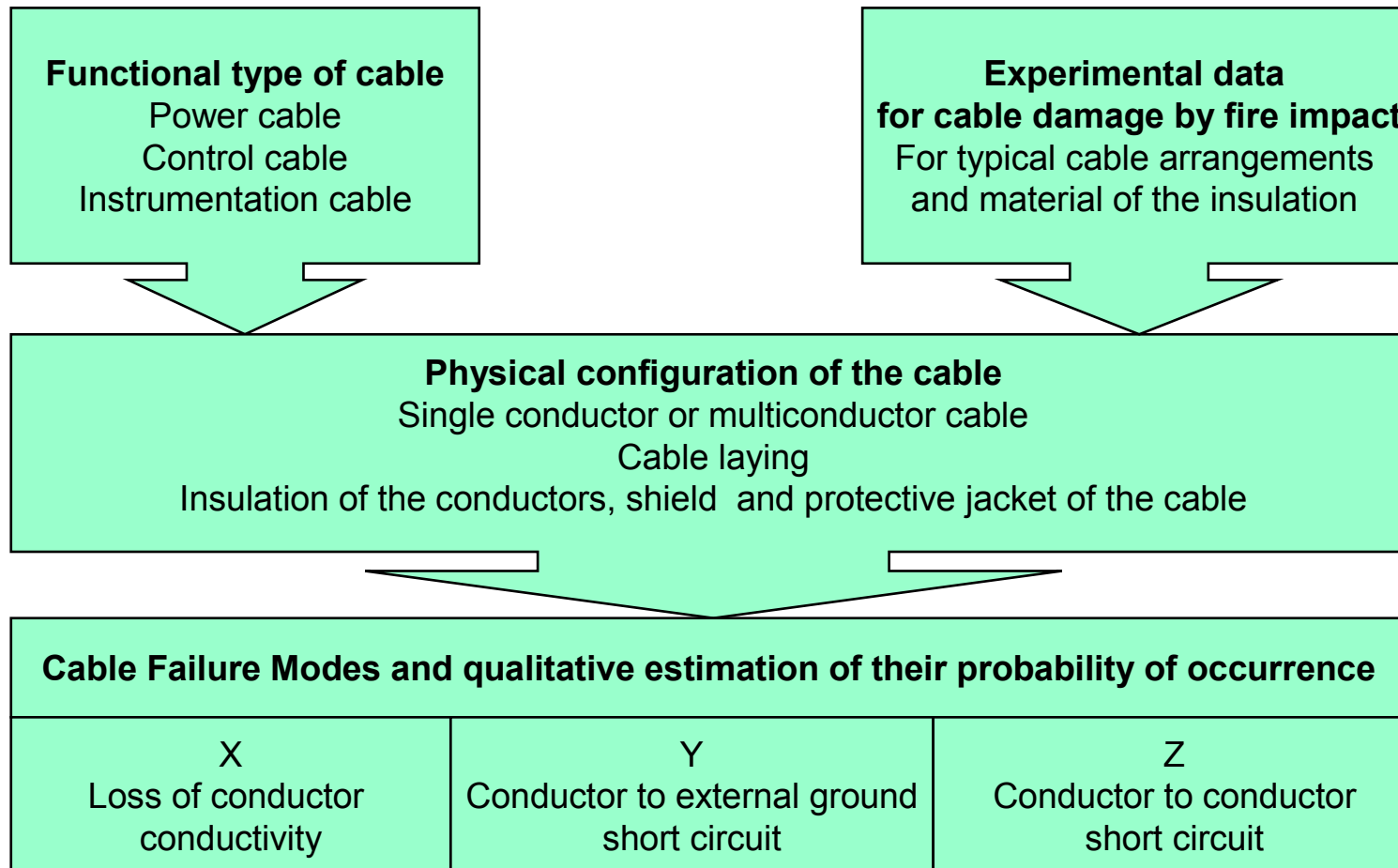




# Generic FMEA



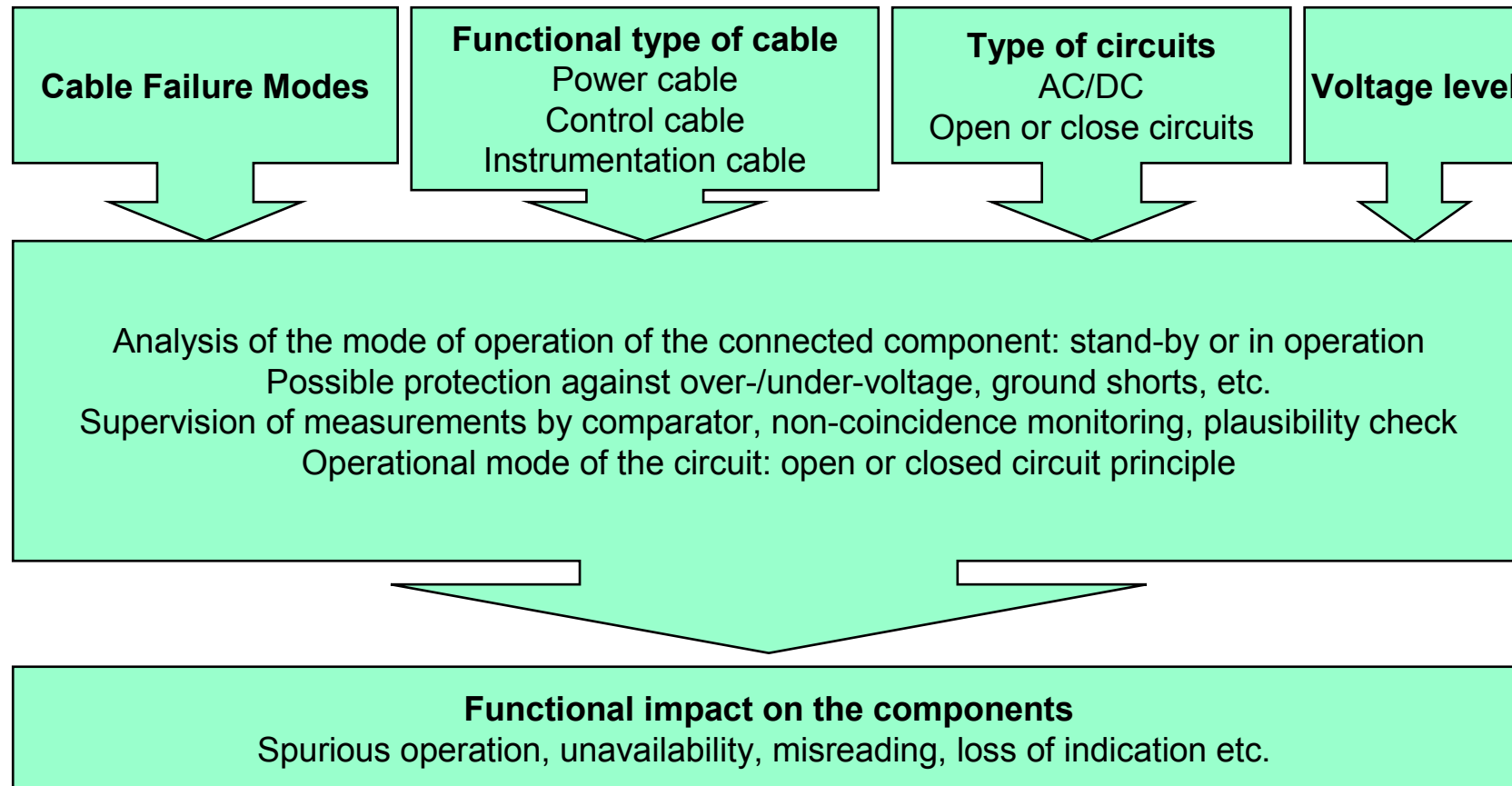
- Step 1: Identify cable failure modes



# Generic FMEA



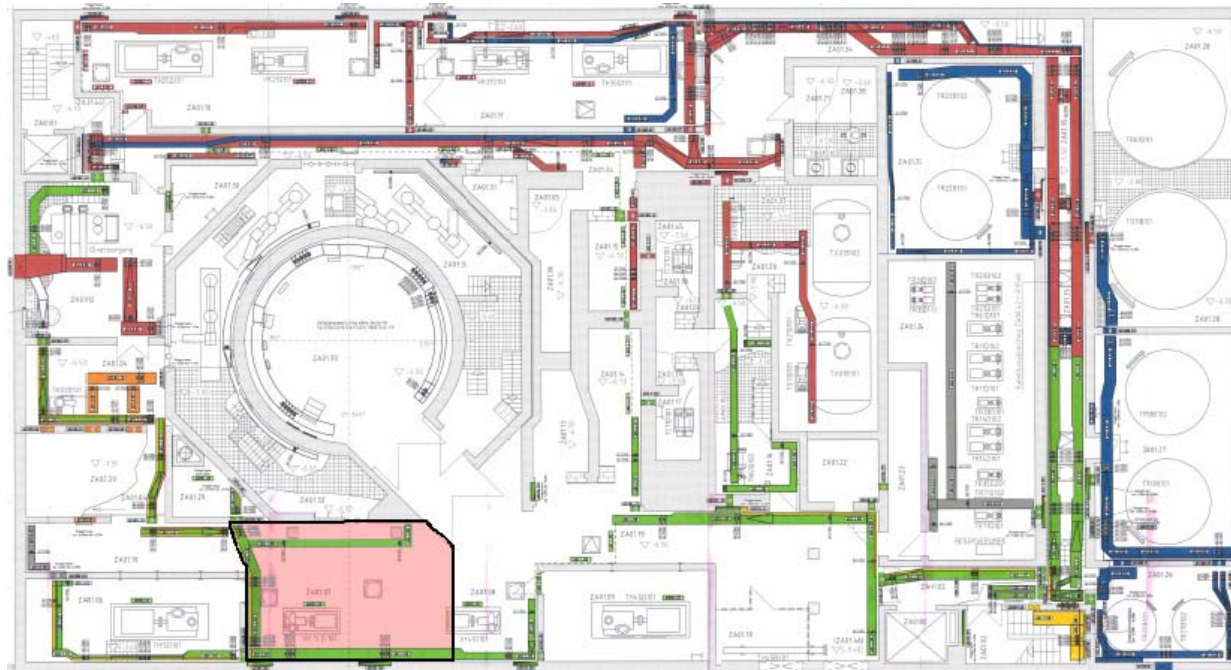
- Step 2: Analysis of circuit fault modes



# Testing the Cable FMEA for a Selected Compartment

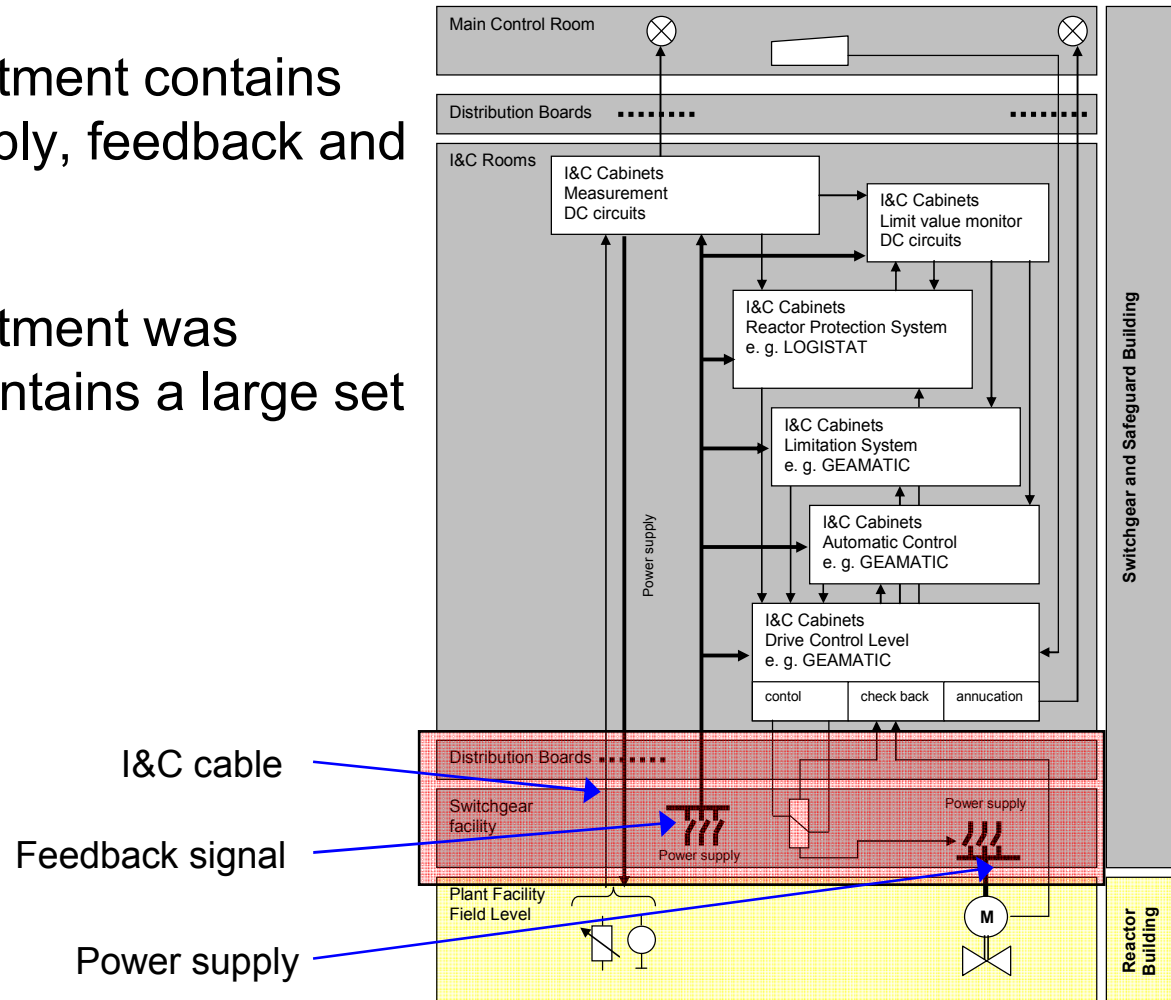


- Selection of a representative compartment in the reactor building of the reference NPP
  - Includes 432 cables with 932 individually identified functions



# Testing the Cable FMEA for a Selected Compartment

- The selected compartment contains cables for power supply, feedback and I&C
- The selected compartment was chosen because it contains a large set of different cables



# Database for FMEA (1)

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- Contains all relevant data on cable
- Contains information on components
  - Description, type, status in undisturbed power state
- Shows information about next but one neighbors of a selected cable
- Is used to record the results of the FMEA

# Database for FMEA (2)



**FMEA Eingabe**

**Raum**

- ZA01-02/G1
- ZA01-04
- ZA01-06
- ZA01-07**
- ZA01-08
- ZA01-09
- ZA01-10
- ZA01-11

**4 Kabel**

\* TH12S1 \*

Kabel-Nr	AKZ	Klartext	VonZielort	NachZielort	KabeltypNumm	Kabeltyp	AderzahlQuerschni	Lev	Redun	Strang	Kabelcod
1KA5021-A	TH12S101	X	1LK03	1KA04N006	7	J-Y(ST)Y	32x2x0,8 SIBD	3	01	1	14
1KA5021-A	TH12S101	X	1LK03	1KA04N006	7	J-Y(ST)Y	32x2x0,8 SIBD	3	01	1	15
<b>1KA5500-A</b>	<b>TH12S101</b>	<b>X</b>	<b>1KA04N006</b>	<b>1TH12S101</b>	<b>23</b>	<b>J-LYY</b>	<b>4x1x0,5 SIBD</b>	<b>3</b>	<b>00</b>	<b>1</b>	<b>14</b>
1KA5501-A	TH12S101	X	1KA04N006	1TH12S101	23	J-LYY	4x1x0,5 SIBD	3	00	1	15

Filter aufheben

**Kabel**

Kabel-Nr: 1KA5500-A  
 Kabelfunktion: Meldung 1 (Stellungsgeber/Endtaster)  
 Kabelfkt. Bemerkung: binäre Meldungen  
 Block:   
 Aderzahl / Querschnitt: 4x1x0,5 SIBD  
 Spannungsebene: MESS- UND STEUERKABEL BIS 60 V  
 Versagensbereich:  D  Schirm

**Komponente**

AKZ: TH12S101  
 Beschreibung: X  
 Von: 1KA04N006 in Raum ZA04-02  
 Nach: 1TH12S101 in Raum ZA01-06  
 Komponententyp: Rückschlagventil  
 Komponentenzustand: geschlossen  
 Stellung laut BHB: ZU  
 Bezeichnung laut BHB: hinter Flutraum Absetzbecken zum NKS 1

**Vorgänger**

VonZielort	Kabel-Nr
1LK03	1KA5021-A

**Nachfolger**

NachZielort	Kabel-Nr
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**Durchquerte Räume**

- ZA01-06
- ZA01-07
- ZA02-06
- ZA03-11/I
- ZA04-02/I

Kabelausfallart	Wahrscheinlich	Stromkreisfehler	Kommentar	Effekt auf Komponent	Basiselereignisse
▶ Unterbrechung	3- weniger wahrscheinlich z. B.	Signalausfall	Unterbrechung der Stromversorgung		
Erdschluss (Massekurzschluss)		Signalausfall		keine Rückmeldung	
mehrpoliger		Signalausfall		keine	

# Results of the FMEA

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- First results show some effects which up to now were not considered in Fire PSA which can be relevant for both the initiation and the control of an event sequence
  - Fire induced cable failures of feedback signals (mostly multiconductor cables) can negatively affect the functional control groups of PSA relevant components
  - Failure of power supply cables for the control circuitry (e.g. for I&C cabinets) which are routed via subdistribution boards, can result in common-cause failures
  - Fire induced spurious signals and failures of the power supply and I&C of the ventilation systems have to be investigated with regard to their Fire PSA relevance
- The results of the cable FMEA can not only be used for Fire PSA but also for other internal or external events which might cause cable failures

- Up to now only qualitative results
- Use of existing or new experiments to determine probabilities for the different cable failure modes
  - Starting from the probability of a fire in a compartment using the conditional probability of a certain cable failure in case of fire the probability of the component effect can be deduced
- Assessment of the different cable failure mode probabilities to determine the probabilities of fire induced
  - Initiating Events
  - Failures of system functions
- Evolution of cable failures over time



# Conclusions

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- Detailed information about all safety relevant cables in the NPP are vital for Fire PSA
- Pilot application of FMEA of all cables in a representative compartment showed the feasibility of the approach
- Up to now only qualitative statements about failure modes and effects have been obtained
- Next step will be an extension to gain quantitative results