FMEA of Cable Failures within a Fire PSA

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

- 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)

- 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

Project Objectives

- 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

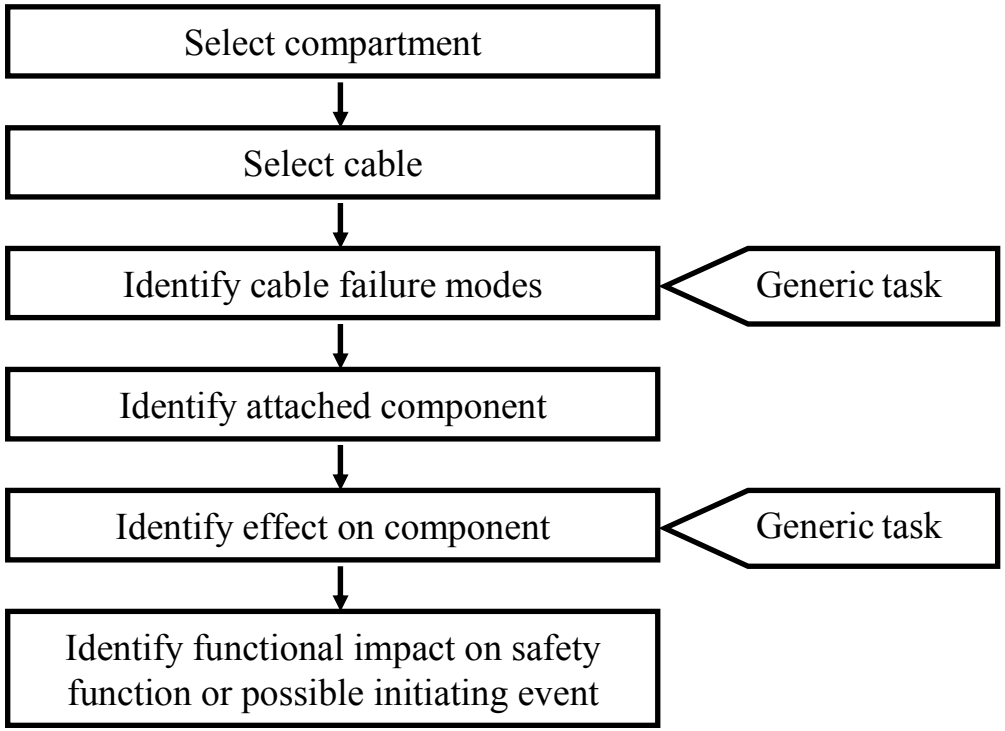
Determination of Necessary Cable Data

- 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

Cable Failures

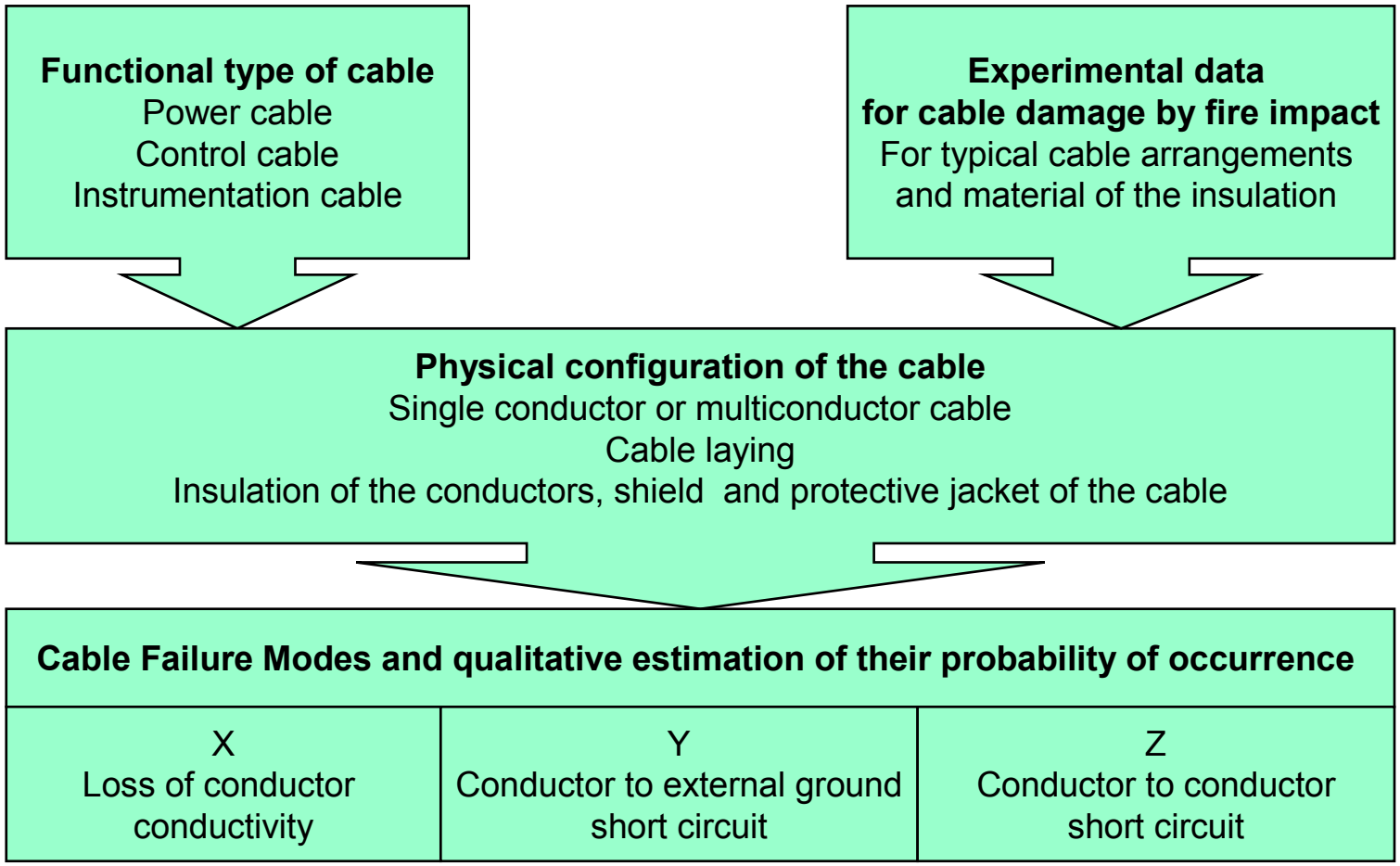
- Failure criteria
  - Critical temperature in compartment depending on cable insulation material and cable function
- Failures types
  - Short to ground
  - Hot short
  - Interruption of cable
  - Multipolar short
- Experimental results for cable failures
  - Results from iBMB of Braunschweig University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

Procedure for Performing the Cable FMEA



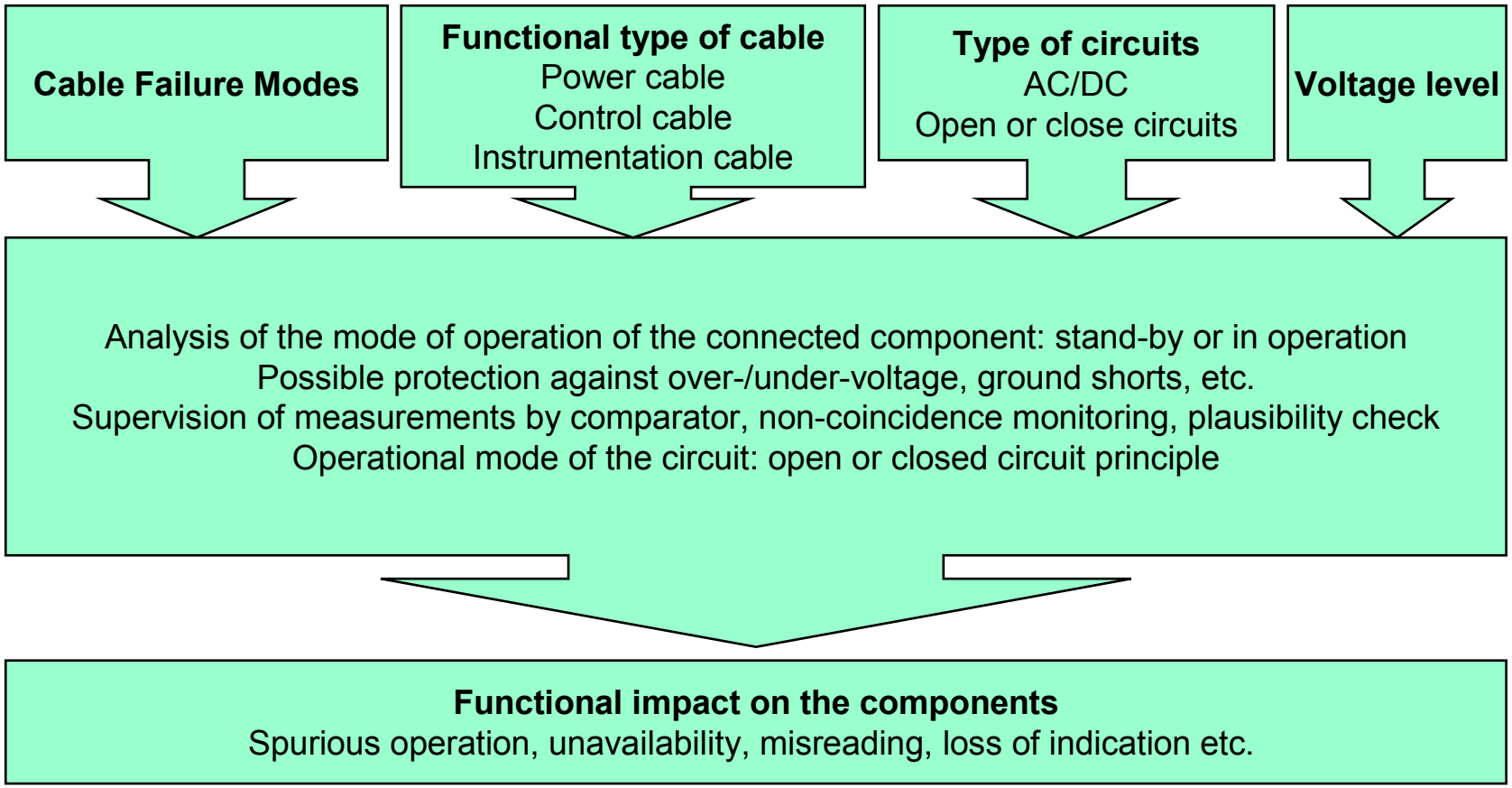
Generic FMEA

- Step 1: Identify cable failure modes



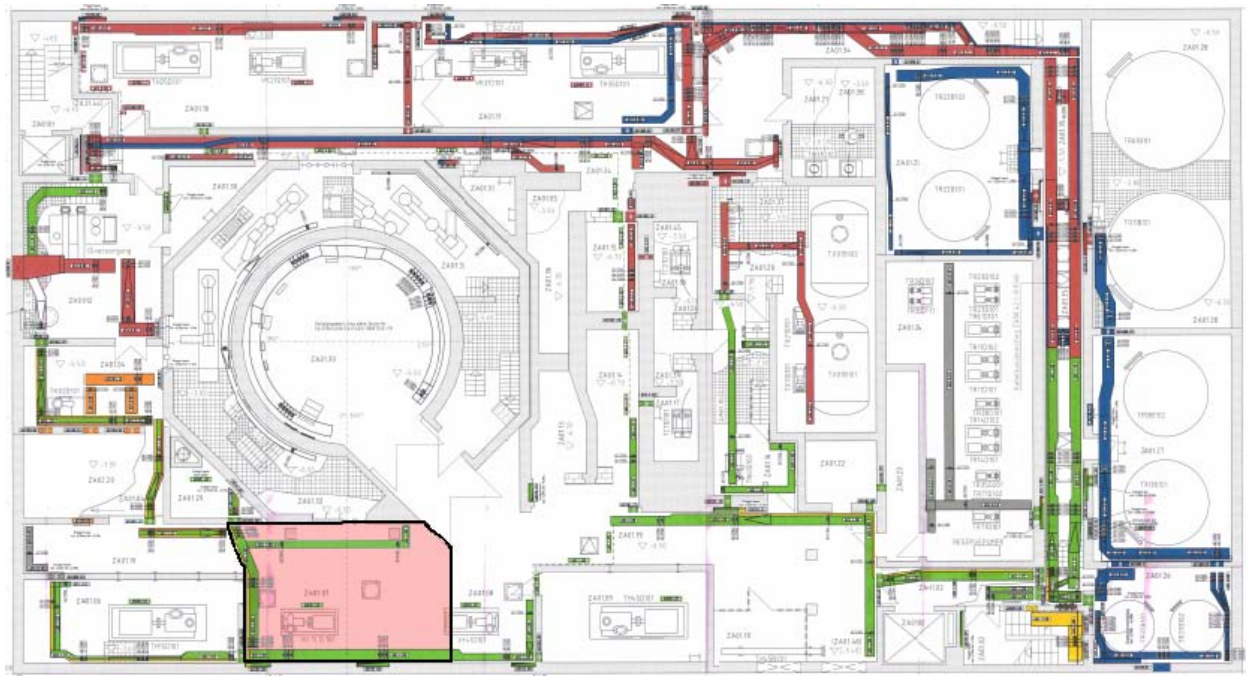
Generic FMEA

- Step 2: Analysis of circuit fault modes



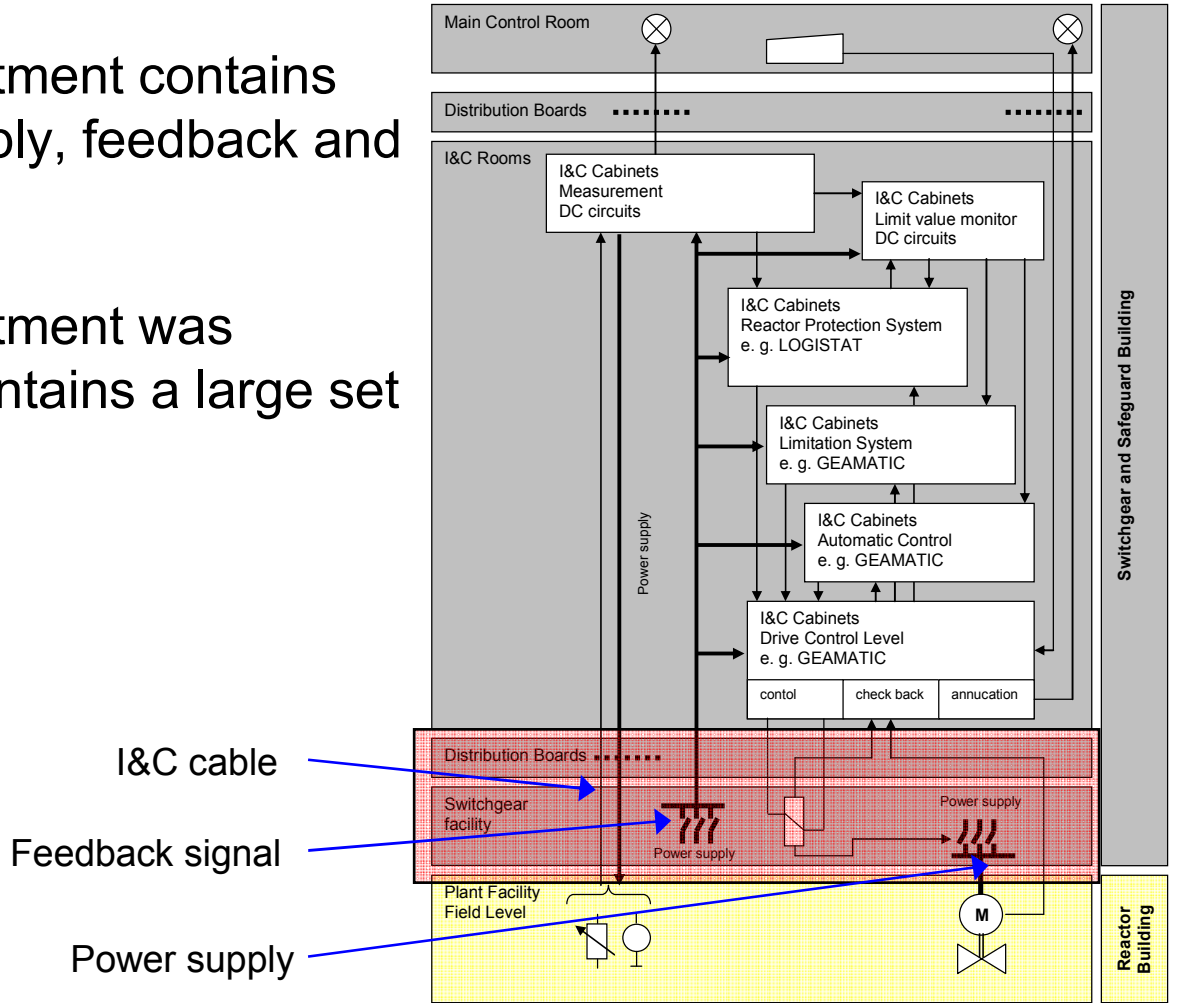
Testing the Cable FMEA for a Selected Compartment

- 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

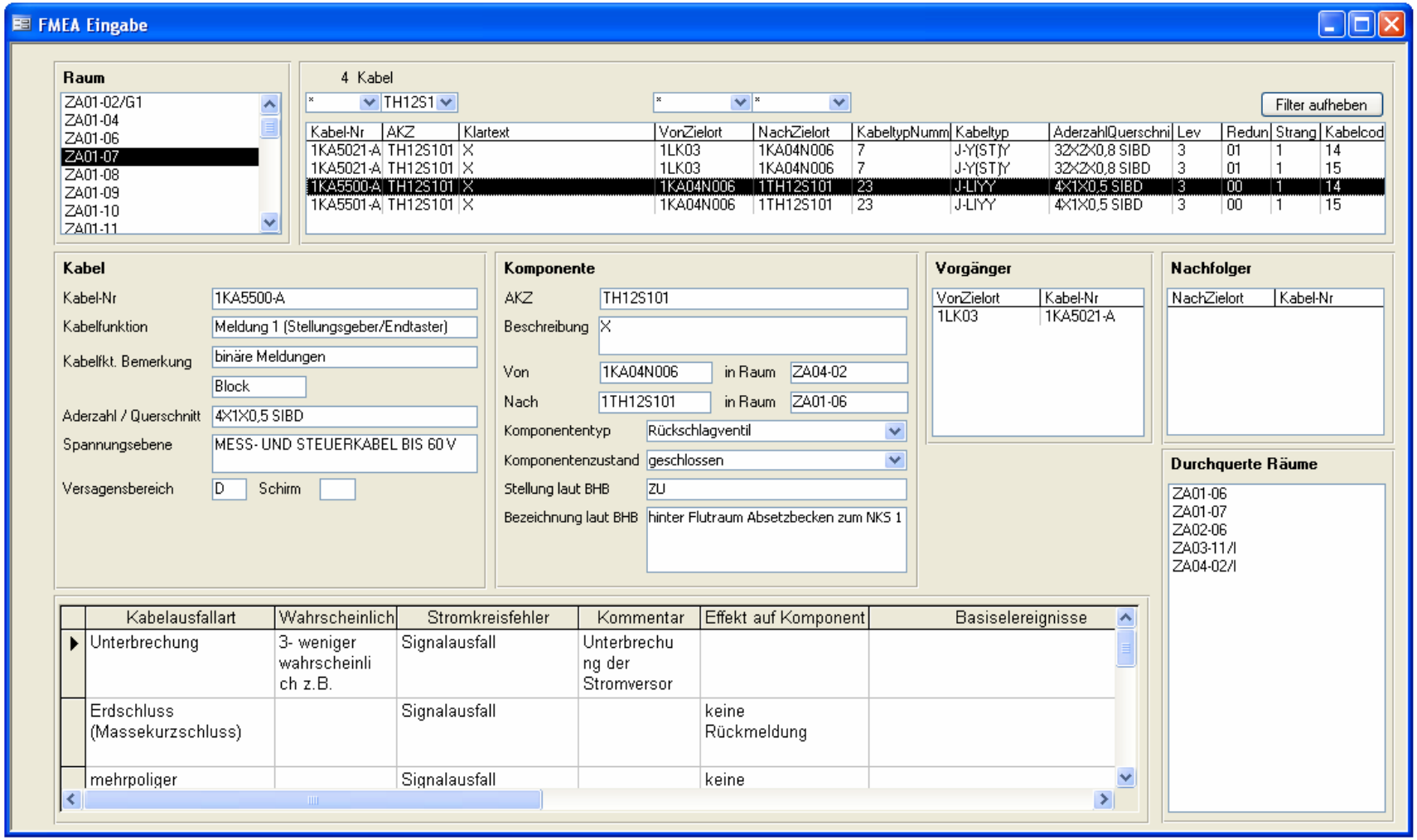
- The selected compartment contains cables for power supply, feedback and I&C
- The selected compartment was chosen because it contains a large set of different cables



Database for FMEA (1)

- 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)



Results of the FMEA

- 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

Proposed Extensions

- 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

- 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