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Internal Flooding according to EPRI guidelines – Detailed Electrical Mapping at Ringhals Nuclear Power Plant

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EPRI Guidelines for performance of Internal Flooding PSA

- Guidelines (EPRI Report 1019194) consists of 11 tasks
  - Tasks 1-4: Qualitative assessment based on identifying flood areas, sources, SSCs and screening.
  - Tasks 5-10: Quantitative modelling based on characterizing flood scenarios, initiating events, consequences and mitigation. At the end of the Quantitative modelling, flooding analysis is modelled and quantified as an integral part of the PSA.
  - Task 11: Documentation
- Focus of paper is on Task 2: Identification of flood sources/mechanisms and SSCs affected by flooding.

EPRI Task 2: Flood sources/mechanisms and SSCs affected by flooding

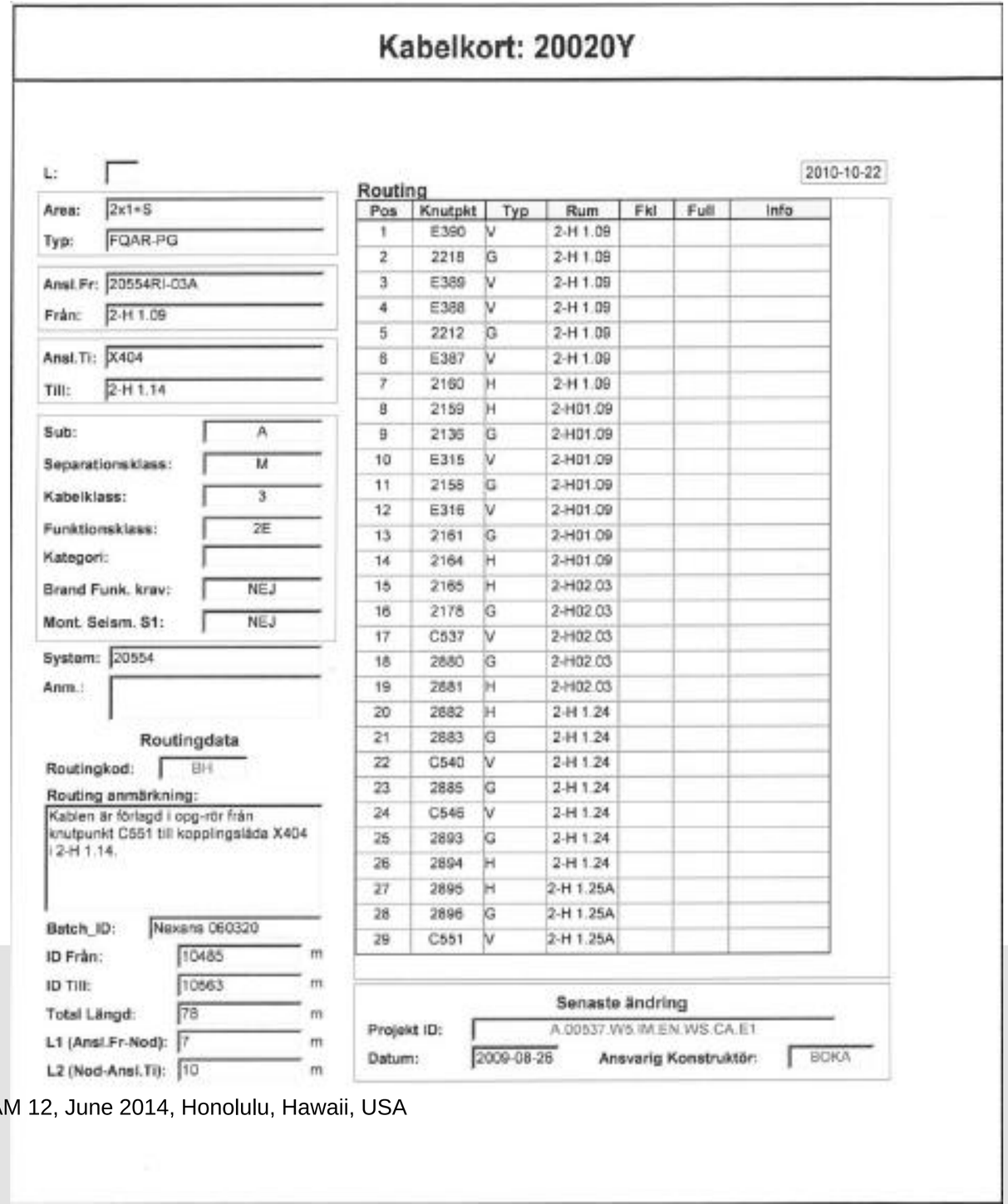
1. Identify the sources of flood in flood areas; steam hazard is also taken into consideration in the evaluation.
2. Identify the plant item affected by flooding (and steam hazard)
   eg pumps or valves.
   - Dependencies to electrical systems are the main focus of analysis
   - An affected valve/pump may be dependent on
     – electrical power for the actuator/pump motive power, ie electrical power system
     – electrical actuation signals, ie I&C
   - Resulting electrical dependencies fan out to sub-components of the electrical system
     – Cables
     – Junction boxes
     – Protection circuitry
3. Electrical Dependencies of sub-components in electrical systems of main components modelled in PSA crucial for capturing consequences of flooding.

Evaluation of Electrical Dependencies at Ringhals

- Detailed information on electrical systems already exists. Information collected in two databases:
  - Cable Database: Lists cables including routing information and connected plant items
  - Circuit Breaker and Plant Item Database: Builds on plant items in cable database by adding micro circuit breaker information
- Internal flooding analysis information collected in new database:
  - Flooding Database: Combines information from Cable and Circuit Breaker and Plant Item Databases with flooding scenario analysis.

Cable Database

- Establishes Connected Plant Items
  - Example cable runs from 20554RI-03A to X404
  - Junction boxes, pumps, actuators (no circuit breakers)
- Establishes Cable Routing
  - Rooms entered
  - Branch points (identifying cable positions within rooms)
- Kept living



Kabelkort: 20020Y

L:

2010-10-22

Area: 2x1+S
Typ: FQAR-PG

Ansl.Fr: 20554RI-03A
Från: 2-H 1.09

Ansl.Ti: X404
Till: 2-H 1.14

Sub: A
Separationsklass: M
Kabelklass: 3
Funktionsklass: 2E
Kategori:
Brand Funk. krav: NEJ
Mont. Seism. S1: NEJ

System: 20554
Anm.:

Routingdata

Routingkod: BH

Routing anmärkning:
Kablen är förlagd i opg-rör från knutpunkt C551 till kopplingslåda X404 i 2-H 1.14.

Batch_ID: Nexans 060320
ID Från: 10485 m
ID Till: 10563 m
Totel Längd: 78 m
L1 (Ansl.Fr-Nod): 7 m
L2 (Nod-Ansl.Ti): 10 m

Routing

Pos	Knutpkt	Typ	Rum	Fkl	Full	Info
1	E390	V	2-H 1.09			
2	2218	G	2-H 1.09			
3	E389	V	2-H 1.09			
4	E388	V	2-H 1.09			
5	2212	G	2-H 1.09			
6	E387	V	2-H 1.09			
7	2160	H	2-H 1.09			
8	2159	H	2-H01.09			
9	2135	G	2-H01.09			
10	E315	V	2-H01.09			
11	2158	G	2-H01.09			
12	E316	V	2-H01.09			
13	2161	G	2-H01.09			
14	2164	H	2-H01.09			
15	2165	H	2-H02.03			
16	2178	G	2-H02.03			
17	C537	V	2-H02.03			
18	2880	G	2-H02.03			
19	2881	H	2-H02.03			
20	2882	H	2-H 1.24			
21	2883	G	2-H 1.24			
22	C540	V	2-H 1.24			
23	2885	G	2-H 1.24			
24	C546	V	2-H 1.24			
25	2893	G	2-H 1.24			
26	2894	H	2-H 1.24			
27	2895	H	2-H 1.25A			
28	2896	G	2-H 1.25A			
29	C551	V	2-H 1.25A			

Senaste ändring

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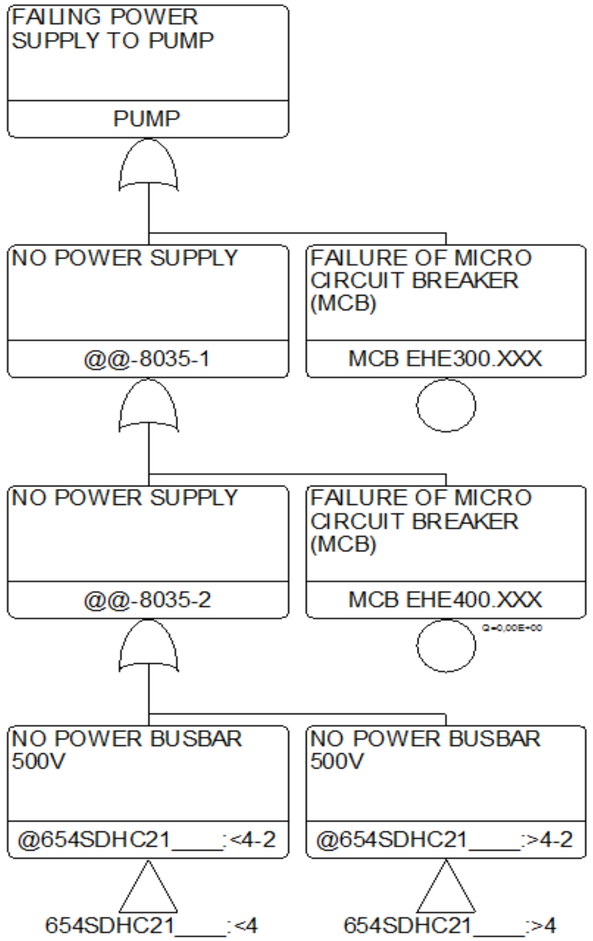
Circuit Breaker and Plant Item Database

Using a sub-set of Cable Database information provides an interface to the PSA

- Provides electrical connections between plant items
- In addition to Cable database plant items, adds micro circuit breakers
- Contains information on dependencies between plant items modelled in the PSA
- Junction boxes and cables not explicitly modelled in PSA
- In PSA the dependencies are modelled through the micro circuit breaker basic events.



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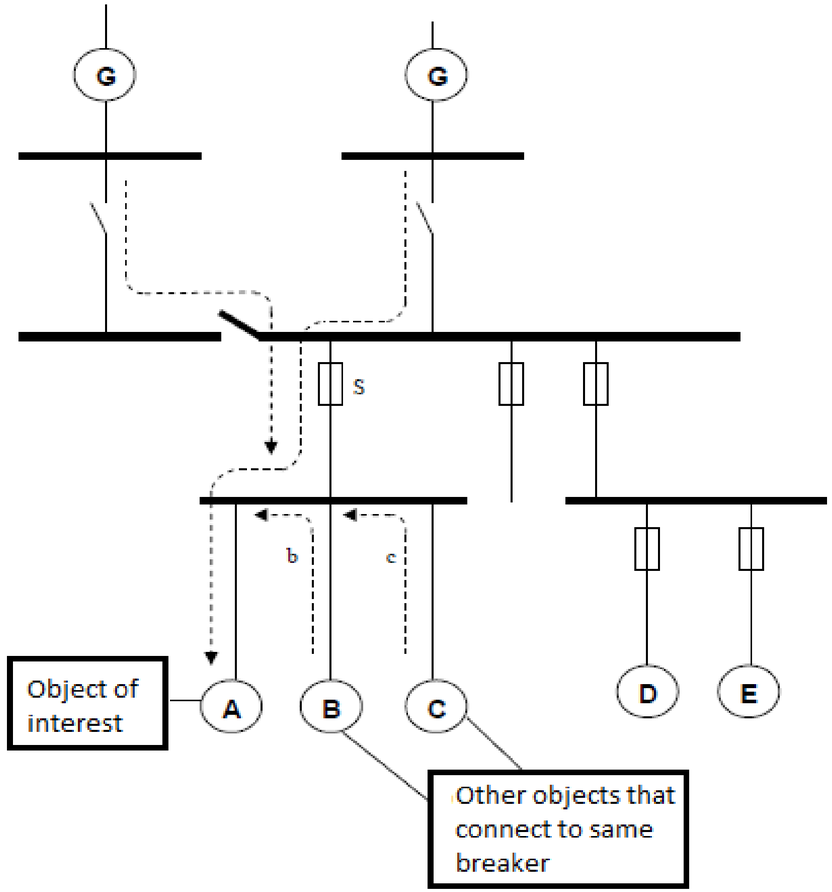
Circuit Breaker and Plant Item Database Example

- Several plant items ((A,B,C) and (D,E)) connected to single Micro Circuit Board, creating dependencies
- Plant items A, B, and C could be located in three different rooms, and cables to plant items could be routed through additional rooms.
- Creates inter-plant item dependencies and associated inter-room dependencies of importance to flooding scenarios
- Several plant items connected to a single Micro Circuit Board creating dependencies
- Critical to correctly track all dependencies before impact of flooding scenarios is superimposed



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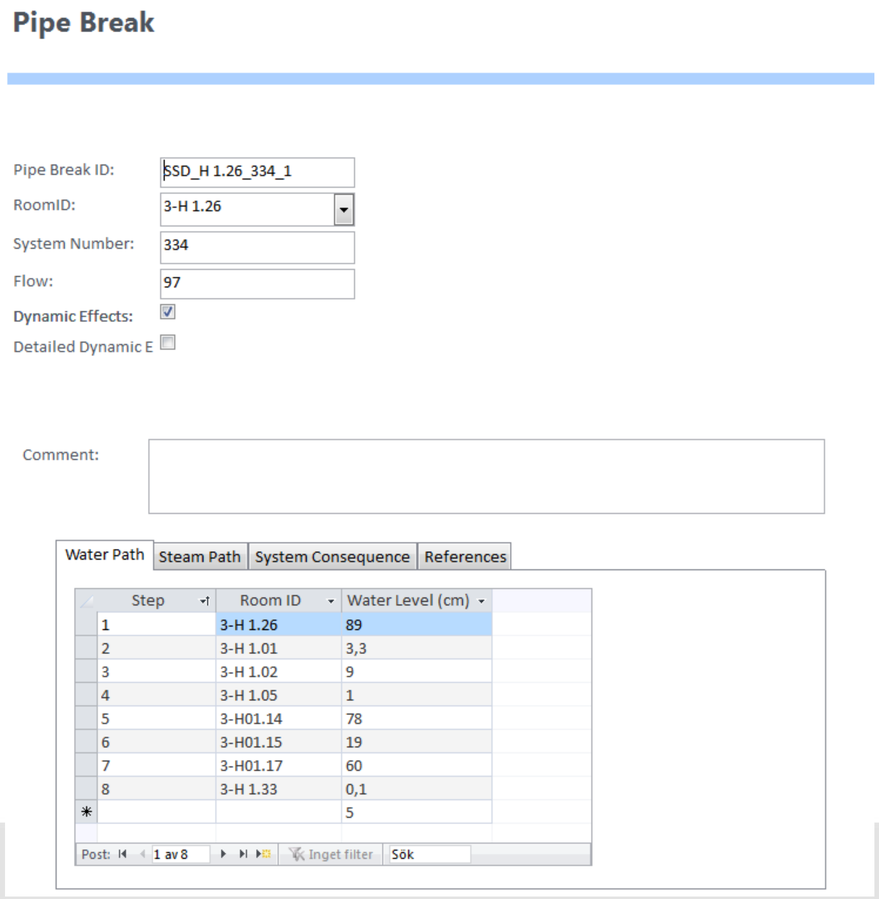
Flooding Database: Superimposing the flooding scenarios

- Includes information on cables (from the cable database) and circuit breakers including connected plant items (from Circuit Breaker and Plant Item database)
- Utilizes flooding scenario information and superimposes it onto the detailed electrical information
- Enables a mapping of micro circuit breakers which can be deemed failed in a given flooding scenario
- PSA only models key plant items (eg valves and pumps) and micro circuit breakers
- Dependencies to room locations and other plant items (eg cubicles) are incorporated into the state of modelled micro circuit breakers
- For a single Ringhals unit, the database includes records for 3000 cables and 800 cabinets

Flooding Database: Example contents

Scenario



Plant Item Hazard Susceptibility Information

ObjectID	Type	Steam Proof	Water Proof	Level (cm)	Fire Proof	Smoke Proof
303348154.41	Valve	False	False	0	False	False
30334CSAPBA-01.01	Pump	False	False	10	False	False
302950	Cable	True	True	0	False	False

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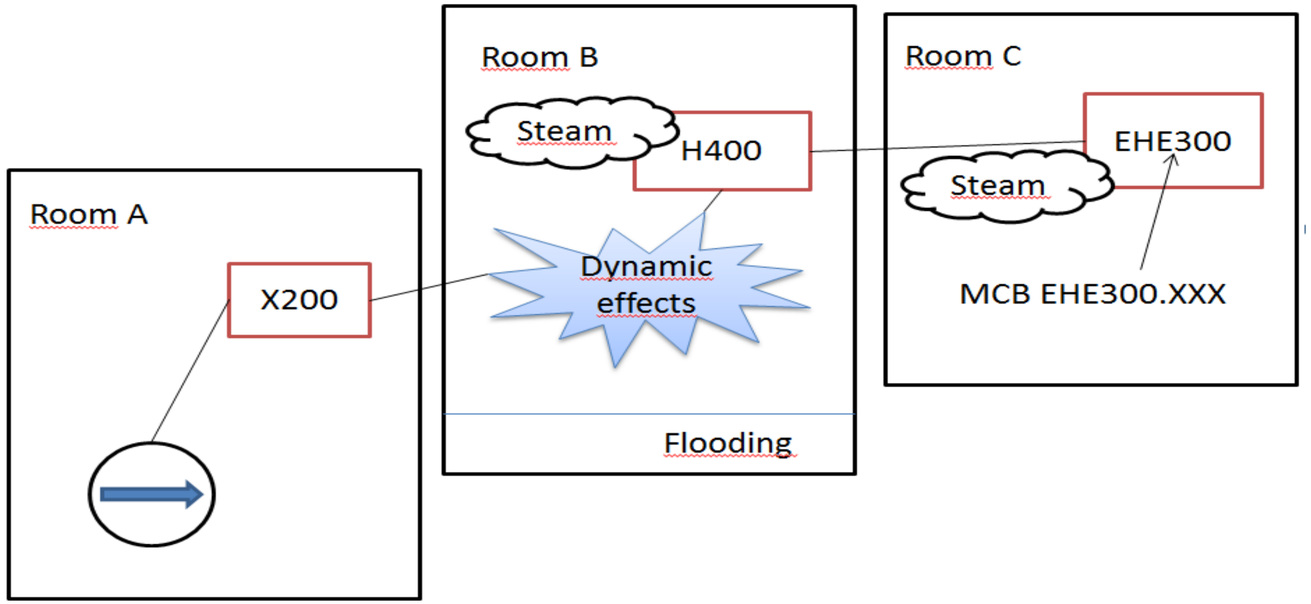
Flooding Database: Example application to flooding scenario

- High-energy break flood scenario
- Dynamic effects impact cable between X200 and H400.
- Flood source contained within source location
- Steam penetrates from source location into Room C
- Steam damages micro circuit breaker EHE300.XXX
- Failed micro circuit breaker modelled in PSA causes pump to fail
- Only through interrogation of flooding database can root cause(s) of plant item failures be established



Concluding remarks on the detailed electrical mapping approach

- Automatic PSA implementation: Flooding analysis cases and boundary conditions are automatically set up in the PSA
- Visualizes dependencies clearly and enables easy interrogation of consequences of a given flood scenario
- The database approach for storing the information facilitates easy update of the detailed underlying information and PSA
- Application of the electrical mapping approach provides a detailed overview of potential vulnerabilities implied by the dependencies
  - May point to relatively benign electrical reconfigurations which could yield significant safety improvement
  - Applied to plant items essential for continued plant operation could lower commercial risk by minimizing risk for unplanned plant shutdowns

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