Internal Flooding According to EPRI Guidelines – Detailed Electrical Mapping at Ringhals

Per Nyström[a], Carl Sunde[a], and Cilla Andersson[b]
[a] Risk Pilot, Gothenburg, Sweden
[b] Ringhals AB, Varberg, Sweden

Abstract: Eleven different tasks should be executed according to the EPRI guidelines for performing internal flooding PSA. Task 2 deals with identification of flood sources/mechanisms as well as with Systems, Structures and Components (SSCs). In this task it is briefly mentioned that not only the main components such as pumps and valves can be affected by flooding but also associated components such as circuit breaker, junction boxes and instrumentation and control circuitry are affected. It is fairly easy to locate the main components as well as the impact of flooding on these components. However it is more difficult to make a detailed mapping of the cable routing and the electrical dependencies (at Ringhals called electrical mapping) for the main components. This paper describes how this type of work is being executed and documented at Ringhals NPP in Sweden.

Keywords: Flooding, PSA, Database, Electrical mapping, Ringhals

1. INTRODUCTION

When performing a flooding analysis in accordance with the EPRI guidelines for performing internal flooding eleven different tasks should be considered [1]. Task 1-4 are associated with qualitative evaluation of flood phases such as defining flood areas and identifying flood sources and components, while task 5-10 are quantitative evaluation phases where evaluation of flood areas, that have not been screened out in the qualitative phases are performed. The quantitative phases consider the implementation of the flooding analysis in the PSA-model. The last task described in the guidelines is documentation. This task is an ongoing work and should be considered during each of the 10 tasks mentioned before.

The main concern in this paper is the second task in the EPRI guidelines, [1], which consists of the identification of flood sources/mechanisms and Systems, Structures and Components (SSCs). More specifically this paper will deal with how to identify and analyze electrical components associated with the plant main components at Ringhals NPP in Sweden.

Ringhals NPP is located on the west coast of Sweden approximately 60 km south of Gothenburg. The site consists of four reactors, one ASEA-ATOM BWR and three WESTINGHOUSE PWRs with the oldest one set in operation in the year 1975.

2. MAIN COMPONENTS AND ASSOCIATED ELECTRICAL COMPONENTS

As explained in the second task of the EPRI guidelines, [1], an identification of all interesting components must be performed to be able to perform a flooding analysis. It is also pointed out that not only the main components should be considered but associated dependent electrical components such as circuit breaker, junction boxes and instrumentation and control circuitry as well. The function of a main component is in most cases dependent on several components and failure of any of these may be crucial. The main components are presented in the PSA-model but the associated electrical components are hidden in the electrical mapping. For example a valve has dependencies to power supply and activation which in turn have dependencies to cables and junction boxes.

How the detailed electrical mapping is performed and used in the flooding analysis at Ringhals NPP will be described in chapter 3.

3. METHOD

In chapter 2 it is described how components at a NPP are dependent on different electrical components and a failure of the electrical components can lead to a failure of the main component. In order to keep track of all different electrical components and how they affect the main components it is of major importance to make a detailed mapping of the cable routing and the electrical dependencies (at Ringhals called electrical mapping) for the main components. The aim of this chapter is to describe the different steps when working with electrical dependencies in the PSA-model at Ringhals NPP and how to use this information when performing a flooding analysis.

The electrical dependencies in the PSA-model at Ringhals NPP are based on three different databases that process information about cables and components. The three databases are:

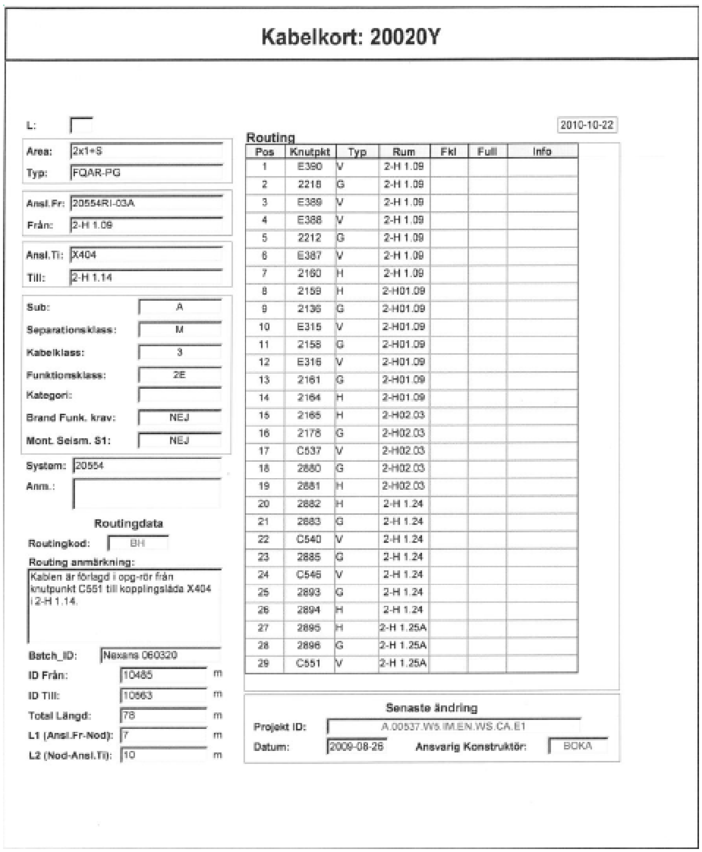
1. Cable database
2. Database of objects and connected micro circuit breaker (Object-MCB)
3. Database that compiles step 1 and 2 with flooding analysis.

The three steps will be described in the following subsections.

3.1. Cable database

The first step in processing information about cables and components consists of a database called cable database where information about all the cables is stored. This database is a living product where information is added whenever a new cable is installed or rerouted. It consists of cable routing (through which rooms the cable runs) and connected objects that can vary from pumps or valves to small cabinets. In Figure 1 an example is given of how the information about cables in the database is presented. The cable normally runs in cable trays that have connection points and this makes it possible to locate the cable in cable drawings and during walk downs. The name of the cable in the example in Figure 1 is 20020Y and it is runs from object 20554RI-03A in room H 1.09 through a number of rooms that can be seen in the right table to object X404 in room H 1.14. This information about cables and connected objects is then used to build up the second database which will be described in the next subsection.

Figure 1: Cable card – routing information



Kabelkort: 20020Y

L:

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
Total Längd: 78 m
L1 (Ansl.Fr-Nod): 7 m
L2 (Nod-Ansl.Ti): 10 m

2010-10-22

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	2136	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			

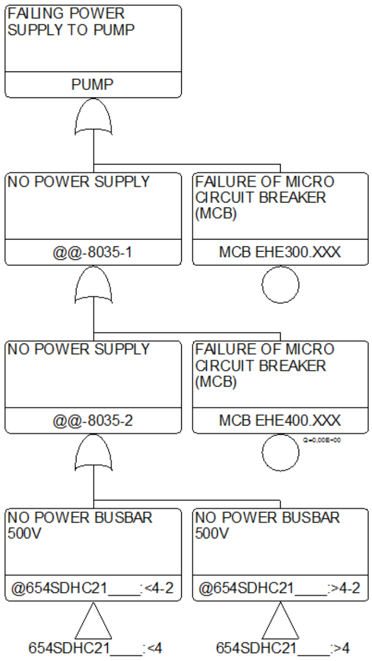
Senaste ändring

Projekt ID: A.00537.W5.IM.EN.WS.CA.E1
Datum: 2009-08-26 Ansvarig Konstruktör: BOKA

3.2. Database of objects and connected micro circuit breaker

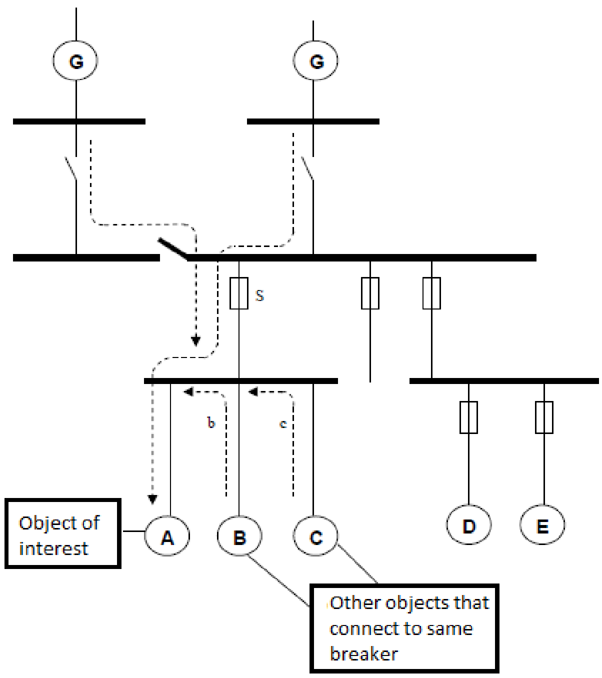
The second step of the electrical mapping consists of making the information about cables compatible with the PSA-model and to identify cables and power supply for objects of interest. Objects in the PSA-model have dependencies to micro circuit breakers (MCB) and analogous for cables. Cables are not presented in the PSA-model explicitly but can be found through their dependencies to the MCBs. The relationship between MCBs, cables and objects are compiled in a second database, called Object-MCB database. This database presents all the room dependencies for the MCBs and connect these dependencies to the objects in the PSA-model. The MCB will represent connected cables and junctions hence the room dependence for the MCB will include all rooms that connected objects pass through. The MCBs with corresponding room dependencies can be found in the PSA-model on each of the interesting objects and therefore the location of objects in the PSA-model and their room dependencies is mapped in a satisfying way. An example of how the components and connected MCBs are presented in the PSA-model can be seen in Figure 2. The example consists of a pump and connected MCBs between the pump and feeding power busbar (power supply). There are two MCBs in the example; EHE300.XXX and EHE400.XXX. In these breakers all the room dependencies from the electrical mapping is collected. Failure of any of these breakers will lead to a failing power supply to the pump, i.e failure of any of the components connected to the MCBs such as cables and junction boxes will lead to a failing power supply to the pump.

Figure 2: Main component and connected MCB:s in the PSA-model



It should also be noted that several objects can be connected to the same MCB and therefore a detailed mapping is of great importance. In the example in Figure 3 three different objects (A/B/C) are connected to the same micro circuit breaker (S) and failure of any of these objects is assumed to trip the MCB and result in failure of all three objects. The objects A, B and C can be located in three different rooms and cables connected to them can be routed through additional rooms.

Figure 3: Dependencies to micro circuit breaker



It is crucial to keep track of these dependencies when performing a flooding analysis because when for example a pump fails it's not always the pump that's the reason but a connected object. The connected object may have a direct connection to the pump or maybe a completely different function in which it is just connected to the same MCB.

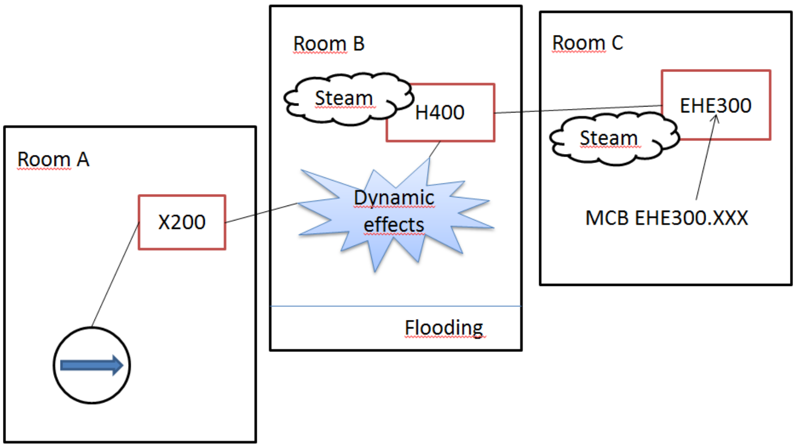
The third step of the work with electrical dependencies in the PSA-model will be described in the next subsection.

3.3. Detailed electrical mapping and flooding analysis

The third and last step of the electrical mapping consists of compiling information from the detailed electrical mapping performed in step 1 and 2 and adding the different flooding scenarios. This compilation is done in a third database which is also used for easily importing the electrical dependencies into the PSA-model.

All micro circuit breakers (MCB) that are represented in the PSA-model and mapped in the previous steps can be found in this third database with connected objects. In the PSA-model only the main components for example pumps are represented and no cables and cabinets can be found. Cables and cabinets can however be found in this third database and therefore it's a powerful tool when determining the reason for a failing object in case of a flooding. The reason for a failure as previously explained, does not always have to be a failure of the main component but could also be a failure of a connected object, for example a cable or a cabinet. In the PSA-model it will only be indicated which MCB that has failed but by using the database additional information can be obtained. An example of how the connections between a main component in this case a pump and the micro circuit breaker can be seen in Figure 4. The component chain in Figure 4 consists of a pump pictured as a circle with an arrow located in room A and three cabinets located in room A, B and C. The pipe break occurs in a high energy line in room B resulting in dynamic effects on the cable between cabinet X200 and H400. The water does not propagate further but steam spreads into room C and damage cabinet EHE300 where the micro circuit breaker (EHE300.XXX) is located. No steam or water propagates into room A where the pump is located and therefore the component chain between the main component and the MCB is crucial. Otherwise the pump function would not seem to be affected by the pipe break which it actually is. In the PSA-model only the failing MCB is shown (see Figure 2). However by using the database one can conclude that it actually is the components located in room B and C that fails.

Figure 4: Components between pump and MCB and their exposure in case of pipe break



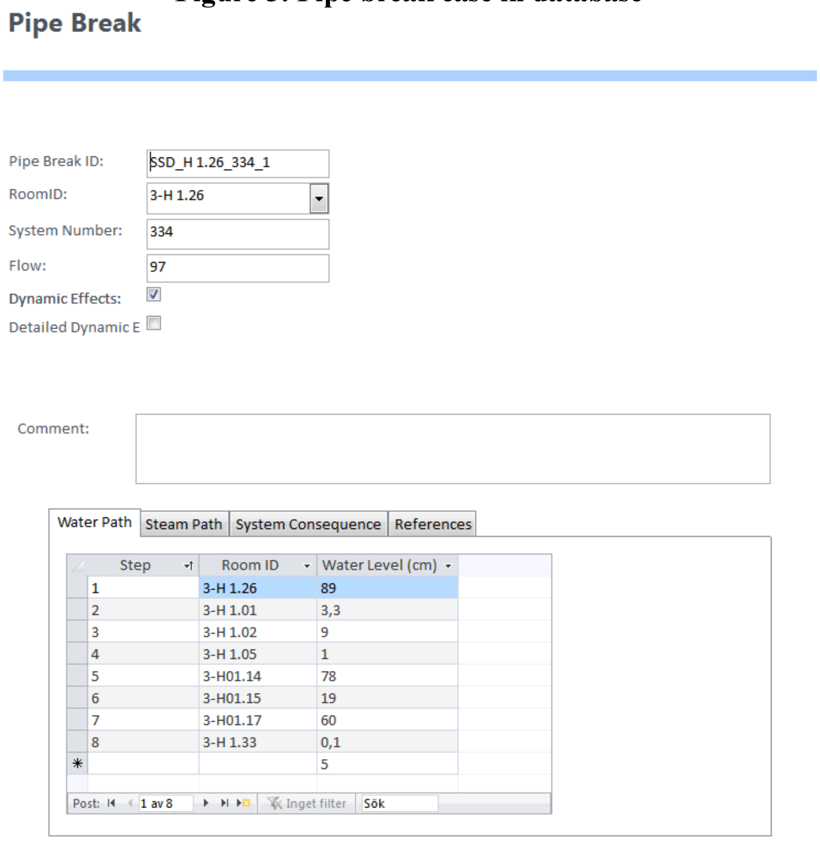
As shown in Figure 4 information about the studied objects are of great interest when performing a flooding analysis, not only in which room they are located but also for example on what level above the floor they are placed and if they are water/steam protected. Therefore all such information that can be of help is collected and compiled in this third database, an example can be seen in Table 1. This information can be of importance when analyzing the consequences of flooding. One example of important information is if an object is above the actual water level or not. If the object is above the actual water level this means that it would not be damaged by water drowning.

Table 1: Collected information about objects

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

Other example of information that is used when performing a flooding analysis and compiled in the database is flow paths for water, blow aperture for steam and potential dynamic effect sources. The information about water paths and blow apertures consist of where the pipe breaks occurs, flow rate, expected water level along the water path and to which rooms the water or steam propagates. Dynamic effects are analyzed in case of pipe break in high energy lines and only analyzed in the room where the pipe break occurs. A piping system is defined as high-energy line if the operating temperature is equal to or exceeding 93^{O}C (200^{O}F) or internal operating pressure equal to or exceeding 20 bara (275 psig). An example of a how a pipe break case is presented in the database can be seen in Figure 5.

Figure 5: Pipe break case in database



Pipe Break

Pipe Break ID: SSD_H 1.26_334_1
RoomID: 3-H 1.26
System Number: 334
Flow: 97
Dynamic Effects: ☑
Detailed Dynamic E ☐

Comment:

Water Path | Steam Path | System Consequence | References

Step	Room ID	Water Level (cm)
1	3-H 1.26	89
2	3-H 1.01	3,3
3	3-H 1.02	9
4	3-H 1.05	1
5	3-H01.14	78
6	3-H01.15	19
7	3-H01.17	60
8	3-H 1.33	0,1
*		5

Post: 1 av 8 Inget filter Sök

This example represents a pipe break in room H 1.26 in system 334. System 334 is defined as a high energy system in room H 1.26 and therefore dynamic effects are analyzed. The water path for a pipe break in room H 1.26 can be seen in the sheet "Water path" and the water propagates in the example from room H 1.26 after reaching 89 cm to room H 1.01, H 1.02 and further. The sheet "Steam Path" is composed in the same way as "Water Path" and therefore no further explanation is needed. The sheet "System Consequence" can be used in case the pipe break results in failure of the whole system or a part of the system. For example a pipe break in a pipe from one pump is not only a source of flooding but the consequence can also be an unavailable pump. The sheet “References” is used to keep track of all references such as separate analysis of water paths and blow apertures for steam.

After collecting all information that could be useful for defining the pipe break cases a group of analysis cases are created and exported to the PSA-model. The analysis cases have corresponding boundary conditions that specifies the water/steam path and possible dynamic effects or system consequences which is also exported to the PSA-model. By using a database this work is automated and possible human errors in implementing the cases in the PSA-model is depleted. This work responds to the quantitative phases of the EPRI guidelines, [1], for performing a flooding analysis which includes implementation in the PSA-model.

Even after implementing the flooding analysis cases in the PSA-model usage of the database continues. If a deeper study of the analysis cases with reason to failing objects needs to be done a complete list of failing objects is to be found in the database and not in the PSA-model. Therefore the work with the database follows through all the tasks which are considered when performing a flooding analysis in accordance with the EPRI guidelines, [1].

4. CONCLUSION

According to the EPRI guidelines, [1], the second step in performing a flooding analysis is identification of flood sources/mechanisms and Systems, Structures and Components (SSCs). In order to completely perform this task it is of major important not only to identify main components but also associated electrical component. Therefore, it is of major importance to make a detailed electrical mapping in order to perform a complete flooding analysis. At Ringhals NPP three different databases are used for the detailed electrical mapping. By storing information in a database it is easy to maintain and update the electrical mapping and it is also easy to update the PSA-model. Quality assurance of electrical mapping is improved by using a database, this since it is more manageable to review and the database also creates a useful overview over large quantity of information. For example there are about 3000 cables and 800 cabinets handled in the final database discussed above for one of the reactors at Ringhals NPP.

The PSA-model only model the main components such as pumps and valves with room dependencies but there are also other objects that affect the main components. These are hidden in the electrical dependencies in the PSA-model. By using a database that compiles these electrical dependencies other objects such as cables and cabinets that affect the main components can easily be detected. Without this information a flooding analysis would be incomplete and would provide an inaccurate image of an actual pipe break scenario.

Acknowledgements

Thanks to Ringhals AB who has made this paper possible.

References

[1] EPRI – Guidelines for Performance of Internal Flooding Probabilistic Risk Assessment