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The FMEA results for a Fuel Handling System at Cernavoda Unit 2 in Romania

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1. Introduction

The FMEA was performed by an independent assessor at the request of the regulatory authority CNCAN to provide an independent overview of all the nuclear safety aspects of Cernavoda Unit 2 under construction and an expert opinion as to whether the completed Cernavoda Unit-2 Nuclear Power Plant would satisfy the current Western European nuclear safety objectives and practices. European Union (EU) required the safety level of Cernavoda unit 2 in Romania to be comparable to those of other European Nuclear Power Plants (NPPs). As a part of the activities to meet these requirements, a safety review for its fuel handling system has been performed. EU requested Romania to perform a Safety Evaluation of this system separately from the conventional safety analysis covering all the Design Bases Accidents when the Cernavoda unit 2 Reconstruction project started in 1995. A report was produced (Cernavoda 2 Nuclear Safety Expert Project, "Task 10–Safety Evaluation Report", A.F. Parsons, NNC Limited, December 2001) and it contains recommendations either mandatory or advisory. The FMEA study, one of the mandatory recommendations, was performed for the fuel handling system and the radioactive waste handling system for Cernavoda unit 2 in Romania. In this paper, only the FMEA study for fuel handling system is presented. which was performed by KHNP(Korea Hydro & Nuclear Power Company) and KAERI(Korea Atomic Energy Research Institute) as requested by SNN (Romanian National Nuclear Company) with the project duration from November 2005 to February 2007.

2. Fuel Handling System in CANDU

The fuel handling system is made up of two sets of fueling machines (FMs), FM support carriages and associated supporting tracks, reactor vault bridges/column assemblies, a new fuel transfer, an irradiated fuel discharge and FM calibration facilities, an irradiated fuel transfer system, plus all the associated auxiliaries, power supplies and control systems. The subsystems considered are the D2O supply system, D2O control system, oil hydraulics system, instrument air system, electrical supply system, and the C&I system. One FM is used for the new fuel bundles transfer and the other FM is used for discharging the irradiated fuel bundles for the same fuel channel.

The level of resolution of the FMEA is to the level of specific Cernavoda unit 2 flowsheets and major component in the mechanical drawings. Failure of control and instrumentation components is not included in this study[1].

For each area the FMEA study identified the safety functions during fault conditions suck as internal mechanical fault, internal fire induced effect, internal flooding induced effect, earthquake induced effect and loss of support service system(instrument air, service water & electrical power).

3. FMEA

To perform the FMEA study for a fuel handling system, the design characteristics of the Cernavoda Units 1 and 2, Wolsong Units 1, and 2/3/4 were all reviewed to understand the design features of fuel handling system. The four representative safety functions of the fuel machine and fuel handling system during fault conditions were identified as follows

- Maintain the PHT pressure boundary during refuelling
- Protect against fuel damage during a refuelling
- Maintain the spent fuel cooing during refuelling
- Protect the radioactive material release

For the whole fuel handling system, a FMEA was performed for each function of the system, and for the flow circuits of each function according to the three selected operational modes in the previous section. The redundancies/diversity and annunciation capabilities were identified for each function. The three representative safety functions of the fuel machine and the fuel handling system during fault conditions were identified as follows. The main safety functions of the fuelling machines during a fuel changing operation are to maintain the integrity of the PHT system pressure boundary and to provide a spent fuel cooling. The identified safety functions are the potential possibilities that cause an actuation of the safety systems such as a plant trip system, emergency core cooling system and a release of radioactive materials also.

- Maintain the integrity of the heat transport system pressure boundary during on power refueling
- Protect against fuel damage during on power refueling
- Maintain a spent fuel cooling during a transfer and discharge to the spent storage bay

The main failure modes that could be vulnerable to the three selected safety functions were classified according to the functions of the fuelling machines and sub-systems during the fuel change operations. The failure modes which can occur during the fuel changing operations are considered as follows.

1) Fuelling Machine Failures

2) Spent Fuel Transfer System Failures.
3) D2O supply system
4) Oil hydraulic system
5) D2O control system
6) Support system(EPS, CCW, etc)

The failure effects caused by the considered failure modes above are a mechanical failure of the fuel bundles, a loss of the D2O inventory, and the possibilities of a radiation release to the environment. The most severe failure effects were found as follows;

- A break of the fuel channel end fitting accompanying an ejection of 12 spent fuel bundles.
- Loss of Coolant Accidents when the F/M is in an on-reactor mode.
- At the spent fuel port, two spent fuel bundles are mechanically damaged when being dropped to the discharge bay floor from the port.

However these kinds of severe accidents are rare from the review results of the Event History Docket. By its nature there have been many incidents of D2O leaks through catenary hoses. However by a well-established maintenance policy, the frequency of this kind of event could be reduced.

The FMEA for external events was performed and the results were as follows. At first the fire areas and flooding areas were defined by reviewing the general arrangement documents and a walkthrough of Cernavoda unit 2. Related to the fuel handling systems a total of 11 rooms inside the reactor building were selected. For each room an FMEA of the fire and flooding events was performed.

For the fire FMEA, the fire ignition sources were identified for each room. The most significant fire area was the D2O supply room (R-012) according to the result of the internal fires FMEA. If a fire occurs in room R-012, two D2O supply pumps (3526-P1 and P2) and pressure control valves will be affected so the F/M could not play its role. However, the fire ignition frequency in this room was very low and there have been no such experiences in CANDU plants.

For the flooding FMEA, the flooding sources were identified in the reactor building. The flooding sources in the reactor building were a spurious operation of the dousing tank spray, a feed line break accident, and a rupture of the recirculated cooling water (RCW) piping. By an analysis, the most significant flooding scenario was identified to be a D2O return pump(3523-P3) failure induced by a malfunction of the dousing system or a feed water pipe break. The D2O return pumps are located on the R-013 and R-014 rooms basements. A failure of these pumps by a flooding of the basement of the reactor building can cause a D2O spill over through a duct of the vapor recovery system in the 3523-TK3. This scenario can only occur in the weir level operation mode. In this case the fuel bundles in the F/M magazine can be damaged due to a loss of D2O inventory to the F/M magazine. The other components related to the fuel handling system except for 3523-P3 are not affected during the flooding conditions because all the components related to the F/M are located 2m above from the basement floor.

The seismic fragility analysis of the fuelling machine of the Wolsong unit 2, 3 & 4 NPP was performed. The most severe failure mode of the fuelling machine was a structural failure of the fuelling machine/pressure tube connection. The high consequence low probability failure (HCLPF) capacity of the fuelling machine was 0.44g. This means that the fuelling machine had a sufficient enough safety margin for a design basis earthquake (DBE) of 0.2g.

4. Conclusion

The FMEA study for a fuel handling system at Cernavoda unit 2 was performed. Through this FMEA study on the fuel handling system of CANDU 6 plants the most significant accident scenario was identified as a small LOCA (single fuel channel LOCA). The most severe radiation release event was an ejection of 12 spent fuel bundles in to the reactor vault. This event can usually be confined to the reactor building.

ACKNOWLEDGMENTS

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