

The FMEA Analysis for Fuel Handling System at Cernavoda Unit 2

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1. Introduction

A Nuclear Safety Evaluation was performed by an independent assessor at the request of the regulatory authority CNCAN (Comisia Nationala pentru Controlul Activitatilor Nucleare – National Committee for Nuclear Activities Control in Romania) to provide an independent overview of all the nuclear safety aspects of Cernavoda Unit 2 under construction and an expert opinion whether the completed Cernavoda Unit-2 Nuclear Power Plant would satisfy current Western European nuclear safety objectives and practices. A report was produced (Cernavoda 2 Nuclear Safety Expert Project, “Task 10 – Safety Evaluation Report”, A.F.Parsons, NNC Limited, December 2001) and contains recommendations either mandatory or advisory. The FMEA study, one of the mandatory recommendatins, is performing now for fuel handling system and radioactive waste handling system for Cernavoda unit 2 in Romania sponsored by KHNP. In this paper, only the FMEA study for fuel handling system is presented[1, 2].

2. Scope of Study

The scope of the study are as follows. The FMEA(Failure Mode & Effect Analysis)[3] study are performed for fuelling machine and fuel handling system. 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 such 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). The results would inform the adequacy for redundancy, alarms and indication to the operator in the MCR to develop the additional operating procedure to recover abnormal conditions.

3. FMEA

To perform the FMEA study for 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[5,

6, 7, 8, 9,10]. The four representative safety functions of the fuel machine and fuel handling system during fault conditions were identified as follows[12, 15].

- maintain the PHT pressure boundary during refuelling
- orotect fuel damage during refuelling
- maintain the spent fuel cooing during refuelling
- protect the radioactive material release

In order to ensure that the analysis covers all parts of the fuel handling system, study on the system familiarity with design documents, safety analysis reports, internal fire, internal flooding and earthquake hazard analysis reports of Cernavoda Unit 2 and Wolsong Unit 1/2/3/4[11, 12, 13 14, 15] were performed. The adequacy of the redundancy, diversity and independence of these systems, including susceptibility to the common cause events such as internal fires, internal flooding, earthquake, and loss of support services (instrument air, service water & electrical power) were evaluated and confirmed. The walkdown of Cernavoda Unit 2, to define the discrepancy between design and construction, was performed. Operating experiences related to the fuel handling systems are collected and reviewed to identify the safety and operational characteristics of the fuel handling system of CANDU-6 plant also. Operating experiences have collected from CANDU Owners Group(COG) event records and INPO, WANO, IAEA data bases and Wolsong plants operational experiences. During these progress, the whole operation of the fuel changing operation by the fuelling machine were divided into 11 specific operation modes. Three of 11 specific operation modes were selected to concern on this study as follows.

- on-reactor mode
- spent fuel transfer mode
- spent fuel discharge mode

Total four events have a potential possibility to release the radioactive material were identified as follows during three operation modes mentioned above.

1. Fueling Machine (FM) induced LOCA including loss of D₂O supply
2. FM failures causing Mechanical damage to fuel

3. Loss of fuel cooling in fuelling machine during spent fuel transfer
4. Spent fuel transfer system failures

The main failure could cause the four events were also classified as follows.

- Fuelling machine failure itself
- Loss of fuelling machine D₂O supply system
- Loss of fuelling machine D₂O control system
- Loss of fuelling machine hydraulic Oil system
- Loss of support system(IA, Cooling, Electrical Power & Digital Computer)

The FMEA study focused on these five failure modes. For each subsystems the failure modes and effect analysis is performed according to the each function of the subsystems, operational flow circuits of each function. The failure effects considered are the mechanical failure of the fuel bundles, loss of D₂O inventory, and loss of clamping, plant shutdown due to inoperable fuelling machine, excessive radiation release and a sample FMEA result are summarized table 1.

4. Conclusion

The FMEA study for fuel handling system in Cernavoda unit 2 are performed. The preliminary most severe event scenarios was found to be as follows. The loss of coolant accident induced loss of D₂O supply when FM is on-reactor state. At the spent fuel port and Discharge port, two irradiated fuel bundles are mechanically damaged by loss of D₂O supply. The main causes of D₂O supply failure was found D₂O feed pump mechanical fault and support system fault caused by common mode failure induced external event such as internal fire and internal flooding.

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Table 1. The FMEA table for fuelling machine in Cernavoda unit 2

Subsystem (BSI)	Component ID	Component Name/Function/ State	Support System	Failure Mode	Mechanism(s) & Causes(s) of Failure	Effect(s) Of Failure
FM D ₂ O Supply (35260)	3526-P1 and 3526-P2	D ₂ O Feed Pumps, D ₂ O Supply for F/M,	Pump Motor Power Supplied by 5433-BUU, Fan Motor Supplied by 5433-MCC13	Pump Failure Loss of Class III Power	Mechanical Failure, Failure due to Loss of Supporting System due to fire, flooding and earthquake	Loss of D ₂ O Pressure of FM Head and Loss of fuel cooling. Loss of inventory from PHT
FM D ₂ O Supply (35260)	3526-PCV11	D ₂ O Pressure Control	Air Operated, Class III 120V BUS/CB, I/A	Open spuriously	Loss of Instrument Air or Loss of Control Loop due to fire, flooding and earthquake	Fail to D ₂ O Pressure & Level control Fail to next step
FM D ₂ O Supply (35260)	3526-PCV11#1 A	D ₂ O Pressure Control	I/A	Loss of IA	Loss of Instrument Air or Loss of Control Loop due to fire, flooding and earthquake	Fail to D ₂ O Pressure control (Fail open-High Pressure D ₂ O supply)