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Reliability Program at Cernavoda NPP

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Abstract

This paper provides an overview of *reliability program* implemented at Cernavoda NPP. It was written to serve the experience exchange between Cernavoda and Wolsung NPPs in the plant safety and systems reliability area.

Introduction

Starting with 1992, during the commissioning of Cernavoda NPP, a reliability program was defined and implemented. It was designed to assist the license for commissioning and operation activities. For the beginning the main aim was to demonstrate to jurisdictional authority the suitable design of the most important safety related systems. After that it has been improved to demonstrate also that these systems are operated as per design intent. Now, the reliability program is used not only to support the operating license but also to assist station management for risk based decision making.

An overview of the reliability program is presented in fig. 1. The main activities and the relationships between them are emphasized. Also, the relationships between Reliability Section and other Plant Departments, which concur for accomplishment of the program, are emphasized.

As parts of the reliability program, the following main activities are to be emphasized:

1. Development and updating of Reliability Analyses

For the following most important safety-related systems in Cernavoda NPP, reliability analysis programs are developed and will be updated periodically:

- SDS#1, ECCS, SDS#2, CONTAINMENT;
- EWS, EPS;
- SDCS, AFWS, RRS(STP), CLASS III SDGs, BCWS.

The *fault tree method* was used to model the systems failures, using the top-down step by step methodology. In this way, it was considered every component which by itself or in combination with other components can result in the system being unable to meet minimum success criteria, as per design intent. For each equipment, both hardware failures and unavailability due to maintenance and testing were modeled in the fault trees.

Generic failure rates, mean times to repair and test intervals based on similar CANDU NPPs operating experience were used for basic events quantification. Based on the resolution of generic data available, the components were grouped by systems, types and failure modes using an unique 16 character identification labeling scheme.

All the procedures used for periodic activities (i.e. routines, call-ups and mandatory tests) were carefully reviewed to identify the components made unavailable. Based on the estimated duration and frequency of each activity, the average unavailability due to testing or maintenance was calculated and used for the quantitative evaluation of fault trees.

Computer **A**ided **F**ault **T**ree **A**nalysis (CAFTA) fault tree development system was used to build, quantify, and analyze fault tree models. CAFTA **B**asic **E**vents database files was linked with a MS ACCESS database program which is used for on line reliability monitoring of the systems. In this way, all the basic events considered in the fault tree models were gathered and considered for the monitoring program (see bellow item 2). Also, the fault tree models provide the information for developing the mandatory testing program (see bellow item 3).

Predicted systems unavailability figures derived in the reliability analyses were stated as *target station performance indicators*. They are used as reference for comparison with *actual past unavailability* figures which are derived from reliability monitoring program.

2. Reliability Monitoring Program

The objective of this program is to detect in time any degradation in system reliability and take the appropriate measures to prevent this kind of degradation.

A computerized database **A**ssessed **F**ault **R**ecord **S**ystem was developed and used to assess and record the unavailability of the monitored components. On a daily basis the reliability performance of the systems is monitored in order to identify and assess component failures, operational and maintenance practices which can impair the systems. The information required to do this is gathered from station logs, mandatory tests results, work requests, work reports, unplanned event immediate reports and discussions with the plant personnel involved in the failure discovery and restoration (i.e. operators, maintenance technicians and responsible system engineers). All the above information are assessed and recorded as an unique record in the database.

Component failures are classified by the impact on the system performance as follows:

Type 1 - the system is not capable to perform its function(s);
Type 2 - a significant reduction of system efficiency;
Type 3 - loss of redundancy or reduction of safety margin; the system is able to fully perform its function(s). Even the type 3 faults do not imply system unavailability, they are carefully monitored to ensure that their duration do not overlaps the *maximum allowed component outage time*. Sensitivity studies are performed to derive this time when required (i.e. delay of fault restoration due to objective problems). These studies are done using CAFTA Cutset Editor which provides the ability to see probability and structural changes, without re-quantification, by on-screen recalculation.

As part of this activity, the reliability engineers are supporting the revision of operating procedures (i.e. testing and maintenance procedures, operating manuals and instructions, work plans). The impact of any modification (including design changes) on the reliability figures are assessed and, based on it, acceptance or recommendation are issued.

The following outputs are provided by this program:

1. *Actual past unavailability* for each monitored system. It is calculated based on AFRS records by adding the duration of type 1 and type 2 (or simultaneous type 3 on redundant trains which means type 1) faults experienced by the system components. The sum is divided to the monitored period. This is done monthly

and reported to management as *station performance indicators*. The root cause is assessed and appropriate actions considered each time when this indicator increases, to prevent it to reach the target value. Annually, the system behavior are documented and the *annual actual paste unavailability* is calculated. It is included in the *plant life unavailability* and reported via the 4th Quarterly Technical Report.

2. *Number of failures, discovery, access and repair times* for each component group and failure mode. These data are used to derive the reliability parameters to update the site specific reliability database and to provide inputs for trend analyses (see below item 4) .
3. *List of significant failures (i.e. type 1, 2 and 3)* is extracted from AFRS records and reported quarterly, on a system by system basis, via Quarterly Technical Report.

We have paid more attention to develop and implement this program which must be continuously improved based on gained experience, because the efficiency of the overall reliability program is strongly dependent on it.

3. Mandatory Testing Program

Mandatory testing program has been developed to demonstrate the reliability of the most important systems and to fulfill the commitments made in the operating license.

The tests procedures has been developed mainly based on the Point Lepreau NGS practices. The testing requirements were reviewed and qualified via the reliability analyses to reflect Cernavoda NPP specific design and operating procedures. Due to the importance of this program and for consistency, all the draft test procedures have been reviewed by Testing Steering Committee (Production Manager, Technical Manager, Operation Superintendent and Testing Coordinator - a member of Reliability Section staff). Field trials and subsequent revisions of test procedures have been performed prior to issuing them for routine performance.

A computerized MS ACCESS database, Mandatory Testing Information System was developed and used for scheduling, assessment and record of the tests results. It is available to all plant personnel via the computer network.

The following departments are involved in the proper functioning of this program:

- Reliability Section responsibility is to establish testing requirement, schedule the tests and assessing the test results to ensure that the tests are performed within the acceptable confidence intervals.
- Other Technical Unit Sections: the responsibility of each Responsible System Engineer is to prepare/revise the test procedures related to his/her assigned system(s), to review the tests results, establish and initiate the follow-up actions when required.
- Operating Crew: performs the test and initiates corrective actions when required.
- Planning Department: include the schedule into the Daily Work Program.
- Operating Document Control: ensure the storage of completed test results documents.

4. Component reliability database.

All the component considered in the fault tree basic events has been gathered into a database named Equipment Library File. They are grouped by type and system. The evidence of time monitored is kept in this file. Component boundary and failure modes has been assigned for each type.

Beside ELF, the following databases and spreadsheets has been developed using MS ACCESS and MS EXCELL:

Observed Component Reliability Data - used to derive the reliability data for each type of component and associated failure modes. Chi- squared distribution is used to derive 5%, 50% and 95% confidence values for failure rates. The input data are coming from AFRS (see above item 2). The derived data are qualified by statistical analysis and will be used to update CAFTA **B**asic **E**vents database files. They are documented in the 4th Quarterly Technical Report. This part of the program is not yet fully implemented. We are looking for the best techniques to qualify data.

Individual Component Groups Database - will be used to perform trend analyses on the component behavior. This program was only tested with sample data because not enough failure data are yet available.

5. Conclusions and Remarks

Even the reliability program was implemented and works very well, it is subject of subsequent development in order to respond to highly demands for safety and reliability.

Data collection, analysis and qualification methods are still weak points and this mainly due to insufficient operating experience at Cernavoda NPP. Experience exchange between the similar CANDU stations are one of the most important way to improve the confidence, specially in the probabilistic safety assessment area.

Another direction for the reliability program improvement is to adjust it to become a powerful tool in support of risk based cost-benefit decision making.

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Fig. 1 OVERVIEW of RELIABILITY PROGRAM at CERNAVODA NPP