SMiRT-12 / K. Kussmaul (Editor)

M06/5

USE OF PROBABILISTIC SAFETY ANALYSES IN BRINGING KOZLODUY NPP UP TO THE REQUIRED SAFETY STANDARDS

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ABSRTACT:

The paper considers the reconstruction measures suggested on the basis of safety systems reliability analyses and implemented for "Kozloduy" NPP in the framework of the "Programme for Restoring of Systems and Equipment Design Functional Availability and Upgrading of the Operational Reliability and Safety of Unit II".

Bulgaria is one of the East European countries where the role of the Nuclear Power Energy is significant for covering of the national electricity demands. There are six units, four with VVER-440 type reactor and two with VVER-1000 type reactor for the operating at the moment "Kozloduy" NPP. First unit was commissioned in 1974. During last several years a special attention was paid on the improvement of the operational safety and reliability. Various international meetings and missions on review of "Kozloduy" NPP safety level took place with the participation of the IAEA and WANO experts from all over the world. As a result, particularly from the ASSET mission in 1990 and OSART mission in 1992 for the first four units, a list of IAEA recommendations was prepared for safety and reliability improvement of the VVER-440 type reactor units in Kozloduy.

Taking into account the scope of necessary restoration activities required for upgrading of the operational safety, first and second units were shut down for outage in September and in November, 1991 respectively.

A special programme for restoring of systems and equipment design functional availability and upgrading of the operational reliability and safety of unit II [1] was than developed jointly by "Kozloduy" NPP and Bulgarian Design and Research Institute "Energoproect" with the assistance of WANO specialists. The safety improvement measures foreseen in this programme had to follow the IAEA and Bulgarian Nuclear Safety Authority recommendations.

In the framework of this programme a lot of reliability analyses [2,3,4], research and design projects were completed and series of safety improving measures were implemented but further are discussed only some of those, concerning safety important and support systems.
Probabilistic analyses of the reliability of the following "Kozloduy" NPP, II unit systems were carried out:

High Pressure Safety Injection System;
Spray System;
Auxiliary Feedwater System
Long therm Core Cooling System;
Service Water System
Steam Dump to the Atmosphere;

The applied method was "fault tree" and different computer codes were used for calculation in order to obtain quantitative results from the analyses.
Component reliability data necessary for these calculations was obtain basically from IAEA Generic Data Base [5] and where it was possible this data was updated by "Kozloduy" NPP relevant data about the equipment failures[6]. The aim of the probabilistic analyses was to perform comparative assessment of the reliability of different proposed new configurations for the safety systems, but not the absolute assessment of the existing systems unavailability. While modelling the above mentioned systems, special attention was put on the possible common cause failure and single failure that may cause system failure. The elements which unavailability contribute mostly to the system unavailability were determined using Fussel-Vesely element importance criterion.

The performed analyses enabled the identification of the weakest points in the existing analyzed systems and definition of the best appropriate measures (from reliability point of view) for their elimination.

The performed analyses showed that the proposed modifications decrease the unavailability for High Pressure Safety Injection System by order of two; for Spray System by order of one; for Emergency Feedwater System by order of two; for Service Water System by order of one; etc.

The list of the reconstruction measures, proposed on the basis of the research reliability analyses is too long and a description of the measures themselves can not be done in the scope of this paper (for understanding of the most of the systems changes we need at least principal layouts of these systems and proposed modifications) and that is why bellow are mentioned only general modifications and additional equipment installation.

- In order to eliminate the possible common cause failures due to boron compartment (where HPSIS and SS pumps are situated) flooding a design for installation of a second drain system in the boron compartment and a

control signal for water presence there have been developed and implemented.
- To reduce the fire risk in the boron compartment an installation of fire protection barriers between HPSIS and SS pumps was foreseen.
- A special procedure for SS test performance is proposed in order to reduce the unavailability of the Spray System due to test.
- Redundancy is provided for Steam Generators (SGs) water level measurements and feasibility study is completed for additional SGs emergency feedwater supply system installation outside the turbine hall.
- A new system with two-chanel structure for long term core cooling is proposed allowing when necessary, simultaneous cooling of first and second units.
- To eliminate the reasons for SWS pumps failures due to flooding, resulting from the check valves leakages, protective casings of the pump motors were installed.
- Measures for providing of additional service water sources were taken and etc.

As it was mentioned already, these are only a part of the huge scope of all restoration activities improving the operational safety for the second unit, that allowed the unit restart in the end of 1992 year.

The approach applied in the framework of this outage programme, for using the results of systems probabilistic reliability analyses as a ground for development of the most appropriate modifications aiming to increase the operational safety, proved to be very efficient and highly applicable for the forthcoming reconstructions of the rest of "Kozloduy" NPP units.

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