IMPROVING NUCLEAR SAFETY OF VVER-440 UNITS

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Bulgaria 3321 NPP Kozloduy Power Production-1

INTRODUCTION

Nowadays 27 VVER-440 units are working in Eastern Europe. Four units' design B230 that is 15 % of all is operating in Bulgaria. The building of the first unit started in 1970 and was finished 1974. Units II, III, and IV started to operate respectively in 1976, 1980 and 1982. Units VVER-440 are designed to operate for 30-fuel campaign tab.1. They were designed during the sixties with the main purpose of maximum electrical output, maximum flexible and large reserve of safety. Main characteristic of units are: six primary loops with primary isolation valves both in the hot and in the cold legs; horizontal steam generators with large coolant inventory, two turbines allowing operation at different power levels, three levels of reactor control and protection before reactor scram, low power density in the core – tab. 2.

TABLE 1. KNPP MAIN Dates

Unit	Start of operation	Current fuel cycle	Expected end of 30^{th} fuel cycle
1	Oct.1974	21	2011
2	Nov.1975	22	2010
3	Dec.1980	17	2015
4	Jun. 1982	16	2016

Units VVER-440 have some failing due to the old design but they have from a safety point of view some specific characteristic of the plants, enhancing their safety. A large part of these positive features have served as a basis in the development of the new units.

PHYSICAL CHARACTERISTIC AND RESISTANCE TO UNCONTROLLED INCREASE POWER:

– Minus thermal coefficient of reactivity at entire work range;

– High minus power coefficient of reactivity;

– Steady spaced distribution released energy (eliminated the demand of special control equipment for suppression of Xe-oscillations).

– There is temperature control system of the most fuel assemblies (more than 60% fuel assemblies);

– High effectiveness of control rods (9-11%) The high effectiveness of the control rod is due to the usage of the EC Assembly.

– Low thermal density in the core;

– Low specific thermal loading respectfully low heat flux.

MAIN-DESIGN SOLUTIONS OF VVER-440 BENEFICIAL TO THEIR SAFETY CHARACTERISTIC

– Multi-loop configuration of the primary circuit. The six primary loops provide reservation.

– Horizontal steam generations have a large coolant inventory which enables removal afterheat cooling from core during 6-7 hours without their feet;

The availability of a large amount of water in the Steam Generators and the Primary circuit provides a natural protection of the core in case of disbalance between the Primary and Secondary circuit. For the most part the deviations, with a higher frequency at that, of the nominal parameters of operation of the Unit in the currently operated reactors are generated by the second. That's why the availability of a large amount of water is an advantage, which allows a weak reflection of the deviations, obtained during the Secondary circuit operation, on the Primary circuit operation. This reduces the probability of severe emergencies for Units WWER-440. For instance, core damage in case of a total loss of water and feedwater of the Steam Generators is expected only after 4-6 hours, a time enough for the operators to undertake restoration actions.

In case of a deviation of the Primary circuit parameters, the large amount of water allows pressure variation within lower limits in comparison with the currently operated PWR.

– Configuration of primary loop and horizontal steam generation enhance the transition to single-phase circulation of the primary coolant.

– Two turbine-generators. This provides safety parameters of the plant softening the loads due to transients initiated in the secondary side. The two independent connections to the electrical grid ensure a higher reliability of the electrical supply system.

VVER-440 UNITS ARE STEADY FOR UNCONTROLLED LOSS OF COOLANT PRIMARY CIRCUIT

– Reactor vessel has not longitudinal welding.

– VVER-440 units have large coolant inventory in primary circuit. This makes the plant steady against different accidents such as blackout, complete loss of feed

water and etc. It is an advantage in case of small LOCA with loss of the high-pressure injection system.

– Minimum attachment to the main coolant circuit.

– Primary circuit has high leak-proof due to the use of hermetic main coolant pump and closed system to clean coolant of primary circuit.

– Pipe' primary circuit, main coolant pumps, isolation valve, collector's steam generators are made from austenitic steel what enable to use " leak before break off" conception.

Independently of that entire positive features as a result from the inspections by IAEA and investigation of the nuclear safety a program for improving nuclear safety has been worked out. This program has been implemented in three stages and more than 120 mil $ have been invested fig. 2.

MAIN DIRECTIONS FOR IMPROVING NUCLEAR SAFETY OF VVER-440 UNITS WERE:

– to expand number of the design accident.

– to increase reliability of equipment important for the safety.

– to decrease the probability of initiating events.

– Improvements the integrity of the primary circuit (application LBB concept, qualification of the pressure safety valves to avoid pressurized thermal shock).

– Improvement of the fire protection.

– Improvement of the operation including upgrading and improvement of operational documents, implementation of new system for training the operators and etc.

– Reassessment of the seismic response of the plant.

MAIN ACTIONS WERE MADE AT NPP KOZLODUY TO INCREASE NUCLEAR SAFETY OF VVER-440 UNITS

1. Modernization of Emergency High Pressure Safety Injection System. The modernization includes dividing of independent channels with reservation of active elements. Pumps were exchanged with more effective and reliable ones. HPSIS was increased reliability in general through decrease number of active elements and exchanged with passive.

2. For the purpose of avoiding fast cooling at the primary circuit and obtaining thermal shock of reactor vessel, Main Safety Insulation Valves are installed at NPP Kozloduy.

3. Modernization of Emergency power supplies AC. Oil breakers VMP-10 are exchanged with gas FS-4.

4. Generator breakers are installed to decrease probability of loss power supply and blackout. They provide reliable power supply to the system important for the safety in case of failure on generator.

5. I&C system has been qualified and optimized.

6. Reassessments of Limiting Conditions of Operation and new scram signals have been introduced.

7. An operators-oriented Informational System has been developed. It includes ensuring and updating of equipment data, new informational support of operator and etc.

8. A new auxiliary independent system for cooling primary circuit through secondary is made. The system provides primary circuit cooling and storage of spent fuel in case of blackout.

9. A Leak Detection System has been used at NPP Kozloduy for more than ten years. ALUS is operating following on the "Leak before Break" conception.

10. New Leak Detection ^{16}N System has been installed for early detection of leaks from primary circuit to secondary.

11. Modernization of water supply system has been made. Independent channels have been constructed.

12. A new fire protection station is constructed.

13. Reassessment of seismic equipment and its updating.

14. New safety valves have been assembled. They provide core cooling using the "feed and bleed" concept.

15. Reduction of the confinement untightness more than 10 times.

16. Management of NPP Kozloduy has been changed. The main improvement of management are:

- New organizational structure;
- Transferring of management goals and policy (new information system used);
- Training for maintenance;
- Training for managers;
- Housekeeping improvements;
- Modern methodology applied at Workshops and Laboratory. The equipment has been renovation;
- A new training center has been constructed;
- New emergency plan has been developed
- New emergency procedures for operation at emergency situations have been worked out.
- Radiation monitoring has been improved.
- Maintenance activity quality has been increased.

RECENT INTERNATIONAL ASSESSMENT OF KNPP NUCLEAR SAFETY

– ANO PC/MC Experts Meeting – Sofia October'97

– Expert Meeting IAEA concerning future modernization of B-230 Units - Vienna F-Safety Assessment Report - presented by Committee of Energy before the EBRD Experts - May'98

– Review of the Program by Expert Team of EdF

- Review of the Program by Expert Team of Siemens February'98 Both studies confirmed the high international standards applied for safety evaluation.

– Results of In Depth Safety Analysis are reported as part of National Report on Convention of Nuclear Safety, Vienna, April'99

– An international OSART Review mission, including IAEA specialists, was performed in January 1999 on the operational level of Units 1-4.

The main conclusions of the Commission are as follows:

The management and personnel are highly motivated

High standards of operation have been established

The operating status of the systems and facilities has been rapidly and essentially improved which is in compliance with the international standards.

– WENRA Review Mission

The WENRA Mission was held in October and a review on the safety operation was performed. The Head of the Mission, Mr. Raponen, and the representatives of six countries gave a high evaluation of the achieved level of safety operation.

CONCLUSIONS

VVER-440 units have proved essential operating reliability. The accumulated operational experience is more than 300 reactor years. Units of the type VVER-440 have a lot of inner positive features and they can also be improved. The operation this type of Units can be in compliance with the strictest requirements for Nuclear Safety.

REFERENCE

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[3] Balabanov, E. Safety of NPP with VVER-440 and VVER-1000 reactors Scientific-technical conference 25-26 October 1994 Kozloduy

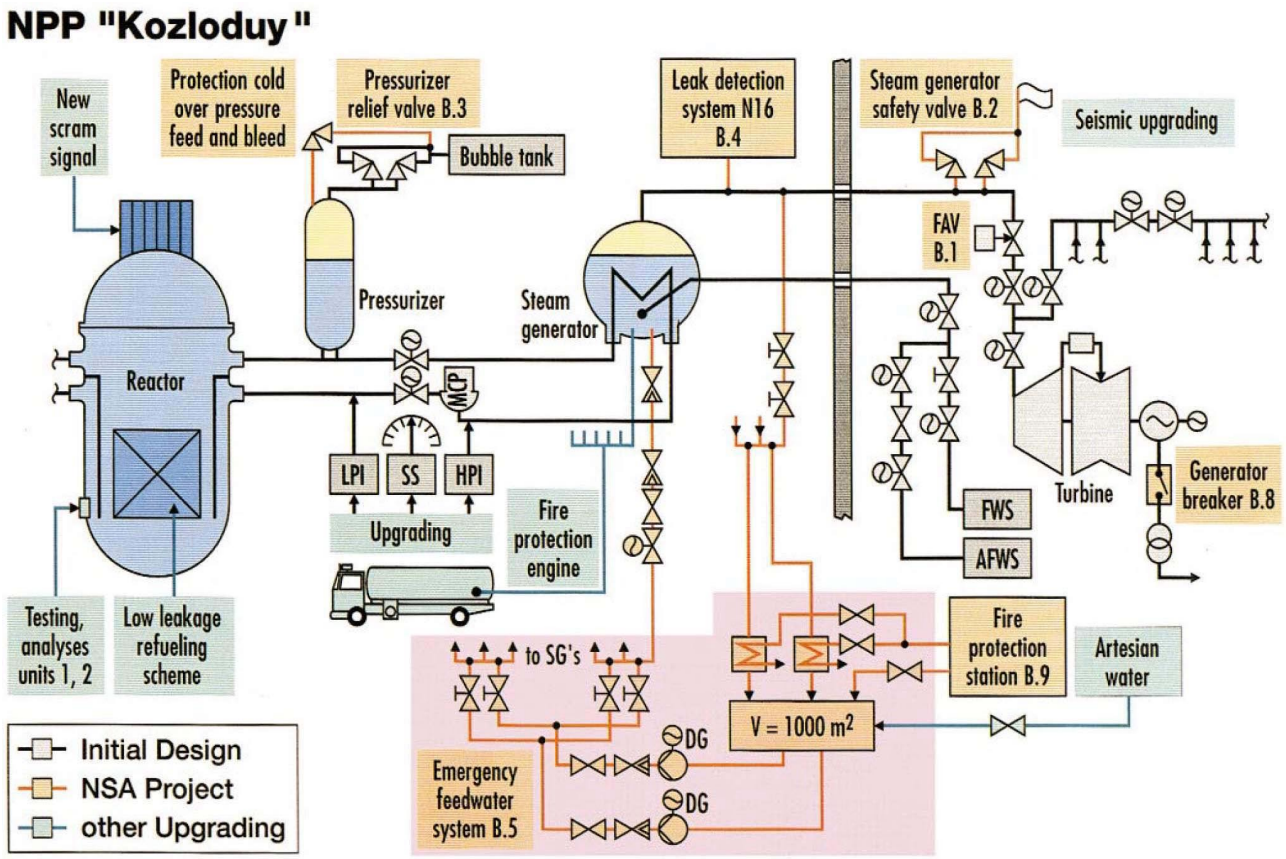


FIGURE 1

Short term Program

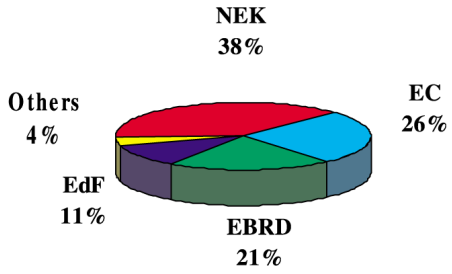
Implementation Summary

- Modifications implemented - more than 1000

- Documents issued - more than 8000

- Manpower used - more than 25 000 manmonths

- Investments - about 129.1 MECU



Contributors

- EC-PHARE	- 30.0 MECU
- EBRD	- 24.0 MECU
- EdF	- 12.7 MECU
- Others	- 4.6 MECU
- NEK	- 57.8 MECU

FIGURE 2