vüje

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MOCHOVCE WWER 440/V213 REACTOR UNITS 3 AND 4 SAFETY IMPROVEMENTS BASED ON ORIGINAL PLANT DESIGN

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INTRODUCTION

The objective of the safety and technical modernization program of MO34 is to improve future:

- **Safe operation,**
- **Reliable operation,**
- **Economical operation**

and to comply ÚJD SR (Regulatory Body of Slovak Republic), IAEA as well as selected EUR and WENRA recommendations and requirements

OVERVIEW OF THE OVERALL SAFETY CONCEPT FOR MO34

Basic procedure used during the preparation of MO34 construction completion has to harmonize into one whole combining:

1. original state of

- **valid Basic Design documentation,**
- **valid PRESAR and other related safety documentation,**
- **valid Quality Assurance Program,**
- **supplies realized for MO34**

and

2. new present requirements on

- **technical leven of the plant, component suppliers, economy, etc.,**
- **operational safety and reliability of the plant,**
- **legislative regarding protection of the plant environment.**

OVERVIEW OF THE OVERALL SAFETY CONCEPT FOR MO34

The percentage of the uncompleted construction of MO34 compared to the originally elaborated MCR documentation separately for construction and extra separately technological part:

- **Civil structure part - actual completion stage of works is 70%**
- **Technological part - actual completion of implementation is 30%**
- **Electrical part - actual completion of works is 1%**
- **I&C systems - actual completion of works is 0%**

This construction completion status quo allows to improve technology and safety of MO34 into higher level, than it was done on EMO12

OVERVIEW OF THE OVERALL SAFETY CONCEPT FOR MO34

The conservation procedure is based on the following principles:

- **The completion of the units 3 and 4 was assumed.**
- **According to the possibilities those ways of component conservation and protection works were adopted will be usable for further works and will enable a smooth construction completion.**
- **The way of „conservation by construction completion“ will be used, i.e. in some cases the structure will be completed according to the project documentation in a way to prevent its further damage.**
- **In well-founded cases (accidents, etc.) such reconstructions will be proposed, which will prevent a further damage of the structure.**
- **Approval of recommendations of UJD SR, as well as recommendations of IAEA.**

OVERVIEW OF THE OVERALL SAFETY CONCEPT FOR MO34

Project of construction completion of MO34 is based on the experience gained during construction and operation of Mochovce NPP unit 1 and 2 (EMO12) and continuity of published valid decisions.

EMO12 passed through intensive modernization and consequential detail investigations of nuclear and operational safety by deterministic, as well as probabilistic approaches with results presenting high international standard of their realization.

Adopted technical solutions realized on EMO12 assure accomplishment of it safety level required by EC, what was confirmed by international audits and IPSARTs realized by IAEA Vienna.

MO34 SAFETY UPGRADE PROJECT

(IN ACCORDANCE TO ATOMIC ACT 541/2004)

MO34 Safety upgrade project is elaborated in accordance to Slovak Atomic Act 541/2004 of the Coll. and:

- **Safety improvements evaluation for Mochovce NPP rev. 16, Risk audit report, IPSN/GRS, December 1994 and**
- **Mission for safety improvements checking on Mochovce NPP, IAEA WWER-SC-102, September 1994.**
- **WENRA and EUR in relation to Safety Measures (SM) adopted on Slovak NPPs EMO12, EBO34 and other similar NPPs with VVER 440/V213 or newly proposed**

MO34 SAFETY UPGRADE PROJECT (cont.)

The objective of the modernization program of MO34 is to attain required units safety by:

- **improving of nuclear safety as a minimum to the level given by the requirements of ÚJD SR and by the IAEA recommendations,**
- **complying as close as possible requirements of EUR and WENRA,**
- **attaining of the confinement tightness by means reducing leakage to minimum level,**
- **achieving of probabilistic targets to EUR level,**
- **creating conditions for prolonging the lifetime,**
- **creating conditions for power margin increasing,**
- **creating conditions for power follow up modes within the range of primary and secondary load follow mode, etc.**

MO34 SAFETY UPGRADE PROJECT (cont.)

Based on the above mentioned EMO12 was taken as reference NPP with the following main areas of proposed strategy of MO34 original design safety and technical modernization:

- **Nuclear safety as minimal level of EMO12 nuclear safety and in conformance with current international requirements on nuclear and operational safety, including handling of catastrophic accident issues.**
- **Totally new integrated I&C system of MO34 based on the concept of digital distributed systems and recent philosophy of defence in depth.**
- **Brand new electric equipment according to STN IEC (Slovak technical norm - The International Electrotechnical Commission).**

MO34 SAFETY UPGRADE PROJECT (cont.)

- New philosophy of fire protection based on the recent international legislature requirements defining requirements on solution of electric and technological components and systems. New valid notices and laws will state basic principles of fire protection philosophy completely different from original solution.
- Seismic improvement based on the site as well as plant civil structures and technology re-evolution in accordance with new Europian requirements.
- Adoption of different technical possibilities to enhance electricity production and the plant maneuvreability.

MO34 SAFETY UPGRADE PROJECT (cont.)

- Implementation of the most recent and modern venting systems with respect on interfaces to fire protection, minimalizing of a space requirements and ensuring secondary containment function .
- Extension of the lifetime up to 40 years of operation as a minimum.
- Elimination of pressure air system by replacement of air controlled valves by motor operated ones, etc.
- Other possibilities for making future operation more safe, reliable and effective.

MO34 SAFETY UPGRADE PROJECT (cont.)

Whole extend of proposed safety measures (SM) and technical improvements (TI) to enhance operational and nuclear safety, and technical and economical parameters of MO34 to meet regulatory requirements by the year 2010 and later covers:

- **Proposed safety measures covering whole scope of the best solution safety measures adopted and implemented on J. Bohunice unit 3 and 4, and Mochovce unit 1 and 2 within design basis accident.**
- **New proposed safety measures dealing with handling of catastrophic accident issues beyond design accident.**
- **Component and system inovation of MO34.**
- **Improving of technical and economical parameters of MO34.**

SAFETY MEASURES WITHIN DESIGN BASIS ACCIDENT

Proposed safety measures covering whole scope of the best solution SMs adopted and implemented on J. Bohunice unit 3 and 4 and EMO12:

GENERAL

G01: Classification of components

G02: Qualification of components

G03: Reliability analysis of safety class 1 and 2 system

REACTOR CORE

RC01: Prevention of uncontrolled boron dilution

SAFETY MEASURES WITHIN DESIGN BASIS ACCIDENT (cont.)

SYSTEM INTEGRITY

CI01: RPV embrittlement and its monitoring

CI02: Non-destructive testing

CI03: Primary pipe whip restrains

CI04: Steam collector integrity

CI05: SG tubes integrity

CI06: SG feedwater distribution integrity

SYSTEMS

S01: Primary circuit cold overpressure protection

S02: Mitigation of a SG primary collector break

SAFETY MEASURES WITHIN DESIGN BASIS ACCIDENT (cont.)

SYSTEMS

S02: Mitigation of a SG primary collector break

S03: Reactor coolant pump seal cooling system

S04: PORV and PSRVs qualification for water flow

S05: ECCS sump screen blocking risk

S06: ECCS suction line integrity

S07: ECCS heat exchanger integrity

S08: Power operated valves on the ESSC injection lines

S09: Feedwater supply vulnerability

S10: SG relief valves qualification for valves

S11: SG relief valves performance at low pressure

S12: Emergency feedwater make-up procedure

SAFETY MEASURES WITHIN DESIGN BASIS ACCIDENT (cont.)

SYSTEMS

S13: SG level control valves qualification for water flow

S14: Primary circuit venting under accident conditions

S15: Essential service water system

S16: Main control room ventilating system

S17: Hydrogen removal system

I&C

I&C01: I&C reliability

I&C02: Safety system actuation design

I&C03: Review of reactor scram initiating signals

I&C04: Physical and functional separation of main and emergency control room

SAFETY MEASURES WITHIN DESIGN BASIS ACCIDENT (cont.)

I&C

I&C06: Primary circuit diagnostic systems

I&C07: Reactor vessel head leak monitoring system

I&C08: Accident monitoring instrumentation

I&C09: Technical support center

I&C10: Water chemistry control and monitoring equipment (primary and secondary)

I&C11: Changing of HINDUKUS and VK3

ELECTRIC SYSTEMS

El01: Start-up logic for the emergency diesels

El02: Diesel generators reliability

SAFETY MEASURES WITHIN DESIGN BASIS ACCIDENT (cont.)

ELECTRIC SYSTEMS

El03: Protection signals of emergency diesel generators

El04: On-site power supply for incident and accident management

El05: Emergency battery discharge time

El06: Reliability of outside top transformer

El07: Reliability of common top transformer system

CONTAINMENT

CONT01: Bubbler condenser strength response (max. pressure difference) under LOCA

CONT02: Bubbler condenser thermodynamic response

CONT03: Containment leak rates

SAFETY MEASURES WITHIN DESIGN BASIS ACCIDENT (cont.)

CONTAINMENT

CONT04: Maximum pressure differences on walls between compartments of hermetic boxes

CONT05: Containment peak pressure & activation of sub-atmospheric pressure after blow-down

CONT06: Experimental verification of thermodynamic phenomena and of BC under LOCA

INTERNAL HAZARDS

IH01: Systematic fire hazards analysis

IH02: Fire prevention

IH03: Fire detection

IH04: Extinguishing

SAFETY MEASURES WITHIN DESIGN BASIS ACCIDENT (cont.)

INTERNAL HAZARDS

IH05: Mitigation of fire effects

IH06: Systematic flooding analysis

IH07: Turbine missiles

IH08: Internal hazards due to high energy pipe breaks

IH09: Heavy load drop

EXTERNAL HAZARDS

EH01: Seismic design

EH02: Analysis of plant specific natural external

EH03: Man induced external events

SAFETY MEASURES WITHIN DESIGN BASIS ACCIDENT (cont.)

ACCIDENT ANALYSIS

AA01: Scope and methodology of accident analysis

AA02: QA of plant data used in accident analysis

AA03: Computer code and plant model validation

AA04: Availability of accident analysis results for supporting plant operations

AA05: Main steam line break

AA06: Overcooling transients related to pressurized thermal shock

AA07: Steam generator collector rupture

AA08: Accidents under low power and shutdown (LPS) conditions

AA09: Severe accidents

AA10: Probabilistic safety assessments (PSA)

SAFETY MEASURES WITHIN DESIGN BASIS ACCIDENT (cont.)

ACCIDENT ANALYSIS

AA11: Boron dilution accidents

AA12: Spent fuel cask drop accidents

AA13: ATWS

OPERATION

OP11: Emergency center

SAFETY MEASURES WITHIN BEYOND DESIGN BASIS ACCIDENT

SMs asigned for beyond design basis accident management are proposed to be implemented on MO34:

TH01: Procedures for sever accident management – SAMG

TH02: System for hydrogen endangering control

TH03: Contorlled flooding of the reactor cavity (pit) and external cooling of the reactor by independent system assigned only for severe accidents

TH04: Extended external coolant sources for spray system, spent fuel pool, primary circuit and opened reacotr long term cooling down operation

TH05: Primary circuit depressurization during severe accidents management

COMPONET AND SYSTEM INOVATION

I&C - Concept of a modern digital in the world distributed systems fulfiling recent requirements of international standards including qualification and classification as follows:

- **completely new integrated I&C system with recent philosophy of the concept of defence in depth,**
- **I&C classification according to IEC 1226,**
- **implementation of recent digital components, consideration of the operational experience and minimalization of component types,**
- **a concept of the unit control from the main and emergency control rooms equiped by new terminal design required by digital technics,**
- **principles of man-machine inteface creation and ergonomy,**
- **new normatives and recommendations for new I&C.**

COMPONET AND SYSTEM INOVATION (cont.)

Electric components – Implementation of new elektric components and systems according to new STN IEC norms. Extend and content of solution has to secure new:

- **concept of MO34 and Slovak electric grid interconnection and power output,**
- **basic philosophy of concept design of house power supply systems,**
- **configuration of house power supply in relation to power supply requirements of safety systems,**
- **requiriments on 6 a 0,4 kV busbars regarding to selectivity, control and I&C,**
- **configuration of the connection of reserve power supply from Slovak grid,**
- **definition of normative basis.**

COMPONET AND SYSTEM INOVATION (cont.)

Reactor cooling pumps.

Proposal to install new type of reactor cooling pums (RCP) without cooling and with long term tightness security of seal system. New RCPs do not requiring oil system for their operation – lubrication of bearnings is secured by internal oil distribution.

Spent fuel pool.

Improvement of spent fuel pool cooling system by the implementation of hird heatexchanger cooled from 2. train of service water system to secure its cooling during reactor power operation.

COMPONET AND SYSTEM INOVATION (cont.)

Reactor in-core and ex-core diagnostics.

Implementation of new system of neutron noise diagnostics (in-core and ex-core) to diagnoze vibrations of reactor internals, including vibrations of fuel rods based on the measurement, analysis and evaluation of the neutron fluctuations in the reactor core, signals from akcelerometers and ΔP of the primary circuit.

Refuelling machine.

Modernization of the refuelling machine based on the replacement of the original electric parts by new modern technics of automation and control.

COMPONET AND SYSTEM INOVATION (cont.)

Service water system.

Inovation of service water system (SWS) over the extent of SM S15 covering:

- **application of a defence in depth philosophy by the implementation of pressure barier against activity penetration into SWS during residual heat removal mode via emergency residual heat removal system,**
- **increasing of SWS resistance against sources of common cause failures by total physical separation of SWS trains,**
- **incresing of safety function of heatexchangres cooled by SWS to avoid their plugging,**
- **improvement of SWS operational reliability,**
- **improvement of SWS seismic resistance.**

COMPONET AND SYSTEM INOVATION (cont.)

System of radiation control.

Realization of new approach according to recent standards and requirements by the implementation of needed steps as:

- **creation of functionally identical monitoring systems according to the safety measure technical specifications realized on EMO12 (SM OP11),**
- **implementation of new monitoring systems based on analyses of radiation control new requirements,**
- **consideration of interfaces between both radiation control systems on EMO12 and MO34**
- **consideration of interfaces of MO34 radiation control with a centre for emergency response,**
- **construction modifications of the radiation control room on EMO12 and MO34.**

INCREASING OF TECHNICAL AND ECONOMICAL PARAMETERS OF MO34

Secondary circuit.

The proposal of a new concept of the secondary circuit to secure a power production by increasing of turbines power up to 276 MW. The concept represents a totally new technical solution including new design of feed water and steam lines eliminating the problem of the corridor +14,5 m.

The solution suppose a modernization of originally supplied turbines TG 220 MW up to the level of the present knowledge by the realization of all required technical measures or a replacement of original turbines by new ones depending on their and connected components of the secondary circuit present technical status quo.

INCREASING OF TECHNICAL AND ECONOMICAL PARAMETERS OF MO34 (cont.)

Maneuvreability.

To analyze of possibility to use MO34 for operation under secondary power maneuvreability and to propose limit margines for an involvement of MO34 into secondary maneuvreability according to Slovak grid requirements.

Fuel.

To use profiled fuel assembly with average enrichment of 4,25 % (first campane) and gadolinium burn-up absorber (7 % benefit of fuel costs).

Fuel cycle extended up to 5 years and fuel burning up prolongation up to 50 MWd/kgU.

Later to use fuel with average enrichment of 4,86 % allowing 6 years fuel cycle and prolongation of fuel burn-up up to 60 MWd/kgU.

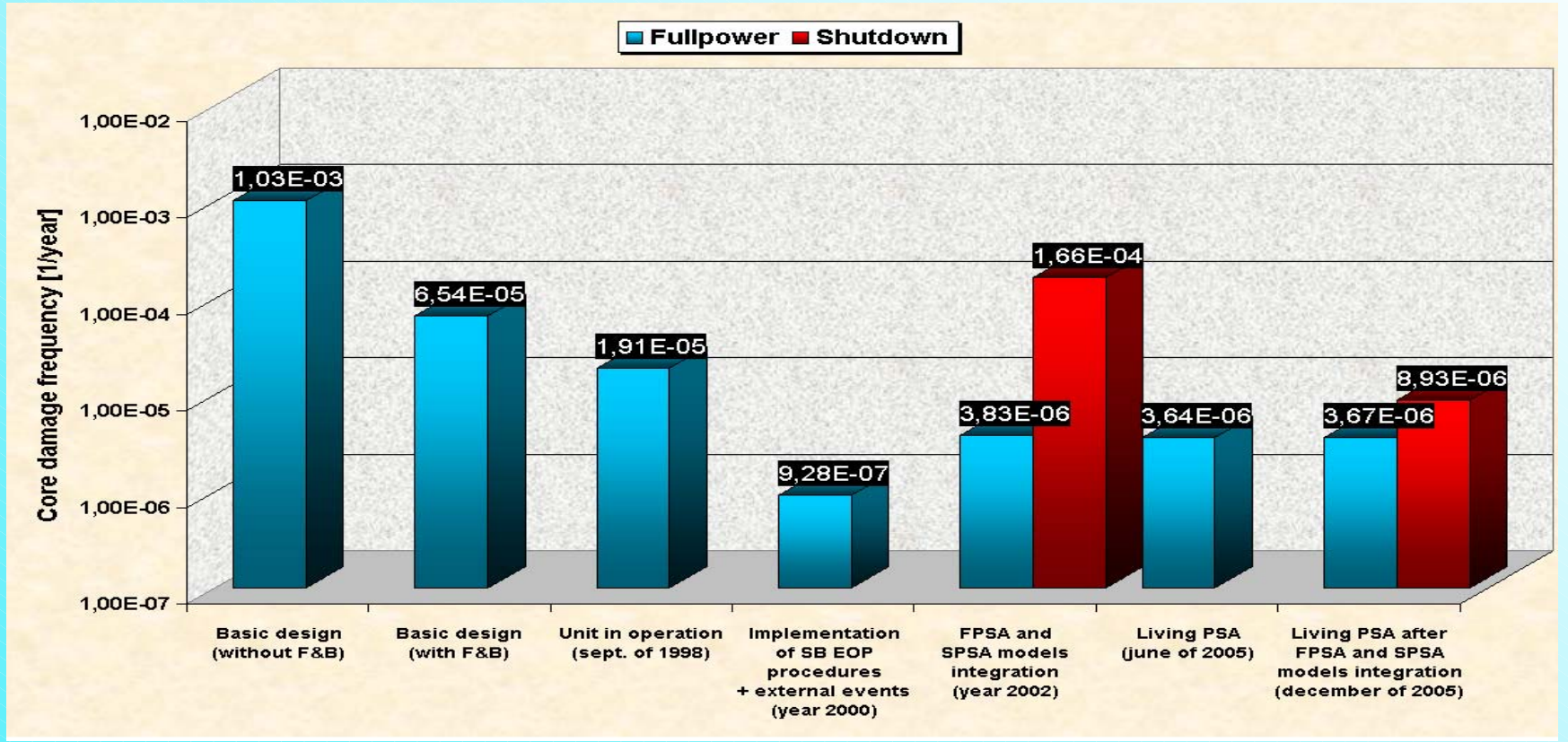
PSA RESULTS

Comparison of Mochovce and Borssele NPP PSA Study results

Event	EMO12	MO34	BORSSELE NPP
Internal events, full power (FPSA)	3.67E-06/year	1.28E-06/year	8,95E-7/year
Internal and external events, shutdown states	8.93E-06/year	8.51E-06/year	1,69E-6/year
Total	1.26E-05/year	9.79E-06/year	2,83E-6/year

PSA RESULTS

Historical overview of total core damage frequency change for level 1 full power PSA study of EMO12 unit 1 based on implementation of SMs:



CONCLUSION

Proposed extent and technical level of MO34 modernization together with physical features of NPPs equiped by reactors of VVER 440/V213 type gives guarantee of accomplishment of high level operational and nuclear safety and reliability, and fulfilment of international requirements on operation of nuclear installations in the future.