«Forum-6 »

UPGRADING OF LENINGRAD NPP BASED ON PSA RESULTS

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- Status of PSA activities for all LNPP Power Units
- Unit 2 PSA within the framework of the International PSA&DSA Project
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- An example of the use of the PSA results to assess priorities of Unit 2 upgrading

PSA status for LNPP Stage 1 Power Units

- Power Unit 2 – full-scale PSA Level 1 activities for the current status (2001) within the framework of ISA Project have been finalised. The relevant documentation issued as LISA Unit 2 Summary Report and Appendices have been submitted to STC GAN RF for expert examination.
- Power Unit 1 - full-scale PSA Level 1 activities for the Power Unit status as upgraded taking into account PSA Unit 2 experience have been started.

PSA status for LNPP Stage 2 Power Units

- Power Unit 3 – Full-scale PSA Level 1 activities within the framework of ISA are being carried out, with RDIPE involvement as the main performer.
- Power Unit 4 - Unit 3 PSA results will be used for Unit 4 after relevent revision and adjustment.

PSA technical and regulatory basis :

- RF Nuclear Law
- Provisions on licensing
- General Provisions : NPP safety assurance
- PF regulatory documents
- «Use of Probabilistic Safety Analysis for the Power Units in Operation. GAN RF Policy Statement».
- ISA Recommendations for operating RBMK and VVER reactors (TS ISAR) RBG- 12 -42-97
- IAEA recommendations:
  - INSAG-6 (PSA general provisions)
  - Safety Series No.50-P-4 (Guideline to perform PSA level 1)
  - INSAG-8 (General basis to assess safety of the first generation NPPs)

PSA&DSA International Project- start of PSA level 1 activities for LNPP Unit 2

Probabilistic and Deterministic Safety Analysis activities for LNPP Unit 2 started within the framework of PSA&DSA International Project in April 1996 and were finalised at the beginning of 1999.

Task description	Participants
1. Full-scale PSA Level 1	Russia: LNPP, RDIPE Sweden: SIP, Relcon, ES Konsult United Kingdom : AEAT Technology USA: PNNL
2. Description of the Power Unit safety relevant systems	Russia: LNPP, RDIPE, VNIPIET USA: PNNL
3. Deterministic analysis of selected accidents	Russia: RDIPE USA: PNNL

The Power Unit 2 rerference status was assumed as upgraded (after completion of the upgrading programme).

Main PSA tasks in PSA&DSA Project

- Assessment of the achieved safety level after the completion of upgrading
- Definition of weak points in the Power Unit Upgrading Project and ways to eliminate the deficiences, improvement of the Upgrading Programme
- Setting priorities for upgrading measures in accordance with their relation to safety

Independent PSA and DSA expert examination in the PSA&DSA Project

GAN RF STC performed the independent expert examination with the involvement of LNPP Gosatomnadzor Inspection and foreign experts (GRS, STUK, Ignalina NPP)

Main PSA achievements in PSA&DSA Project

- Wide range of initiating events :
  - primary circuit LOCA accidents – 11 events
  - different types of transients – 8 events
  - Internal impacts (fires, flooding, missiles)– 36 events
- Accident sequences (event trees) were developed on the basis of DSA neutronic and thermal-hydraulic calculations
- Data on the equipment reliability specific for the given Power unit were widely used
- Assessment of the equipment and cable routes dependence on the internal impact covered 36 rooms(compartments)
- 8 operator's actions were studied in detail in accordance with the special procedure (THERP method)

Main PSA Results in PSA&DSA Project

- After upgrading, the core damage frequency (CDF) value of ~ $2*10^{-5}$ 1/reactor year is achieved, which corresponds to an acceptable safety level for the first generation NPPs
- The Upgrading Programme is of great importance and allows to considerably decrease the severe accident risk
- Several possibilities to supplement and improve the upgrading programme were studied, which will allow to achieve the core damage frequency equal to $6*10^{-6}$ 1/reactor-year.

Main PSA Results in PSA&DSA Project(continued)

- **Till the upgrading completion, the CDF equal to ~ 4*10^{-4} 1/reactor-year can be achieved by means of comparatively easy updating of the emergency instructions in regard to the personnel actions and by means of comparatively low-cost measures to upgrade the existing safety relevant systems**

- **Extra safety improvement measures were developed and implemented for Unit 2 based on the PSA results (M-584)**

Extra measures for Unit 2 safety improvement based on PSA results (in the framework of PSA&DSA Project)

- Assurance of the operation of one emergency feedwater pump in case of the service water loss
- Supplement made to the existing instructions for the Power Unit safe cool-down in case of the service water loss
- Increase of reliability of stand-by service water supply for DG cooling from Unit 1 (updating of instructions)
- The emergency instructions updating in regard to the make-up of the emergency feedwater pump tank and condensers by chemically treated water.
- Training Programmes for the operating personnel of Stage 1 Power Units now include the most important emergency sequences (including operator's actions)

Conclusions and recommendations of independent expert examination of PSA&DSA :

- Assessment of Unit 2 PSA&DSA results :
  - PSA&DSA targets and contents were generally approved
  - PSA&DSA results and conclusions were confirmed
- General recommendations for ISA (next step in the Power Unit safety study) were developed based on PSA&DSA study
- Specific recommendations for PSA and DSA development were worked out:
  - extension of the analysis and PSA model updating
  - development of Unit 2 current status model

Updating and extension of Unit 2 PSA in the framework of ISA Project

- International PSA&DSA Project results for LNPP Unit 2 have become one of the basic prerequisites to perform the in-depth safety analysis of LNPP Unit 2 (LISA -2).
- The assessment of Unit 2 current status (as of 2001) was performed in ISA Project.
- Unit 2 PSA was significantly extended and updated in the ISA project (taking into account the Power Unit current configuration, other ISA tasks results, etc.)

ISA Targets:

1. *Development of ISA Report for LNPP power units. Submission of the Report to Gosatomnadzor of Russia to obtain a long-term operating licence.*

2. *Use of the ISA results, procedures and documentation for the power plant safety analysis on the permanent basis during further operation.*

3. *Transfer and use of Western safety analysis procedures during further development of LNPP infrastructure in this area.*

Unit 2 PSA targets in ISA Project

- Development of Unit 2 PSA model for the power unit current status (as of 2001)
- Contribution to Unit 2 ISA Project (PSA documentation to be included in the ISA Unit 2 Summary Report and Appendices to be submitted to GAN RF to obtain the long-term operating licence)
- Extension and updating of the PSA model taking into account the recommendations of the independent expert examination of PSA&DSA Project and other ISA activities results (DSA, Engineering Assessment, Analysis of External Impact, Fire Safety Analysis, etc).
- Formation of the basis for the PSA to be used as a permanent tool in the generation of LNPP technical policy and safety improvement measures (implementation of On-Line PSA).

Main PSA tasks in the course of the ISA Project implementation

Analysis of initiating events (to be put in compliance with the list of IE from "Recommendations"… of TS ISAR
Analysis of emergency sequences (revision of success block-diagrams and event trees taking into account the DSA results and power unit configuration)
System analysis (systems reliability models) (updating or adding the system models taking into account the power unit configuration and other ISA tasks results)
Analysis of operator's actions reliability (data updating taking into account the power unit configuration)
Analysis of equipment reliability and Initiating Events frequency data (updating or addition of new data)
PSA model calculations, submission of the results and development of safety improvement recommendations (PSA updated model calculations and the development of power unit safety improvement related to the current configuration)

Main activities to cover PSA tasks in the course of ISA Project implementation

All activities for each PSA task within the framework of the ISA Project are subdivided into several directions:

- Provision of data for the PSA tasks and request for data from other ISA tasks
- PSA updating based on the results of independent expert examination of PSA&DSA Project
- Extension of PSA area of activities required for ISA (initiating events spectrum, etc)

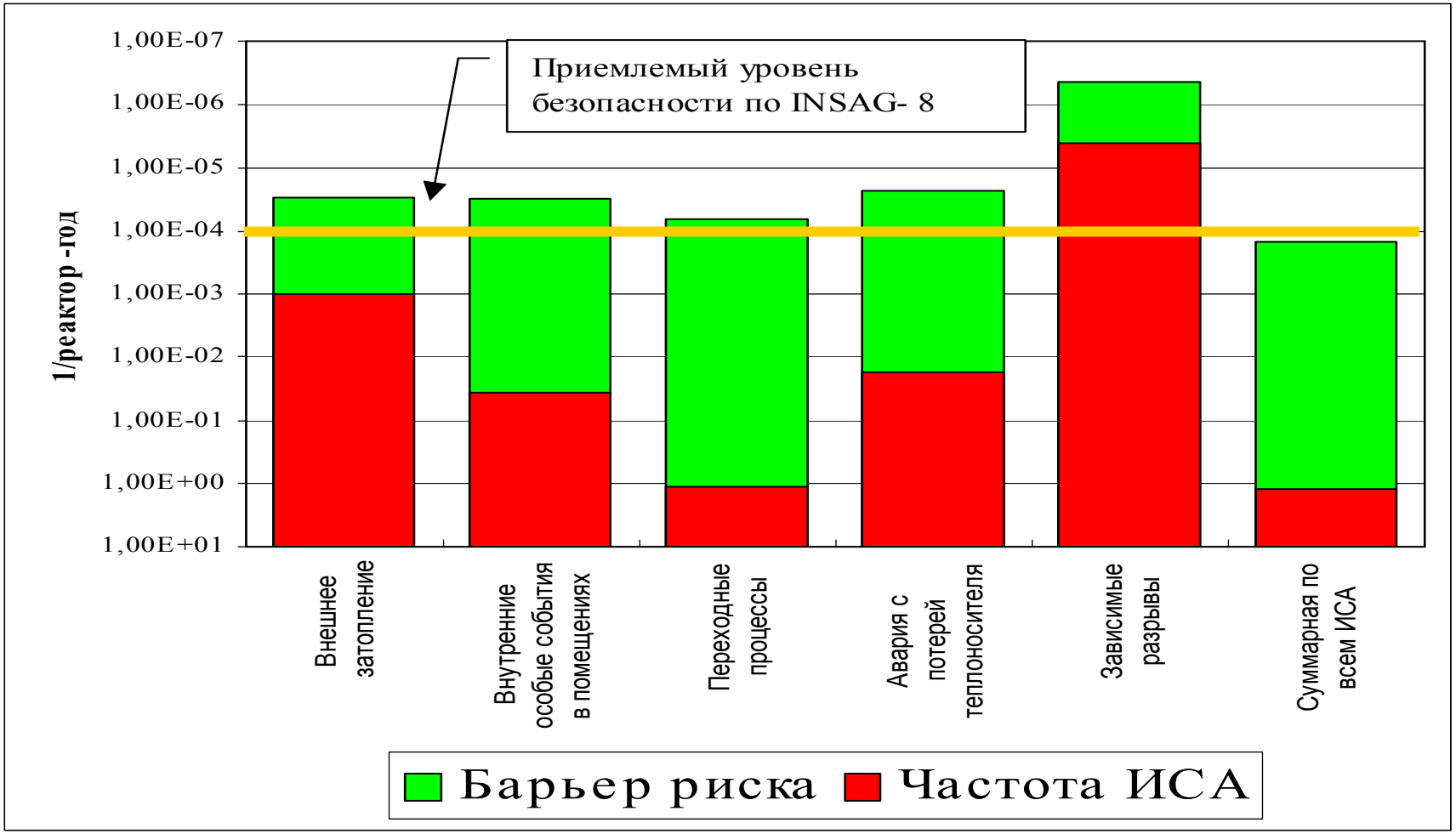
Main PSA results in the ISA Project

- Unit 2 PSA current status model was developed based on :
  - PSA methodology recommended by IAEA
  - RISK-SPECTRUM software
  - PSA&DSA Project experience
  - other ISA tasks results and data
- 24 systems were modelled in detail
- 8 operator's actions were scrutinised
- The required spectrum of initiating events was considered :
  - 13 groups of accidents with MFCC pipelines rupture
  - 8 groups of transients (including common cause failures initiators)
  - 59 internal events in power units compartments (fire,flooding, flying fragments)
  - 1 external initiating event– flooding from the Gulf

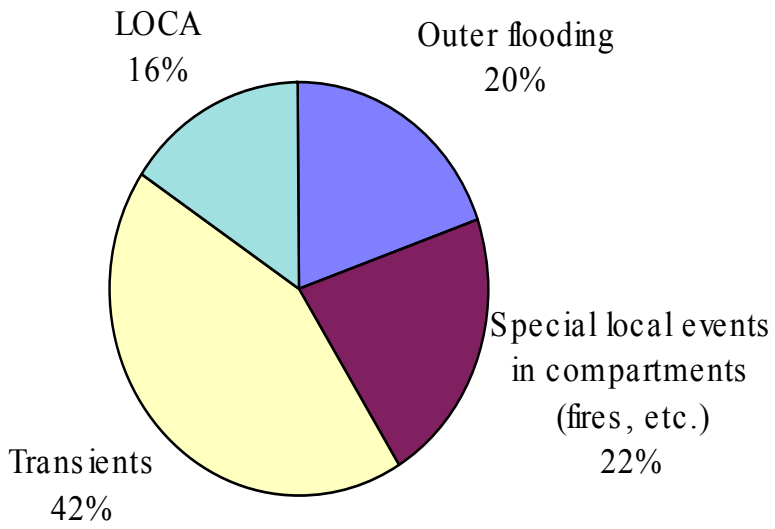
PSA organisation within the ISA framework

- The work was performed by :
  - PSA Laboratory, LNPP
- Technical support :
  - RDIPE; SGPII «VNIPIET»;
- Consulting support :
  - RELCON, ES-Konsult (Sweden); AVAPLAN OY (Finland);
- 38 technical reports were issued.

PSA results in ISA Project



Relative contribution of Initiating Events of different type in total CDF



Total CDF frequency is ~ 1,5E-4 1/reactor-year

PSA summary results in ISA Project

- The current probabilistic safety indicator for Unit 2 is $1{,}5 \cdot 10^{-4}$ 1/reactor-year, which is practically acceptable according to IAEA recommendations for power units of the first generation.
- Unit 2 PSA model was developed for the power unit current status, which allows to quantify and prioritise any proposed power unit modifications.
- A number of new organisational and technical measures aimed at the efficient power unit safety improvement were developed and are being implemented based on the PSA results.

Main directions of Unit 2 safety improvement based on PSA results

- Development of symptom-based emergency operating procedures and improvement of accident management instructions
- Upgrading of Control Safety System (with the introduction of an Emergency Control Room)
- Upgrading of the ECCS (Emergency feedwater supply- Feedwater cooling system)
- Protection of Service Water Pumps from flooding
- Upgrading of Emergency Power Supply and segregation of cable routes

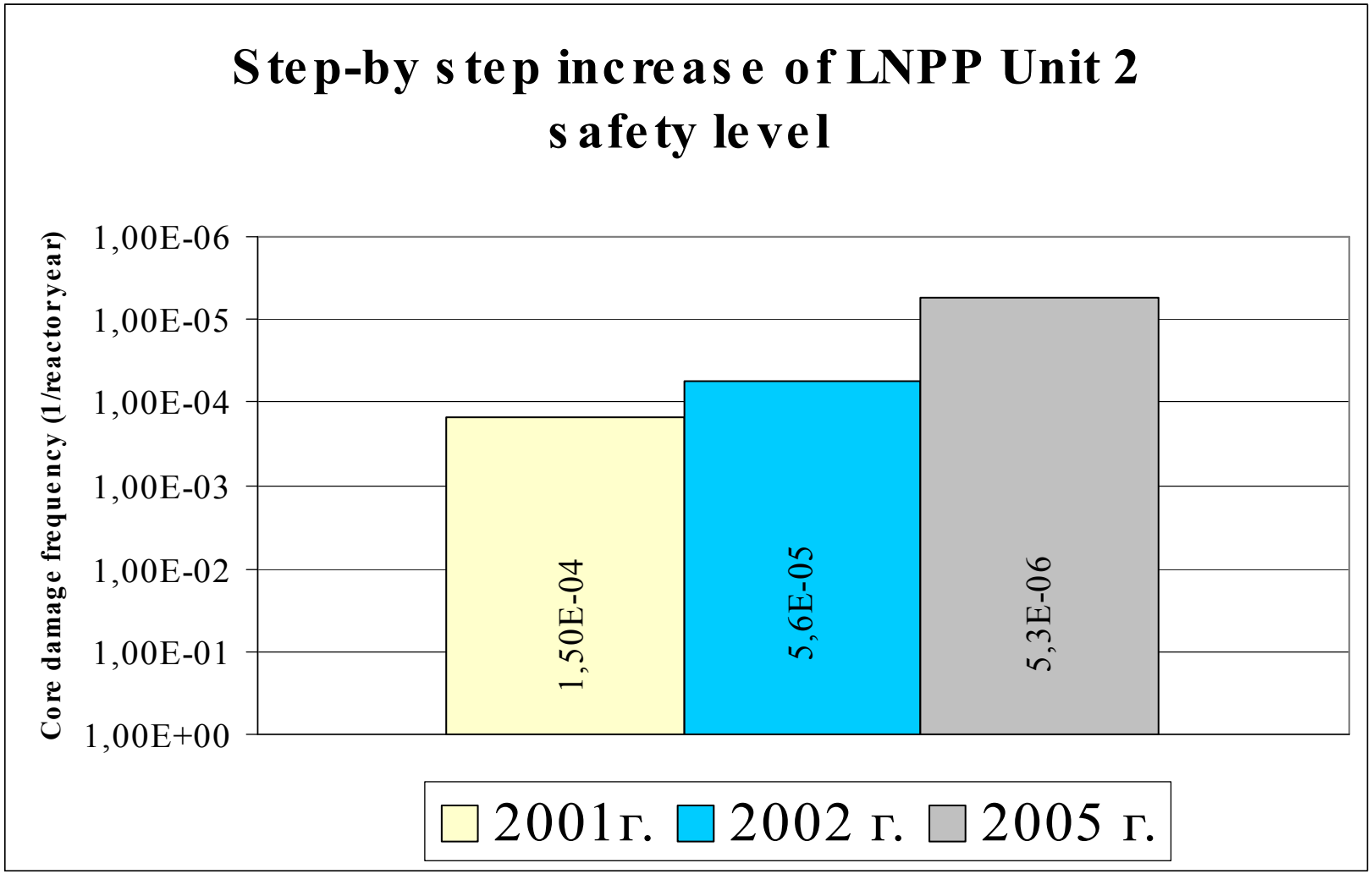
Extra short-term compensating measures for Unit 2 safety improvement based on PSA results

- Development of detailed emergency procedures for accident Initiating Event with power unit cables damage (fires, LOCAs, etc)
- Updating of algorithm for Feedwater Cooling System and Emergency Feedwater Supply
- Replacement of PU pumps and provision of additional air cooling for emergency feedwater pump motors
- Segregation of MPEN intermediate circuit from PEN (Main feedwater pump)
- Increase of batteries discharge time and provision of reliable power supply for the equipment of chemically treated water emergency stock system.

Perspective low-cost measures for Unit 2 safety improvement based on PSA results

- Implementation of one independent long-term cooldown ECCS channel
- Implementation of feedwater supply system emergency lines (by-passing the feedwater units)
- Implementation of a stand-by control board and segregation of safety-relevant system control cabinets
- Upgrading of EPRP (Emergency Protection for Reactor Process Parameters) in regard to AZ (BAZ) signals generation for dominating Initiating Events
- Improvement of equipment diagnostics, tests and maintenance methods

Forecast for Unit 2 safety improvement



Perspectives of the PSA use for the interaction with the regulatory authority

Long-term licensing

Level 1 PSA results to be presented within the power unit ISA Report

Justification of safety improvement measures

Based on Level 1 PSA results, an assessment and prioritisation of of various versions of upgrading and safety enhancement measures development is possible

PSA for licensing –generally recognised main parameters of high-quality PSA

Methodological basis and software used for the PSA shall be in compliance with the international practice	For Unit 2 Level 1 PSA the IAEA basic methodology and RELCON (Sweden) software were used (the software was used for Sweden and Lithuanian NPPs PSA as well as in the PSA&DSA Project)
The personnel of the NPP where the PSA is performed participates in all stages of the analysis	Unit 2 Level 1 PSA was performed by LNPP personnel, with the involvement of engineering institutes personnel, when necessary
Technical information and data on the equipment and systems reliability that give the most comprehensive characteristics of the power unit shall be used as the PSA initial data	For Unit 2 Level 1 PSA the unit-specific data on the equipment reliability and IE frequency were used

PSA use for safety improvement measures justification

An example based on Unit 2 current status model

The analysis of the safety measures effectiveness was performed using Unit 2 current status PSA model.

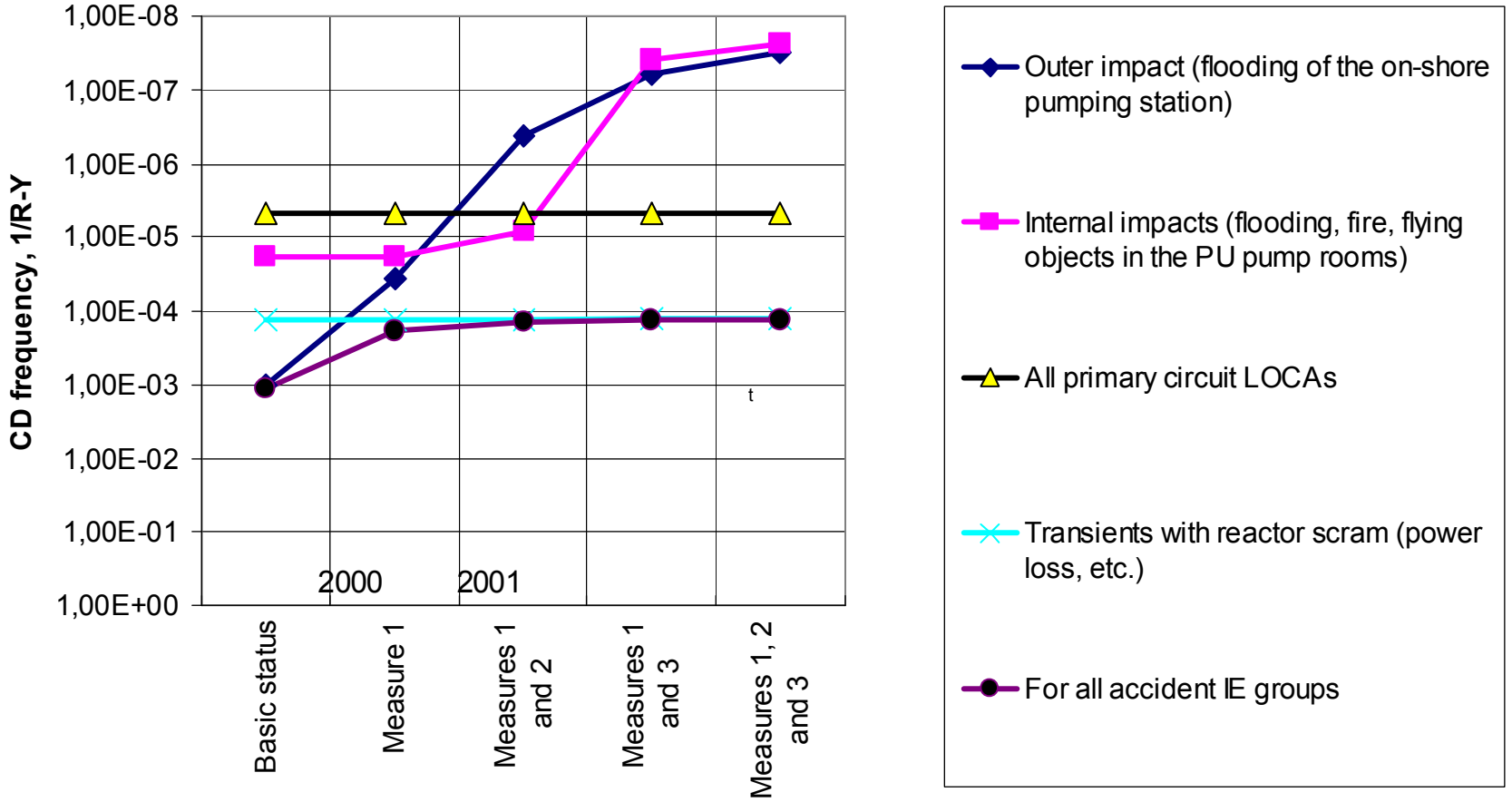
A comparative risk analysis (CDF calculation, 1/reactor year) was performed for Unit 2 four configurations determined by a sequential implementation of the Service Water Supply system (SWS) reliability improvement measures.

Unit 2 configurations considered for the analysis of the SWS reliability improvement

1. Basic configuration - prior to the implementation of any safety improvement measures
2. Power unit configuration (as of 2000) – taking into account the implementation of the measure including 2APN-1 emergency feedwater pump transfer to an open cooling circuit (independent of the SWS).
3. Power unit configuration (as of 2001) – the power unit configuration in the nearest future taking into account the measure including the replacement of two SWS pumps (PU) with those of a new type (fault-tolerant in case of flooding).
4. Prospective configuration – on-shore pumping station commissioning (Building 480 - Independent Service Water Supply System - ISWS)
5. Complete configuration – implementation of both (3) and (4) + on-shore pumping station commissioning

Results of the SWS safety improvement measures analysis using PSA

**Measure 1 - 2APN-1 transfer to open circuit; Measure 2 - installation of two new pumps;
Measure 3 - a new on-shore pumping station construction (Bldg.480)**



Conclusions based on the analysis of the SWS safety improvement measures with the help of PSA

- The measures assessed are most effective in case of Building 401 outer flooding danger (on-shore pumping station - PU pumps)
- The availability of the procedure for using one Emergency Feedwater Pump (APN) motor open cooling circuit (Measure 1) decreased the frequency of the core damage (CDF) in case of the outer flooding for 1.5 order, and the summary frequency for all IE for about 1 order.
- The replacement of two PU pumps improves only the first index - the core damage frequency from the outer flooding (for approximately 2 orders) but makes no significant influence on the changes of the summary CDF.

Conclusions based on the analysis of the SWS safety improvement measures with the help of PSA (continued)

- The introduction of the ISWS (in Building 480) influences significantly (for about 2 orders) the power unit safety improvement in case of special events in the PU machine compartment (Building 401), including fires, explosions, etc.
- After the replacement of two SWS pumps with new ones, fault-tolerant in case of flooding, the construction of a new on-shore pumping station in Building 480 is not a priority since the summary frequency of the core damage will be determined by other dominant contributers (internal impacts in other compartments of the power unit as well as transients).