Development of the Regulatory Norm Document «*Requirements to the Quality of Level-1 Internal Event PSA*» in Russia

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MAIN PSA-RELATED DOCUMENTS

Russian Federal Norms and Rules in the Field of Use of Atomic Energy "General Provisions of Nuclear Power Plants Safety OPB – 88/97"

→ **Provides for Safety Goals**

- Does not provide for explicit requirements for PSA performance

(1) "Requirements to the content of the safety justification report for NPPs with VVER reactor-type"

(2) "Recommendation to the content of report on in-depth safety assessment of NPP units with VVER and RBMK reactor-type"

(3) "Requirements to the composition and content of the documents justifying nuclear and radiation safety of nuclear facility, storage facility, radiation source and/or stated activity (for NPPs)"

→ **Provide for the statement on the necessity of performance PSA for NPPs**

- Recommending nature of documents
- Absence of a rigid regulation for PSA performance and application

Policy Statement "Application of Probabilistic Safety Analysis for Operating Units of Nuclear Power Plants"

→ **Provides for main purposes and perspectives for performance and application of the PSA for operating NPPs in Russia**

- Does not provide for specific requirements to PSA contents and quality

NECESSITY OF DEVELOPING A PSA NORM DOCUMENT

- **Existing norm and PSA-related documents in Russia do not provide specific criteria for the quality and acceptability of PSA for the Regulatory Body**
- **Experience of PSA Regulatory Reviews performed by the PSA Department of the Scientific & Engineering Centre for Nuclear and Radiation Safety (SEC NRS) of the Russian Nuclear Safety Authority shows that quality of PSA studies varies significantly**
  - **Not sufficient justification for data and methods used**
  - **Missing some important aspects of PSA**
  - **Not sufficiently qualitative documentation and results presentation**
  - **Insufficient quality assurance**
- **Various guidelines are used by PSA analysts in Russia**
  - **In addition to the IAEA PSA Guidelines, a number of other Guidelines is used**
  - **Sometimes treatment of PSA issues in Guidelines is different**

☛ *To overcome the existing deficiency, it was decided by Gosatomnadzor RF to develop the norm document: «Requirements to PSA Quality» ("RPSAQ")*

PSA Comparison:
SEC NRS OBSERVATION

- During years 2000-2001 SEC NRS performed a number of Reviews of PSAs developed in Russia
- The conclusion is close to the IAEA observation
- PSAs for similar plants vary significantly
  - Assumptions and limitations
  - Data used
  - Modeling approaches

† This leads to decreasing of

  † *Creditability to PSAs in Regulatory Authority*

  † *Applicability of PSA results in Regulatory Practice*

REVIEW OF PSA STUDIES IN RUSSIA

GENERAL REMARKS

- Goals of performing the PSA either are wrong or are not defined (unclear)
  - Major Goal: "To justify high safety level of NPP under consideration" !
- A quality assurance program including internal review and the procedure for providing for integral correspondence of PSA models and documentation
  - Even developed on paper were never used in the process !
- PSA specialists qualification
  - non-qualified specialists
    - ✓ non-technical specialists (i.e. mathematicians without technological background), students
    - ✓ Non- involvement of plant specialists and/or engineers from utility and design organizations
- Lack of the initial data/information for PSA
  - non-correspondence of the unit to "as-built-as-operated" conditions
  - incompleteness and inconsistency of data used in PSA
- Independent review
  - In a number of PSAs, the quality was not confirmed by independent review
  - Delay in on-line review (not reflected in the PSA results/documentation)
- Declared scope of the PSA does not corresponds to actual PSA status
  - Few fire scenarios were considered - declared as Fire PSA
  - Scenario with heavy loads drop into the core during refueling - declared as Shutdown PSA

MAJOR ERRORS IN "IE SELECTION"

- **Definitions of the IE vary significantly in different PSAs**
  - (1) Abnormal events leading to reactor scram or trip
  - (2) Abnormal events leading to reactor scram
    - leads to screening out of the PSA significant events requiring reactor trip
      - caused by partial failures in front-line&support systems
      - run-back events
      - very small leaks, etc
  - (3) Abnormal events leading to immediate reactor scram
    - leads to additional screening out of the PSA events not requiring immediate reactor scram
      - events which could be mitigated with appropriate operator interactions
      - events, slow in developing
        - ✓ opening of secondary side safety/relief valves
        - ✓ small breaks in feadwater/streamlines , etc
- **Incompleteness of the initiating events (IE) lists**
  - **Lack of systematic approach in consideration of possible events caused by**
    - front-line and support systems failures (interfacing systems, power supply and fan systems, etc.)
    - human errors
    - TS requirements
- **Incorrect screening out of the selected IEs based on:**
    - low occurrence probability
    - potentially low impact to CDF
    - long interval between the moment of IE occurrence and safety systems actuation
    - limitations and restrictions of the analysis !

MAJOR ERRORS IN "IE GROUPING"

- **The IE are grouped without considering:**
  - environmental impact
  - procedural requirements
  - possible dependent failures, associated with the IEs
  - accident progressions after the IE

    Examples:

    (1) Spurious opening of SG SVs + unisolable steam line break

    (2) Transformers failures + spurious reactor scram

    (3) Spurious RS + turbine stop valves closure

- **The IE group representative used for further accident sequence analysis does not include the most conservative features of the IEs included in the group**
  - environmental impact of each IE in the group
  - dependent failures, associated with each IE in the group
  - accident progression after the IE

- **The frequency for IE group is defined based only on the consideration of the representative IE data**

  Example :

  Small LOCA group includes:

  - Small LOCA (representative IE)

  - Pressurizer valves spurious opening

  Frequency for the group is derived based on zero statistic for the event "Small LOCA"!

MAJOR ERRORS IN "ACCIDENT SEQUENCES MODELING"

- Not all accident sequences models are justified by specific deterministic analyses
  - success criteria
  - end states
  - accident progression, etc.
- The mission time always assigned as 24 hours
  - No extension in case if safe end state could not be assured after 24 h due to:
    - depleting of oil/water storage tanks
    - stable development of negative processes, etc.
- Simplification of the accident sequence models
  - non-conservative (leads to omitting of accident sequence minimal cut sets)
  - undeveloped transfer ETs (considered as non-CD end states)
- Accident sequence models developed without account for:
  - influence of IE on equipment availability and possibility of specific human interactions
  - procedural requirements
  - real accident progressions after the IE(plant interlocks)
  - time, needed to perform the action and/or actuate system
- The ETs do not reflect the stated assumptions, initial or boundary conditions

  Examples

  (1) Heading "NHRS" for ET "Loss of Feedwater" is the same as for ET "Reactor Scram"

  (2) ETs do not account for TS requiring "Cold shutdown" for LOCA IEs, etc.

  (3) FAIVs closure at secondary pressure decrease

MAJOR ERRORS IN "SYSTEM ANALYSIS"

- System models do not account for:
  - Possible equipment failures dealing with change of system operation mode in specific sequences
    - failure to start of stopped pumps
    - opening of reclosed valves
  - Interconnection to associated systems for specific accident sequences
    - depleting of shared water tanks by spray and HPECCS systems
- System models do not include unavailability's due to test and maintenance and do not account for possible dependencies dealing with test/maintenance activities/procedures for various components
- System success criteria are defined and modeled without accounting for features and requirements of each accident sequence in AS models
  - System models for headings in ETs are the same for different ETs and ASs
- Loss of dependencies in case of simplifications in system models
  - dependencies on power supply
  - C&I dependencies

NOTE: (1) most errors in FTs are omissions!

(2) review of FTs is the most time consuming part of the review process

MAJOR ERRORS IN "DATA ANALYSIS"

- **Component data analysis**
  - non-consistent classification of failure events (partial failure/degradation or fatal failure) and allocation them to failure modes (i.e. failure to start, failure to run, etc.)
    - must be defined taking into account the requirements for equipment operation within the required mission time during accidents
  - wrong assessment of unavailability due to test/maintenance
  - generic data used without taking into account component boundaries defined in the PSA study
    - no analysis of the applicability of the generic data
    - non-consistent approaches for usage of generic data and plant-specific data
      - ✓ generic data used in case if specific data provides high unavailability !
- **IE frequencies analysis**
  - Overestimated exposure time
    - for rare events exposure time is defined based on all VVER experience (not on the basis of real time interval for available data)
  - Incorrect frequency assessment for IEs dealing with plant systems failures
    - generic data used instead of FTs models
- **CCF data**
  - For a number of equipment failure modes, CCF data are not defined
    - breakers (all failure modes)
    - pumps (failure to run)
    - valves (spurious actuation), etc.

MAJOR ERRORS IN «HUMAN RELIABILITY ANALYSIS»

- The following human error (HE) types are not considered in a number of PSAs:
  - Pre-accident human errors
  - Human errors as IE initiators
- This leads to the following errors:
  - pre-accident human errors dealing with maintenance/test activity were not identified
  - HEs leading to simultaneous loss of several trains/systems were not accounted at frequencies assessment stage
- Non-systematic approach for human interactions (HIs) identification
- Incorrect (non-conservative) screening analysis for HEs
- Usage of the HRA methods without justification of their applicability to researched plant unit
  - TRC - for the units where SOAD implemented
- Incorrect analysis of dependencies between human errors
  - not all MCS are analyzed for HEPs dependencies
  - incorrect assumptions on the independence between specific HEs
- HRA performed only by HRA specialist without involvement of plant specialists
- Poor documentation and reproducibility
- Usage of unknown computer tools
- Lack of documentation and justification for the HEPs obtained

MAJOR ERRORS IN «ANALYSIS OF DEPENDENCIES» and «PLANT MODEL QUANTIFICATION»

Dependencies analysis

- Inadequate analysis of dependencies
  - Non-systematic analysis of functional dependencies (direct and indirect)
  - Lack of analysis of subtle interactions
    - only few PSAs analyze non-functional dependencies
- Lack of consistent approaches for accounting for and implementing in PSA models of all dependencies identified

CCF

- Non-justified and non-consistent grouping of the components in component groups susceptible to CCF
  - similar components are allocated to different CCF groups based on different system identifies!

Model quantification

- Bad documenting of the quantification process
- “Disappearing” MCSs
- Non- symmetry in MCSs

MAJOR ERRORS IN «UNCERTAINTY, SENSITIVITY and IMPORTANCE ANALYSES»

- **Only parametric uncertainties analyzed**
  - Lack of the analysis of uncertainty dealing with
    - Incomplete knowledge on physical processes
    - Assumptions and limitations
- **Sensitivity analyses are performed only in a few PSAs and only for analysis of possible modifications**
  - Assumptions and limitations are the same as for the base case
  - The impact of the assumptions and limitations on the results never analyzed
  - † Sensitivity analyses presented in PSA studies could not justify the benefit of PSA-based recommendations regardless uncertainty associated with lack of knowledge on sensitive issues
- **Importance analyses are performed for:**
  - IEs
  - Equipment failures
  - Only F-V importance measures are used
  - No explanations provided for :
    - the reasons of the importance of specific equipment
    - non-symmetry in the importance results, etc.

GOALS, SCOPE, AND ADDRESSEES OF «RPSAQ»

- **Goals and Scope:**
  - To establish requirements aimed at providing the quality of level-1 internal event (full power) PSA through:
    - Establishing the principles for achievement of PSA quality
    - Definition of the minimum PSA task list (ET, FT, HRA, CCF, Data, etc.)
    - Establishing the requirements to key aspects of PSA tasks
    - Establishing the requirements to software used at conducting the PSA;
    - Establishing the requirements to results presentation and PSA documentation.
  - Not to restrict PSA developers in methods and approaches used, but to provide qualitative criteria for various PSA tasks
- **Addressees:**
  - Must be used by organizations developing level-1 internal event PSA (for power operation mode) *with the aim of inclusion of the PSA in the set of documents justifying nuclear and radiation safety of NPPs* (operating and being designed)
  - Must be used at conducting the PSA review

✓ ***IAEA PSA guidelines and PSA-related documents, as well as the Draft PSA Standards (US) were used during the development process***

GENERAL PSA-RELATED REQUIREMENTS STATED IN «RPSAQ»

- **Goals of performing the PSA must be defined prior to starting the work**
- **A quality assurance program must be developed, including internal review and the procedure for providing for integral correspondence of PSA models and documentation**
- **PSA must be performed by qualified specialists with involvement of utility representatives and/or NPP personnel**
- **The initial data/information for PSA must be collected in a scope required for providing the completeness and consistency of analyses, as well as correspondence of the plant unit to "as-built-as-operated" conditions**
- **PSA must provide for quantitative risk estimates along with uncertainty characteristics, and identify factors causing the significance of risk contributors**
- **PSA Guidelines presenting PSA methodology and technical contents for all PSA tasks must be identified and/or developed**
- ***PSA procedures and results must satisfy the requirements stated in "RPSAQ"***
- **PSA quality must be confirmed by independent review**

PSA TASKS LIST REQUIRED BY «RPSAQ»

- The following major PSA tasks are required to be performed:
  - ***IE selection and categorization***
  - ***Accident sequences modeling***
  - ***Qualitative and quantitative system analysis***
  - ***Data analysis (IE frequencies and equipment unavailability data)***
  - ***Human reliability analysis***
  - ***Analysis of dependencies***
  - ***Plant model integration***
  - ***Model quantification (including importance, sensitivity and uncertainty analysis)***
  - ***Analysis of the results***
  - ***Documentation***

Expectations

- **The directions of PSA practical use for NPP safety goals**
- ***Utilities:***
  - ✓ *continue safety studies with the use of PSA, especially for "old" units and for operating life extension purposes*
  - ✓ *PSA models and results for NPP operation*
  - ➢ ***Results and methods – systematic discussion between utilities and regulatory body***
  - ➢ ***Results – review – base for interaction in regulatory decision making***
  - ➢ ***Avoid of PSA overestimation***
  - ➢ ***CDF – safety reference point and base for NPP safety improvement programs***
- **Conclusions**
  - ☛ ***Gosatomnadzor of Russia expects that NPP operating organisations in order to get systematic and comprehensive information on all safety aspects of the units they operate will make efforts to realise the large scale PSA Level 1 for all operating NPP units and to develop PSA Level 2 and Level 3.***
  - ☛ ***Gosatomnadzor of Russia intends to continue development of requirements to the safety probabilistic analysis, preparation of methodical and administrative documents on NPP PSA and also on PSA application in safety assessment of other nuclear facilities.***

FEEDBACK AND CONCLUSIONS

- **The Final draft of "RPSAQ" was forwarded for review and comments to utility and research organizations dealing with PSA activities**
  - ***In general, the document is considered as a necessary and timely initiated***
  - ***Some organizations do not agree with strict requirements related to PSA tasks (mainly IE and ET -related tasks)***
- **After receiving comments, several meeting of representatives of SEC NRS and other institutions was held, where the issues being argued at most were discussed and solved**
- **A Working Group of representatives of SEC NRS, utilities, and research organizations involved in PSA development and review, is being created now to find a consensus position and produce the Final Version of "RPSAQ"**