Deterministic Analysis Support for the Leningrad NPP Unit 2 ISA

Bruce Schmitt
Battelle, PNNL

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LNPP ISA Development

- **The LNPP Unit 2 In-Depth Safety Assessment was a multinational cooperative effort**
  - Russia, United States, Sweden, Finland and Great Britain
- **Through the USDOE International Nuclear Safety Program, resources were allocated to support the LNPP Unit 2 ISA development**
  - Battelle, Pacific Northwest National Laboratory provided management and technical support
  - This presentation will review the deterministic support for the ISA

LNPP ISA Development

- **The current LNPP Unit 2 ISA grew from the P&DSA started in 1996**
  - level 1 PRA
  - limited DSA support
- **The P&DSA deterministic support at that time was based on a fully reconstructed Unit 2**
  - analysis support included 9 cases
  - DSA was to provide verification of selected success criteria

LNPP ISA Development

- **The original P&DSA analyses included:**
  - cavity venting assessment
  - control rod success criteria (local and global)
  - control withdrawal (central and peripheral rods, hi and low power)
  - group distribution header blockage
  - group distribution header full break LOCA
  - loss of AC (preferred) power
  - main steamline LOCA
  - multiple MSRV stuck open
  - station blackout

LNPP ISA Development

- **In 1998-1999, the Unit 2 P&DSA was expanded to an ISA**
  - As-built configuration for June 2001 ISA submittal
- **LNPP responsible for development of final ISA documentation**
- **Within the ISA deterministic analysis support:**
  - USDOE provided financial support, Battelle provided management and technical support
  - LNPP provided data collection and subcontracting oversight
  - Kurchatov Institute (KI) was subcontracted to perform the deterministic assessments

ISA Deterministic Support

- **Deterministic analyses were needed to support both PSA conclusions and design basis events**
  - verification of ISA success criteria
  - verification of DB events
  - assessment of the impact of BDB events
  - support conclusions regarding EOI and plant performance within the AEA, OA and other related ISA studies

ISA Deterministic Support

- **Lessons learned from the P&DSA were implemented in selecting the initiating events (IE)**
  - KI was contracted to perform a review of the RF-GAN and LNPP Unit 2 TOB lists of IE
  - LNPP coordinated efforts between PSA group and KI for IE needed to support PRA conclusions
  - Multinational participants provided additional insights for needed IE
  - The KI review then provided a priority for selection of IE

ISA Deterministic Support

- **As part of the contracted work for the deterministic assessments, KI was also required to provide the following:**
  - Methodology descriptions for the selected IE
  - Justification for the selection of computer codes used
    - primary codes used were STEPAN and RELAP5
  - Current status of computer code validation efforts
  - Detailed calculation notebooks that documented the models and analyses
  - Review and concur with LNPP as-built design information
  - LNPP required to review and approve any generic RBMK data used (where Unit 2 specific data was not available)

ISA Deterministic Support

- **The deterministic support was split between four major contracts and included:**
  - **26 deterministic analysis reports**
    - 20 thermal hydraulic assessments
    - 5 neutronic assessments
    - 1 radiological assessment
  - **5 engineering assessment reports**
    - 4 thermal hydraulic assessments
    - 1 neutronic assessments
    - engineering assessments filled in gaps where computer code analyses were not needed to address an IE
  - **6 summary reports for the ISA report**
    - included a review of PSA success block diagrams

ISA Deterministic Support

- **For RBMKs, the design basis IE are grouped into 6 main categories**
  - Loss of Coolant Accidents
  - Reactivity Accidents
  - Core Cooling Accidents
  - Operational Accidents
  - Other Accidents
  - Beyond Design Basis Accidents

ISA Deterministic Support

- **Combining the RF-GAN list and Unit 2 TOB yield approximately 66 different IE for assessment**
  - approximately 25 IE were not specifically identified for assessment (within this contract area)
  - most of these were not thermal hydraulic or neutronic related (such as fire, flooding, earthquake, fuel cask drop, etc.) and were addressed elsewhere
- **The PSA needed an additional 8 IE to be reviewed**

ISA Deterministic Support

- **LOCA IE assessed include:**
  - Full break of group distribution header after non-return valve
  - Full break DGH upstream of CV (prior to ECCS actuation)
  - Full break of separator downcomer
  - Break of channel inlet pipe
  - Channel partial rupture
  - Rupture upstream of ICV
  - Break of channel outlet pipe
  - Break of main feedwater pipe: before power assembly non-return valve
  - Break of main feedwater pipe: after power assembly non-return valve
  - Main steam header valve does not fit (stuck open)
  - Small break beyond tightly sealed units of filling lines
  - Small break beyond tightly sealed units of pressure instrumentation lead

ISA Deterministic Support

Reactivity Accident IE assessed include:

- Continuous CPS rod withdrawal at rated and low power
- Continuous CPS rod withdrawal at zero power
- Continuous group rod withdrawal at rated and low power
- Continuous group rod withdrawal at zero power
- Additional absorber withdrawal
- Refueling error, including incorrect fuel loading
- Evacuation or entry of gas into CPS cooling channels
- Failure of one (any) CPS hardware component or logic resulting in spontaneous withdrawal or shutdown of a CPS rod group
- Spontaneous movement of one CPS rod beyond core

ISA Deterministic Support

- **Operational Transients assessed include:**
  - Generator load rise (generators 1 and 2)
  - Turbine trip (turbines 1 and 2)
  - Excessive feedwater flow
  - Reduction in feedwater temperature (loss of feedwater preheaters)
  - Excessive steam flow because of steam pressure regulator failure
  - Excessive steam flow because of unintentional turbine bypass valve opening
  - False ECCS actuation (high power and low power)
  - Trip of one (50%) or two (100%) operating turbine generators
  - Trip of one of two operating turbine generators

ISA Deterministic Support

- **Other Transients**
  - (not addressed within this work … fire, explosion, cask drop, etc.)
- **Beyond Design Basis Accidents assessed include:**
  - Full pipe or MCP header break
  - Main steam line break
  - Total loss of plant power (Station Blackout)
  - Loss of AC Power
  - Loss of Feedwater
  - Partial flow rate loss
  - Main heat sink loss
  - Maximum reactivity insertion with continuous CPS rod withdrawal at minimum controllable power level 5% of rated
  - Maximum reactivity insertion with continuous CPS rod withdrawal at rate power

ISA Deterministic Support

- **PSA and other deterministic analyses include:**
  - Determination of reactivity local and global success criteria
  - Determination of short-term ECCS success criteria
  - Determination of long-term ECCS success criteria
  - Use of CPS for long-term cooling
  - Recovery of over-heated core
  - Use of Spir for long-term cooling
  - ECCS header rupture
  - Depressurization of the deaerators under long-term cooling

Significant Conclusions from Analyses

- **Short-term ECCS (accumulators) not required**
  - Note: not included in ISA submittal as this still under assessment
- **Reduced number of control rods required for shutdown**
  - Note: not included in ISA submittal as this still under assessment
  - Does not yet include long-term shutdown requirements (xenon burnout)
- **DBA IE were effectively validated**
  - Exception: ISA did identify potential single failure in LT ECCS
  - Corrective actions identified

Significant Conclusions from Analyses

- **Feedwater Pipe Rupture**
  - BDBA for Unit 2
  - Operators have >1 hr to align AFWP for recovery
- **ECCS Header Rupture**
  - Operator recovery actions identified, with 20-30 minute timeframe
- **Downcomer Rupture**
  - Operator actions identified for early shutdown of MFWP
  - Operator actions identified for recovery from DGH CV non-closure, with 40-50 minute timeframe

Significant Conclusions from Analyses

- **Recovery from an over-heated core**
  - Potential operator recovery actions identified and timeframe available
- **Accident management for long term-term loss of makeup**
  - Potential operator recovery actions identified and timeframe available
  - Use of CPS and SPiR for long-term cooling to limit consequences of BDBA
- **Long-term Deaerator pressure control**
  - Possibility for loss of LFWP and FWP (long-term deaerator pressure loss)
  - Potential operator recovery actions and design changes identified

Significant Conclusions from Analyses

- **Provided verification of required plant equipment performance**
- **Operator actions defined throughout the assessments**
  - Provided verification of many PSA operator actions
- **Operator actions were identified that were not within current procedures**
  - Primarily in the area of accident management for BDB events
  - Most significant fractional contribution to improve plant risk is through EOI