AREVA

U.S. EPR™ Diversity and Defense-in–Depth (D3) Analysis Methodology

U.S. EPR ™
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AREVA

D3 Perspective

- A software common cause failure (SCCF) of the digital Protection System (PS) is postulated
  - The SCCF is due to a latent software error in all redundant divisions of the PS that is triggered by an Anticipated Operational Occurrence (AOO) or a Postulated Accident (PA)
  - Failure of the PS is due to a common cause software failure; it is <u>not</u> a single failure
  - The Postulated SCCF is a low probability event and is evaluated as a *Beyond Design Basis Event (BDBE)*
  - The D3 Analysis is performed using best estimate (BE) Methods

D3 Analysis Methodology

▶ D3 Analysis Using Best Estimate Approach

- ◇ Use NRC approved SRELAP5 code for plant system response
  - FSAR models adapted for BE analyses

- ◇ Normal operating plant systems not actuated by PS remain available
  - Examples:
    - Main Feedwater Control is available and in automatic
    - Main Steam System is operating normally, including Turbine Bypass System
    - Other plant support systems continue to operate normally (HVAC, Component Cooling Water, etc…)

D3 Analysis Methodology (cont.)

▶ D3 Analysis Using Best Estimate Approach (cont.)

◇ **Plant Initial Conditions**

- Plant is operating at nominal conditions; rated reactor power, temperature and pressure
- All control rods withdrawn
  - Control rod withdrawal and rod ejection events evaluated from PDIL (Power Dependent Insertion Limit) to enable event
- BE neutronics parameters and power distributions
  - Includes BE core decay heat
  - Equilibrium cycle basis

D3 Analysis Methodology (cont.)

▶ D3 Analysis Using Best Estimate Approach (cont.)

◇ Plant End State

- Post-trip mitigation actions completed
- Plant in stable controlled condition (e.g., Hot Standby for non-LOCA events)

◇ Basic Analysis Assumptions

- No concurrent Loss of Offsite Power (LOOP)
- No "additional" Single Failures postulated
- No concurrent Preventive Maintenance
- No stuck Control Rods
- Nominal control and trip setpoints
- No manual operator actions credited before 30 minutes (without justification)

D3 Analysis Methodology (cont.)

▶ BTP 7-19 Acceptance Criteria

- ◇ AOOs: Radiological releases less than 10% of 10CFR100 limits
- ◇ PAs: Radiological releases less than 100% of 10CFR100 limits
- ◇ Integrity of the primary coolant pressure boundary maintained
- ◇ Integrity of the containment maintained

D3 Analysis Methodology (cont.)

▶ AREVA U.S. EPR™ D3 Analysis Targets

- ◇ AOOs: Preliminary conservative target
  - Show that DNB (Departure from Nucleate Boiling) will not occur; therefore, FSAR radiological dose analysis remains bounding
- ◇ PAs: Preliminary conservative target
  - Show that fuel failures in FSAR remain bounding; therefore, FSAR radiological dose analysis remains bounding
- ◇ Maintain peak RCS pressures below 120% of design pressure (consistent with ATWS)
- ◇ Maintain containment pressure below structural integrity limit for ultimate pressure capacity (consistent with SRP 3.8.1)

Chapter 15 Event Evaluation

- **Evaluation Approach**
  - All FSAR Chapter 15 events evaluated
  - Events dispositioned into categories
    - Event is bounded by another event of the same type (i.e., same SRP section) based on qualitative arguments
    - Event is analyzed to demonstrate that acceptance criteria are satisfied

- **Event Example Selection**
  - Examples selected that cover a representative spectrum of events involving different process parameters and mitigation requirements

Chapter 15 Events, Examples

- **15.1.3 Increase in Steam Flow – Calculation Performed**
  - PS protection primarily from low DNB reactor trip (RT)
  - DAS protection primarily from high neutron flux RT
    - Will cause increased peak core power compared to FSAR analysis
  - Calculated to confirm DNB ratio limits not exceeded
    - BE analysis assumptions greatly increase DNB ratio margin
  - Post-RT response is controlled by normal process system operation

- **15.2.2 Turbine trip – Qualitative Argument**
  - PS protection primarily from RT on high RCS pressure
  - DAS protection primarily from RT on high RCS pressure
    - DAS setpoint selected to allow PS actuation first, while providing adequate protection
  - RCS pressure limit not challenged
  - Post-RT response is controlled by normal process system operation

Chapter 15 Events, Examples (cont.)

▶ 15.3.2 Complete loss of RCS flow – Calculation Performed

- ◇ PS protection from RT on low RCS flow
- ◇ DAS protection from RT on low RCS flow
- ◇ Calculated to confirm adequate DNB ratio margin
  - DAS setpoint selected to allow PS actuation first, while providing adequate protection
  - BE analysis assumptions greatly increase DNB ratio margin
- ◇ Post-RT response is controlled by normal process system operation

Chapter 15 Events, Examples (cont.)

- **Section 15.6.5 Loss of Coolant Accidents (SBLOCA) – Combination of Qualitative Argument and Calculation**
  - PS protection
    - RT on low RCS pressure
    - SIS actuation on low RCS pressure
  - DAS protection
    - RT on low RCS pressure
      - DAS setpoint selected to allow PS actuation first, while providing adequate protection
    - SIS actuation on low RCS pressure
      - DAS setpoint selected to allow PS actuation first, while providing adequate protection
  - BE model assumptions
    - BE decay heat and break flow model
    - All four MHSI trains available
    - Partial cooldown by Turbine Bypass System (Automatic MSRT actuation not available with postulated PS failure)
      - Reduces RCS pressure to below MHSI cutoff pressure
  - FSAR analysis bounding for peak cladding temperature (PCT)

Chapter 15 Events, Examples (cont.)

- **Section 15.6.5 Loss of Coolant Accidents (SBLOCA) – Combination of Qualitative Argument and Calculation (cont.)**
  - ◇ No automatic RCP trip included in DAS
  - ◇ Calculated to confirm manual RCP trip is acceptable
    - Cover full break spectrum of SBLOCAs
    - Cover manual trip times up to 30 min
  - ◇ Post-RT response is controlled
    - Heat removal by steam generators (MFW, turbine bypass)
    - RCS makeup by MHSI/LHSI
    - Containment isolation by DAS
    - Manual main control room HVAC re-alignment

Overall D3 Conclusions

- AREVA D3 Analysis Methodology is systematic and comprehensive
- Analysis is consistent with BTP 7-19 and DI&C-ISG-02
- Results of Analysis Methodology will provide a basis for design of an effective diverse actuation system (DAS)
- Docketed analysis (November 2009) will provide a basis to close D3 issue

Next Steps

- Complete the D3 analysis and submit November 2009
- Meet in early January 2010 to address any NRC review questions