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Digital Instrumentation and Control

Oconee Nuclear Station's Diversity and Defense in Depth Analysis for the Digital RPS / ES Upgrade

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Diversity and Defense in Depth Analysis

Historical Perspective

- In 2001, ONS elected to replace its originally installed analog RPS/ES System with a digital based system
- Framtome's Teleperm XS operating system was chosen as the platform for the new system.
- This platform is also utilized for the site's emergency power supply's governor system.

Diversity and Defense in Depth Analysis

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BTP-19 Requirements

- Analyze UFSAR Transients & Accidents and Demonstrate Acceptability of a SWCMF in RPS&ES
- Recognizes SWCMF is Beyond Design Basis
- Realistic Demonstration of Unit Capability to Accommodate SWCMF with No Unacceptable Consequences

Diversity and Defense in Depth Analysis

BTP-19 Requirements

- SWCMF is not considered single failure based on NRC endorsed guidelines for licensing digital upgrades.
- NRC RIS 2002-22 endorsed EPRI TR-102348 Rev.1
  - D^3 analysis is considered a beyond design basis concern
  - Recognizes the likelihood of a common case software failure in a high quality digital system is significantly below that of a single active hardware failure

Diversity and Defense in Depth Analysis

D^3 Assumptions

- Typical conservative initial conditions
- No loss of offsite power
- No single failures
- Integrated Control System (ICS) in automatic
- Realistic core power distribution (SBLOCA only)
- Realistic core flood tank initial conditions (SBLOCA only)
- Realistic operator actions and times
- Credit for AMSAC (trip turbine and start EFW on loss of main feedwater)
- Credit for existing Diverse Scram System (DSS) at 2450 psig RCS pressure
- Credit for Automatic Feedwater Isolation System (AFIS) on low SG pressure
- Pre-existing SG tube leakage at administrative limit

Diversity and Defense in Depth Analysis

Analyzed UFSAR Transients & Accidents

- Bank Withdrawal @ Zero Power
- Bank Withdrawal @ Full Power
- Boron Dilution @ Full Power
- Loss of Coolant Flow
- Locked Rotor
- Dropped Rod
- Turbine Trip
- FDW Line Break
- Steam Generator Tube Rupture
- Rod Ejection
- Large Steam Line Break
- SBLOCA (limiting case)
- Small Steam Line Break
- Loss of MFW
- LOOP

Diversity and Defense in Depth Analysis

Acceptance Criteria

- Offsite dose limits based on R. G. 1.183
  - Large steam line break 25 rem TEDE (EAB & LPZ)
  - Loss of flow 2.5 rem TEDE (EAB & LPZ)
  - Control Room 5 rem TEDE
- RCS overpressure limit is 3250 psia (ASME Service Level C), same as ATWS acceptance criterion for B&W plants
- Reactor Building overpressure limit is 125 psi based on 98% of ultimate strength (design pressure is 59 psig)

Diversity and Defense in Depth Analysis

Results Categories

1. RPS and ESPS not actuated / no adverse impact
2. Event terminated by DSS actuation / no adverse impact
3. Event bounded by another event
4. Analysis required and results show acceptance limits are met
5. Acceptance limits not met / fail diversity and defense-in-depth

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Analysis Results

Category 1 – RPS and ESPS Not Actuated / No Adverse Impact

- Dropped control rod
- Steam generator tube rupture
- Small steam line break (for RCS pressure response and offsite doses)

Note:
The UFSAR analysis does not credit automatic RPS or ESPS actuation

Analysis Results (cont.)

Category 2 – Event Terminated by DSS Actuation / No Adverse Impact

- Control rod bank withdrawal at zero power
- Turbine trip
- Loss of main feedwater
- Loss of offsite power
- Main feedwater line break

Note:
The DSS mitigates the event when RCS pressure reaches 2450 psig

Analysis Results

Category 3 – Event Bounded by Another Event / No Adverse Impact

- Boron dilution at full power (bounded by control rod bank withdrawal)
- Control rod ejection containment response and dose results (bounded by LOCA)
  - Manual actuation of HPI at 5 minutes credited
  - Manual actuation of RBCS and RBS at 8 minutes credited
- SBLOCA containment response and doses (bounded by LOCA)
  - Manual actuation of RBCS and RBS at 8 minutes credited

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Analysis Results

Category 4:
Analysis Required and Acceptance Criteria Met

- Control rod bank withdrawal at full power
  - No cladding failures, so offsite doses are not significant
  - RCS and Reactor Building pressure limits not challenged
- Loss of coolant flow (four-pump coastdown)
  - 26.0% cladding failure and 2.14% fuel melt
  - Radiological doses bounded by two-pump coastdown
  - RCS and Reactor Building pressure limits not challenged

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Analysis Results

Category 4:
Analysis Required and Acceptance Criteria Met

- Loss of coolant flow (two-pump coastdown)
  - 26.6% cladding failure and 2.46% fuel melt
  - RCS and Reactor Building pressure limits not challenged
  - Radiological doses
    - EAB boundary = 2.0 rem TEDE (2.5 rem is limit)
    - LPZ boundary = 0.4 rem TEDE (2.5 rem is limit)
    - Control Room = 1.2 rem TEDE (5 rem is limit)

Diversity and Defense in Depth Analysis

Analysis Results

Category 4:
Analysis Required and Acceptance Criteria Met

- Large steam line break
  - 34.0% cladding failure and 4.75% fuel melt
  - RCS pressure limit is not challenged
  - Peak containment pressure is 44 psig
  - Radiological doses
    - EAB boundary = 4.4 rem TEDE (25 rem is limit)
    - LPZ boundary = 0.9 rem TEDE (25 rem is limit)
    - Control Room = 3.4 rem TEDE (5 rem is limit)

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Analysis Results

Category 4:
Analysis Required and Acceptance Criteria Met

- Locked rotor
  - No cladding failures, so offsite doses are not significant
  - RCS and Reactor Building pressure limits not challenged
- Small steam line break
  - Peak containment pressure is 45 psig
  - Manual actuation of RBCS and RBS credited at 8 minutes

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Analysis Results

Category 4:
Analysis Required and Acceptance Criteria Met

- Small-break LOCA
  - Reactor manually tripped by the operator at 2 minutes
  - Reactor coolant pumps manually tripped by the operator at 2 minutes
  - HPI and LPI manually started by the operator at 5 minutes
  - Peak cladding temperature is limited to around 1000ºF
  - RCS pressure limit not challenged

Analysis Results

Category 5 – Acceptance Limits Not Met

- Large-break LOCA
  - Crediting manual start of HPI and LPI at 5 minutes is not early enough to maintain a coolable geometry
  - LBLOCA does not meet the diversity and defense-in-depth requirements
  - A diverse actuation of LPI is required since LOCA is within the scope of the D^3 study

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Conclusions

- Diversity and defense-in-depth demonstrated for all events except large-break LOCA
- Existing diverse plant systems credited for automatic mitigation
  - **Diverse Scram System (DSS)**
  - **AMSAC**
  - **Automatic Feedwater Isolation System**
  - **Integrated Control System**

Conclusions

- New manual operator action times credited
  - Manual reactor trip at 2 minutes (SBLOCA)
  - Manual start of HPI and LPI at 5 minutes (SBLOCA, REA)
  - Manual start of RBCS and RBS at 8 minutes (SBLOCA, REA)
- Acceptance criteria met (except for LBLOCA)
  - Diverse actuation of LPI required for LBLOCA with failure of RPS/ES