Loss of Offsite Power Modeling

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July 15, 2015

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LOOP/SBO Modeling Guidance Documents

- Generally in compliance with "Treatment of Loss of Offsite Power (LOOP) in Probabilistic Risk Assessments: Technical Basis and Guidelines", Draft EPRI report.

- NUREG/CR-6890, Volume 1 and 2. provides industry average initiator frequencies and recovery curves. (Data updated yearly and posted to NRC website.)
  - Plant centered, switchyard centered, grid related, weather related (extreme weather related for some plants) initiators and recovery curves.
  - One set of industry average frequencies and offsite power recovery curves for all plants.
  - One set of diesel recovery curves for all plants.

LOOP/SBO Modeling Details

- Initiating event frequency (per reactor critical year)

- Standardized event naming
    - Ex: OEP-XHE-XL-NR01HPC   (Offsite power recovery)
    - Ex: EPS-XHE-XL-NR01H   (Diesel recovery)
    - Ex: OEP-XHE-XX-NR02H0   (Convolution correction)

- Template data set includes all OEP and EPS recovery values for 0-24 hours (1 hour increments)

LOOP/SBO Modeling Details – continued

- Conditional LOOP.
  - Modeled using transfer from transient event trees. (TRANS, LOCHS, LOMFW, risk-insignificant xfrs commented out)
  - Modeled with fault tree logic in LOCA scenarios
- Switchyard components included (but not recoverable)
- Logic loop broken at power supply to ESW pumps
- SBO Sequences developed to full 24 hour mission (and extended logic commented out if no significant risk contribution found)

LOOP/SBO Modeling Details – continued

- Diesel mission time: 24 hours for all sequences.

- DG FTR probability is based on a two-part hazard curve.
  - ZT-DGN-FR-E, 0 to 1 hour, 3.8E-3
  - ZT-DGN-FR-L, 1 to 24 hours, 1.0E-3/hr
  - The parts are automatically summed using a SAPHIRE utility module.

- DG non-recovery probability is based on unplanned outage duration. (not included in convolution calcs)

LOOP/SBO Modeling Details – continued

- Convolution corrections available for up to 4FTR terms.
  - CCF is treated same as 1FTR term.
  - Standard recovery rule set is made plant-specific by macros at top of rule section.
  - Convolution correction is applied by recovery rules.
  - Models transitioning to use of automated application of convolution corrections
    - Benefits include automatic generation of new convolution factors each time DG FTR data is updated

SAPHIRE Macro Example

- Project-level recovery rule macros for applying convolution correction.

```
|======================================================================
| Convolution correction rules.

| Define all possible combinations of fail-to-run event
|
zCCF  = EPS-DGN-CF-RUN ;
z1FTR = EPS-DGN-FR-DGA +
        EPS-DGN-FR-DGB +
        EPS-DGN-FR-DGC +
        EPS-DGN-FR-DGD ;
z2FTR = EPS-DGN-FR-DGA * EPS-DGN-FR-DGB +
        EPS-DGN-FR-DGA * EPS-DGN-FR-DGC +
        EPS-DGN-FR-DGA * EPS-DGN-FR-DGD +
        EPS-DGN-FR-DGB * EPS-DGN-FR-DGC +
        EPS-DGN-FR-DGB * EPS-DGN-FR-DGD +
        EPS-DGN-FR-DGC * EPS-DGN-FR-DGD ;
z3FTR = EPS-DGN-FR-DGA * EPS-DGN-FR-DGB * EPS-DGN-FR-DGC +
        EPS-DGN-FR-DGA * EPS-DGN-FR-DGB * EPS-DGN-FR-DGD +
        EPS-DGN-FR-DGA * EPS-DGN-FR-DGC * EPS-DGN-FR-DGD +
        EPS-DGN-FR-DGB * EPS-DGN-FR-DGC * EPS-DGN-FR-DGD ;
z4FTR = EPS-DGN-FR-DGA * EPS-DGN-FR-DGB * EPS-DGN-FR-DGC * EPS-DGN-FR-DGD;
```

SAPHIRE Recovery Rule Application

- Project-level recovery rule for application of convolution correction.

```
|-------------------------------------------------------------------------
| Frequency weighted average

if      (zCCF)  * OEP-XHE-XL-NR01H then
  AddEvent = OEP-XHE-XX-NR01H0;
elseif (z4FTR) * OEP-XHE-XL-NR01H then
  AddEvent = OEP-XHE-XX-NR01H4;
elseif (z3FTR) * OEP-XHE-XL-NR01H then
  AddEvent = OEP-XHE-XX-NR01H3;
elseif (z2FTR) * OEP-XHE-XL-NR01H then
  AddEvent = OEP-XHE-XX-NR01H2;
elseif (z1FTR) * OEP-XHE-XL-NR01H then
  AddEvent = OEP-XHE-XX-NR01H1;
endif
```

SAPHIRE Recovery Rule Application – Automated Interface

Key PWR Operator Actions

- Key operator actions to extend SBO coping time.
    - AFW TDP control beyond battery lifetime
    - CST refill
    - Manual depressurization beyond battery lifetime
    - Alignment of power independent injection source

- AC power recovery following battery depletion.
    - Typically not allowed in SPAR model
    - Remains a key modeling uncertainty

Key BWR timing limitations

- RCIC SBO limitations (Plant X PSA).
    - Exhaust Pressure (about 10 hours)
    - Suction Temperature (about 11 hours)
    - Pressure Suppression Curve (about 17 hours)
    - HCTL (about 14 hours)
    - High Drywell Temperature (about 20 hours)
    - High Area Temperature (> 12 hours)
    - CST inventory (very plant specific)
    - Battery Depletion (very plant specific)

Key BWR timing limitations - continued

- HPCI SBO limitations (Plant X PSA)
  - Exhaust Pressure (N/A)
  - Suction Temperature (8 hours)
  - Pressure Suppression Curve (14 hours)
  - HCTL (11 hours)
  - High Drywell Temperature (17 hours)
  - Area Temperature (>12 hours)
  - CST inventory (very plant specific)
  - Battery depletion (very plant specific)
- 12 hours maximum credit for HPCI/RCIC in SPAR SBO models
  - based on NUREG-1953 'Confirmatory Thermal-Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models—Surry and Peach Bottom'

Key BWR Operator Actions

- Key operator actions to extend SBO coping time.
    - DC load shedding
    - RCIC control beyond battery lifetime
    - HPI suction maintained on CST
    - CST refill
    - Manual depressurization beyond battery lifetime
    - Firewater alignment or alternate engine-driven source
    - Containment venting
- AC power recovery following battery depletion.
    - Typically not allowed in SPAR model
    - Remains a key modeling uncertainty