

Loss of Offsite Power Modeling

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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, $3.8\text{E-}3$
 - ZT-DGN-FR-L, 1 to 24 hours, $1.0\text{E-}3/\text{hr}$
 - 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

Convolution Event Mapping

(Model Type / Phase) **RANDOM** / CD

Loop Recovery Types (LRT)

Name	Code
Plant Centered	PC
Switchyard	SC
Grid Related	GR
Weather Related	WR
Freq. Weight Avg.	

Add Delete

Failure Times (FT)

Time divisions

30M
01H
90M
02H
03H
04H
05H

Minute Add Delete

Failure Combinations (FC)

N of M Common Cause

#	Code	Basic Event
1	1	A EPS-DGN-FR-DGA
2	2	B EPS-DGN-FR-DGB
3	3	C EPS-DGN-FR-DGC
4	4	D EPS-DGN-FR-DGD

Add Delete

Recovery Event Mapping

Name Prefix: OEP-XHE-XL-NI + Map Type: FT + Map Type: LRT Check Events

	Name	Description
1	OEP-XHE-XL-NR30MPC	OPERATOR FAILS TO RECOVER
2	OEP-XHE-XL-NR30MSC	OPERATOR FAILS TO RECOVER
3	OEP-XHE-XL-NR30MGR	OPERATOR FAILS TO RECOVER
4	OEP-XHE-XL-NR30MWR	OPERATOR FAILS TO RECOVER
5	OEP-XHE-XL-NR30M	OPERATOR FAILS TO RECOVER
6	OEP-XHE-XL-NR01HPC	OPERATOR FAILS TO RECOVER
7	OEP-XHE-XL-NR01HSC	OPERATOR FAILS TO RECOVER
8	OEP-XHE-XL-NR01HGR	OPERATOR FAILS TO RECOVER
9	OEP-XHE-XL-NR01HWR	OPERATOR FAILS TO RECOVER
10	OEP-XHE-XL-NR01H	OPERATOR FAILS TO RECOVER

Set As Default Load Defaults

Convolution Event Mapping

Name Prefix: OEP-XHE-XX-N + Map Type: FT + Map Type: LRT + Map Type: FC Generate Names

	Name
642	OEP-XHE-XX-NR24HWR1
643	OEP-XHE-XX-NR24HWR2
644	OEP-XHE-XX-NR24HWR3
645	OEP-XHE-XX-NR24HWR4
646	OEP-XHE-XX-NR24H0
647	OEP-XHE-XX-NR24H1
648	OEP-XHE-XX-NR24H2
649	OEP-XHE-XX-NR24H3
650	OEP-XHE-XX-NR24H4

OK Cancel

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