Estimating Conditional Probability of LOOP Given a Large Break Loss of Coolant Accident (LBLOCA/LOOP)

Presented to NRC Staff

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BWROG

Introduction and Purpose

- The methodology of estimating the conditional probability of LOOP given a LBLOCA contained in the LTR is based on the BNL approach.
- Because of NRC concerns expressed in the RAI, the BWROG is proposing an alternate methodology developed by EPRI for consideration.
- The methodology acceptable to NRC will be included in the LTR.

EPRI Methodology

- EPRI approach is premised on the fact that the pre-trip house load on the power grid is much larger than the post-trip, post-ECCS actuation load on the power grid.

In House Loads	
Operating	**Shutdown**
Reactor Coolant Pumps	RHR Pumps
Circulating Water Pumps	Circulating Water Pump
Electric Main Feedwater Pumps	AFW (PWR only)
Condensate Pumps	Condensate Pump
Containment Fan Coolers	Containment Fan Cooler
TBCCW Pumps	TBCCW Pumps

NPP Large Pump Motor Loads

- BWR
  - Rx Recirc Pumps: 2 X 5 MWe each (6700hp)
  - Circ. Water Pumps: 3++, X 1750+ hp each
  - RHR/LPCI Pumps: 4 X 4160V; (700hp) each
- PWR
  - RCP: 2→4, 13.8kV or 6.9kV; 6000→9000hp
  - Circ. Water Pumps: 3++,
  - SDC Pumps: 4160V; 200hp

Effect of LBLOCA on NPP Electrical System

- One of the first NPP responses to a LBLOCA will be a main-generator trip.
- It is the main-generator trip that may or may not induce a LOOP.
- The probability of main-generator trip following LBLOCA is 100%.
- However, there are many other events that will cause a main-generator trip.

Surrogate Events is a Function of NPP Configuration

- Plants Equipped with Fast Transfer: Appropriate surrogate for a LBLOCA/LOOP is failure to fast transfer the plant loads from the main-generator to the off-site source in response to a transient (i.e., main-generator trip).
- Plants without Fast Transfer: Appropriate surrogate for LBLOCA/LOOP is “main-generator trip/undervoltage relay actuation” or “main-generator trip/diesel generator start”.

Probability Derived from Event History

- A fair estimate of consequential LOOP in response to LBLOCA is the ratio the number of coincident LOOP events over the number of main-generator trips, excluding LOOPs that induce a main-generator trip.
  - Numerator counts each real sequence having an initiator followed by a main-generator trip, which is then followed by a LOOP.
  - Denominator counts each real event with a main-generator trip in the sequence as an endogenous initiator.

Event History

- From LERs and 50.72 Event Reports
- The data contains a total of 232 main-generator trips in all NPPs (BWRS and PWRs) from 1999 to 2006
- Only four out of the 232 main-generator trips were associated with a plant-induced LOOP.
- Events caused by grid-disturbances are not “consequential” because the proximate cause was off-site.

Sites with endogenous initiators and LOOP

Site	Date
Indian Point	31-Aug-99
Diablo Canyon	15-May-00

Plant-specific Estimate Using Bayesian Method

- Step 1:Construct an exogenous prior – the valid trips, and appropriate conditional LOOP events that did not happen at that plant.
- Step 2: Bias the exogenous prediction with endogenous experience (Bayesian method).

Industry Prior:232 Events 1999 → 2006

Year A	All Plant-Centered Events B	All Consequential LOOPS C
1999	37	1
2000	32	1
2001	26	
2002	20	
2003	25	
2004	30	
2005	33	
2006	29	
	232	

Plant-centered events including the NPP switchyard, excluding weather, that caused the main-generator to trip.

Sites with endogenous initiators and LOOP

Site	Date
Indian Point	31-Aug-99
Diablo Canyon	15-May-00

Industry Prior:232 Events 1999 → 2006

Weather-Related and Grid-Centered are exogenous initiators.

All EPRI LOOP Categories and Descriptions

Ia	No off-site power available for 30 minutes or longer to the safety buses.
Ib	No off-site power available for less than 30 minutes to the safety buses.
IIa	With the unit on-line, the startup/shutdown sources of off-site power for the safety buses become deenergized. The main generator remains on-line (connected to the off-site grid) and power for the safety buses is available from a unit auxiliary transformer.
IIb	With the unit on-line, the startup/shutdown sources of off-site power for the safety buses remain energized but in question. There is low or unstable grid voltage, or there might be if the unit trips, or trips along with a LOCA and emergency safety feature actuation. The main generator remains on-line (connected to the off-site grid) and power for the safety buses is available from a unit auxiliary transformer.
III	The unit auxiliary source of power for the safety buses becomes deenergized or unavailable, but off-site power for the safety buses remains available, or can be made available, from a startup/shutdown source. Utilization of this source may require a fast or slow automatic transfer, or manual switching from the control room. A loss of unit auxiliary power that is the result of a unit trip is not a Category III event. To be a Category III event the loss of power from the unit auxiliary source must be the initiating event and precede the unit trip. Most problems that trip the unit off-line are not Category III events. A Category III event is more properly associated with a failure of main electrical power hardware that makes near term availability of the unit auxiliary source of power for the safety buses unlikely.
IV	No off-site power available during cold shutdown because of special maintenance conditions that does not occur during or immediately following operations.
None	Event of interest

Date	Plant	EPRI Cat	P/W/G
01-Apr-97	Pilgrim	Ia	W
31-Aug-99	INDIAN POINT 2	Ia	P
15-May-00	DIABLO CANYON 1	Ia	P
02-Aug-01	Quad Cities 2	Ib	W
14-Aug-03	Nine Mile Point 1	Ia	G
14-Aug-03	Indian Point 2	Ia	G
14-Aug-03	Indian Point 3	Ia	G
14-Aug-03	Ginna	III	G
14-Aug-03	FitzPatrick	Ia	G
14-Aug-03	Nine Mile Point 2	Ia	G
14-Aug-03	Oyster Creek	III	G
14-Aug-03	Perry	Ia	G
14-Aug-03	Fermi 2	Ia	G
14-Jun-04	Palo Verde 1	Ia	G
14-Jun-04	Palo Verde 2	Ia	G
14-Jun-04	Palo Verde 3	Ia	G
02-Aug-06	GINNA	IIb	G

Example Posterior Calculation

A “real NPP” using a list of 232 events with endogenous trip of the main generator. Four trips were endogenous, 228 exogenous. All consequential-LOOP were exogenous.

			NPP			
Year	All Plant-Centered Events	All Consequential LOOPS	Exogenous Trips	Exogenous Loops	Endogenous Plant Trips	Endogenous Plant Consequential Loops
A	B	C	D=B-F	E=C-G	F	G
1999	37	1	36	1	1	0
2000	32	1	32	1		0
2001	26		26	0		0
2002	20		20	0		0
2003	25		25	0		0
2004	30		29	0	1	0
2005	33		33	0		0
2006	29		27	0	2	0
	232		228	2.5	4	0
				1.10%		**1.08%**
				(SUM(E)+0.5)/SUM(D)		(SUM(E)+SUM(G)+0.5)/(SUM(D)+SUM(F))

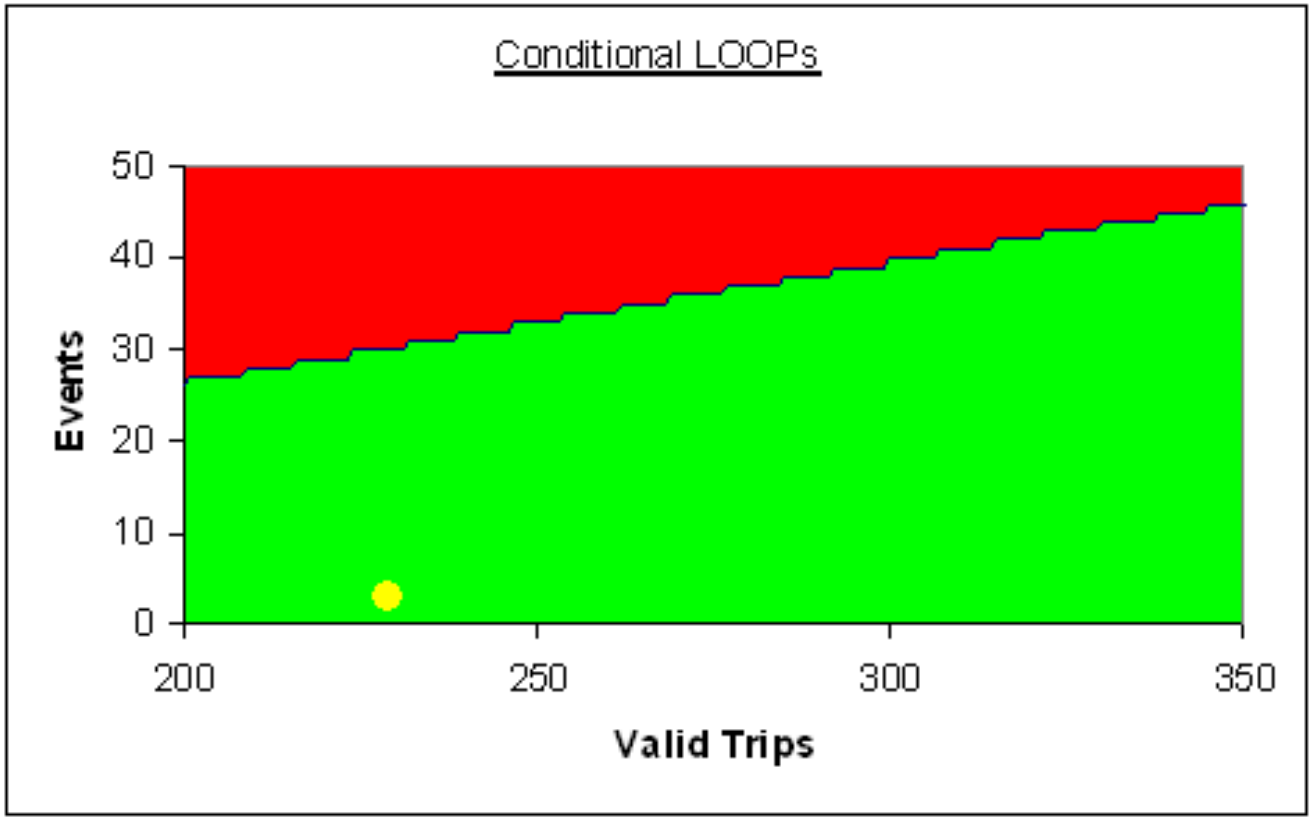
Jefferies Uninformed Prior in a gamma distribution causes one to count 0.5 for the zeroth interval.

Example Posterior Calculation

A “one NPP on a two unit NPP site” using a list of 232 events that tripped the main generator. Five trips were endogenous to the site, 227 exogenous. One consequential-LOOP is endogenous.

			NPP			
Year	All Plant-Centered Events	All Consequential LOOPS	Exogenous Trips	Exogenous Loops	Endogenous Plant Trips	Endogenous Plant Consequential Loops
A	B	C	D=B-F	E=C-G	F	G
1999	37	1	36	0	1	1
2000	32	1	30	1	2	0
2001	26		26	0		0
2002	20		20	0		0
2003	25		25	0		0
2004	30		30	0		0
2005	33		32	0	1	0
2006	29		28	0	1	0
	232		227	1.5	5	1
				0.66%		**1.08%**
				(SUM(E)+0.5)/SUM(D)		(SUM(E)+SUM(G)+0.5)/(SUM(D)+SUM(F))

Conditional LOOP Probability Relation to RG 1.174 Goal



Good faith evaluations of industry events will result in different counts for trips in general as well as deciding whether or not a conditional LOOP occurred.

This analysis finds 2 conditional LOOPs originating at the NPP out of 232 trips of the main generator.

Conclusion

- **An appropriate surrogate for a LBLOCA/LOOP is**
  (a) failure to fast transfer the plant loads to the off-site source in response to a generator trip event, or
  (b) a transient that activates the UV relays for all NPP safety buses.
- **By reviewing the generator trip events for plant-specific applicability, plant-specific LBLOCA/LOOP probability can be estimated.**
- **By the nature of the process, all NPPs assuming 232 valid events and 2 consequential LOOPs will have a LBLOCA/LOOP probability of 1.08%.**
- **Combined with a LBLOCA frequency of 7.6E-6/year, the LBLOCA/LOOP probability will have a frequency of ~8E-8/year, far less than the applicable core damage guideline values of RG 1.174.**

Supplemental Slides

Risk

- Risk = Probability * Consequence
- Risk Frequency
  = Frequency * Probability * Consequence
- CORE DAMAGE =
  IE * [Mit Failure PROB1] * [Mit Failure PROB2] * …
  * [Mit Failure PROBn] * HRA1 * HRA2 * … * HRAn
- Risk of LOCA with Conditional LOOP =
  LOCA Freq * Conditional LOOP PROB

Bounding Values for Conditional LOOP

- Risk of LOCA with Conditional LOOP = LOCA Freq * Conditional LOOP PROB
- LOCA Frequency = 7.6E-06/year
- Conditional LOOP = f(Trips, Events)
- Trips in eight years 1 → 232
- Conditional LOOPs in eight years 1 → 232
- Maximum LOCA-LOOP frequency is 100% * 7.6E-6

Limiting Value for Conditional LOOP

- Maximum value is 100% * 7.6E-6
- Maximum value of conditional LOOP to achieve RG 1.174 goal of 1E-6 is 1/7.6 or ~1.32E-01
- To reach 1.32E-01, the number of conditional LOOP events would have to exceed 13.2% of all of the valid industry events for the plant.

Spectrum of Trips and Events to reach 1E-6 goal

- At least 2 conditional LOOPs in 15 valid trips.
- At least 15 conditional LOOPs in 110 valid trips.
- At least 30 conditional LOOPs in 230 valid trips.
- At least 42 conditional LOOPs in 320 valid events.