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From Data to Decisions: The Role of Standardized Plant Analysis Risk (SPAR) Models in Nuclear Safety

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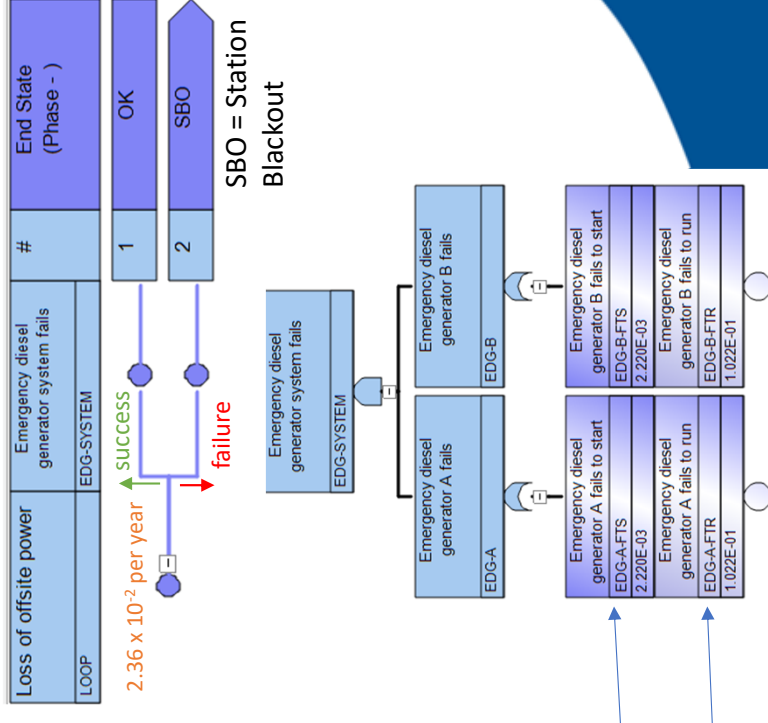


Data

- System information
 - Licensees share system information with Idaho National Laboratory
 - Idaho National Laboratory develops the SPAR models

• Quantitative → <https://nrcoe.inl.gov/>

- **Initiating event frequencies**
 - Example: loss of offsite power
- Basic event probabilities
 - Number of failures and number of demands: failure probability per demand; typically, fails to start
 - Number of failures and number of hours: failure rates per time; typically, fails to run



Case Study: Using the SPAR Model for Inspection Planning

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Inspection guidance from Inspection Procedure 71111.04 ([ML23121A148](#))

*“Select systems or trains with a high risk significance for the **current plant configuration** (considering out-of-service, inoperable, or degraded condition)...”*

Hypothetical inspection sample:

“Emergency diesel generator DGN02 and support systems during emergency diesel generator DGN01 maintenance the week of January 30, 2025.”

Next step: Map the **current plant configuration** into the SPAR model

Disclaimer: The model used in this exhibit does not represent an actual plant. It is a model the NRC uses for training purposes.

Case Study: Using the SPAR Model for Inspection Planning

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1. Select the **system**.
2. Select the **component**.
3. Modify the component failure mode to **Out for Test & Maintenance**.

Significance Determination Process [project: "G-PWR - Generic Pressurized Water Reactor (PWR)"]

Significance Determination Process

Step 1. **Identify affected initiators and components** Select a system on the left to view its associated components. Mark the components/initiators affected by the condition being analyzed.

Initiators	High Pressure Injection (HPI)
Accumulators (ACC)	Low Pressure Injection (LPI)
Ac Power System (ACP)	Low-Pressure Recirculation (LPR)
Auxiliary Feedwater (AFW)	Main Feedwater (MFW)
Component Cooling Water (CCW)	Main Steam (MSS)
Containment Sump (CSS)	Primary Pressure Relief (PPR)
Chemical and Volume Control (CVC)	Reactor Coolant (RCS)
DC Power (DCP)	Reactor Protection (RPS)
Emergency Power (EPS)	Safety Injection Sump (SIS)
FLEX Equipment (FLX)	Service Water (SWS)

Emergency Power (EPS)

- ☐ CIRCUIT BREAKER-A104 FOR TRAIN-A (EPS-CRB-A104)
- ☐ CIRCUIT BREAKER-B104 FOR TRAIN-B (EPS-CRB-B104)
- ☒ EMERGENCY DIESEL GENERATOR DGN01 (EPS-DGN-DGN01)
- ☐ EMERGENCY DIESEL GENERATOR DGN02 (EPS-DGN-DGN02)
- ☐ FAILURE OF SEQUENCER OF DGN01 (EPS-SEQ-DGN01)
- ☐ FAILURE OF SEQUENCER OF DGN02 (EPS-SEQ-DGN02)
- ☐ SBO DG (EPS-DGN-SBO)
- ☐ SBO DIESEL GENERATOR HVAC UNIT (EPS-FAN-SBOHVAC)

Significance Determination Process [project: "G-PWR - Generic Pressurized Water Reactor (PWR)"]

Significance Determination Process

Step 2. **Modify Component States** Indicate the modifications to the applicable failure modes of the components selected on the previous step.

Component Failure Type	Modification Type	New Failure Probability
Emergency Power (EPS)		
EMERGENCY DIESEL GENERATOR DGN01 (EPS-DGN-DGN01)	Out for Test & Maintenance	1.000E+0
Component unavailable due to test and maintenance (TM)	Not applicable	
Fail to continue running (FR)	Not applicable	
Fail to start (FS)	Not applicable	
Load/Run (LR)	Not applicable	

Workspace Options
Save Workspace As... Go

Exit Analysis

Uncheck All Components

Search

Workspace Options
Save Workspace As... Go

Exit Analysis

Back Next

Case Study: Using the SPAR Model for Inspection Planning

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4. Change the duration to **3 days**.
5. Add **short analysis title**.
6. Document basis for duration in the **analysis notes**.
7. Select **Finish**.
8. Allow time for calculation to run.

Significance Determination Process [Project: "G-PWR - Generic Pressurized Water Reactor (PWR)"]

Significance Determination Process

Step 3. Analyze Changes

Specify the start time and end time (or duration) for the configuration indicated on the previous step. Optionally, provide a name and notes for the report/workspace.

Specify the start date and time

Start Date: 01/30/2025 End Date: 02/02/2025

Specify the duration of the condition

Duration: 3 day(s)

Model Types

☐ INT-FIRE ☐ INT-FLOOD ☒ RANDOM

Report Format

☒ HTML ☐ PDF

Other analysis settings

☐ Turn off all normal test and maintenance events [P (T/M) = 0].

☒ Calculate Screening LERF?

Short analysis description or title

Emergency diesel generator DGN 01 inspection sample

Analysis notes or information

The 3-day duration is based on Limited Condition for Operation 3.8.1.1, Action b.2 in the plant's technical specifications, that is, "Restore at least two emergency diesel generators to OPERABLE within 72 hours."

Exit Analysis Save Workspace As... Go

Back Finish

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Decision Input: Using the SPAR Model for Inspection Planning

Insights

- Increase in core damage frequency dominated by fire (FRI) events and human performance (i.e., "XHE" basic events)
- **Suggested systems for inspection:** Station Blackout Diesel Generator (SBO DG) and Auxiliary Feedwater (AFW)

Takeaway: SPAR models provide an input for performing risk-informed inspections, which enable nuclear safety.

I. Assessment Summary

Duration:	3 days	Project:	Generic Pressurized Water Reactor (PWR)
CCDP:	7.3E-7	Model Version:	1.2
CDP:	2.4E-7	Model Date:	05/19/2021
Increase:	4.8E-7 /year	Saphire Version:	Saphire 8.2.1.1
Color:	Green		

III. Sequence Summary

The following accident sequences contributed at least 1% to the total increase:

Event Tree	Sequence	CCDP	CDP	Increase	%Total	Sequence Logic
FRI-AB-LOOP-DIVB	2-18-06	2.9E-7	2.0E-8	2.7E-7	55%	ZV-TOP, RPS-FT, EPS-FT, AFW-B-FT, PORV-B-FT, RCP-LOC-A-FT, OPR-02H-FT, DGR-02H-FT
FRI-AB-LOOP-DIVB	2-18-12	8.7E-8	5.8E-9	8.1E-8	17%	ZV-TOP, RPS-FT, EPS-FT, AFW-B-FT, OPR-01H-FT, DGR-01H-FT
LOOPWR	18-06	2.7E-8	1.3E-9	2.6E-8	5%	/RPS-FT, EPS-FT, /AFW-B-FT, /PORV-B-FT, RCP-LOC-A-FT, OPR-02H-FT, DGR-02H-FT
LOOPCR	18-06	2.4E-8	8.9E-10	2.3E-8	5%	/RPS-FT, EPS-FT, /AFW-B-FT, /PORV-B-FT, RCP-LOC-A-FT, OPR-02H-FT, DGR-02H-FT
LOOPSC	18-06	2.2E-8	8.7E-10	2.2E-8	4%	/RPS-FT, EPS-FT, /AFW-B-FT, /PORV-B-FT, RCP-LOC-A-FT, OPR-02H-FT, DGR-02H-FT
FRMCR	2-5	1.6E-8	1.2E-9	1.5E-8	3%	EVAC, /RPS-FT, /ASD-XHE-FT, EPS-FT
LOOPCR	18-12	9.3E-9	3.4E-10	9.2E-9	2%	/RPS-FT, EPS-FT, AFW-B-FT, OPR-01H-FT, DGR-01H-FT
LOOPSC	18-12	9.2E-9	3.4E-10	8.9E-9	2%	/RPS-FT, EPS-FT, AFW-B-FT, OPR-01H-FT, DGR-01H-FT
LOOPWR	18-12	8.8E-9	4.8E-10	8.3E-9	2%	/RPS-FT, EPS-FT, AFW-B-FT, OPR-01H-FT, DGR-01H-FT
14160ACB	19	7.2E-9	6.3E-10	6.6E-9	1%	/RPS-FT, AFW-FT, MW-FT, F8B-FT

SEQUENCE: FRI-AB-LOOP-DIVB, 2-18-06				
INITIATOR: IE-FRI-AB-LOOP-DIVB (2.0E-3 PER YEAR)				
DELTA	CCDF	%TOTAL	CUT SET EVENT INFORMATION	
2.9E-7	3.5E-5	100.0%		
1.1E-7	1.4E-5	39.6%	EPS:XHE:XL:NR02H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 2 HOURS
			EPS:XHE:XL:SBO-DG	OPERATOR FAILS TO START AND ALIGN SBO DIESEL GENERATOR
			RCS:MDP:LK	RCP SEALS FAIL
9.6E-8	1.2E-5	33.6%	EPS:DGN:FR:SBO	SBO DG FAILS TO RUN
			EPS:XHE:XL:NR02H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 2 HOURS
			RCS:MDP:LK	RCP SEALS FAIL
3.8E-8	4.6E-6	13.3%	EPS:DGN:TM:SBO	SBO DIESEL GENERATOR TEST OR MAINTENANCE
			EPS:XHE:XL:NR02H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 2 HOURS
			RCS:MDP:LK	RCP SEALS FAIL
1.3E-8	1.6E-6	4.5%	EPS:FAN:FR:SBOHVAC	SBO DIESEL GENERATOR HVAC UNIT FAILS TO RUN
			EPS:XHE:XL:NR02H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 2 HOURS
			RCS:MDP:LK	RCP SEALS FAIL
1.1E-8	1.3E-6	3.7%	EPS:DGN:LR:SBO	SBO DG FAILS TO LOAD/RUN
			EPS:XHE:XL:NR02H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 2 HOURS
			RCS:MDP:LK	RCP SEALS FAIL
8.2E-9	1.0E-6	2.9%	EPS:DGN:FS:SBO	SBO DG FAILS TO START
			EPS:XHE:XL:NR02H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 2 HOURS
			RCS:MDP:LK	RCP SEALS FAIL
5.8E-9	7.1E-7	2.0%	ACP:CRB-OO-SWGC	CIRCUIT BREAKER SWG-C FAILS TO CLOSE ON DEMAND
			EPS:XHE:XL:NR02H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 2 HOURS
			RCS:MDP:LK	RCP SEALS FAIL
SEQUENCE: FRI-AB-LOOP-DIVB, 2-18-12				
INITIATOR: IE-FRI-AB-LOOP-DIVB (2.0E-3 PER YEAR)				
DELTA	CCDF	%TOTAL	CUT SET EVENT INFORMATION	
2.8E-8	3.3E-6	100.0%		
			AFW-TDP:FR-TDP	AFW TDP FAILS TO RUN
			EPS:XHE:XL:NR01H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 1 HOUR
			EPS:XHE:XL:SBO-DG	OPERATOR FAILS TO START AND ALIGN SBO DIESEL GENERATOR
2.3E-8	2.8E-6	26.9%	AFW-TDP:FR-TDP	AFW TDP FAILS TO RUN
			EPS:DGN:FR:SBO	SBO DG FAILS TO RUN
			EPS:XHE:XL:NR01H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 1 HOUR
9.2E-9	1.1E-6	10.6%	AFW-TDP:FR-TDP	AFW TDP FAILS TO RUN
			EPS:DGN:TM:SBO	SBO DIESEL GENERATOR TEST OR MAINTENANCE
			EPS:XHE:XL:NR01H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 1 HOUR
3.5E-9	4.3E-7	4.0%	AFW-TDP:FS-TDP	AFW TDP FAILS TO START
			EPS:XHE:XL:NR01H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 1 HOUR
			EPS:XHE:XL:SBO-DG	OPERATOR FAILS TO START AND ALIGN SBO DIESEL GENERATOR
3.2E-9	3.9E-7	3.7%	AFW-TDP:TM-TDP	AFW TDP IS IN TEST OR MAINTENANCE
			EPS:XHE:XL:NR01H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 1 HOUR
			EPS:XHE:XL:SBO-DG	OPERATOR FAILS TO START AND ALIGN SBO DIESEL GENERATOR
3.1E-9	3.8E-7	3.6%	AFW-TDP:FR-TDP	AFW TDP FAILS TO RUN
			EPS:FAN:FR:SBOHVAC	SBO DIESEL GENERATOR HVAC UNIT FAILS TO RUN
			EPS:XHE:XL:NR01H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 1 HOUR
3.0E-9	3.6E-7	3.4%	AFW-TDP:FS-TDP	AFW TDP FAILS TO START
			EPS:DGN:FR:SBO	SBO DG FAILS TO RUN
			EPS:XHE:XL:NR01H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 1 HOUR
2.7E-9	3.3E-7	3.1%	AFW-TDP:TM-TDP	AFW TDP IS IN TEST OR MAINTENANCE
			EPS:DGN:FR:SBO	SBO DG FAILS TO RUN
			EPS:XHE:XL:NR01H	FAILURE TO RECOVER AN EMERGENCY DIESEL IN 1 HOUR
2.5E-9	3.1E-7	2.9%	AFW-TDP:FR-TDP	AFW TDP FAILS TO RUN
			EPS:DGN:LR:SBO	SBO DG FAILS TO LOAD/RUN