Standardized Probabilistic Safety Assessment Models: Applications of SPAR-CSN Project

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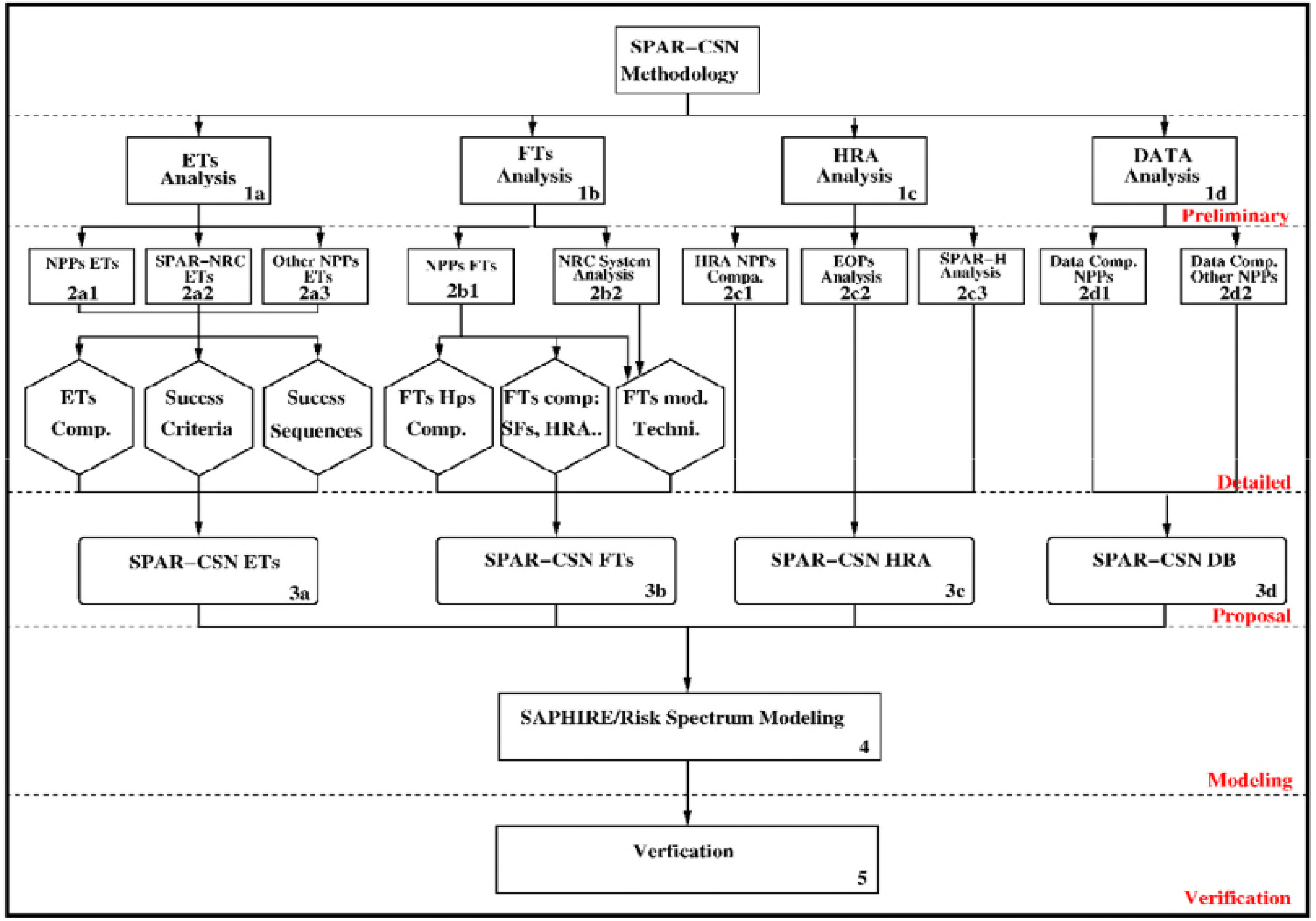
1 OBJECTIVES OF THE SPAR-CSN MODELS

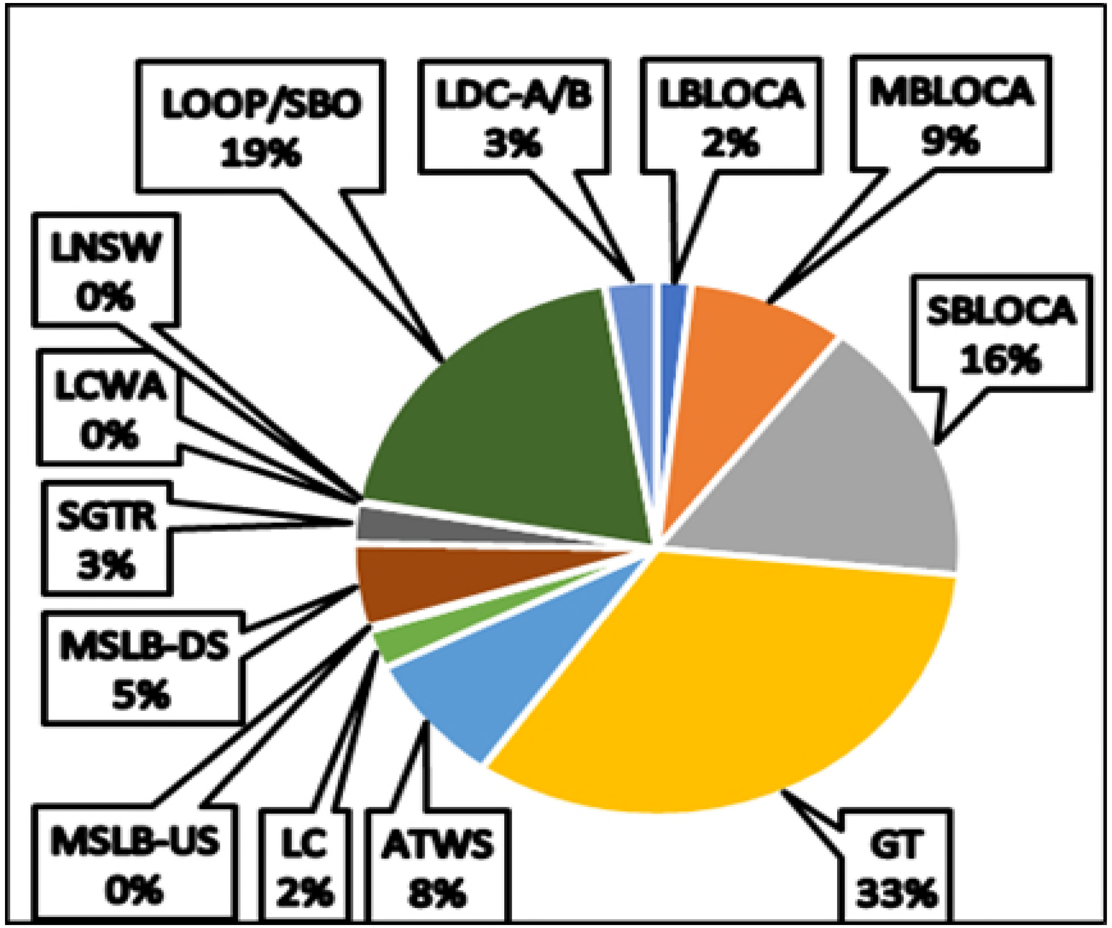
- Development of standardized models of Spanish NPP
  - Unified view of risk models
  - Caveat: differences in technology/design
- Qualitative:
  - Better understanding of the main contributors to risk in Spanish NPPs
  - Assess plant-specific models
- Possible uses
  - Prioritizations in inspection and oversight tasks over Spanish NPPs
  - Precursor analysis of operational incidents occurred in Spanish NPPs
  - Assessment of inspection findings within the Spanish regulatory system, SISC.
  - Training of CSN personnel, including system-wide presentation of the models and results

1 Methodology

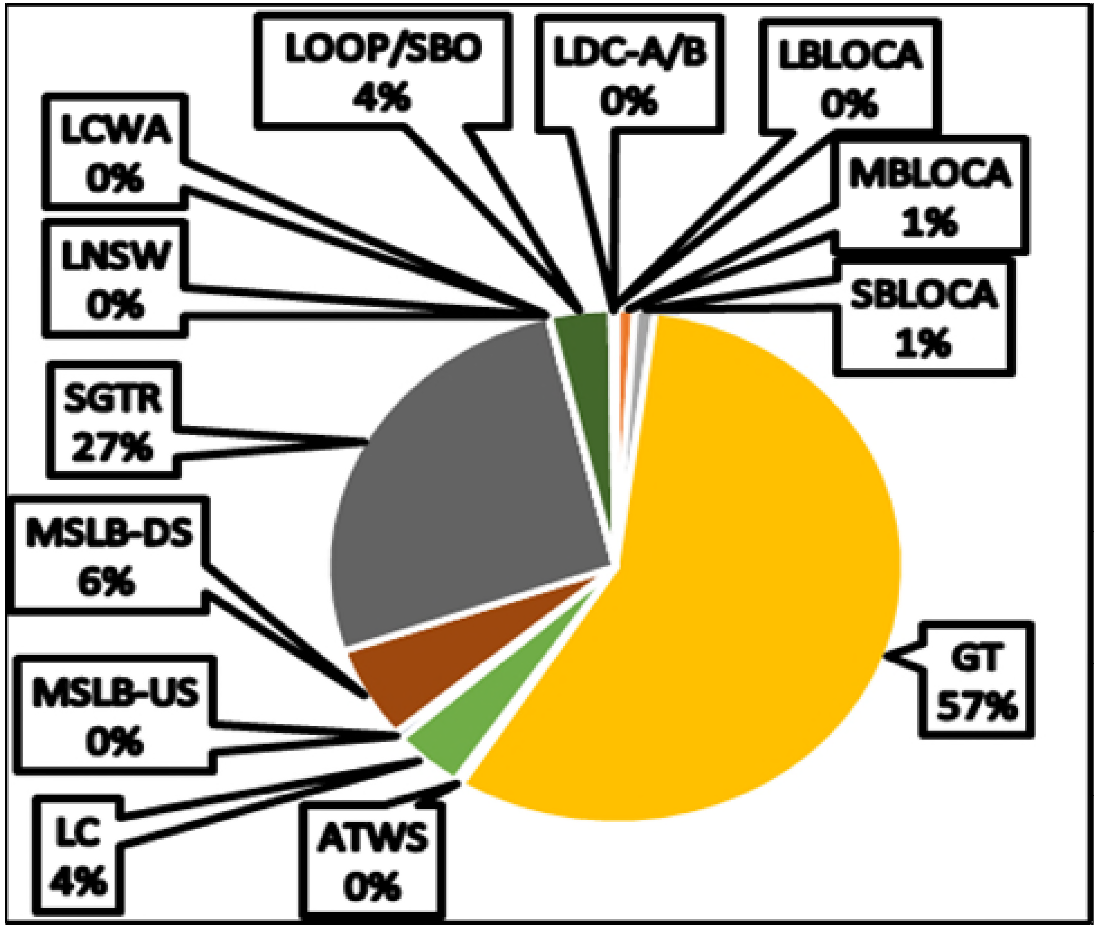


- **Methodology:** analysis and comparison of plant-specific PSA and available SPAR models
- **Tasks:** Event Trees (ET), Fault Trees (FT), Human Reliability Analysis (HRA), Data Analysis (DA), Quantification (Q)
- **Steps:**
  1. Analysis of existing models
  2. Comparison
  3. Standardization
  4. Model development (RiskSpectrum); quantifications
  5. Model verification

1 Results



No Dependency between Human Actions



Dependent Human Actions

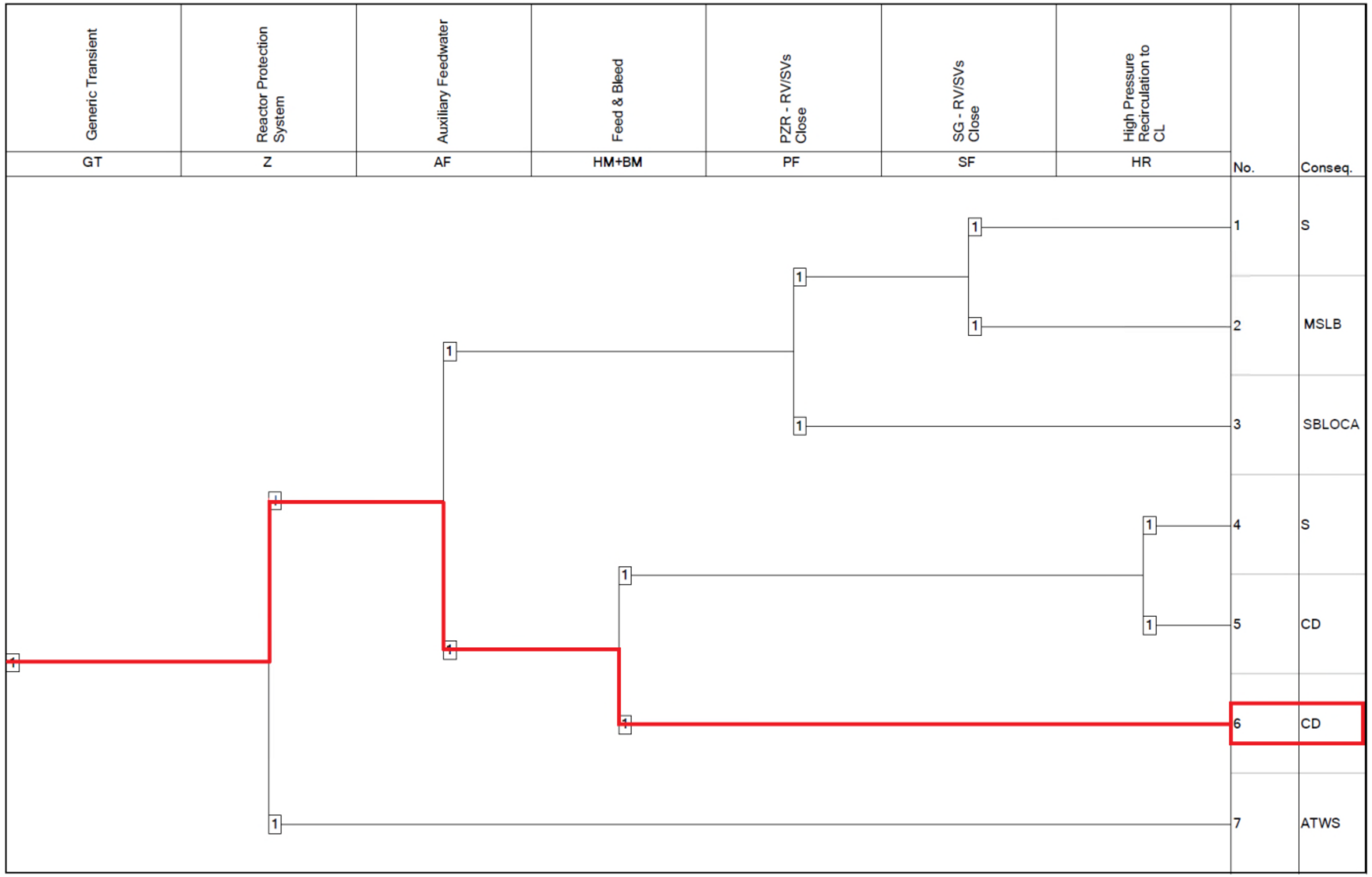
2.A Partial Failure of Auxiliary Feedwater

With the NPP operating at nominal power, a failure of an electronic card caused the reactor protection system to trip the reactor automatically, which caused the reactor to shut down. During this event, the auxiliary feedwater system was automatically started-up as expected, but the turbine-driven auxiliary feedwater pump (TDAFWP) stopped (failed) due to over speed

- SPAR-CSN model assumptions: TDAFWP Failed. Generic transient probability set to P=1; all other initiator probabilities set to P=0. Reactor SCRAM succeeds.

	SPAR-CSN	APP-1
CCDP GT	1.09E-05	1.22E-05

2.A Event Tree. Dominant sequence



- Contribution: 69.29%, CCDP = 8.44E-06
  - Generic Transient,
  - Reactor SCRAM succeeds,
  - Auxiliary feedwater (AF) fails,
  - Feed & Bleed fails.

2.B LOOP in a Twin-Unit NPP

- The site experienced a LOOP event. All EDGs and SBO-DG started automatically.
- Unit 1 TDAFW pump was not immediately available due to surveillance testing; operators stopped the test, restarted, and aligned the TDAFWP flow to SG-A.
- Unit 2 EDG tripped due to a coolant leak; operators aligned the SBO-DG to Unit 2
- Three hours after the EDG trip, a Reserve Station Service Transformer (RSST), was returned to service; operators realigned offsite power to a Safety Bus in Unit 1.
- Nine hours after the initiating event, the offsite power was restored to all four safety

2.B LOOP in a Twin-Unit NPP

SPAR-CSN model assumptions for Unit 1:

- The probability of LOOP was set to 1. All other initiators' probabilities were set to 0.
- EDG-SBO is not available.
- Automatic TDAFWP start failed because it was undergoing a surveillance test.
- Two new basic events were added:
  - TDAFWP was undergoing surveillance testing and was not immediately available
  - Operators had to stop the test, restart and align TDAFWP flow to one SG P= 2.0E-02
- Batteries depletion time in the SPAR-CSN model: 5.2 hrs.

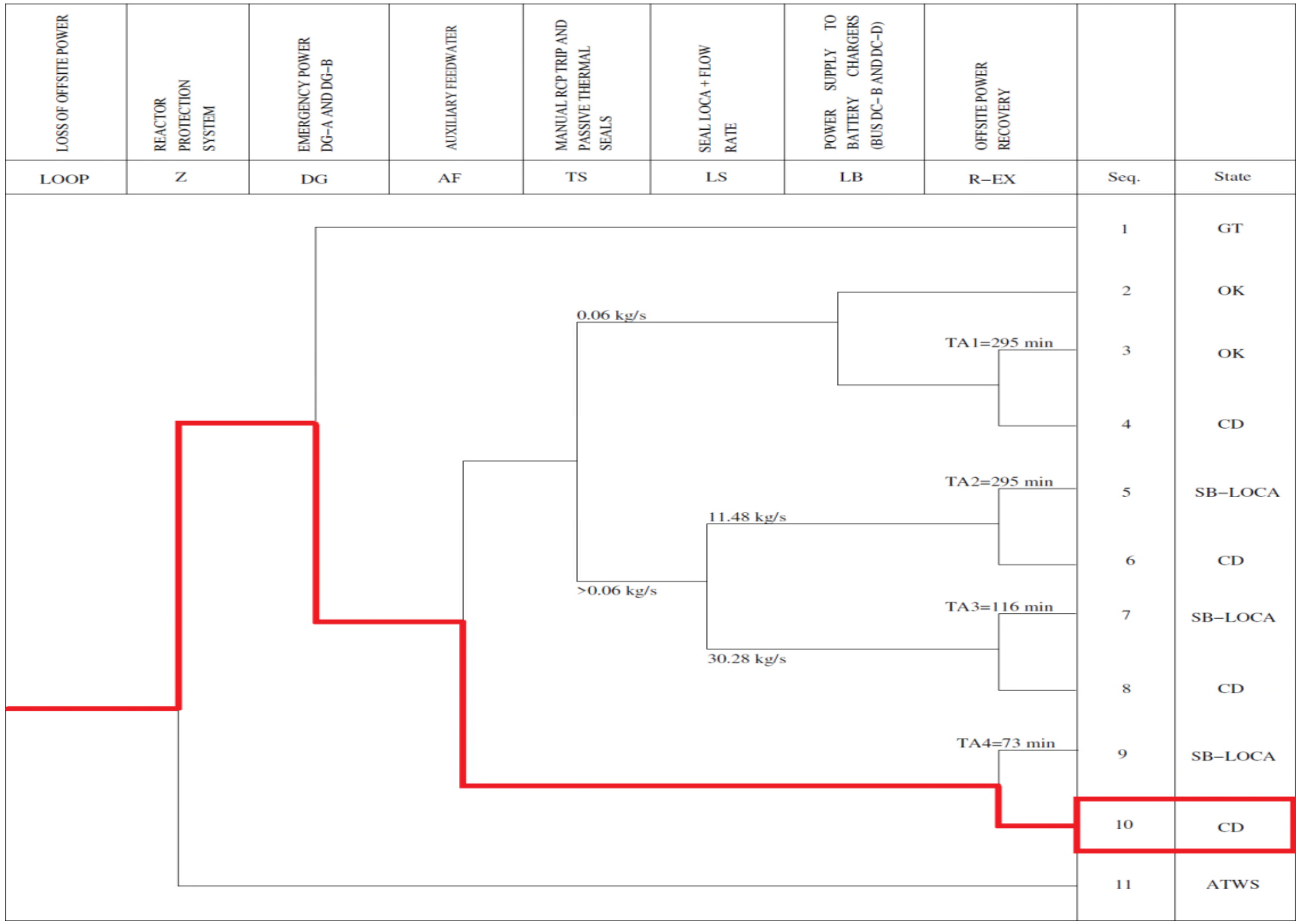
2.B LOOP in a Twin-Unit NPP

- The Offsite Power Recovery Time include four cases:
  - Base case: T > 3 hrs. Event actual time.
  - Sensitivity cases: T > 1 hr. T > 1.5 hrs. T > 5.2 hrs.
- The mission time in SPAR-CSN model it is 24 hrs. (1 hr. base case + 23 hrs.). A modified mission time of 9 hrs. (1 hr. base case + 8 hrs.) has been included to reflect the actual timing of the event.
- For this scenario (Case 1) the SPAR-CSN model obtains a CCDP of 1.66E-04, a result very close to that obtained in the public documentation on the incident (2.00E-04).

2.B LOOP in a Twin-Unit NPP

LOOP	Unit 1	Rec AC [h]	Mission [h]	SBO-DG	Rec Ex Train B	Seals/TDP-AFW	CCDP
SPAR-CSN	Case 0	> 0.0	24	Available	Available	Available	1.43E-05
Base case RecAC > 1 h	Case 0.1	> 1.0	24	NO	Available	Available	1.81E-05
Base case RecAC > 1.5 h	Case 0.2	> 1.5	24	NO	Available	Available	1.66E-04
Base case	Case 1	> 3.0	24	NO	Available	Available	1.66E-04
Base case	Case 2	> 3.0	24	NO	NO	Available	1.66E-04
Base case RecAC > 5.2 h	Case 3	> 5.2	24	NO	Available	Available	2.43E-03
Case 1 - 2, T mission = 9 h	Case 4	> 3.0	9	NO	Available	Available	1.14E-04
	Case 5	> 5.2	9	NO	Available	Available	2.43E-03
Case 1 - 4, DG-SBO available	Case 6	> 3.0	24	Available	Available	Available	1.63E-04
	Case 7	> 5.2	24	Available	Available	Available	6.35E-04
	Case 8	> 3.0	9	Available	Available	Available	1.11E-04
	Case 9	> 5.2	9	Available	Available	Available	5.88E-04
Case 1 - 4, seal failure	Case 10	> 3.0	24	NO	Available	NO	1.78E-04
	Case 11	> 5.2	24	NO	Available	NO	2.43E-03
	Case 12	> 3.0	9	NO	Available	NO	1.26E-04
	Case 13	> 5.2	9	NO	Available	NO	2.11E-03

2.B LOOP in a Twin-Unit NPP



- By increasing the mission time, the CCDP increases slightly, because the increase in the operation times of the components implies an increase in their probability of failure.
- By increasing the time it takes to recover external AC, the CCDP increases by as much as an order of magnitude, as a larger number of sequences cannot be recovered.
- The influence of SBO-DG increases as the external AC recovery time increases and becomes significant for long external recovery times.
- The relative influence of seal failure is larger in incidents with shorter recovery times.

2.C Battery lifePP

- Model how the increase in battery life due to load shedding, impacts the CCDP in the case of LOOP under normal conditions and with the same assumptions as application 2.
- Model the increase in battery life up to either 8 or 24 hours.
  - Impact: non-recovery of external power probability, human actions
- Modified event tree for battery life increased up to 24 hrs.
- LOOP-SPAR-CSN (DC=5.2 hrs.): 1.43E-05
- LOOP-SPAR-CSN (DC=8 hrs.): 1.41E-05
- LOOP-SPAR-CSN (DC=24 hrs.): 1.39E-05

LOOP	Unit 1	Rec AC [h]	Mission [h]	SBO-DG	Seals TDP-AFW	Battery [h]	CCDP
SPAR-CSN	Case 0	> 0	24	OK	OK	5.2	1.43E-05
SPAR-CSN	Case 0.3	> 0	24	OK	OK	8	1.41E-05
SPAR-CSN	Case 0.4	> 0	24	OK	OK	24	1.39E-05
Base case battery 8 h	Case 14	> 3	24	NO	OK	8	1.64E-04
Base case RecAC > 8 h	Case 15	> 8	24	NO	OK	8	2.43E-03
Base case battery 24 h	Case 16	> 3	24	NO	OK	24	1.63E-04
Base case RecAC > 8 h	Case 17	> 8	24	NO	OK	24	1.86E-04

3 CONCLUSIONS

- The methodology delineated for the development of SPAR-CSN models has demonstrated the feasibility to standardize ETs, success criteria, FTs and human actions for the Spanish NPPs tackled in this project.
- Standardization features allow identifying and modeling the specific design differences between the plants and departures from the generic model; some effort is being invested for that purpose within the current project.
- The method has allowed to identify and assess relevant differences between the Spanish NPPs PSA models. These differences are seen in ETs (e.g., transfers between ETs, requirements for the containment safety systems, classification of LOCA break size categories), FTs (e.g., system operating modes and main failures distribution in the FT, transfer gates use, impossible failure combinations removal techniques, etc.) and modeling hypotheses, as well as Human reliability analysis results, and Data sources for equipment failure probability values.
- The SPAR-CSN model was applied to the analysis of two incidents with several sensitivity analyses cases. The results obtained are similar to those obtained in other SPAR models and show the importance of the Offsite Power recovery time and batteries depletion time.
- The SPAR-CSN models are valuable tools to understand and evaluate the risk associated with the operation of Spanish NPPs.

Thank You