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Analysis of Postulated Design Basis Accidents in General Integral PWR Small Modular Reactors: Outcomes on Integral Codes' Modelling Capabilities from the Horizon Euratom SASPAM-SA Project

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Motivation

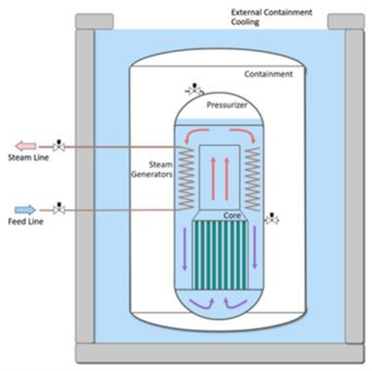
- 'Safety Analysis of SMR with PAssive Mitigation strategies - Severe Accidents' (SASPAM-SA) project (2022-2026), coordinated by ENEA (F. Mascari) - 23 partners from 13 European countries
  - assessing the applicability of knowledge gained from large Light Water Reactors (LWRs) to iPWRs, supporting licensing and siting activities and contributing to a European, independent perspective on iPWR safety for DiD levels 4 and 5

WP2 (SCENARIO): Objectives

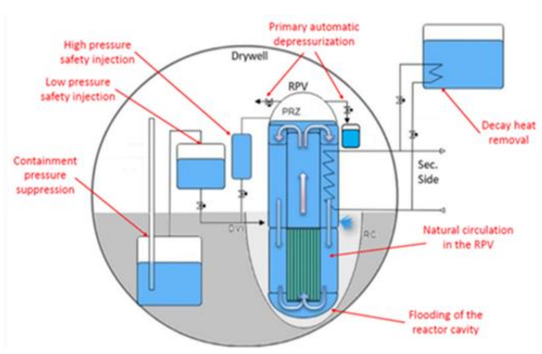
- **Evaluating the capabilities of state-of-art European and non-European integral SA codes and Computational Fluid Dynamics (CFD) tools to simulate the key phenomena occurring in generic iPWR designs**
- Methodology:
  - iPWR Design-1 and Design-2 database (generic designs, decay heat) based on open-literature
  - Assessment of generic, but representative, SA and CFD codes' datasets
  - Postulating Design Basis Accident (DBA) and SA sequences
  - Analysis the postulated DBA and SA scenarios
  - No PSA assessments employed in postulating the scenarios (generic designs)
  - Codes' datasets shared among the partners upon request

The generic iPWR Design-1 and Design-2

iPWR Design-1 (P~60 MWe)
Submerged containment



iPWR Design-2 (P~300 MWe)
Dry containment, several passive systems



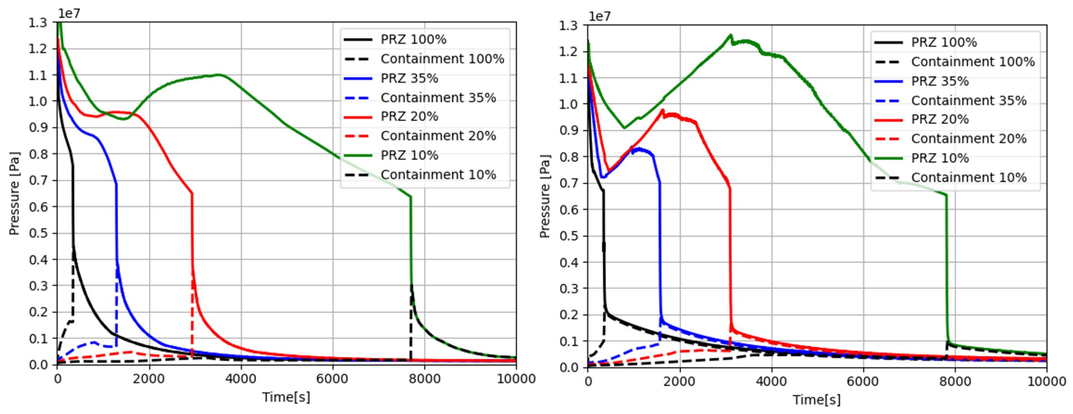
Codes, Partners, and Contribution

Code	Partners	Contribution/Role
ASTECv3.1 (CPA)	KIT	Contribution to a new dataset
ASTECv2.2 (CESAR)/ v3.1 (CPA)	Tractebel	Dataset sharing
MELCORv2.2	PSI/KTH	Dataset sharing/Use
EdF-MAAP5.04	EdF	New dataset
AC²	RUB	New dataset
ANSYS CFX	SSTC NRS	New dataset
AC²	GRS	AC2 user support
ASTEC	ASNR	ASTEC user support
—	RATEN	Support in the definition of the scenarios

Code	Partners	Contribution/Role
ASTECv3.1	ENEA	Dataset sharing
MELCORv2.2	ENEA, UNIROMA1 /CIEMAT, KTH	Dataset sharing/Use
MAAP5.06	JRC	New dataset
AC²	LEI	New dataset
CAD and containmentFOAM	FZJ	New dataset
AC²	GRS	AC2 user support
ASTEC	ASNR	ASTEC user support
—	RATEN	Support in the definition of the scenarios

iPWR Design-1: Results

- **Postulated DBA scenario: Chemical and Volume Control System (CVCS) make-up line break with loss of AC (different break sizes: 10%, 20%, 35%, and 100%)**
- Transient progression: Loss of FDW, Reactor SCRAM, Isolation of the MSL
  - Activation of the ECCS: (RPV –CNMT pressure < 62 bar) & CNMT level > 5.8 m, Opening of 3 RVVs and 2 RRVs



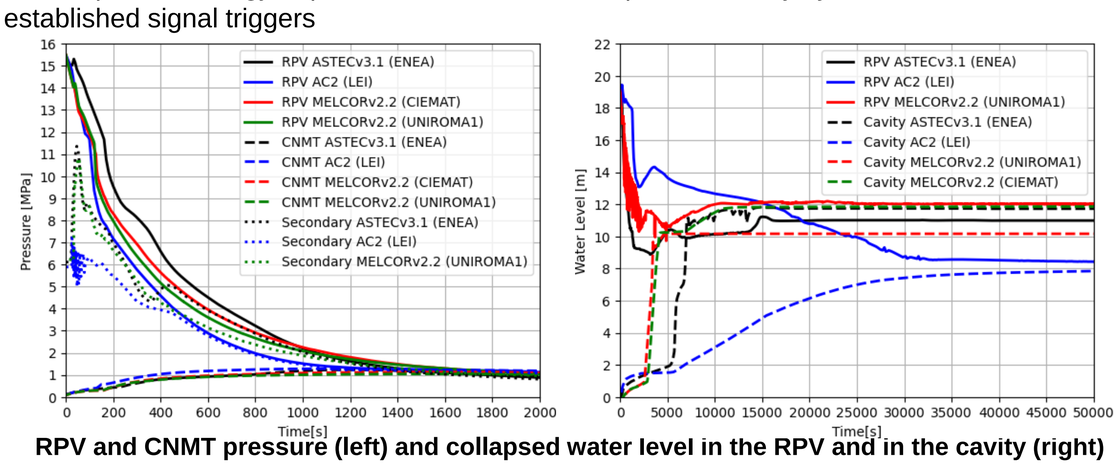
RPV and CNMT pressure computed by ASTECv3.1 (left) and EdF-MAAP (right)

iPWR Design-1 – key events during the DBAs (break size, 100%, 35%, 20%, and 10%)

Parameter/Event	ASTECv3.1 (KIT)	ASTECv2.2 CESAR (Tractebel)	ASTECv3.1 CPA (Tractebel)	EdF-MAAP (EdF)	MELCORv2.2 (PSI)	AC² (RUB)	MELCORv2.2 (KTH)
Actuation of the ECCS (s)	339 1286 2933 7696	259 1142 2427 6612	319 1213 2736 6117	349 1571 3100 7814	339/341 1060/1035 1830/1815 4380/4705	1439 1741 2568 3850	510
Max. liquid level in the CNMT [m]	6.6 6.8 6.9 7.2	6.8 7 7.2 7.5	7.1 7 7.9 7.9	8.1 8.2 8.3 8.5	6.8 7 6.9 6.9/6.5	5.8 5.8 5.9 6.3	6.3
Min. liquid level above TAF [m]	0.8 0.9 0.8 0.9	2.7 1.5 1.4 0.8	1.8 1.4 1.2 0.96	0.8 0.8 0.9 1.8	1.3 0.6 0.5/0.6 0.6/0.9	- - - -	4.7
Max. CNMT Pressure [MPa]	4.47 3.85 3.54 3	5.4 4.8 4 3.1	4.8 4 3.6 2.9	2.5 2 1.7 1.1	5.9/6.0 6.7/7.0 6.8/7.2 6.6/7.3	5.2 4.7 4.7 5.3	

iPWR Design-2: Results

- **Postulated DBA scenario: double-ended break of the Direct Vessel Injection (DVI) line, considering the availability of all safety systems**
- The scenario represents a serious and challenging safety concern for generic iPWR Design-2
- The response strategy depends on the activation of passive safety systems based on the established signal triggers



RPV and CNMT pressure (left) and collapsed water level in the RPV and in the cavity (right)

iPWR Design-2: relevant phenomenological events during the postulated DBA

Parameter/Event	ASTECv3.1 (ENEA)	MELCORv2.2 (UNIROMA1)	MELCORv2.2 (CIEMAT)	MAAP 5.06 (JRC)	AC² (LEI)
High CNMT pressure set-point [s]	**20**	**27**	**28**	**31**	**28**
Low PRZ level signal [s]	**68**	**88**		**50**	**62**
Low PRZ pressure signal [s]	**160**	**109**	**108**	**170**	**92**
Actuation of EBT [s]	165		112	121	97
Actuation of ADS-1 [s]	168	117	128		100
Low DP RPV-CNMT signal [s]	**1466**	**1780**	**1750**	**1274**	**1904**
Actuation of LGMS [s]	1470		1770	1279	1909
Low LGMS mass signal [s]	**13459**	**13620**	**11030**	**25920**	**14301**
Start of reverse flow in the PSS [s]	4950	2850	4170	5050	15400*
Actuation of ADS-2 [s]	13460	13620		25920	14301*
Collapsed Max. liquid level in the CNMT [m]	11.7		11.8		8.4
Collapsed Min. level in the core from LP bottom [m]	3.84	2.98	4.52		5.5
Core TAF refilled - collapsed [s]	5500	1000	5650	4320	

Conclusion

- **The codes are able to predict the key TH phenomena during DBA scenarios** (e.g., single and two-phase natural circulation in RPV, primary/CNMT natural circulation coupling, energy removal from the external pool)
- **Good agreement among the codes**, e.g., timing of activation of the safety systems and results of the key TH figures-of-merit

Acknowledgements

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