

The role of scaled experiments in supporting system code validation and licensing

EASI-SMR – Scaling workshop

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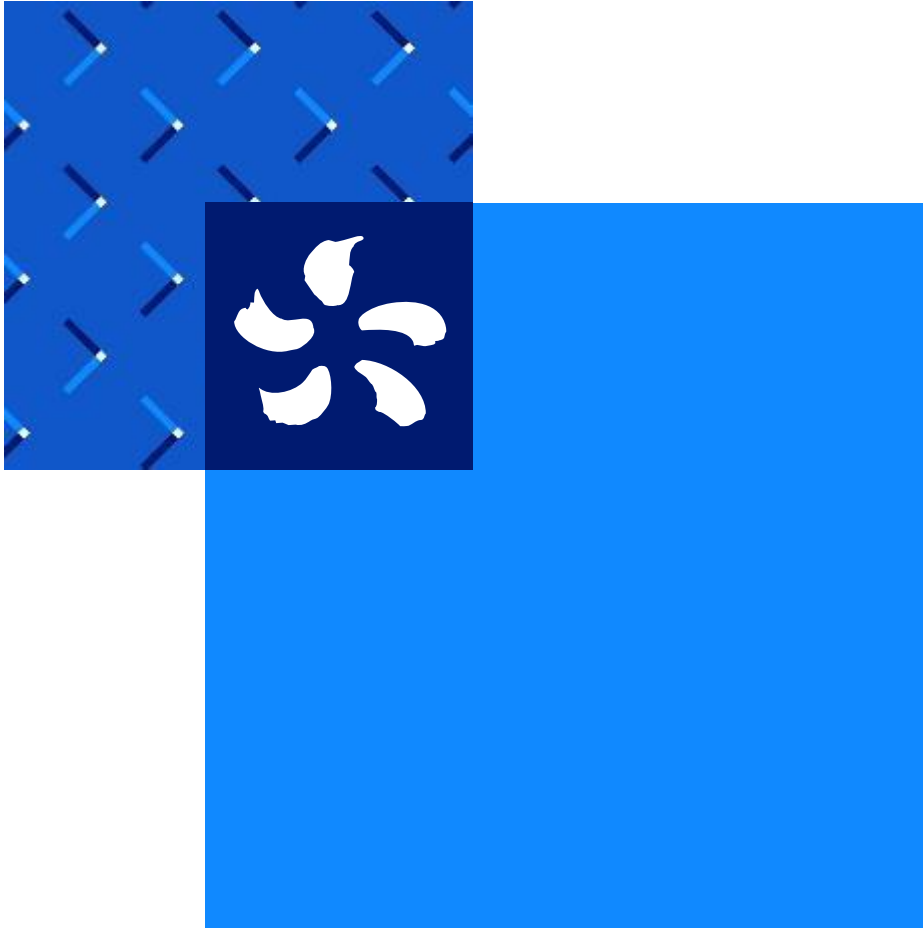


1. Introduction about scaling in EDF for safety demonstration

1. Scaling in safety demonstration - Introduction

Scaling demonstration is part of the evaluation model building for the safety demonstration but also in the qualification of our TH-system code for each scenario.

- This work was done during decades without clear requirements.
- This context evolved in 2017 with a guide edited by the French Safety Authority – **Guide n°28**
 - This guide defines the expectation about V&V on codes involved in the first barrier safety demonstration. Scaling is a topic specified in this guide.
- Moreover, the increase of **quantitative approaches** development in the community since the 90's opens also a way to develop more robust methodologies on this topic.
- In this context, EDF launched different works about scaling analysis in system codes. Those works are performed in collaboration with our French partners (CEA and Framatome).
 - **Short term analysis** specification to answer to the Guide n°28 requirements,
 - **Long term development** to evaluate the quantitative analysis which could be used in an industrial environment.



2. French context – Guide n°28 ASNR – Scaling requirements and treatment

2. French context – Guide n°28 ASNR

Guide n°28 published in 2017 defines the requirements for the code involved in the safety demonstration 1st barrier.

- For a calculation tool used for the **safety demonstration of the 1st barrier**, this guide deals with the requirements about :
 - Verification,
 - Validation,
 - Uncertainty quantification,
 - Scaling analysis.
- All those requirements aim **to demonstrate the qualification of the calculation tool for the use targeted**
 - This analysis is performed for each scenario of the safety demonstration, 1 qualification diagnosis/scenario for each calculation tool.
 - 1 scaling analysis needed/scenario.



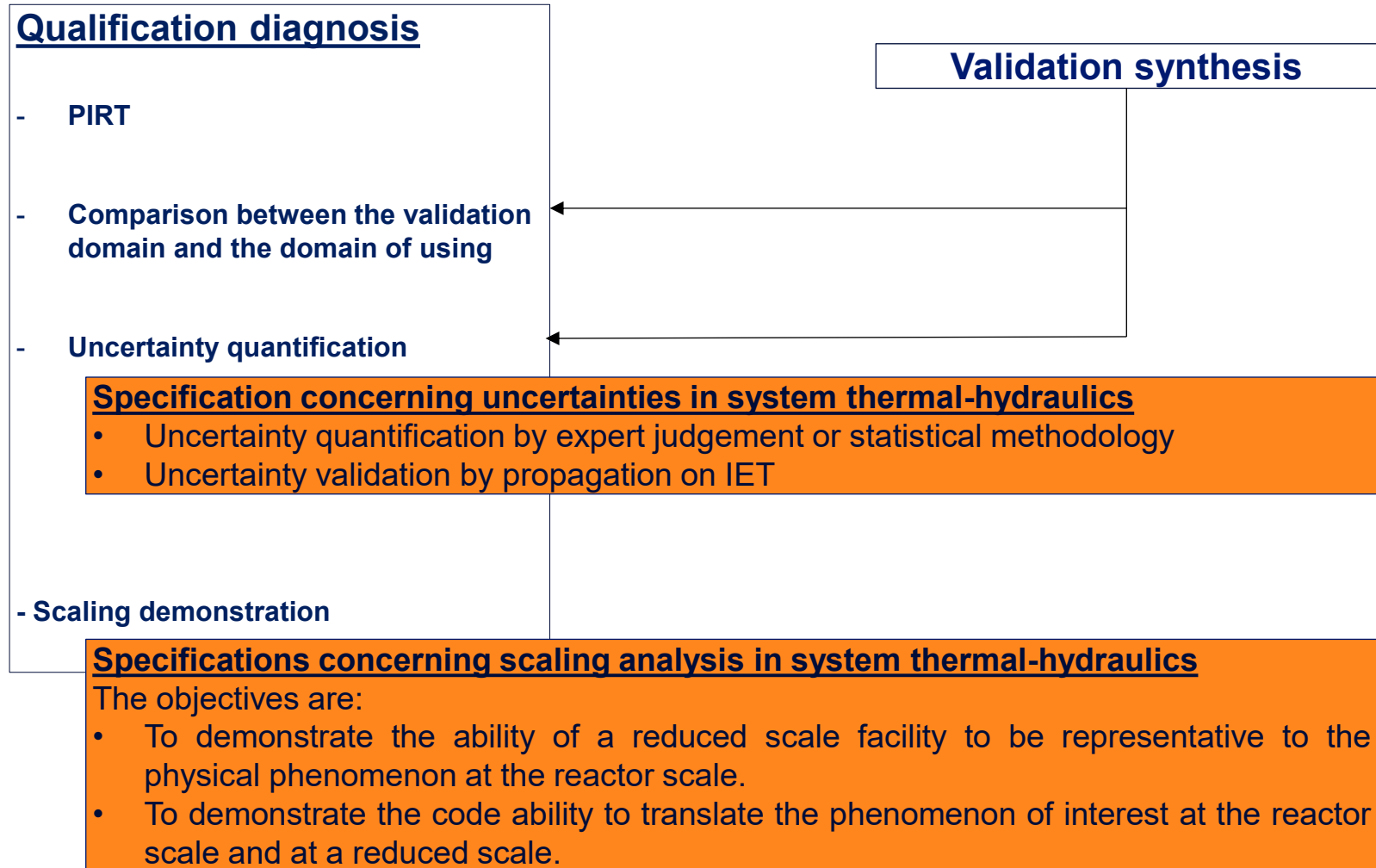
2. French context – Guide n°28 ASNR

Guide n°28 published in 2017 defines the requirements for the code involved in the safety demonstration 1st barrier.

➤ The scaling is defined as the way to specify how the conclusions of the validation (in general, at a reduced scale) can be applied to the intended scope of use at the reactor scale.

➤ To answer to this requirements, EDF and Framatome proposed a qualitative analysis for the scaling demonstration.

- Up to know, the quantitative approach are not considered enough mature to be used at the industrial scale.



2. French context – Guide n°28 ASNR

The qualitative approach is divided into different topics for both SET/CET/IET. This qualitative approach is widely by the OECD/WGAMA state of the art

➤ About SET/CET, the topics addressed in the argument writing are :

- Facility design (PtoV, FSA, 3LS, DSS...) : Design methods of the facility in order to conclude about the ability to transpose the validation results.
- Adimensional approach in the facility/closure law definition to ensure the scalability of the results.
- Counterpart test validation available.
- Reference calculation tools results availability (numerical benchmark in case of lack of experimental data).
- Consistency of the boundary conditions, the geometry and the instrumentation between the facilities and the reactor concerning the phenomenon analyzed.

➤ About IET, the topics addressed in the argument writing are :

- Availability of an IET and/or some phases of the transient can be analyzed based on another scenario.
- Facility design (PtoV, FSA, 3LS, DSS...) : Design methods of the facility in order to conclude about the ability to transpose the validation results.
- Counterpart test validation available.
- Reference calculation tools results availability (numerical benchmark in case of lack of experimental data).
- Consistency of the boundary conditions, the geometry and the instrumentation between the facilities and the reactor concerning the phenomenon analyzed.



3. Scaling R&D activities in support to safety demonstration

3. Scaling R&D activities

In parallel to the points detailed in section 2, some activities are in progress to prepare the future.

➤ Those works are performed in collaboration with CEA and Framatome. The objective is to use the TH-system code **CATHARE** to evaluate the similarity between the validation tests and the reactor analysis.

- CEA is in charge of the scaling tools development based on the FSA approach. These works are managed by Sofia Carnevali. 2 thesis followed from 2020 to develop these tools.
- Some tools handled by the industrials, as the Global Sensitivity Analysis, are also evaluated by EDF and Framatome to bring another view about scaling analysis.
 - Both graphical (parallel plot, pair plot...) and quantitative tools (HSIC, PLI).

➤ This collaboration is illustrated through the following publication

- “Combining sensitivity analysis and scaling for nuclear thermal-hydraulic studies” – S.Carnevali, P.Gaillard, J-L.Vacher, T.Fercoq, D.Bestion – Nuclear Engineering and Design 444 (2025)

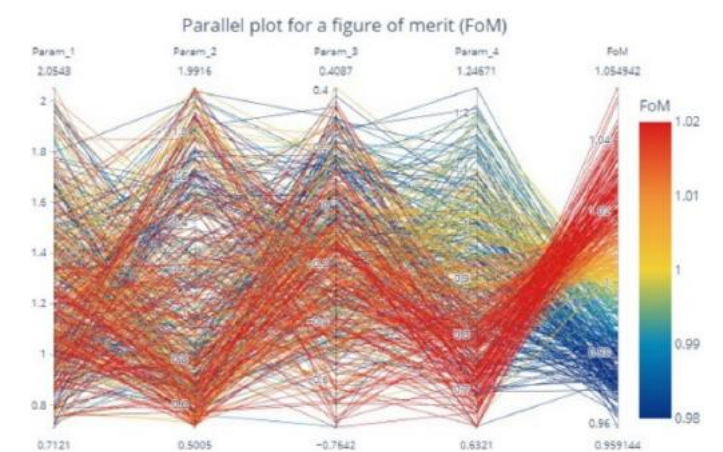
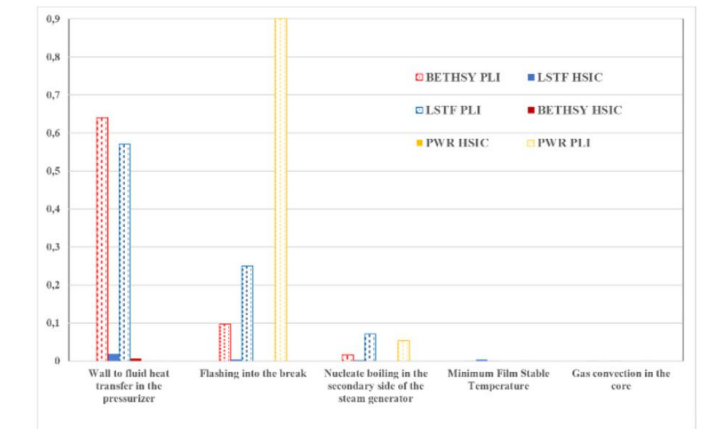
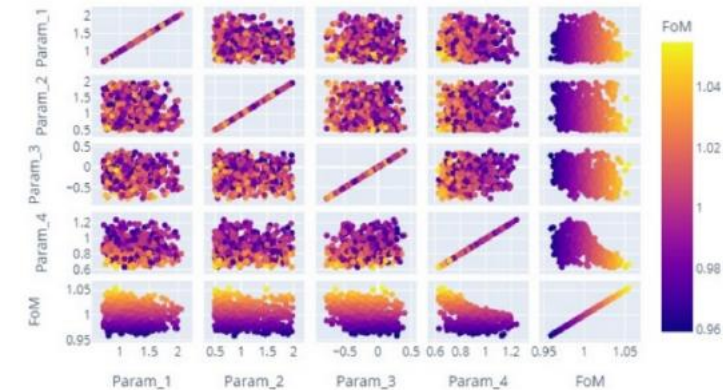


Figure of merit (FoM) - pairplot

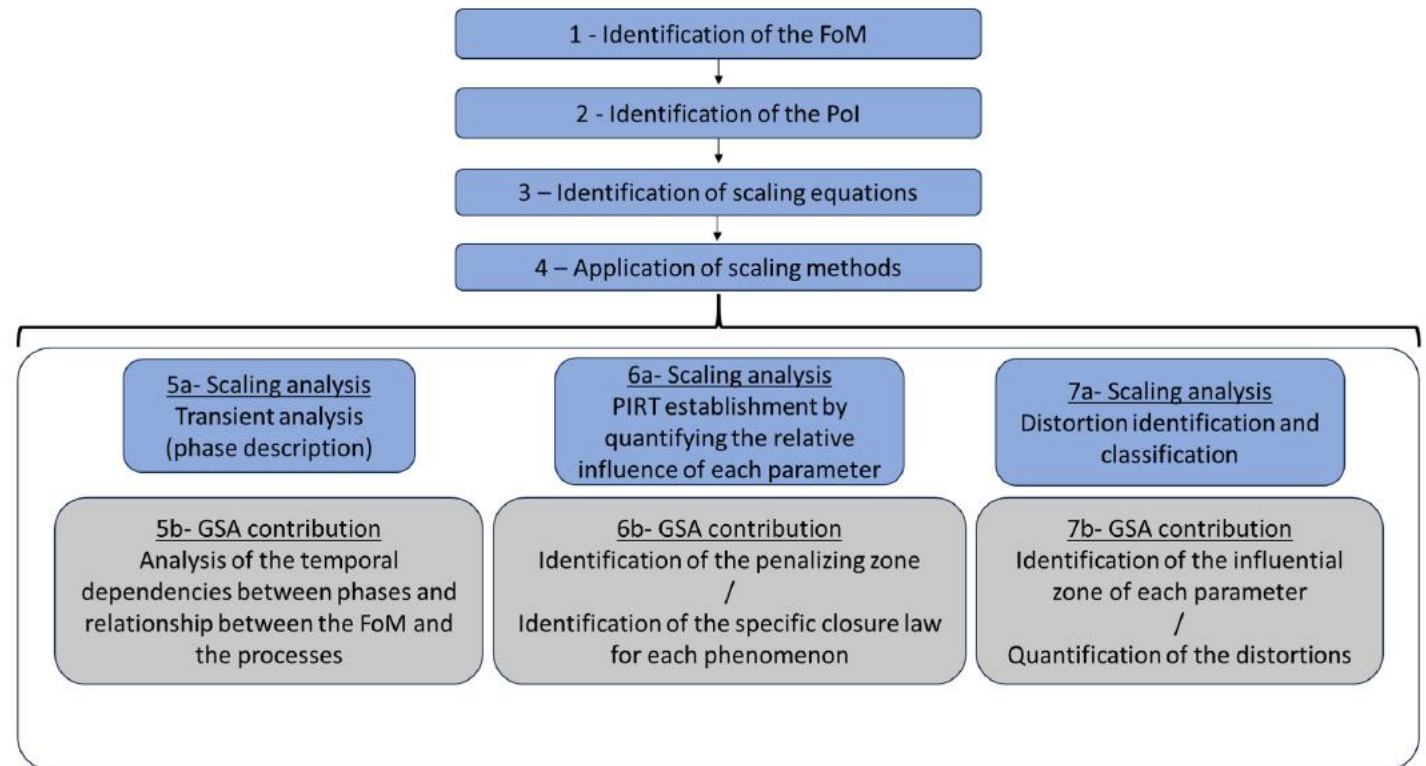


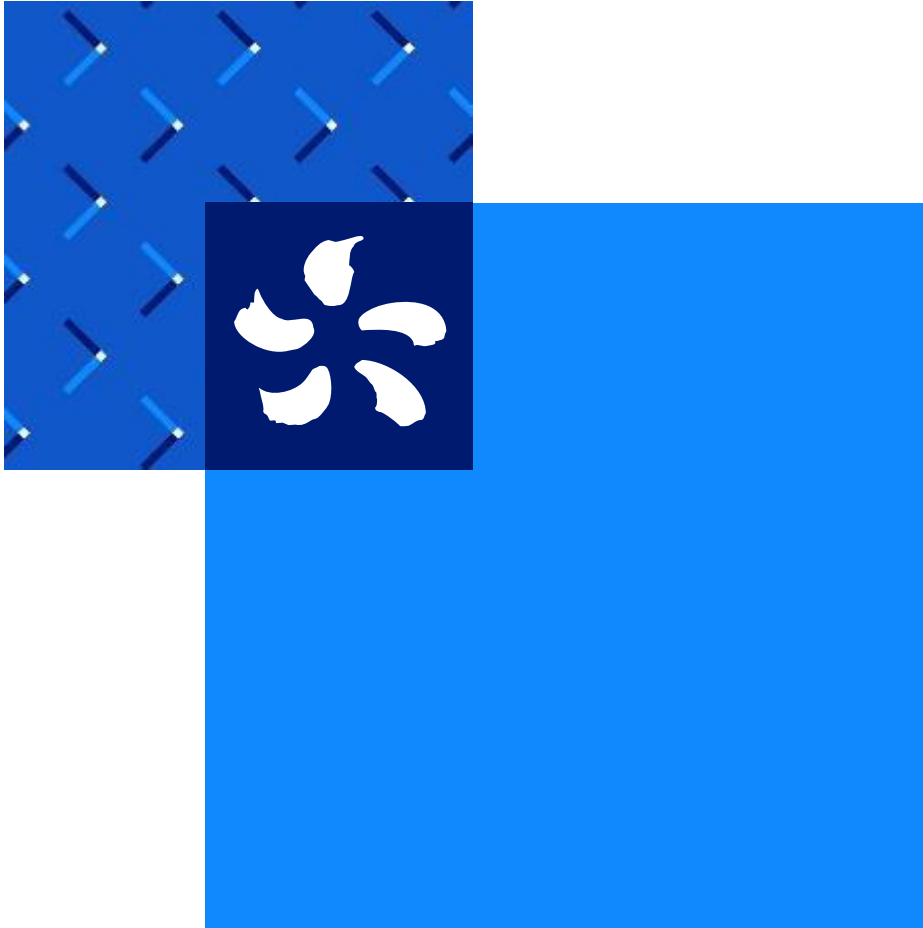
3. Scaling R&D activities

Global approach in progress

➤ The interest to combine both scaling and GSA tools is **to cover the whole perimeter of the scaling analysis** to be able to conclude about the representativity of the validation tests.

➤ **Those works are still in evaluation and need further developments/validation.** Those works will help to evaluate the interest to use this kind of approaches for the long-term future.





4. Conclusions

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Scaling in the past, the present and the future

- **The scaling analysis has been always part of our evaluation model development** to demonstrate the ability of our simulations tools to be relevant at the reactor scales.
- **The scaling analysis requirements were detailed since 2017 with the Guide n°28 (ASNR)** and we proposed a qualitative way to answer to those requirements. **The scaling analysis is applied for the qualification diagnosis writing, 1 qualification report per scenario.**
- To prepare the future, **we are following closely the recent developments about scaling tools and we also participate to those research topics** to evaluate the introduction of some well known tools from the industrial point of view in the scaling demonstration.
- This presentation is only focused on the safety demonstration topic (a posteriori analysis), it is important to keep in mind that the scaling topic is also of major interest for our colleagues involved on the experiments.



Thank you