MSc thesis proposal with international collaboration

(in collaboration with Massachusetts Institute of Technology)

❖ Title of the research

Real-Time Condition-Informed Safety Assessment of a Microreactor

❖ Objectives of the research

Nuclear Batteries (NBs) are a distinct category of nuclear microreactors, which are gaining attention for their potential to offer a flexible, affordable, decentralized and transportable solution to the challenge of reducing carbon emissions and providing energy access to people worldwide (Buongiorno et al., 2021). NBs are relatively novel designs that remain largely untested and lack failure data and past information and, therefore, their licensing and commercialization stand on dedicated advanced risk assessments to address potential hazards, threats and vulnerabilities that may challenge both the safety and the security of the installation (Testoni et al., 2021). Also, NB operations require real-time monitoring and risk control in order to provide online risk insights during accident scenarios, for a prompt response of the safety systems to mitigate the consequences of the scenarios.

In this context, advanced frameworks based on system theory and Modeling and Simulation (M&S) have been developed for the risk assessment of novel designs such as the NBs, without the need to rely on prior operating experience (Antonello et al., 2022); whereas the Condition-Based Probabilistic Safety Assessment (CB-PSA) framework makes use of monitoring and inspection data to provide up-to-date risk measures and insights (Di Maio et al., 2018).

With respect to the above-mentioned frameworks, the goal of this thesis is to leverage and combine them to eventually provide a real-time condition-informed assessment of the risk profile of a NB. The considered design is a semi-autonomous 5 MW (thermal) high-temperature heat-pipe-cooled yttrium-hydride moderated NB designed at MIT.

The thesis project consists in the following steps:

- Literature review, especially on *i*) microreactors and nuclear batteries design, ii) CB-PSA framework, and iii) system theory and modeling and simulation;
- Understanding the already performed NB risk assessments and getting acquainted with the modeling and simulation tool of the NB developed in RELAP5-3D.
- Methodology development;
- Implementation of the algorithms in Python (and Matlab);
- Application and validation of the methodology.

References

Antonello, F., Buongiorno, J., & Zio, E. (2022). A methodology to perform dynamic risk assessment using system theory and modeling and simulation: Application to nuclear batteries. *Reliability Engineering & System Safety*, *228*(August), 108769. https://doi.org/10.1016/j.ress.2022.108769

Buongiorno, J., Carmichael, B., Dunkin, B., Parsons, J., & Smit, D. (2021). Can Nuclear Batteries Be Economically Competitive in Large Markets? *Energies*, *14*(14), 4385. https://doi.org/10.3390/en14144385

Di Maio, F., Antonello, F., Zio, E. Condition-based probabilistic safety assessment of a spontaneous steam generator tube rupture accident scenario Nucl Eng Des, 326 (2018), pp. 41-54. https://doi.org/10.1016/j.nucengdes.2017.10.020

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