KIT Multi-physics/-scale Methods and Tools for Advanced Core Analysis of LWR and Water-cooled SMRs

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The deployment of nuclear power plants worldwide is advancing for the CO_2-free to provide electricity and heat, etc. Among the most reactor designs being built are the VVER-1200, APR-1400, AP-1000, and EPR. In addition, the deployment of Small Modular Reactors (SMR), and in special water-cooled SMRs have experienced a considerable progress [1]. Among the nine SRM-design selected by the European Industrial Partnership for the deployment of SMRs, five concepts are water-cooled SMRs. European designs such as the NUWARD and the LDR-50 are in the advanced design phase. Both designs rely on boron-free cores built of shorter standard Fuel Assemblies (FA) of type FA 17x17-25. The Roll Royce SMR will be built in Czech Republic. NuScale and SMART use the same FA-design but they consider boron in the coolant. In general, SMRs are designed for electricity generation, water desalination, industrial heat production, hydrogen production, etc. The BWR-X-300 is going to be built in Canada, Poland, and Sweden. It works without pumps based on natural convection as the larger ESBWR unit. The CAREM, ACP-100 and the RITM-200N are under construction in Argentina, China, and Russia. In Canada, the BWR-X-300 was selected for new-build and demonstration by 2028. In the EU, different research projects such as ELSMOR [2], McSAFER [3], are focused on the licensing, experiments for thermal-hydraulic phenomena (cross-flow, performance of helical heat exchanger, CHF), and safety evaluation methods for the core and plant behaviour and on advanced Multiphysics analysis of core transients including diffusion, transport and Monte Carlo methods coupled with thermal hydraulic solvers.

KIT is involved in McSAFER and in German SMR-projects with focus on the development of new core analysis tools (neutronics and thermal hydraulics) as well as multi-physics and -scale methods for the improved analysis of core and plant transients [4]. This lecture will describe the KIT computational chains under development and validation for large reactors and SMRs. It will start with the discussion of the challenges for reactor physics and thermal hydraulics. Then, the different tools will be shortly described including the coupling approaches. Finally, selected applications to large PWR and water-cooled SMRs will be presented. An outlook about further development directions ends the presentation.

References

[1] OECD, "Small Modular Reactors: Challenges and Opportunities. NEA Nr. 7560," OECD, Paris, 2021.

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[3] V. H. Sanchez-Espinoza, S. Gabriel, H. Suikkanen, J. Telkkä, V. Valtavirta, M. Bencik, S. Kliem, C. Queral, A. Farda, F. Abéguilé, P. Smith, P. V. Uffelen, L. Ammirabile, M. Seidl, C. Schneidesch, D. Grishchenko and H. Lestani, "The H2020 McSAFER Project: Main Goals, Technical Work, Program, and Status," *Energies,* vol. 6348, p. 14, 2021.

[4] V. H. Sanchez-Espinoza, U. Imke, K. Zhang, J. Duran-Gonzalez, A. Campos-Muñoz and G. Huaccho-Zavala, "KIT Numerical Simulation Tools for the Transient Analysis of Water-Cooled Small Modular Reactors," in *ICAPP 2024*, Las Vegas, 2024.