PRELIMINARY RESULTS OF SIMULATING SELECTED ACCIDENTS PROGRESSION FOR LDR LITE SMALL DISTRICT HEATING REACTOR WITH AC² COMPUTER CODE

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The assessment has been conducted as part of the "Pilot study with the LDR-50 district heating reactor" [1] task of the Project "Ensuring Assessment of Safety Innovations for SMR" (EASI-SMR)*. The objective of the study is to analyze transient response of the LDR Lite (Low temperature District heating Reactor) to selected accidents through comparison of the simulations conducted by several participating partner organizations with application of different lumped parameter computer codes. This conference presentation discusses preliminary results of the containment model development and pilot calculations with the COCOSYS simulation code of the AC² code package (GRS, Germany, [2]).

LDR Lite is the public version of the LDR-50 design of the small modular reactor (SMR) intended for low-temperature district heat production [3, 4]. The integrated design of this SMR, utilizing conventional pressurized water reactor technology, features the reactor vessel (RPV) that encapsulates the entire primary circuit (see Figure 1, right side). There are no reactor coolant pumps, as the primary coolant flow is driven by natural circulation, and there is no conventional pressurizer: instead, the reactor is pressurized with nitrogen, and the nitrogen bubble at the upper part of the RPV provides for self-pressurization. Heat is transferred to the secondary circuit through the set of primary heat exchangers embedded in the RPV, and then to the district heating network through the secondary heat exchanger(s). The RPV is enclosed in the containment, partially filled with water, which is submerged in the water pool.

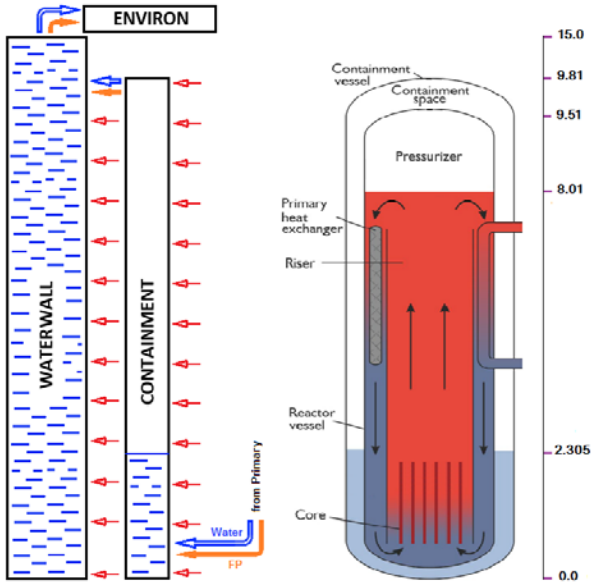

Figure 1. Schematics of LDR Lite module and modeling approach

The scope of analysis has included simulation of the LDR Lite containment response to the two selected accidents: small break loss of coolant accident (LOCA) and station blackout (SBO). The containment model has been developed with the COCOSYS code, following modeling approach illustrated in the Figure 1 (left side). The model allows to simulate transfer of the heat generated in the reactor vessel and/or injected to the containment through the break to the water in the pool surrounding the containment. It is also capable to simulate transportation and distribution of the fission products released from the reactor.

Mass and energy releases to the containment for both accidents have been calculated by the project partners (Ukrainian company Energorisk) with the ATHLET code of the AC² code package as a separate activity, and included in the COCOSYS model as the boundary conditions (details on the results of ATHLET simulations are provided in [1]).

The COCOSYS calculations have revealed good performance of the LDR Lite containment and its capability to perform the intended function of the passive decay heat removal system under both selected

accidents. Figure 2 illustrates the containment pressure build-up under the small break LOCA.

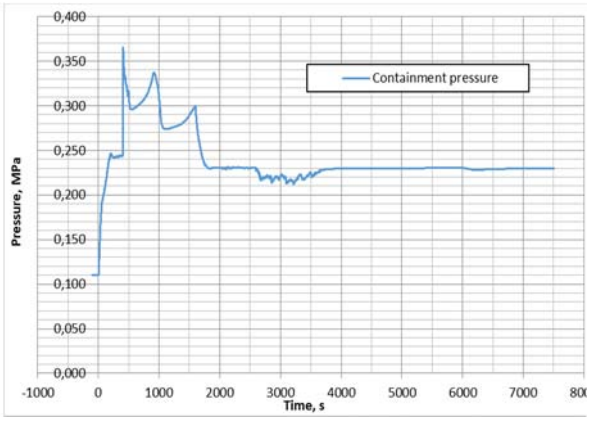

Figure 2. Containment pressure, small break LOCA

Coolant release from the reactor system has led to relatively prompt increase in the containment pressure during initial stage of the accident. In less than 10 min the pressure has reached its peak value. At this stage the mass and energy release to the break has decreased, being much smaller than the heat transfer through the containment wall to the water pool. As a result, the pressure and temperature in the containment start to decrease and stabilize at approximately half of the peak value after 30 min of transient.

Conclusions and next steps

The simulation model of the LDR Lite small district heating reactor containment has been developed with the COCOSYS code of the AC^2 code package and applied for preliminary calculations of the small break LOCA and SBO accidents. Simulations have confirmed capability of the LDR Lite design to ensure efficient cooling of the reactor and containment in the passive decay heat removal mode. Also, capability of the model to simulate the accident progression and key phenomena occurring in the LDR Lite containment has been demonstrated. Further plans include benchmarking of the calculation results with the analyses being conducted by other participants of the EASI-SMR project with other computer codes and models (to be published in [1]). It is also envisaged to perform analysis of the load-follow scenarios, which are of especial interest for the district heating reactor, since demand for load following operation is essential for reactors operating in district heating networks.

1. Euratom R&D Project, “Ensuring Assessment of Safety Innovations for SMR”. D1.12 Pilot study with the LDR -50 district heating reactor (to be issued).
2. H. Wolff N. Reinke C. Spengler. COCOSYS 3.1, Short Description. GRS, June 2022, Revision 3.
3. R. Komu, R. Tuominen, V. Valtavirta. LDR lite benchmark specification (2025). LDR design document LDR-PUB-VTT-10002-R4, VTT Technical Research Centre of Finland.
4. IAEA-TECDOC-2056, “Nuclear Cogeneration for Climate Change Mitigation and Sustainable Development Goals”. IAEA, Vienna, 2024.

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