CAMIVVER

Codes And Methods Improvements for VVER comprehensive safety assessment

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Introduction from the Project Coordinator

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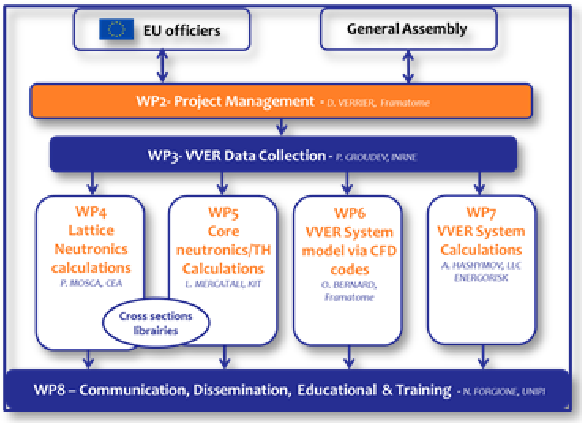
The CAMIVVER project was launched more than one year ago. My project partners and I are pleased to introduce you to this first issue of our project newsletter. It provides you with an introduction to activities performed in the different work packages and will keep you up to date with what was done during the past period. Indeed, significant work progress has been made despite difficult working conditions due to the COVID pandemic.

I wish you an interesting reading.



WORK PACKAGES HIGHLIGHTS

WP2 - Project Management

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CAMIVVER project kick-off meeting was held on September 8th 2020 via a web conferencing tool, and that has been the case of all meetings held up to now. Executive Committee meetings are held every 3 to 4 months.

Apart from usual project management activities, WP2 is responsible of the setting up and administration of the project website and of the implementation of a Data Management plan. The public website has been set up at the beginning of this year and provides information about project activities and gives access to the public deliverables of the project and related international publications. A first version of the Data Management Plan is also available.

WP3: VVER Data Collection

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WP3 "Establishment of a common VVER database for codes verification and validation" is dedicated to establishing a common and shared database for VVER comprehensive safety assessment codes and methods verification and validation. WP3 intends to prepare requested input data for fulfillment the objectives described in other technical WPs. To achieve this, the WP3 is organized in three sub tasks:

- Within **Task 3.1** "Analysis and classification of available VVER data for verification and validation of neutronics and thermal-hydraulics codes", Deliverable D3.1, issued on April 2021, has been developed by Energorisk and INRNE-BAS to provide an overview of the main VVER experimental and benchmark data available to the International Community (IAEA, OECD/NEA, past European projects, publications, etc.) for verification and validation of neutronics and thermal-hydraulics codes. The information of past experiences on VVER safety analysis, relevant to the project, has been summarized to give general information for VVER reactors.
- Within **Task 3.2** "Establishment of a common database to describe primary and secondary circuits geometry", a Definition report with specification for NPP with VVER-1000 reactor with respect to selected transients (Deliverable 3.2, issued on July 2021) has been developed by INRNE-BAS to provide requested input data for fulfillment the objectives described in the WP6 and WP7, as well as neutronics specifications to be used in WP4 and WP5. The following design data for VVER-1000 were collected and included in the definition report with respect to expected nuclear power plant transients which will be simulated:
  - ✓ Description of the nuclear power plant systems, equipment and plant state information (initial and boundary conditions);
  - ✓ Steady state data before initiating transient;
  - ✓ Nuclear fuel, geometric, thermal-hydraulic, neutronics, effective day of operation and technological data;
  - ✓ Drawing of major primary and secondary systems;
  - ✓ Safety and regulating systems involved in simulation of transients.
- Within **Task 3.3** "SB LOCA specification + SG line break specification" a Definition report of SB LOCA + SG tubing break benchmark (Deliverable 3.3 issued on August 2021) has been developed by INRNE-BAS. The main objectives of this report are to prepare a plant specific scenario for the VVER-1000 and to provide information on all equipment and systems expected to be initiated during the progression of the selected accident including operator actions if they are assumed based on existing emergency operating procedures.

WP4: Lattice Neutronics Calculations

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In the framework of the H2020 CAMIVVER project, the activities within Work Package 4 (WP4) aim to propose improvements in the generation framework of multi-parametric neutron data libraries for Gen II and III LWR (VVER and PWR geometries) using the capabilities of the APOLLO3® code and to analyze the possibility towards an industrialization of a multi- parametric neutron data library generator based on APOLLO3. Four tasks are identified to meet these objectives:

- Task4.1 "*VVER multi-parametric neutron data libraries generation*" concerns all the activities of specification and development of the multi-parametric neutron data library prototype for industrial applications (PWR and VVER) based on the APOLLO3 code. *The first deliverable (D4.1) related to definition of use cases and requirements of multi-parametric neutron data libraries prototype has been issued on November 2021;*
- Task 4.2 "*Verification of the consistency of the prototype libraries generator based on APOLLO3"* join all the work of result comparisons between the prototype library generator based on APOLLO3, the industrial neutron data library generator based on APOLLO2 (validated on PWR configurations) and reference stochastic codes, namely SERPENT and TRIPOLI-4®, for PWR et VVER configurations. *The first deliverable (D4.3) related to PWR and VVER assembly cases has been issued on February 2021.* Figure 1 depicts some preliminary results on UOX assembly;

- Task 4.3 “*Investigation of possible VVER assembly calculation schemes”* defines calculation schemes for VVER configurations using APOLLO3, investigates and proposes options to optimize the calculation time without altering the accuracy of the results. Figure 2 shows an example of spatial mesh optimization for self-shielding and flux calculations considering 1/6th of VVER assembly;
- Task 4.4 “*Evolution of libraries generation by using new advanced 2D and 3D models*” analyses possible improvements in the multi- parametric neutron data library generation thanks to the new APOLLO3 capabilities in term of self-shielding models, leakages treatment and 3D modeling. In particular, the activities will be focused on the modeling of the radial reflector considering light and heavy reflector (e.g. Figure 3 left) and the treatment of the axial reflector through 3D models (e.g. Figure 3 right).

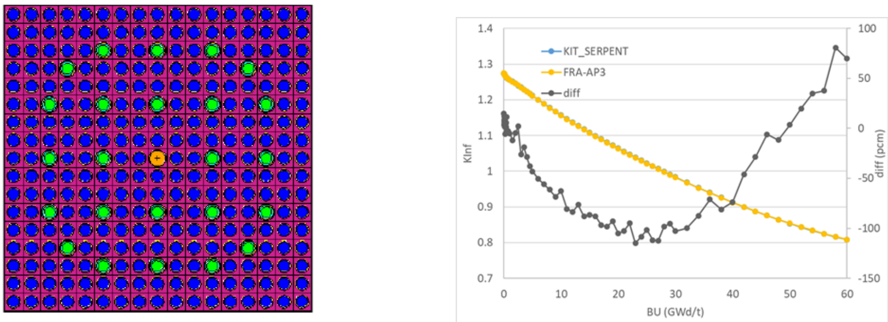
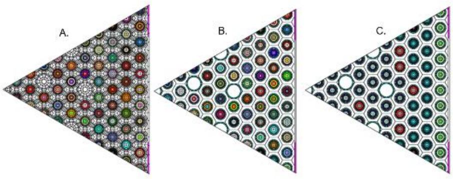


Figure 1: First verifications on a PWR assembly. AP3 stands for APOLLO3



	Case 1 (ref.) (A)	Case 2 (C)	Case 3 (B+A)	Case 4 (C+A)
Kinf t0/ Δρ	1.27396	1.27286 / -68 pcm	1.27386 / -6 pcm	1.27386 / -6 pcm
max Δρ over depletion	-	+179 pcm (10.5 GWd/t)	+12 pcm (60 GWd/t)	+11 pcm (60 GWd/t)
Time in self-shielding	16’	4’	4’	40s
Time in transport calc.	2’30s	1’30s	2’30s	2’30s
Total	18’30s	5’30s	6’30s	3’10s

Figure 2: APOLLO3 calculation optimization on a VVER assembly

Figure 3: Radial (left) and axial (right) reflector benchmark configurations

WP5: Core Neutronics/TH Calculations

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In the framework of the H2020 CAMIVVER project, the activities within Work Package 5 (WP5) are intended to analyze and provide coupled core neutronics-thermal-hydraulics best estimate transient calculations for VVER and PWR reactors. These results will serve as a starting point for future industrial level discussions on tools and methodologies to be adopted, also in view of better answering to safety regulations. Two main benchmark test cases will be analyzed (Figure 4), namely a 7-fuel assemblies VVER-type configuration and a 32-fuel assemblies PWR-type configuration. The main transient scenario to be investigated within WP5 consists in a Reactivity Insertion Accident (RIA) initiated by fast a control rod ejection (0.1 seconds) from a HFP critical condition. The system evolution is simulated up to about

2 seconds and the aim of this transient scenario is to have a high enough reactivity to analyse a fast transient, but low enough to stay as close as possible in monophasic conditions at all times. As an alternative to the rod ejection scenario, a transient based on a sudden change of the thermal-hydraulics boundary conditions will be also investigated in order to be representative of the physics of a Main Steam Line Break (MSLB) event, mainly for what concern a temperature decrease transient. These two types of scenarios will be simulated with coupled neutronics and closed channel thermal-hydraulics tools (APOLLO3®, SERPENT/SubChanFlow, PARCS/TRACE). Moreover, efforts will be also made to develop a 3D neutronics-thermal-hydraulics reference calculation based on APOLLO3®/CATHARE3 coupling. *The benchmark cases are described in deliverable 5.1 issued on August 2021.*

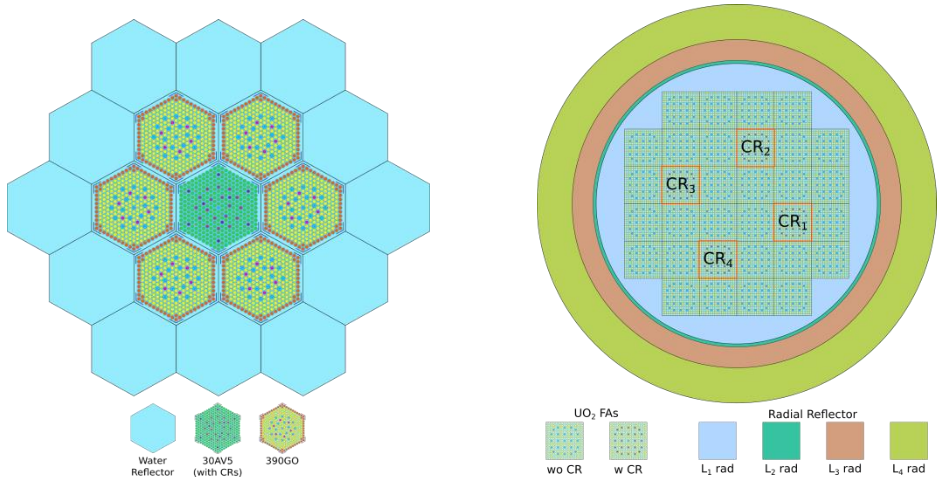

Figure 4: VVER (left) and PWR (right) benchmark configurations

WP6: VVER CFD analyses

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WP6 objective is to improve and validate CFD modelling of the mixing inside VVER primary vessel. CFD models will include the primary vessel from cold legs to hot legs nozzles. The core-outlet temperature-field is the main output to be analysed.

WP6 is organized in the 3 tasks:

- Task 6.1 is dedicated to the development of VVER-vessel CFD model. A common geometry CAD file has been built and shared among partners. A first benchmark is being performed on normal-operation steady-state configuration to check the consistency of partners models (example of temperature fields on figure 5)
- Task 6.2 is dedicated to the demonstration and validation of CFD models ability to evaluate the mixing in the vessel in case of unsymmetrical feeding. In particular, CFD models will prove to be able to produce VVER-vessel mixing matrices. Task 6.2 will be based on Kozloduy-6 mixing experiment.
- Task 6.3 is dedicated to the propagation of input-data uncertainties through these CFD models. Deterministic sampling method will be used to achieve this propagation.

Participants	CFD code
FRAMATOME	STAR-CCM+
UNIPI	STAR-CCM+
KIT	CFX
ENERGORISK	FLUENT
CEA	TRIO-CFD

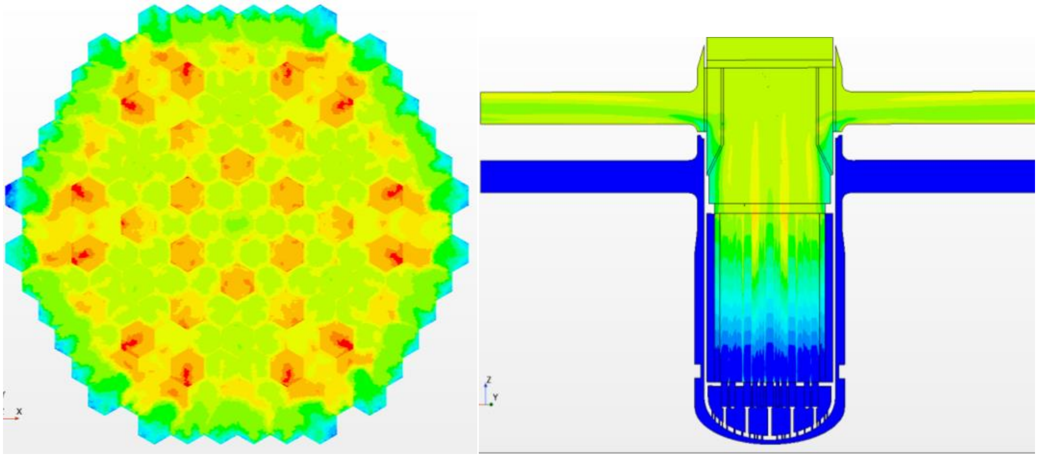

Figure 5: temperature field at core outlet (left) and in the vessel (right)

WP7: VVER System Calculations

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WP7 objectives are to improve thermal-hydraulics modelling of VVER plant, especially implement 3D modelling of VVER system with 3D modules available in thermal-hydraulics code.

As part of the WP7 implementation, Task 7.1 "Development of thermal-hydraulics-code models of VVER primary and secondary circuits; Perform steady-state benchmark to check model's consistency" has been completed.

When performing Task 7.1, based on the prepared set of initial data for the Kozloduy-6 Power Unit (WP 3), models of the VVER-1000 were developed. The models were developed using computer codes:

- RELAP5 – INRNE, Energorisk.
- TRACE – KIT, and
- CATHARE3 – FRAMATOM.

The use of CATHARE3 for modelling VVER-1000 was carried out for the first time. In the models, detailed modelling of first-circuit systems and functional modelling of second-circuit systems are performed, which allows the calculation of the stationary state and transients. Special attention is paid to the modelling of the core and reactor. The development of models was completed by numerical simulation of the stationary operation of the VVER-1000. Comparison of the calculation results (pressure of the first and second circuits, coolant flow through the core, reactivity reserve, temperature distribution and levels in the pressure compensator and steam generator) showed a good coincidence of the main parameters between the developed models and with the data of the Kozloduy-6.

Completion of the model development allows you to start the next stage of Task 7.2 "Simulation of Kozloduy-6 Main Coolant Pump start-up transient". It is expected that the implementation of steps 7.2 - 7.4 will allow to evaluate the accuracy of modelling transient processes in the core and the first circuit of the reactor plant, as well as to confirm the applicability of the calculation codes used for the analysis of VVER-1000 processes.

WP8: Communication, Dissemination, Educational and Training

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The Dissemination, Communication and Exploitation (DC&E) strategy plan has been developed within Task 8.1 “Development of the CAMIVVER dissemination and exploitation plan” by Framatome and UNIPI.

Starting from the determination of the CAMIVVER project needs, the goals of the DC&E have been identified as well as how to achieve them.

The CAMIVVER DC&E strategy plan includes:

- ✓ A detailed planning of all communication actions, their goals and timing;
- ✓ Key messages and defined target audiences;
- ✓ An event and publications management plan;
- ✓ Identification of DC&E key performance indicators for the goals to be reached, as the number of international journal papers, the number of website views or the engagement on social media.

A series of communication actions have been implemented following the DC&E (Deliverable 8.1 issued on February 2021):

- ➢ A **project brand** (logo and visual identity) has been realized including templates for presentations, deliverables and milestones to ensure the project's visibility among all relevant stakeholders;
- ➢ A **flyer/leaflet** including the main message, keywords and consortium members of the project that will be distributed at workshops and events organized by CAMIVVER, as well as in external events;
- ➢ A **roll-up/poster** including the main message, keywords and consortium members of the project for presenting the project itself;
- ➢ A **public website** as the main communication channel towards the project's stakeholders and the target audiences;
- ➢ A **LinkedIn account** order to extend the information about CAMIVVER, promote its results and advertise future initiatives.

THE CAMIVVER TASK LEADERS

WP3	WP4	WP5
A. Hashymov (LLC ENERGORISK)	*A. Previti (Framatome)*	*J.A. Blanco (KIT)*
P. Groudev (INRNE)	*A. Willien (EDF)*	*B. Calgaro (Framatome)*
	J.-F. Vidal (CEA)	
	S. Santandrea (CEA)	

WP6	WP7	WP8
O. Bernard (Framatome)	*P. Groudev (INRNE)*	*L. Mercatali (KIT)*
M. Böttcher (KIT)	*O. Bernard (Framatome)*	*D. Verrier (Framatome)*
		B. Vezzoni (Framatome)

UPCOMING INTERNATIONAL EVENTS

- ➢ **NURETH 19 (International Topical Meeting on Nuclear Reactor Thermal Hydraulics)**
  6-11 March 2022, Brussels, Belgium. **Information & Registration**
- ➢ **PHYSOR 2022 (International Conference on Physics of Reactors)**
  15 May 2022 - 20 May 2022, Pittsburgh, PA, United States. **Information & Registration**
- ➢ **NUTHOS-13 (International Topical Meeting on Nuclear Reactor Thermal Hydraulics, Operation and Safety)**
  04 Sep 2022 - 09 Sep 2022, Taichung, Taiwan. **Information and Registration**
- ➢ **CONTE 2023 (Conference on Nuclear Training and Education)**
  06 Feb 2023 - 09 Feb 2023, Amelia Island, FL, United States. **Information and Registration**

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