OECD Benchmark First Workshop for Kalinin-3 Coupled Code Calculations and Uncertainty Analysis in Modelling (K-1)

University Park / State College, Pennsylvania, USA

April 27-28, 2009

Hosted by

The Pennsylvania State University (PSU)

SUMMARY RECORD

Sponsorship

The first workshop for the OECD Benchmark for Kalinin-3 Coupled Code Calculations and Uncertainty Analysis in Modelling (K-1) was held from April 27 to April 28, 2009 in University Park / State College, Pennsylvania, USA. During the last several years considerable effort and progress have been made in various countries and organizations in incorporating full three-dimensional (3D) reactor core models into system transient codes. The coupled thermal-hydraulic (TH) and neutron kinetics (NK) code systems allow performing of a "best-estimate" calculation of interactions between the core behavior and plant dynamics. Several benchmarks have been developed to verify and validate the capability of the coupled codes to analyze complex transients with coupled core-plant interactions for different types of reactors.

The Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD) has recently completed the VVER-1000 Coolant transient benchmark (V1000CT-1) and (V1000CT-2) for evaluating coupled TH system NK codes by simulating transients at the Bulgarian NPP Kozloduy Unit #6. The available real plant experimental data made these benchmark problems very valuable.

This benchmark is a continuation of the above activities and it defines a coupled code problem for further validation of thermal-hydraulics system codes for application to Russian-designed VVER-1000 reactors based on actual plant data from the Russian NPP Kalinin Unit #3 (Kalinin-3). The selected transient 'Switching-off of one Main Circulation Pump (MCP)' is performed at a nominal power and leads to asymmetric core conditions with broad ranges of the parameter changes. The experimental data is very well documented. These are measured with a quite high frequency and the measurement errors are known for almost all measured parameters. This fact allows applying the studied transient not only for the validation purposes but also for uncertainty analysis as a part of the NEA/OECD LWR Uncertainty Analysis in Modelling (UAM) Benchmark.

This workshop (K-1) was held in conjunction with other meetings, in order to facilitate co-ordination and sharing of work. Two other meetings are being held during the same week in order to combine efforts in common areas such as CFD modelling and uncertainty analysis and to make participation more efficient. The meetings concerned are the Third OECD LWR Uncertainty Analysis in Modelling Workshop (UAM-3) and the OECD/NRC BFBT-6 benchmark workshop. The OECD/NRC BFBT-6 and the First OECD Kalinin-3 workshops were held in parallel on April 27-28 2009 followed by the OECD UAM-3 benchmark workshop (April 29 - May 1 2009) and will be hosted by PSU, USA. The 3 workshops took place in University Park / State College, Pennsylvania (located in the Happy Valley) – home of PSU.

Background and Purpose of the Benchmark Workshop

Under the guidance of the NEA/OECD many benchmarks have been performed concerning the application of coupled 3D TH/NK codes. Some of them have utilized code-to-code comparisons, others have compared code predictions with real measured data.

Most transients in a VVER reactor can be properly analyzed with a system thermal-hydraulics code, with simplified neutron kinetics models (point kinetics). A few specific transients require more advanced modeling for neutron kinetics for a proper description. A coupled thermal-hydraulics 3D neutron kinetics code would be the right tool for such tasks.

The proposed benchmark problem has already been analyzed by the coupled system code ATHLET-BIPR-VVER. This allowed a better definition of the Benchmark Specifications. However, within the present context the results of participants will be compared against the measurements. Interesting additional problems have to be solved in order to perform correctly the comparisons. This experience is incorporated in the text of the specification.

The reference problem chosen for simulation is the MCP #1 switching off at nominal power when the other three main coolant pumps are in operation, which is a real transient of an operating VVER-1000 power plant. This event is characterized by rapid rearrangement of the coolant flow through the reactor pressure vessel resulting in a coolant temperature change, which is spatially dependent. This leads to insertion of spatially distributed positive reactivity due to the modeled feedback mechanisms and a non-symmetric power distribution. Simulation of the transient requires evaluation of core response from a multi-dimensional perspective (coupled 3D neutronics/core thermal-hydraulics) supplemented by a one-dimensional (1D) simulation of the remainder of the reactor coolant system. The purpose of this benchmark is four-fold:

- To verify the capability of system codes to analyze complex transients with coupled core-plant interactions and complicated fluid mixing phenomena.
- To fully test the 3D neutronics/thermal-hydraulic coupling.
- To evaluate discrepancies between predictions of the coupled codes in best-estimate transient simulations with measured data.
- To perform uncertainty analysis having at disposal not only the measured values but also their accuracy

The benchmark includes a set of input data for the NPP Kalinin-3 and consists of four exercises:

Exercise 1 – Point kinetics plant simulation

The purpose of this exercise is to test the primary and secondary system model responses. Provided are compatible point kinetics model inputs, which preserve the axial, and radial power distribution, and CR #10 and #9 reactivity obtained using a 3D code neutronics model and a complete system description.

Exercise 2 – Coupled 3-D neutronics/core T-H response evaluation

The purpose of this exercise is to model the core and the vessel only. Inlet and outlet core transient boundary conditions are provided by the benchmark team on the basis of calculations performed with the ATHLET-BIPR-VVER coupled code system: alternatively the participants can apply the measured data. HFP state (Exercise #2a) of the core is required for comparison.

Exercise 3 – Best-estimate coupled code plant transient modeling

This exercise combines elements of the first two exercises of this benchmark and represents an analysis of the transient in its entirety. For participants that have already taken part in the Kozloduy-6 NEA/OECD Benchmark [6], it is suggested to start directly with this exercise. As a preliminary step for these latter participants it is recommended to perform steady state core calculations at HZP state (Exercise #3a), HFP (Exercise #3b) and deliver the results for comparisons. Exercise #3a and Exercise #3b will ensure and check out the correct application of the cross section libraries, the core loading and the core design geometry.
Exercise 4 – Performing of uncertainty analysis for the purpose of Phase-III (System Phase) of the OECD Benchmark for Uncertainty Analysis in Best –Estimate Modelling (UAM) for Design, Operation and Safety Analysis of LWRs.

The aim and the specification of this exercise will be described in a separate volume, which will depict the state of the art of the results and requirements identified after performing the UAM Phases I and II.

The specification document (Edition 1) that covers Exercises 1-3 of the OECD Kalinin-3 VVER-1000 Coupled Code Benchmark was distributed to the participants in advance.

Scope and Technical Content of the Benchmark Workshop

The technical topics addressed at the workshop included:

- Introduction of the Kalinin-3 benchmark and Edition 1 of the benchmark specification
- Discussion of the benchmark neutronics core data
- Discussion of the benchmark thermal-hydraulic data
- Discussion of thermal-hydraulic coupling and reactor control system modelling
- Discussion of initial steady state and transient scenario
- Discussion of the different benchmark exercises
- Discussion of the available measured data and comparisons with ATHLET-BIPR-VVER results
- Presentations on participants' experience and expertise in VVER coupled code calculations, and uncertainty and sensitivity analysis of VVERs
- Defining a work plan and schedule outlining actions to progress on the different exercises of the benchmark activities

Organization and Programme Committee of the Benchmark Workshop

An Organization and Programme Committee has made the necessary arrangements for the fifth Benchmark Workshop, organized the Sessions, and prepared the final program. The general chair was Kiril Velkov (GRS). The other members were José Aragonés (UPM), representing the NSC, Francesco D'Auria, representing CSNI, Michael Lizorkin (RSC KI), Sergey Nikonov (RSC KI), Soeren Kliem (FZD), Jan Hadek (NRI), K. Ivanov (PSU), and E. Sartori, representing the OECD/NEA Secretariat.

Opening Session – Introduction and opening remarks

The meeting was opened by K. Unlu, director of the PSU TRIGA reactor and Radiation Science and Engineering Center (RSEC) at PSU. He presented the RSEC activities and accomplishments, welcomed the participants on behalf of the PSU and wished them a successful work. K. Velkov

welcomed the participants on behalf of the GRS. J-M Aragones welcomed the participants on behalf of the Nuclear Science Committee (NSC) of NEA/OECD.

The agenda was approved with minor adjustments (see Annex I).

The workshop was attended by 23 participants from 14 organizations in 8 countries (see Annex II). The interest in this benchmark is very large as shown by the participation from international agencies, research institutions, national laboratories, universities and industry.

K. Velkov, on behalf of the benchmark team, made a presentation giving an overview and status of the Kalinin-3 benchmark activities.

Technical Sessions

Sessions 1 to 2 were devoted to the specification of the Kalinin-3 benchmark. The benchmark team summarized, in six presentations the benchmark neutronics, thermal-hydraulic, and control system data as well as the definition of initial steady state and transient scenario and preliminary results for the benchmark. In session 3 the participants presented their developments and experience in VVER modeling and analysis.

In sessions 4 and 5 the benchmark team discussed in four presentations the benchmark cross-section library and format, requested output, exercises and available measured data. Based on these presentations the following issues were discussed and decisions made:

1. Due to the lack of ADFs in the second (thermal) group of the prepared cross-section libraries, which can lead to incorrect implementation of the data in a number of nodal core models it was decided to generate new libraries at PSU. For this purpose Dr. Lizorkin from RSC KI will be contacted. The reflector data also available for this benchmark will be utilized in preparation of the new cross-section libraries. Other important information to be accounted for when performing the cross-section library calculations is that one of the assemblies was changed after 90 EFPD and the pre-history of reactor operation. The available KI cross-section library will be used for cross check purposes and can be also applied for uncertainty and sensitivity analysis in the future exercises of UAM Benchmark. In that case of application the library should be made more compact by merging the big amount of files describing the different compositions into one file.

2. Additional Kalinin-3 specific information will be added to the Specification: decay heat part, pump specifications if different from Kozloduy-6, the angles of flow shift at reactor bottom (wirl), simplified figure with the dimensions of the regions of the control rod absorption parts (dysprosium and boron carbide).

3. The potential participants are divided into two groups:
   - Group 1 - Participants who already participated in the OECD Coolant benchmark for Kozloduy-6 and have system code input with the BOP model of VVER NPP.
   - Group 2 - Participants with no experience with VVER NPP.

Conclusions, Actions and Schedule for completing the BFBT benchmark

The action items and schedule for the Kalinin-3 benchmark activities were discussed. They are provided in the following list:

List of Agreed Actions on Kalinin-3

1. The K-1 workshop summary will be prepared by the benchmark team and distributed by the end of May 2009.
2. End of May 2009 – deadline for all participants to sign the declaration of OECD for participation in the benchmark and return the document to the NEA. The possibility for additional potential participants to be explored (China, India, etc.).
3. End of August 2009 – deadline for generation of the new cross-section libraries.
4. End of December 2009 – deadline for submitting results for Exercise #1 from Group 2
5. End of February 2010 – deadline for submitting results for Exercise #3 from Group 1
6. End of February 2010 – deadline for submitting results for Exercise #2 from Group 2
7. End of May 2010 - deadline for submitting results for Exercise #3 from Group 2
8. The second Kalinin-3 (K-2) workshop will be held on April 12-13, 2010.

The K-2 workshop will be held in conjunction with other meetings, in order to facilitate co-ordination and sharing of work. The three other meetings will be held at the same place and during the same week in order to combine efforts in common areas such as thermal-hydraulic modelling and uncertainty analysis and to make the participation more efficient. There are two options for location of the four workshops in April 2010 – one is in the NEA/OECD, Paris, France (room reservations have been made) and the other is University of Pisa, Pisa, Italy. The NSC committee will decide the location of the four workshops. The meetings concerned are the fourth workshop on the OECD Uncertainty Analysis in Modelling (UAM) Light Water Reactor (LWR) benchmark (UAM-4) and AER Working Group D workshop (VVER dynamics and safety), which will take place on April 14-16, 2010. In parallel with the K-2 meeting the first workshop on the OECD PWR Sub-channel Bundle Test (PSBT) benchmark (PSBT-1) will be held at the same premises. The objectives of the K-2 workshop will be the following:

a) Discussion of the final Kalinin-3 benchmark specification and updated cross-section library
b) Discussion of support studies performed by the benchmark team
c) Discussion of preliminary results submitted for the first 3 exercises
d) Discussion of Exercise 4 – uncertainty analysis of coupled VVER calculations and its relation to the OECD UAM benchmark.

Acknowledgments

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Annex 1

OECD Benchmark for Kalinin-3 Coupled Code Calculations and Uncertainty Analysis in Modelling - First Workshop (K-1)

Hosted by
The Pennsylvania State University (PSU), USA
April 27-28, 2009

AGENDA [K101]

Day 1: April 27 2009 - Vanderbilt Room at the Atherton Hotel

Opening Session – Chair K. Velkov

09:00-09:30 Introduction and opening remarks and list of participants [K102]
- Prof. K. Unlu, Director of PSU TRIGA Reactor [K103]
- Dr. K. Velkov, GRS [K104]
- Prof. J-M Aragones, NSC, NEA/OECD [K105]

09:30-10:00 Introduction to proposed OECD benchmark and its objectives – K. Velkov [K106]

10:00 -10:15 Coffee Break

Technical Sessions

Session I – Chair C. Parisi

10:15-11:00 Specification of the Kalinin-3 Coolant Transient Benchmark
- V. A. Tereshonok, S. P. Nikonov, M. P. Lizorkin, K. Velkov, A. Pautz, K. Ivanov [K107]

11:00-11:45 Neutronics core data
- M. Lizorkin, K. Velkov [K108]

12:00 – 13:00 Lunch – Tarragon restaurant at the Atherton Hotel

Session II – Chair – S. Kliem

13:05-13:30 Thermal-hydraulic data
- N. Kolev [K109]

13:30 – 14:15 Thermal-hydraulic coupling and reactor control system modelling

- S. Nikonov, K. Velkov [K110]

14:15 – 15:00 Initial steady state and transient scenario
- S. Nikonov, K. Velkov [K111]

15:10-15:35 Preliminary Results of Kaliin-3 Benchmark by the coupled code ATHLET-BIPR-VVER [K112]
- S. Nikonov, M. Lizorkin, K. Velkov [K113]

15:35-15:50 Coffee Break

Session III – Chair – N. Kolev

15:50-16:15 Validation of the coupled code system DYN3d/ATHLET on the basis of transients at NPPs with VVER reactors
- . S. Kliem, U. Rohde, F.-P. Weiss [K114]

16:15-16:40 VVER coupled and transient benchmarks, using COBAYA3-ANDES and COBRA3 in triangular-Z mesh
-J.A. Lozano, J. Jimenez, J. Herrero, N. García-Herranz, D. Cuervo, C. Ahnert, J.M. Aragonés [K115]

16:40-17:05 Validation of Thermohydraulic Computing Model of VVER-1000/320 Temelin NPP for Calculation with Coupled DYN3D/ATHLET Codes - SDA Test
- J.Macek, R.Meca, J. Hadek [K116]

19:00 – Banquet – Regency A room at the Atherton Hotel

Day 2: April 28 2009 – Vanderbilt Room at the Atherton Hotel

Session IV – Chair J. Hadek

09:00-09:30 Cross-section library and format - discussion
-K. Ivanov [K117]

9:30-10:00 Requested output
- S. Nikonov, K. Velkov [K118]

10:00 -10:15 Coffee Break

Session V – Chair J-M Aragones

10:15 – 10:45 Benchmark exercises
- S. Nikonov, K. Velkov [K119]

10:45 – 11:15 Available measured data

- S. Nikonov, K. Velkov [K120]

12:00 – 13:00 Lunch – Regency A Room at the Atherton hotel

Session VI – Chair K. Ivanov

13:05-13:30 Defining a work plan and schedule outlining actions to progress on the three phases of the benchmark activities

13:30-14:15 Discussions of the interactions between Exercise 4 of the Kalinin-3 benchmark and Phases I and II of the LWR UAM benchmark

14:15-14:30 Conclusions and closing remarks

15:45 – 18:30 Visit to Advanced Multi-Phase Flow Laboratory and TRIGA research reactor at PSU

Annex 2

OECD/NEA Workshops in University Park / State College, PA, USA

OECD Kalinin-3 Coupled Code Benchmark – First Workshop (K-1)

Host Organization
The Pennsylvania State University (PSU), USA
April 27 – 28, 2009

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* regret not to have been able to attend this time