McSAFE – High Performance Monte Carlo Methods for SAFEty Demonstration

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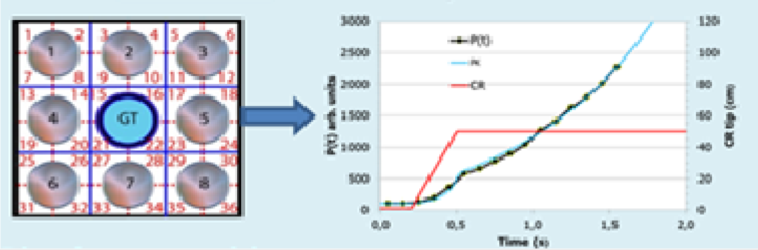
Basic informations

- European project funded by Horizon-2020
  - 9/2017 – 8/2020
- Goal: Move MC methods towards industrial applications
  - quasi-static calculations with burnup
  - short-time kinetics calculations
- Demonstrate capability of
  - whole core burnup with TH and TM feedback
  - evaluation of transient experiments (SPERT-III E-core RIA)
- Validate the tools using experimental data

Groundwork

- Foundations layed down by HPMC project
  - High Performance Monte Carlo
  - 2011 – 2014
  - KIT, DNC, VTT, KTH
  - SERPENT, MCNP, SubChanFlow
- Given the proof of principle
  - coupling with TH
  - methods development (stability, efficiency)
  - small scale simulations (pin cluster, FA)



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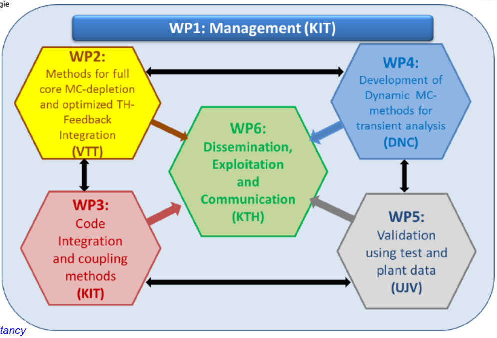
Partners and work packages

Karlsruher Institut für Technologie

VTT

ÚJV

amec



WP1: Management (KIT)

WP2: Methods for full core MC-depletion and optimized TH-Feedback Integration **(VTT)**

WP3: Code Integration and coupling methods **(KIT)**

WP4: Development of Dynamic MC-methods for transient analysis **(DNC)**

WP5: Validation using test and plant data **(UJV)**

WP6: Dissemination, Exploitation and Communication **(KTH)**

Preussen Elektra

cea

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Delft Nuclear Consultancy

JRC
EUROPEAN COMMISSION

CEZ GROUP

KTH ROYAL INSTITUTE OF TECHNOLOGY

eDF

Numerical tools

- Focus on the further development of European MC, TH and TM codes
- Application of tools developed within previous projects
    - Nuresim platform, Salome (Nuresafe, Nuresim projects)
    - HMPC project developments

Static MC

- NF: SERPENT, TRIPOLI, MONK
- TH: SCF
- TM: TRANSURANUS

Dynamic MC

- NF: dynSERPENT, dynTRIPOLI, dynMCNP
- TH: SCF
- TM: TRANSURANUS

Current status

Aim of the project

- Demonstration of whole core fuel cycle burnup calculation with TM, TH burnup
    - VVER-1000 core
    - PWR (Konvoi) core
- Demonstration of small core dynamic simulation
- Comparison to plant data & core simulator results

- Currently passed 1 out of 3 years
- Coupled codes not yet ready
- Good progress achieved
- Examples of problems being dealt with

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1. What is McSAFE
2. **Benefits for AER community**
3. Examples of problems being dealt with
4. User group and results dissemination
5. Conclusions

Validation? – Motivation

- Core analysis relies on deterministic codes
- Two strata approach
    - 2D single assembly transport calculation
    - 3D whole core in diffusion approximation
- Multiple approximations on the way
    - 2D – axial reflectors, absorber-FA interface in VVER-440
    - infinite lattice used for cross section data preparation
    - homogenization – discontinuity factors
    - …
- Validation against experimental data of uppermost importance

Validation? – Motivation (cntd)

Validation of codes

- integral data (criticality)
- power distribution on nodal level
- all the data correspond to normal operation

Application of codes

- control of limits at pin level
- inputs for safety analysis (temperature feedback at LOCA conditions)

- Options:
  - Sufficient margin
  - Improved validation

Validation using MC results

- Coupled MC/TM/TH codes use far less approximations
    - whole core transport calculation
    - critical spectrum
    - feedback at pin level
- Not applicable to routine calculations
- May serve as a benchmark reference
    - not as good as experiment
    - far better than current code-to-code

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Burnup - memory

Problem description

- Have to keep in memory thousands of nuclides for each axial layer of the fuel pin
- Hardly possible for one FA
- Impossible for whole core

Current progress

- Collision based decomposition is being implemented
  - collaboration of KIT and VTT
- Memory demand is distributed among domains (MPI tasks)
- Particles are transferred between MPI tasks when they have a collision in decomposed materials.
- Promising direction

Burnup - stability and efficiency

Problem description

- Common numerical schemes used for burnup are not stable
    - explicit Euler, predictor – corrector
- Stable schemes must be implemented
- Efficient implementation needed

Current approach

- Stochastic Implicit Euler method has been implemented
    - end-of-step flux and composition used for burnup
    - multiple criticality calculations needed for one step
- Optimization of
    - statistics of one MC criticality solution
    - number of MC criticality calculations per step
    - length of time step

MC dynamic calculations

- New codes are being developed
    - dynSERPENT – SCF
    - dynTRIPOLI – TH
    - dynMCNP – SCF
- Computer time is critical
- Variance reduction methods need to be developed

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5 Conclusions

User group

- Assess the results from the user's point of view

UG member rights

- Information on methods and results
- License to some codes to run the benchmarks

UG member contributions

- Feedback on methods, codes and results
- Suggestions for further developments
- Production of benchmark results
- Sharing the data for validation

User group

- Organizations from Europe, Asia, America . . . are welcome
- Utilities, vendors, regulatory bodies, TSO, research labs, universities
- Active interest from
  - BME
  - LTU
  - NRG
  - ENEA
  - UNISTC university (Korea)
- Candidacy still possible: Victor Sanchez, KIT, victor.sanchez@kit.edu

Training course

- Training course will be organized before the end of the project
- Main outcomes of the project will be presented
- Work with the coupled codes will be explained
- Participants from industry, regulators, universities . . . expected

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Conclusions

- The project will deliver improved high-fidelity numerical simulation tools
    - Developers of major European MC codes working together
- Tools applicable both for static and dynamic calculations with feedback
- Tools will be applicable to any reactor type
- The results will be compared to experimental data
    - VVER-1000
    - Konvoi PWR
    - SPERT-III E-core RIA experiments
- If validation proves successful, tools will be ready for industrial applications
    - Reference (benchmark) solutions to deterministic codes
- User group participants welcome