# Study of a High Conversion Small Modular Reactor

## ► Context

The worldwide fleet of nuclear reactors is steadily growing. As a consequence, tensions over uranium ressources are expected in the coming decades.

High conversion light water reactors can reduce uranium needs by:
- preventing the degradation of fissile materials (e.g. $^{241}Pu$);
- increasing the production of fissile materials.

High conversion refers to an increase of the conversion rate $T_{Conv}$:

$$T_{Conv} = \int_{irradiation\ time} F_{Conv} = \int_{irradiation\ time} \frac{\sum_{fertiles\ isotopes} C_k}{\sum_{fissiles\ isotopes} A_k}$$

A and C are the absorption and capture rates respectively.

Small reactors have several industrial advantages. From a physical perspective, small cores lead to an increase in neutron leakage. This helps to maintain a negative reactivity coefficient in the event of an unprotected void accident.

These criteria render the High Conversion Small Modular Reactor (HCSMR) a design suitable for a multi-criteria core optimization.

## ► HCSMR

Higher conversion rate can be obtained by (see figure 1):
- reducing the moderator to fuel ratio (Rmod);
- changing the fuel: enrichment, mixed oxide of uranium, plutonium or thorium;
- adapting the core cycle burnup.

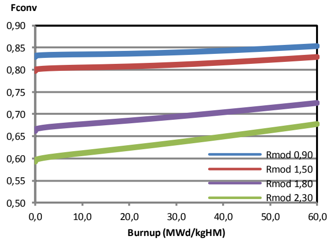


Figure 1
Fconv vs. burnup for a 15% Pu MOX fuel for 4 moderation ratios, Rmod.

A tighter fuel assembly lattice reduces the moderation ratio. Such cores are called "under-moderated" designs. To limit the degradation of thermo-hydraulic performances, an hexagonal lattice is used.


**Acknowledgements**
This project is performed at CEA/DM2S/SERMA and is funded by E.ON Kernkraft GmbH.



**For further questions, please contact**
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**HCSMR main characteristics:**

| | |
|---|---|
| - power | 600 MWth |
| - primary loop type | integrated |
| - conversion rate $T_{Conv}$ | ≥ 0,8 |
| - void coefficient | < - 500 pcm |
| - reactivity control | no soluble boron |

**Example of parameters to be optimized:**
- moderation ratio
- fuel type and enrichment
- linear power
- cycle length and fuel management

## ► PhD Objectives

- Define HCSMR main parameters
- Develop a validated computation scheme for an under-moderated small core
- Design a core reactivity management strategy
- Implement a multi-criteria optimization approach
- Perform transient analysis on the optimized design

## ► Methodology

The lattice code APOLLO2 will be used for fuel assembly deterministic transport calculations (see figure 2). Core calculations will be performed using the CRONOS2 code with diffusion and using the APOLLO3 code with simplified transport. To compare, Monte Carlo calculations will be performed at the fuel assembly and core scales, including depletion steps, with use of the TRIPOLI4 code.

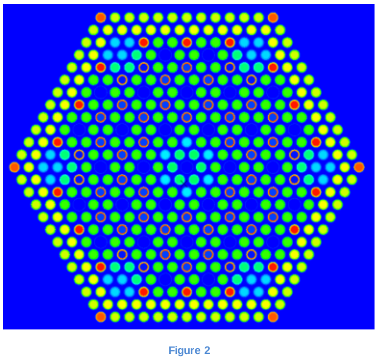

Figure 2
HCSMR fuel assembly. Radial view. Colors identify the 11 self-shielding regions.

A multi-criteria optimization of the HCSMR design will be performed. Based on the optimization criteria and parameters, a research plan will be defined. A meta-model using neuronal networks will be designed to replace the validated computation scheme. The optimization itself will be done using genetic algorithms.


Issue Date
September 2014