From neutronics to nuclear scenarios

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Aware of issues related to energy challenges, some countries initiate an energy transition that involves structural changes in energy supply and consumption systems. The substantial inertia in the energy system and the high investments such a transition requires impose a high level of anticipation. For those reasons, prospective studies are used to assess main technical and economic drivers in order to help identify most efficient policy levers. French case is specific since there is a significant amount of the energy used that comes from nuclear source. This is why nuclear scenario constitutes one of the strategic tools for producing expertise and knowledge related to the future of the electricity mix. Nuclear scenarios are based on nuclear fuel cycle simulators which aim to model an entire fleet of nuclear facilities. Fuel cycle simulators are used worldwide and by many institutions for wide range of applications. First, those tools are used to produce data for assessing the future of nuclear energy and highlight decision making process. Also, they help to optimize industrial operations related to an existing nuclear fleet in support of the operator. Those codes could also be used by national or international safety authorities to evaluate nuclear fleet and/or fuel strategy. Finally, they are often used as effective research and development training tools because of their ability to highlight nuclear fleet main technical drivers. To consider complex physical phenomena related to reactors management, a fuel cycle simulator should feature two physics models used to:

- Determine the fresh fuel composition according to available isotopes and reactor requirements,
- Calculate the fuel isotopic evolution in a relatively low calculation time.

A major effort in neutronic simulations is required to develop robust physics models. Nevertheless, several bias and uncertainties still remain and need to be investigated further. The first part of the lecture will be dedicated to the description of neutronic calculations used to build fuel cycle simulators physics models. In the second part, physics models will be described with a focus on calculation bias and uncertainty. The lecture will finally persent fuel cycle simulation examples from recent research applications.

Some review papers:

[1] Nicolas Thiollière, Jean-Baptiste Clavel, Fanny Courtin, et al.. A methodology for performing sensitivity analysis in dynamic fuel cycle simulation studies applied to a PWR fleet simulated with the CLASS tool. *EPJ Nuclear Sci.Technol.*, 2018, 4, pp.13. ⟨10.1051/epjn/2018009⟩. ⟨hal-01851230⟩

[2] B. Leniau, B. Mouginot, N. Thiolliere, et al.. A neural network approach for burn-up calculation and its application to the dynamic fuel cycle code CLASS. *Annals of Nuclear Energy*, Elsevier Masson, 2015, 81, pp.125-133. ⟨10.1016/j.anucene.2015.03.035⟩. ⟨in2p3-01158081⟩

[3] Fanny Courtin, Baptiste Leniau, Nicolas Thiollière, et al.. Neutronic predictors for PWR fuelled with multi-recycled plutonium and applications with the fuel cycle simulation tool CLASS, Progress in Nuclear Energy, Volume 100, 2017, Pages 33-47, ISSN 0149-1970.

[4] A.-A. Zakari-Issoufou, Xavier Doligez, Alice Somaini, et al.. Americium mono-recycling in PWR: A step towards transmutation, Annals of Nuclear Energy, Volume 102, 2017, Pages 220-230, ISSN 0306-4549.