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3.2.2 Whole core simulation and advanced applications

Full-core Monte Carlo analyses: When and why do we need them?

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Full-core Monte Carlo analyses:
When and why do we need them?

Monte Carlo analyses for nuclear rectors are a fairly complicated issue. The computer resources needed to carry out a full-core Monte Carlo analysis of a power reactor are extensive. Therefore, it took quite some time before this kind of analysis became feasible. Even nowadays it is rather unpopular, as deterministic analyses carried out for existing reactors can yield accurate predictions for the reactor behaviour.

Therefore, one could question the usefulness of Monte Carlo analyses in this field. Are the extra expenses in computer time and man-hours worth the effort?

We will try to answer this question using three sample sample cases:

- a small research reactor (the 45 MW High Flux Reactor in Petten)
- an aging PWR (the Borssele NPP)
- the ITER fusion reactor

In the end, we will demonstrate that full core Monte Carlo analyses for nuclear reactors have their specific advantages and are even indispensable for determining important parameters.

1 Sample case 1: a small research reactor

One of the cases were Monte Carlo analyses can be shown to be indispensable, is the neutronics analysis of a research reactor. Research reactors are used to produce an intense neutron source, which can be used to study the response of materials under neutron bombardment or to produce artificial materials.

Irradiation of structural materials has proven to be indispensable in the design of current reactors, but is also needed if new reactor types with different neutronic conditions are considered. Furthermore, the irradiation of new fuel types provides the type of information needed for the qualification of these fuels. Finally, material can be irradiated to produce radioactive isotopes. These have a widespread use in the medical field as diagnostic or therapeutic agents. Also in the industry radioactive sources are widely used.

Contrary to power reactors, research reactors are usually small. Taking the High Flux Reactor (HFR) in Petten as an example, this reactor produces its 45 MW of thermal power in a core with a size of around $60 \times 60 \times 60$ cm^3. The core of the HFR has a checkerboard-like structure, in which half of the positions contain fuel and half of the positions can be used for material irradiations.

It is obvious that in such a heterogeneous situation full-core Monte Carlo analyses are essential if a reliable prediction of the neutronic conditions is requested. Detailed attention has to be paid to all issues which are relevant for neutronics analyses, such as the modelling of the geometry, but also the choice of the cross-section data. Comparisons with measured data will be given, showing that if enough attention is paid to the important issues, Monte Carlo analyses can give a good prediction of the 3-dimensional neutronic behaviour of a reactor.

2 Sample case 2: an aging PWR

The second sample case deals with a subject of increasing importance: the aging PWR. In the Netherlands the only existing PWR is the Borssele reactor (512 MWe). The reactor dates from the early 70's and recently obtained a lifetime extension up to 2030. Originally the reactor was designed for a 40 years lifespan, which implies that extra information is needed to show that the reactor can safely operate for the years to come. Studies were carried out to predict the radiation damage in the steel of the reactor pressure vessel in the course of the time. An essential ingredient in these analyses was the validation of the calculational methods, using experimental information of radiation monitors close to the pressure vessel.

Only Monte Carlo analyses can provide this very detailed information. Using full-core Monte Carlo analyses for each of the cycles of the reactor since it started operation, the response of the detectors was simulated. It will be shown that a good agreement was obtained, supporting the lifetime extension of the reactor.

3 Sample case 3: the ITER fusion reactor

The ITER fusion reactor, which is currently under construction, is quite unlike any other nuclear reactor. The neutronic conditions will be completely different, because the neutrons will be born with an energy of 14 MeV in an intense plasma. This implies that one cannot rely on the operational experience in existing reactors. Instead, detailed simulations are the only source of information. Due to the fact that the geometry will be rather heterogeneous, which all kinds of nooks and crannies, Monte Carlo analyses of the complete ITER geometry are required (this is the equivalent of a full-core reactor analysis).

The importance of these Monte Carlo analyses will be demonstrated. The details of the modelling approach will determine important responses, and in the end the safety of the maintenance personnel.

4 Summary

Full-core Monte Carlo analyses can be shown to be of vital importance for the calculation of important parameters in existing and forthcoming nuclear reactors.