CORTEX

Core monitoring techniques and experimental validation and demonstration

Required data for modelling the reactor transfer function

Final CORTEX workshop

Online

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This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 754316.

Core modelling requirements

- Extremely large sets of simulations required for training the AI architecture

➢ Fast running models required

- Neutron transport modelled using the diffusion approximation with only a few energy groups

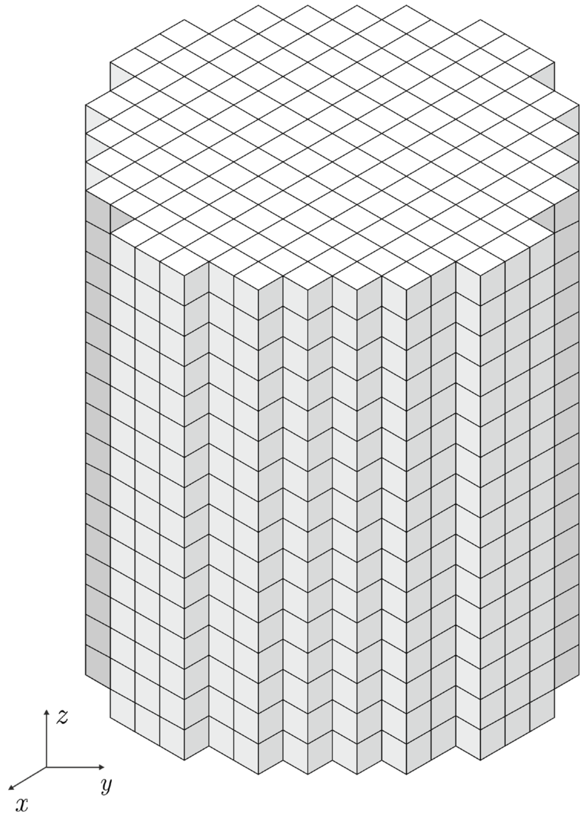
$$\frac{1}{v_g}\frac{\partial \phi_g}{\partial t}(\mathbf{r},t) = \nabla \cdot \left[D_g(\mathbf{r},t)\nabla \phi_g(\mathbf{r},t)\right] + \sum_{g'=1}^{G}\Sigma_{s0,g'\to g}(\mathbf{r},t)\phi_{g'}(\mathbf{r},t)$$

$$+\left[1-\tilde{\beta}(\mathbf{r})\right]\chi_g^p(\mathbf{r})\sum_{g'=1}^{G}\nu_{g'}(\mathbf{r})\Sigma_{f,g'}(\mathbf{r},t)\phi_{g'}(\mathbf{r},t) + \sum_{i=1}^{N_g}\lambda_i(\mathbf{r})\chi_{i,g}^d(\mathbf{r})C_i(\mathbf{r},t) - \Sigma_{t,g}(\mathbf{r},t)\phi_g(\mathbf{r},t)$$

$$\frac{\partial C_i}{\partial t}(\mathbf{r},t) = \tilde{\beta}_i(\mathbf{r})\sum_{g'=1}^{G}\nu_{g'}(\mathbf{r})\Sigma_{f,g'}(\mathbf{r},t)\phi_{g'}(\mathbf{r},t) - \lambda_i(\mathbf{r})C_i(\mathbf{r},t), i = 1,\ldots,N_d$$

Core modelling requirements

- Calculations can be performed:
  - In the time-domain:
    - \+ Non-linear effects accounted for
    - \- Lengthy calculations
  - In the frequency-domain:
    - \- Accounting for non-linear effects not easy
    - \+ Fast calculations
- For practical applications, core represented by piece-wise homogeneous regions



Core modelling requirements

- Leading to the following set of balance equations:

$$\frac{1}{v_g}\frac{\partial \phi_{g,n}}{\partial t}\left(t\right) = -\sum_{\aleph=x,y,z}\frac{J_{g,n}^{\aleph}\left(t\right) - J_{g,n-1}^{\aleph}\left(t\right)}{\Delta\aleph} - \Sigma_{t,g,n}\left(t\right)\phi_{g,n}\left(t\right) + \sum_{g'=1}^{G}\Sigma_{s0,g'\to g,n}\left(t\right)\phi_{g',n}\left(t\right)$$

$$+\chi_{g,n}^{p}\left(1-\tilde{\beta}_{n}\right)\sum_{g'=1}^{G}\nu_{g',n}\Sigma_{f,g',n}\left(t\right)\phi_{g',n}\left(t\right) + \sum_{i=1}^{N_d}\chi_{i,g,n}^{d}\lambda_{i,n}C_{i,n}\left(t\right)$$

$$\frac{\partial C_{i,n}}{\partial t}\left(t\right) = \tilde{\beta}_{i,n}\sum_{g'=1}^{G}\nu_{g',n}\Sigma_{f,g',n}\left(t\right)\phi_{g',n}\left(t\right) - \lambda_{i,n}C_{i,n}\left(t\right), i = 1,\ldots,N_d$$

Core modelling requirements

- Leading to the following set of balance equations:

$$\frac{1}{v_g}\frac{\partial \phi_{g,n}}{\partial t}(t) = -\sum_{\aleph=x,y,z}\frac{J^{\aleph}_{g,n}(t) - J^{\aleph}_{g,n-1}(t)}{\Delta\aleph} - \Sigma_{t,g,n}(t)\phi_{g,n}(t) + \sum_{g'=1}^{G}\Sigma_{s0,g'\to g,n}(t)\phi_{g',n}(t)$$
$$+\chi^{p}_{g,n}\left(1-\tilde{\beta}_n\right)\sum_{g'=1}^{G}\nu_{g',n}\Sigma_{f,g',n}(t)\phi_{g',n}(t) + \sum_{i=1}^{N_d}\chi^{d}_{i,g,n}\lambda_{i,n}C_{i,n}(t)$$

$$\frac{\partial C_{i,n}}{\partial t}(t) = \tilde{\beta}_{i,n}\sum_{g'=1}^{G}\nu_{g',n}\Sigma_{f,g',n}(t)\phi_{g',n}(t) - \lambda_{i,n}C_{i,n}(t), i = 1,\ldots,N_d$$

Nuclear data

- Need to get the nuclear data at the **steady-state conditions** of the reactor (corresponding to the measurement data to be analysed)
- Those nuclear data need to be generated using common reactor physics methods and methodologies

➢Lattice calculations accounting for the effect of burnup, instantaneous and history effects

Noise source representation

- Once the steady-state conditions are computed using static core calculations, the effect of the perturbations in the macroscopic cross-sections can be assessed
- This requires a model for "translating" a physical perturbation into a cross-section perturbation $\delta\Sigma_{\alpha,g,n}\left(t\right)$

➢ "Expert opinion" often required

Conclusions

- Modelling of neutron noise requires:
  - Pre-generation of macroscopic cross-sections and kinetic parameters
  - Modelling of the steady-state conditions of the system
  - Modelling of the perturbations in terms of cross-section variations
  - Modelling of the effect of those cross-section variations

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