7 Assessment of ACR Core Modeling

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Presentation Objectives

- To demonstrate a high confidence on the adequacy of the current methodology for nominal core-configuration calculations
- (Presentation 8 will describe use of MCNP in short term for configurations having large heterogeneity, such as checkerboard voiding)
- To discuss longer term development tasks undertaken to address transient core-simulations and tasks planned to address heterogeneous core states during transients
- To describe collaborative program with EP for development of ACR core modeling capability using an independent code set

Presentation Outline

- ACR core design features and requirements on code capabilities
- Current WIMS/RFSP methodology
- Core-Modeling Assessment
  - number of energy groups
  - spatial mesh structure
  - device modeling
  - assembly discontinuity factors
  - comparisons to MCNP (details on checkerboard voiding in presentation by Rouben)
- Development of RFSP core-modeling capabilities
- Collaboration program with Ecole Polytechnique

ACR Core-Design Features
(In comparison to current CANDU)

- Flat global flux shape across the core
- Small core size, relatively higher importance of leakage
- Flux rise in peripheral core and reflector region upon loss of coolant, further enhanced negative coolant void reactivity
- Higher neutron utilization in SEU fuel
- Lower absorber worth and moderator poison worth
- Zone control elements inserting from top and bottom
- New SOR design, Poison Injection nozzles in reflector region

Core-Modeling Considerations and Current WIMS/RFSP Methodology

- Accuracy of diffusion theory, especially with regards to steep flux gradients at core / reflector interface

  [Finite-Difference solution, nodal method under development]

- Number of energy groups

  [2 energy groups]

- Spatial flux convergence – sensitivity to mesh structure

  [Fine mesh in production model]

- Fidelity of lattice cell properties, net current at cell boundary

  [zero net current]

Core-Modeling Considerations and Current WIMS/RFSP Methodology (con't)

- Neutron leakage model, accuracy of diffusion coefficients

  [Benoit diffusion coeff., averaged over axial and radial directions]
- Homogeneous flux vs heterogeneous flux – discontinuity factors

  [Provision for discontinuity factors under development]
- Device modeling

  [DRAGON supercell incremental properties]
- Benchmark Data – Inter-code comparisons

  [MCNP, DONJON]

Sensitivity to Number of Energy Groups
- RFSP / DONJON Diffusion Solution Method

- RFSP-IST currently formulated in 2 energy-group
- DONJON has multi-group capability – not an IST code
- RFSP vs DONJON (2-group)
- Accuracy of 2-group calculations
  - DONJON 2-group compared with N-group (N up to 32 groups)
  - variations in key core parameters
    - k-eff
    - CVR
    - power distribution
    - mechanical zone controller (ZCR) device worth

Accuracy of 2-Group Core Calculations

Quarter of a Coarse Mesh Model - X-Y Plane

Quarter of a Fine Mesh Model - X-Y Plane

Radial Flux Sensitivity to Mesh Size (Voided Core)

Sensitivity to Core Mesh Structure

Device Modeling

- **Current Methodology**
  - DRAGON transport calculations
  - 89-group
  - super-cell model: 2 lattice-pitch x 1 bundle-length
  - reflective boundary conditions at outer surfaces
  - with and without device, delta cross-sections used to represent the effect of the device
  - background fuel usually assumed to be at mid-burnup, same delta cross-sections used in most situations
- **Assessments**
  - sensitivity to background fuel burnup (completed)
  - sensitivity to background fuel with coolant voided and checkerboard voided (planned)

DRAGON Super-Cell Model

Preliminary Assessment of Discontinuity Factors for ACR Modeling

- Discontinuity factors used to ensure node-integrated reaction rates from homogeneous model same as those from heterogeneous model
- Defined discontinuity factor as ratio of surface-average heterogeneous flux to surface-average homogeneous flux
- Discontinuity factor depends on cell boundary conditions
- Preliminary assessments:
  - whether discontinuity factors are needed for ACR-core calculations
  - whether the use of assembly-discontinuity factors (ADF - ratio of average flux on thin (1 mm) boundary region to cell average) is sufficient to obtain an accurate core-level flux, or if better (leakage-corrected) discontinuity factors are needed

Discontinuity Factor Assessment Methodology

Two-Node and Three-Node Configurations - DRAGON Models

Modeling Constraints

Discontinunity Factor Assessment Conclusions

RFSP / MCNP Comparisons

- Full Core models without devices
- Various representations of fuel burnup distribution
- Fully cooled, fully voided, checkerboard voided comparisons
- Flux shape comparisons for nominal core, distributed burnup in next 2 overheads
- Sensitivity to various core parameters

More details on comparisons for checkboard voided core in next presentation by B. Rouben / D. Jenkins

Development of Core-Modeling Capabilities in RFSP (I)
(Time-Dependent Calculations)

Development of Core-Modeling Capabilities in RFSP (II) (Currently underway or planned)

U of Montreal GAN CRD Project
– ACR Computational Reactor Physics

- GAN at Ecole Polytechinque has been involved in computation physics research, developed codes capable of analyzing various reactor configurations
- Provide alternate set of computation scheme and tools
- Current Collaborative Research Development (CRD) Project aiming at development specific to ACR
- Collaboration with AECL expected to provide greater insight on ACR physics, and reduce uncertainties

CRD Project Topics

- ZED-2 Reactor Model using DRAGON/DONJON
- ACR Model using DRAGON/DONJON
- Comparisons with WIMS/RFSP Results
- Environment Dependent Lattice Properties
- CVR
- Loss of Coolant Accident
- Nodal Methods, Discontinuity Factors and Kinetics Analysis
- Fuel Management Optimization in DONJON
- Multi-Parameter Reactor Database
- Improvement to TRIVAC Flux Solution Operators in DONJON
- Improvement of Resonance Self-Shielding model in DRAGON
- Improvement of Geometry modeling in DRAGON

Summary

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