RIC 2013

TH33: Thermal Hydraulic & Severe Accident Research

TRACE/PARCS Coupled Calculations

Dr. Nathanael Hudson
US NRC
Office of Nuclear Regulatory Research
March 14, 2013

Coupled Thermal-Hydraulic/ Neutronic Analysis

- Coupled thermal-hydraulic (TH)/neutronic capabilities used to perform independent analyses for new reactor designs, licensing actions for operating plants, evaluation of generic safety issues, support for rulemaking, & analyses of plant events
  - Reviews of operating Boiling Water Reactor (BWR) Extended Power Uprates (EPUs) & maximum extended load line limit analysis plus (MELLLA+) operations stability & Anticipated Transient Without SCRAM (ATWS) events, & Anticipated Operational Occurrences (AOOs)
  - New & advanced light water reactor (LWR) & high temperature gas reactor (HTGR) designs
- Predict: Peak pin powers in relation to fuel thermal limits, reactivity & power control, safe shutdown margin, slow xenon/samarium tracking, critical heat flux margin, etc.

2

NRC Code Suite

- SCALE – Standardized Computer Analyses for Licensing Evaluation – Cross section processing package
- PARCS – Purdue Advanced Reactor Core Simulator – Steady State Core Simulator (TH + neutronics) for depletion calculations to get core state
- GenPMAXS – Code for Generating cross section interface file PMAXS. Translates lattice code format cross sections to PMAXS format & also generates cross sections for radial reflectors
- TRACE/PARCS – TRAC (*Transient Reactor Analysis Code*) RELAP (*Reactor Excursion and Leak Analysis Program*) Advanced Computational Engine - Transient TH+ 3D kinetics solver use cross sections at a given core state
- SNAP – Symbolic Nuclear Analysis Package

3

TRACE/PARCS Status

- Best practices methodology – Effort into guidelines to inform the cross section branch structure and TRACE/PARCS nodalization, as well as channel grouping studies
- Code Software Quality Assurance (SQA) – Common test suite across SCALE and GenPMAXS was developed. PARCS being re-structured to interface better with the NRC code suite, and to also make code maintainability & testing easier
- Code development – A multi-cycle BWR depletion capability is being developed to support control rod drift studies: Fuel shuffling, shutdown margin, user interface with SNAP, cross section development methodology, documentation, high worth control rod worth search

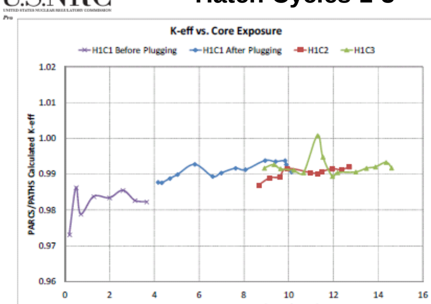
4

BWR Depletion Methods

- Ongoing enhancements to PARCS such that it can predict onset of re-criticality (margin) during inadvertant control rod (CR) drift events in BWRs – considering various #'s of withdrawn blades
- Analysis capability to identify criticality margin for limiting combinations of exposure, thermal conditions, & withdrawn blades – probability of prompt criticality
- User ease and automation through enhancement of PARCS and SCALE plug-ins within SNAP
- Developed best practices NUREG/CR-7041 for LWR cross section generation
- PATHS being developed: PARCS Advanced Thermal Hydraulic Solver; simplified incompressible flow, drift flux TH model

5

Hatch Cycles 1-3*



(*) Yarsky et al., "The Application of PARCS/PATHS to Depletion of Hatch Cycles 1-3," to appear in NURETH-15

6

Control Rod Search Methodology

- Deplete reference cycle from beginning to end
- Branch at each depletion point to a cold zero power, all rods in condition and track the k-eff for each point. Identify the most reactive point in cycle
- At the most reactive point in cycle, evaluate various temperatures to determine the most reactive core conditions
- Execute CR group search algorithm at the most reactive point and state
- Algorithm works by successively sorting CR worth (reactivity) and ranking groups of rods repetitively. High worth groups make it to top of ranking

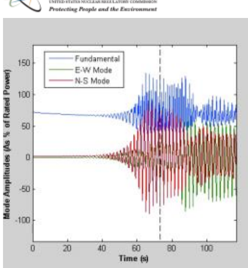
7

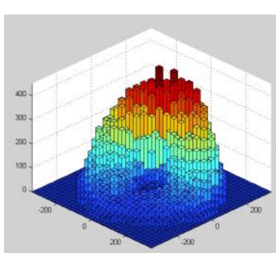
BWR Best Practices

- BWR Cross Section (XS) Tabulation – Developing user guidance as to the wide range and detail of independent state and history variables at which to tabulate XS's:
  - State variables: CR insertion, fuel temperature, coolant density, & soluble poison concentration, & isotopic concentration
  - History variables: CR & coolant density – effect spectrum
- Beta effective – transient sensitivity to assumptions & boundary conditions in lattice code
- Explored axial nodalization strategies to minimize "user effect" & the engineering judgment necessary to keep node length within the material Courant limit
- Explored optimal channel grouping strategy in search for rotating mode of power shapes in BWR oscillations

8

Oscillatory Modes*





(*) Calculated by Oak Ridge National Laboratory

9

Conclusions

- Coupled thermal-hydraulic/neutronic analysis plays a role in confirmatory safety calculations at the NRC
- TRACE/PARCS is the NRC tool for core physics, steady-state, & transient neutronics problems
- Recent heavy usage on complex and difficult plant simulations has led to several improvements
- NRC's goal is continuous improvement in capabilities, automation of routine tasks, & expansion of the assessment basis of TRACE/PARCS
- The results presented here were developed by NRC staff, Oak Ridge National Laboratory, and the University of Michigan

10