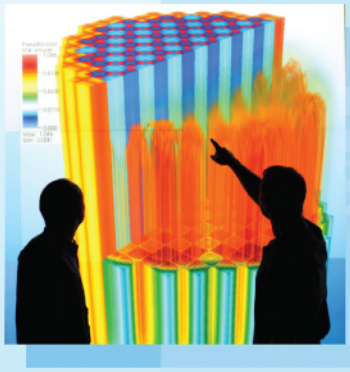
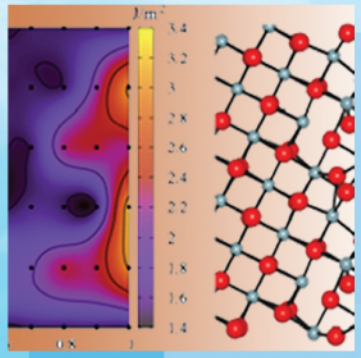
CASL-U-2014-0133-000

Power uprates
and plant life extension



Engineering design
and analysis

Science-enabling
high performance
computing



Fundamental science

Plant operational data

Consortium for Advanced Simulation of LWRs

Presentation Poster: Watts Bar Unit 1 MCNPX Simulations with KENO-VI Comparisons

William Gurecky
University of Texas at Austin

August 4, 2014

U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Watts Bar Unit 1 MCNPX Simulations with KENO-VI Comparisons

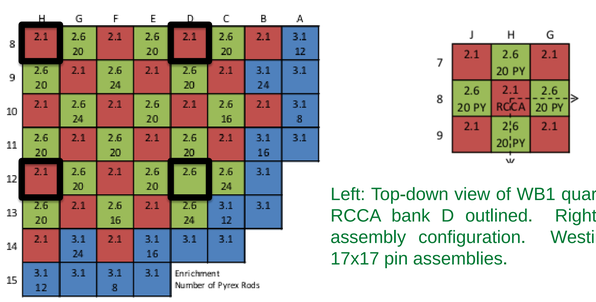
William Gurecky - The University of Texas at Austin

Mentor: Andrew Godfrey **Program:** HERE

Introduction

The Virtual Environment for Reactor Applications (VERA) is a central component of the Consortium for Advanced Simulation of LWRs' (CASL) technical portfolio. VERA provides an environment to investigate coupled thermal hydraulics, fuel performance, and neutronics problems. Neutronics packages selected for use in VERA must be validated against available experimental and golden-standard Monte Carlo (MC) simulation results. To this end continuous energy (CE) MCNPX computational models of the Watts Bar Unit I (WB1) reactor are compared with CE KENO-IV results in support of the CASL project. Results are provided for select problems from CASL's VERA benchmark progression problem suite. The goal of this work is to provide MCNPX models to compare against the current KENO-VI reference solution standard and ultimately to aid in CASL's validation effort of the neutronics packages available in VERA.

Watts Bar Unit 1



Left: Top-down view of WB1 quarter core. RCCA bank D outlined. Right: A 3x3 assembly configuration. Westinghouse 17x17 pin assemblies.

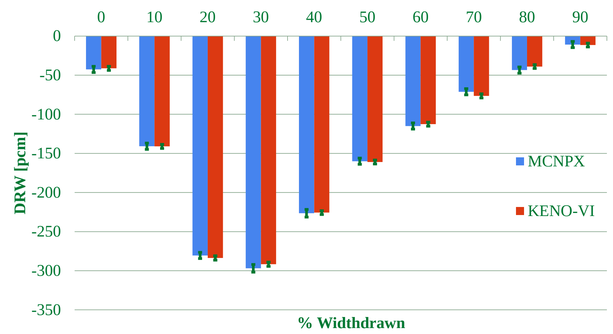
The presented models were constructed to approximate Watts Bar Nuclear Unit 1 at beginning of cycle (BOC), hot zero power (HZP) cycle 1 conditions. A 3x3 fuel assembly configuration is used as a stepping-stone to the quarter core WB1 case. 3D pin power distributions are obtainable with modest computational power for this case. The quarter core calculations focus on eigenvalue only results as pin power distributions are prohibitively expensive to compute. Control rod bank worth and the isothermal temperature coefficient (ITC) can be computed from the quarter core eigenvalue results.

Bank D [%] Withdrawn	MCNPX (+/- 2e-5)	KENO (+/- 1e-5)	Diff [pcm]
0	0.99244	0.992755	-31
10	0.99286	0.993162	-30
20	0.99425	0.994555	-31
30	0.99703	0.997369	-34
40	0.99999	1.000279	-29
50	1.00226	1.002542	-28
60	1.00387	1.004163	-29
70	1.00503	1.0053	-27
80	1.00575	1.006073	-32
90	1.00619	1.006468	-28
100	1.0063	1.006584	-28

Bank D's position effect on k_{eff} is shown in the table. All quarter core rod worth cases were conducted at a fuel and moderator temperature of 565K.

Results

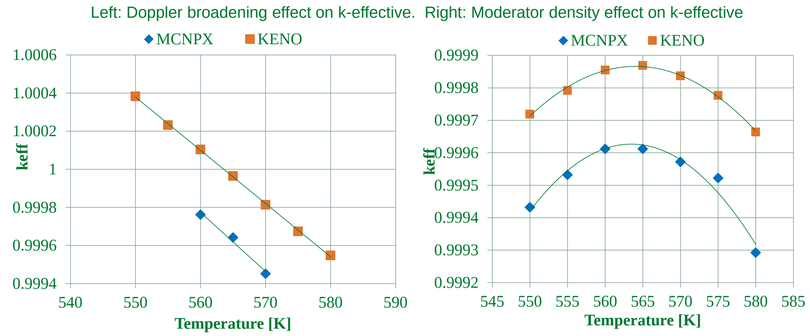
WB1 Quarter Core Bank Differential Rod Worth



The maximum differential rod worth discrepancy is only *5* pcm at the 30% withdrawn state. The average MCNPX and KENO differential rod worth uncertainty is ±4 pcm and ±2.7 pcm respectively.

WB1 quarter core ITC calculations were performed at 565K with ±5K perturbations in an all rods out configuration. The results were obtained by splitting the Doppler broadening, thermal scattering, and moderator density effects into separate calculations. This procedure avoids potential statistical noise that would cloud the result of a single perturbation calculation in MCNPX. NJOY 2012 was utilized to generate Doppler broadened cross sections for use in the MCNPX ITC calculations.

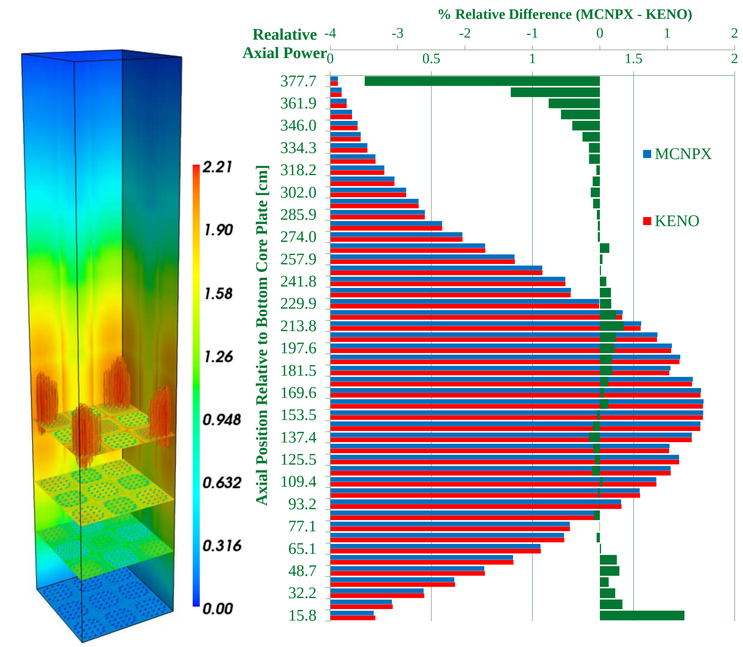
Left: Doppler broadening effect on k-effective. Right: Moderator density effect on k-effective



. The moderator density coefficient (MDC) was found by evaluating the derivative of a quadratic interpolant. The Doppler temperature coefficient (DTC) calculations included free gas thermal scattering temperature changes, however, the eigenvalue sensitivity to the *S(α,β)* thermal scattering treatment of the H1 isotope was split into a separate series of calculations.

	MCNPX [pcm/K]	KENO-VI [pcm/K]	Measured WB1 [pcm/K]
MDC	-0.357± 0.075	-0.144± 0.036	-
DTC	-3.100± 0.285	-2.790± 0.036	-
S(α,β)	-2.860± 0.056	-2.790± 0.054	-
ITC	**-6.317± 0.416**	**-5.724± 0.072**	**-3.888**

3x3 Array BOC HZP Axial Pin Power Distribution



The control rod bank position for the BOC HZP 3x3 assembly case is set to 257.9 cm from the bottom core plate. The RMS axial power difference between the two codes for this case is 1.25%. MCNPX results average a normalized axial power uncertainty of 0.32% with a maximum uncertainty of 1.12%. The eigenvalue results for this configuration are provided in the following table.

Case	MCNPX (+/- 2e-5)	KENO (+/- 1e-6)	Diff [pcm]
257.9cm Rod. Position	0.99869	0.998981	-29

Conclusions

- MCNPX and KENO-VI eigenvalue results agree within 35 pcm for all cases.
- MCNPX v. KENO-VI RMS pin power difference within 1.25% for 3D 3x3 fuel array with control rod insertion.
- The KENO-VI results are suitable for use in benchmark and validation studies involving deterministic neutronics packages available in VERA.

Acknowledgments

Funding for this research is provided by the Consortium for Advanced Simulation of LWRs, a U.S. Department of Energy innovation hub.