Validation of UNIST MCS Monte Carlo Code System for OPR-1000

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Introduction

- This poster presents the validation of Monte Carlo (MC) code development at Ulsan National Institute of Science and Technology (UNIST) for the OPR-1000 reactor.
- The 3D whole-core depletion calculation for OPR-1000 reactor in MCS model is coupled with various feedback options such as one dimensional thermal hydraulics (TH1D), depletion, Critical Boron Concentration (CBC), Equilibrium Xenon (Eq-Xe), quadratic and OpenW.
- MCS calculated results of CBC is compared with the measured data and Nuclear Design Report (NDR) data.
- MCS calculated results of axial and radial power distribution at Middle Of Cycle (MOC) and End Of Cycle (EOC) are compared with measured data.

OPR – 1000 Core Design

- Pressurized Water Reactor (PWR) to operate at 2,815 MWth
- **Number of Fuel Assemblies (FAs)**: 177
- **FA type** : PLUS7 (16 x 16 array of 236 fuel rods and 5 guide tubes)
  - Fuel pellet: UO_2 with low enriched ^{235}U (1.2 ~ 3.42 w/o)
  - Burnable Poison: Gadolinia fuel with Gd_2O_3 contents of 6 ~ 8 w/o
- **Loading Pattern of Reference Core OPR – 1000 Cycle 01**

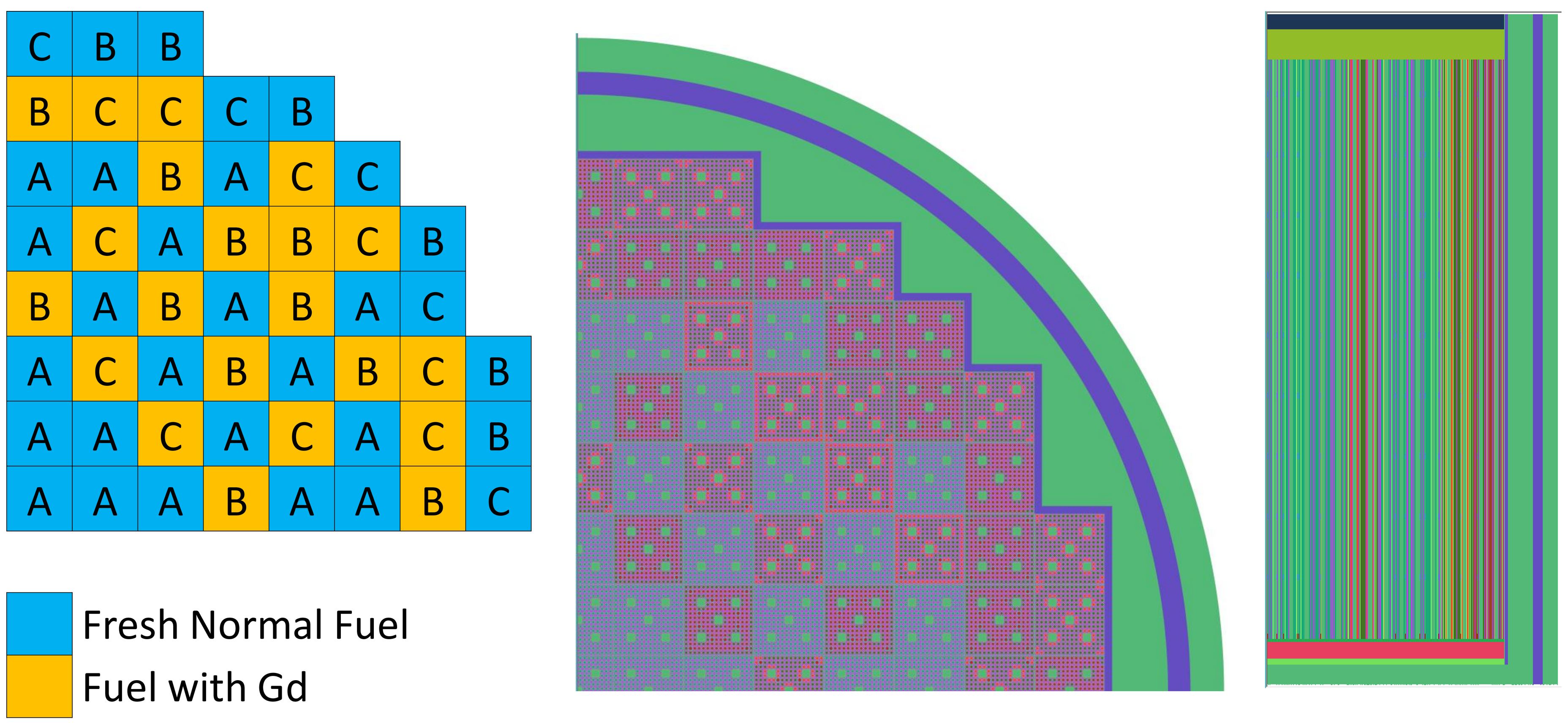


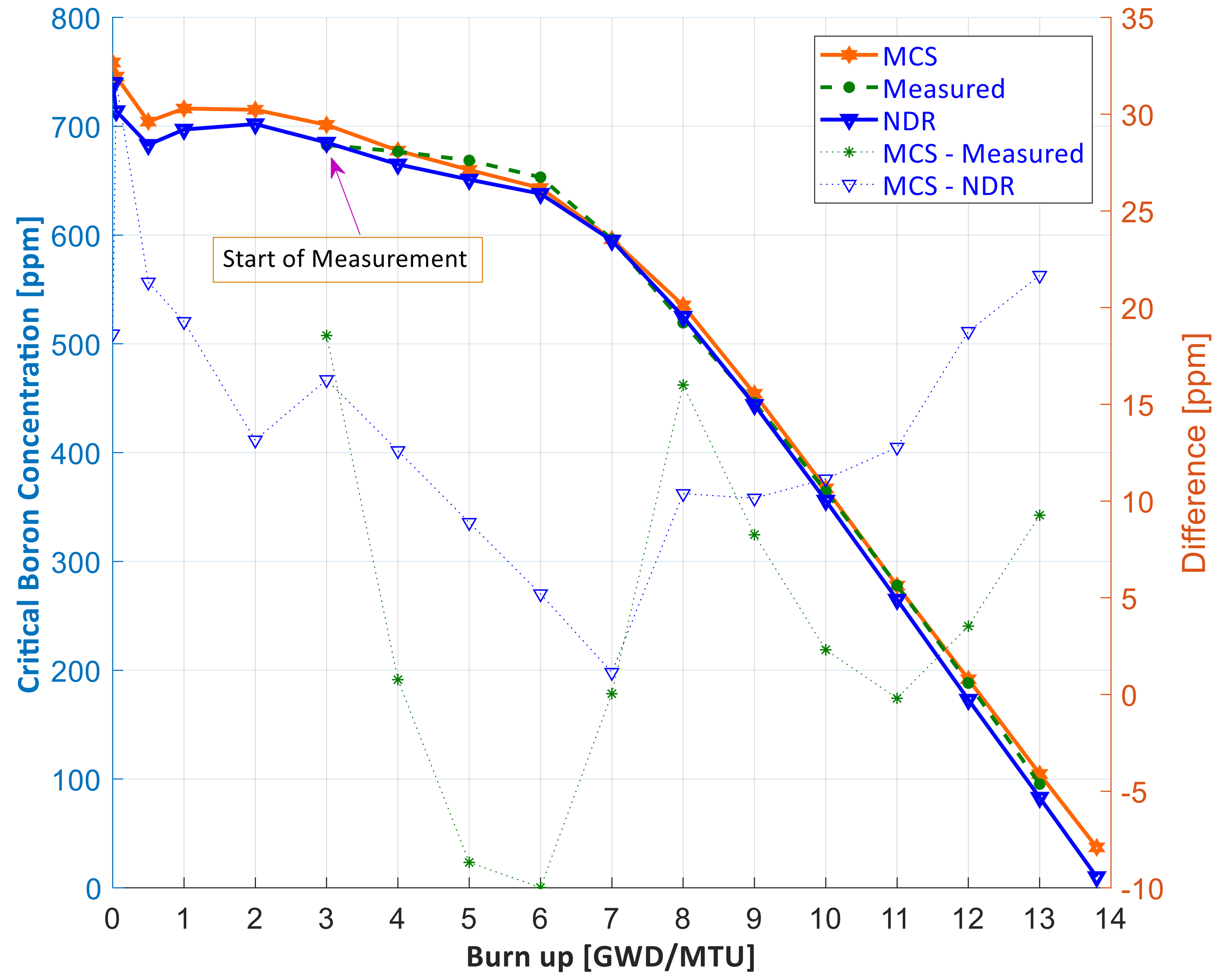
Fig. 1. MCS Quarter Core Model for OPR-1000.

Simulations and Results

Table I. Problem Description.

Core Parameter	**Value**
Core Power (MW)	2,815
Inlet Coolant Temperature (K)	569.26
Average Moderator Temperature (K)	584
Pressure (psia)	2,250
Core Flow Rate (kg/s)	16,315
Control Rod Position	ARO
Simulation Conditions	
Modeling	Quarter Core
Library	ENDF/B-VII.1
Active/inactive/history/sub-cycle	20 / 5 / 10,000 / 100
Quadratic, Eq-Xe	ON
TH1D - Division of UO_2 pin - Division of Gd_2O_3 pin	 - 1 ring / 10 axial nodes - 10 rings / 10 axial nodes
Depletion	34 steps (13.978 GWD/MTU)
Whole Core Calculation	
Execution Time (core hour)	3,925
Memory usages (MB)	6,500
CBC uncertainty (ppm)	1.506

➢ **Boron Letdown Curve**



➢ **Normalized Radial and Axial Power Distributions at MOC (6.0GWD/MTU)**

	H	J	K	L	M	N	P	R
8	0.741	0.796	0.919	1.272	0.966	0.935	1.159	0.886
9	0.794	0.851	1.259	0.990	1.308	0.951	1.171	0.777
10	0.917	1.263	0.990	1.295	0.992	1.200	1.061	0.592
11	1.263	0.996	1.295	1.015	1.256	0.896	0.907	
12	0.965	1.309	0.998	1.260	1.228	1.024	0.579	
13	0.936	0.957	1.210	0.900	1.030	0.718	RMS	1.10
14	1.170	1.186	1.064	0.900	0.577		Min	-2.47
							Max	3.32
15	0.892	0.785	0.598					

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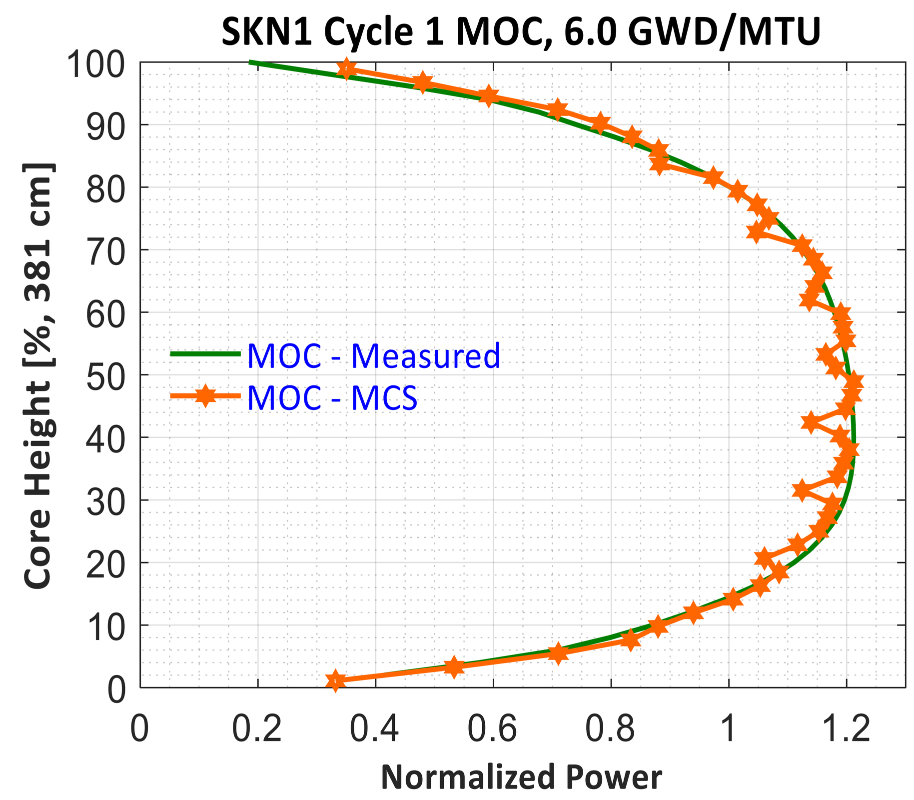
MCS

Rel. Error (%)



➢ **Normalized Radial and Axial Power Distributions at EOC (13.8 GWD/MTU)**

	H	J	K	L	M	N	P	R
8	0.864	0.900	0.959	1.188	0.955	0.946	1.149	0.885
9	0.898	0.926	1.238	0.976	1.227	0.961	1.184	0.797
10	0.960	1.251	0.980	1.183	0.968	1.163	1.112	0.640
11	1.205	0.984	1.195	0.983	1.177	0.918	0.923	
12	0.968	1.248	0.974	1.176	1.193	1.085	0.632	
13	0.940	0.962	1.157	0.918	1.072	0.776	RMS	1.67
14	1.126	1.169	1.092	0.914	0.628		Min	-3.27
							Max	4.47
15	0.864	0.779	0.633					

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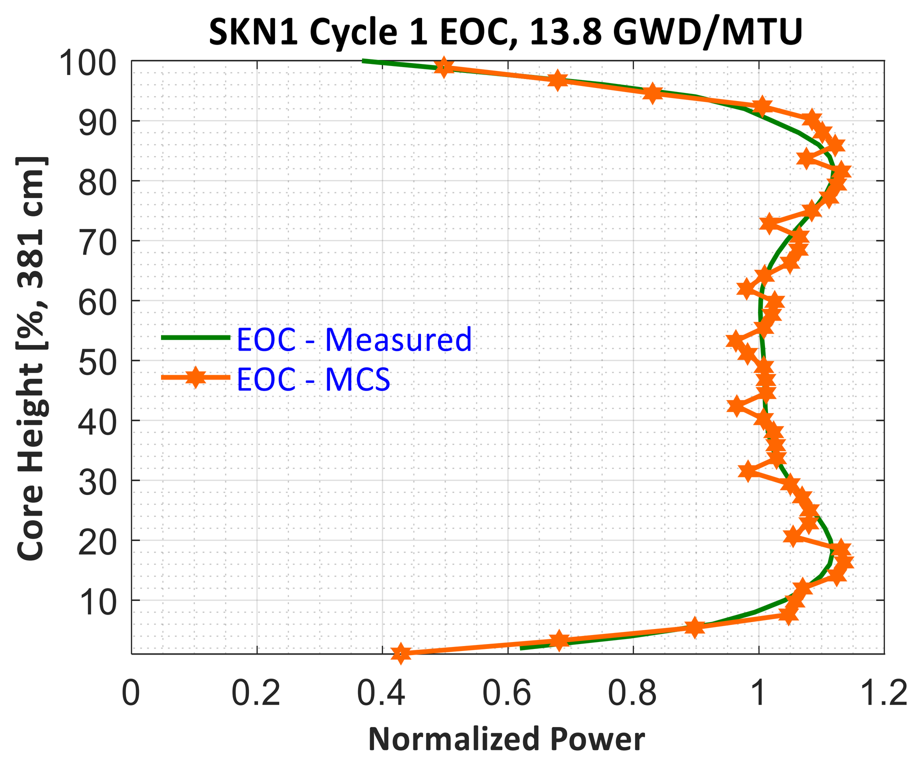
MCS

Rel. Error (%)



Discussion and Summary

- Successful validation of MCS model for OPR-1000 cycle 01
- Good agreement of the power distribution results of MCS at MOC and EOC agreement with the measured data, with a maximum relative difference less than 5%.
- The critical boron concentration results are closer to the measured data than the NDR.
- Future work
  - Compare TH parameters (fuel temperature, moderator temperature and density) and burn up distribution with measured data
  - Perform Refueling and compute the successive operation cycles (Cycle 02, 03, 04)