Generation of 3-D Power Distribution Synthesis Library for SMART Core Monitoring System

Abdullah Obaid Albugami[a]*, Dong Yeong Kim[b], Bon-Seung Koo[b]
[a] *King Abdullah City for Atomic and Renewable Energy*
[b] *Korea Atomic Energy Research Institute*
* *Corresponding author: a.bugami@energy.gov.sa*

Introduction

The Korea Atomic Energy Research Institute (KAERI) has developed a System-integrated Modular Advanced ReacTor (SMART) for a seawater desalination and electricity generation. Online digital core monitoring system for SMART was developed as a part of plant monitoring system. The system is called SMART Core Monitoring System (SCOMS). SCOMS is one of the application programs executed in the information processing system. It calculates the Limiting Condition for Operation (LCO) with measurable process variables and provides related information to the operator.

A Power Connection Method (PCM3D) for 3-D power distribution synthesis was developed, and its implementation to SMART core was evaluated.

In this paper, SCOMS library was newly generated with 365MW$_{th}$ core power, and the library was verified with reference power distributions.

Methodology

Nuclear Design Core System

- The two-step procedure based on DeCART2D and MASTER4.0 code system for the nuclear design has been developed by KAERI.

DeCART2D — DeCART2D perform transport lattice calculations to generate cross sections group.

MASTER — MASTER perform nodal diffusion calculations with tabularized cross sections.

3-D Power Synthesis

- SCOMS library contains Power Sharing Factor (PSF), Power Connection Factor (PCF), etc.
- Instrumented node power is determined by using a power sharing factor and power connection factors are used for calculating the undetected node power.
- A detected node power can be calculated as shown in Eq. 1. *k* and *k'* are axial indices for the detector and the neutronics node, and *l* is the radial index for neutronics node. Furthermore, the superscript "*d*" means the detected power.

$$P^d_{l,k} = \frac{1}{w_k}\sum_{k'} F_{l,kk'}P^d_{l,k'} \qquad \text{Eq.1}$$

where,

$P^d_{l,k}$ = Detected node power at node (l,k)
$P^d_{l,k'}$ = In-core detector power of detector unit *k'*
$F_{l,kk'}$ = PSF from detector *k'* to node *k* $(\approx \frac{w_{kk'}P^C_{l,k}}{P^C_{l,k'}})$
$w_k = \sum_{k'} w_{kk'} \quad (w_{kk'} = h_{kk'}/h_k)$
h_k = Height of detector unit
$h_{kk'}$ = Height of plane *k* included in detector unit

- An undetected node power can be determined using the neighboring powers and 3-D power connection factor. PCF is defined by the ratio of the power of a node (l,k) to the power average of the neighboring nodes as in Eq. 2.

$$C_{l,k} \approx C^C_{l,k} = \frac{1}{P^C_{l,k}(N_l + N_k)}\left(\sum_{j=1}^{N_l} P^C_{j.k} + \sum_{j=1}^{N_k} P^C_{l,j}\right) \qquad \text{Eq.2}$$

- The final governing matrix equation for the undetermined node power can be established as in Eq. 3. This equation is a fixed source problem and can be solved by iterative scheme.

$$C^C_{l,k}(N_l + N_k)P_{l,k} - \sum_{j\in U} P_{j,k} - \sum_{j\in U} P_{l,j} = \sum_{j\in I} P^d_{j,k} + \sum_{j\in I} P^d_{l,j} \qquad \text{Eq.3}$$

PREPCM3D

- PREPCM3D code is to produce SCOMS Library, Signal Data Library, and Reference Data Library.

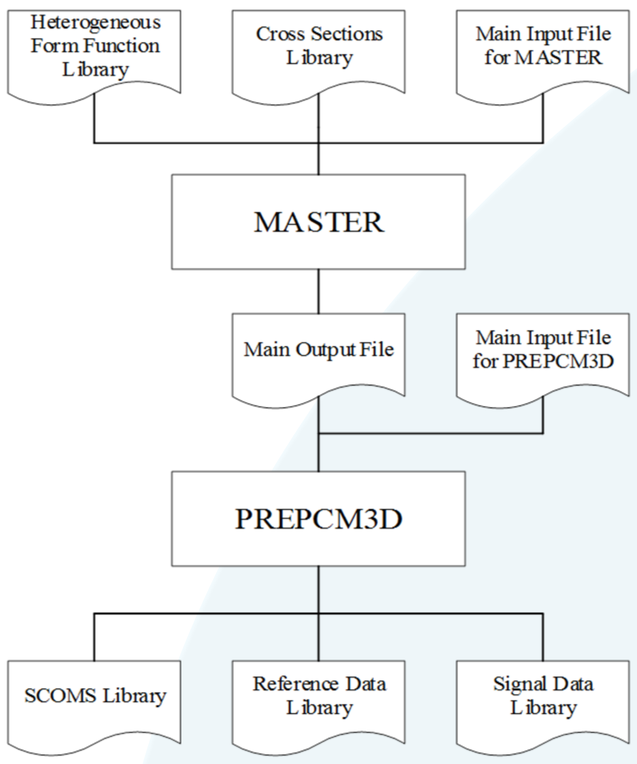

Fig. 1. PREPCM3D flow chart

PCM3D

- The PCM3D is used to determine if a coefficient library is valid.

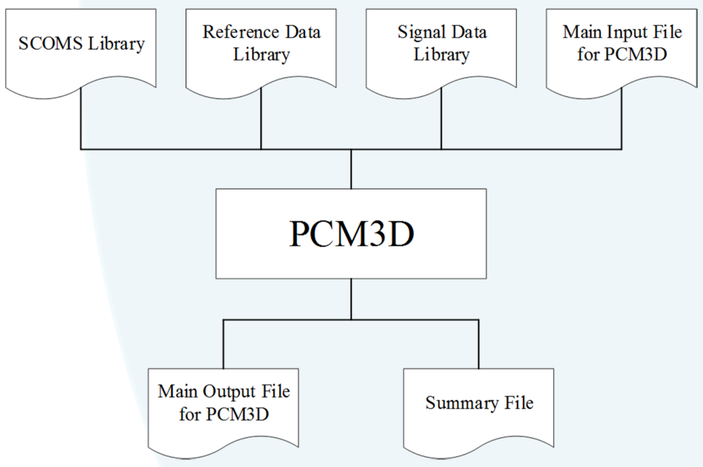

Fig. 2. PCM3D flow chart

Library Generation

- Coefficients for 3-D power synthesis are provided in the form of library and those are generated as a function of burnup, core power, and total travel length.

2 power points: 100% and 30%

Burnup interval: depletion step of neutronics code.

Total Travel Length: summation of total movement of regulating groups

- About more than 4,000 cases for library are generated.
- If core power, burnup, and TTL are determined, coefficients are automatically searched from library with linear interpolation method in SCOMS.

Results

- The results shown SCOMS library is properly verified for use in SCOMS code.

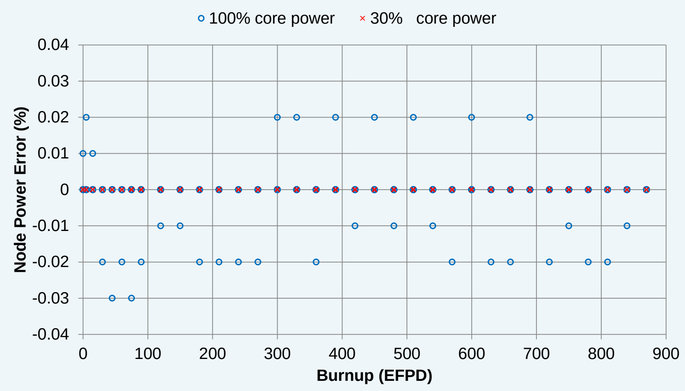

Fig. 3. Relationship between burnup and node power error

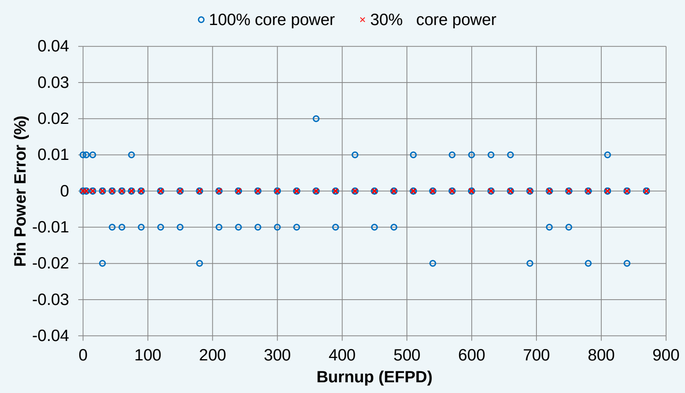

Fig. 4. Relationship between burnup and pin power error

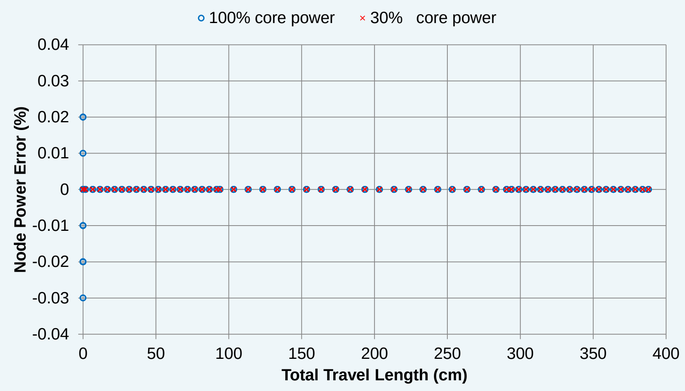

Fig. 5. Relationship between TTL and node power error

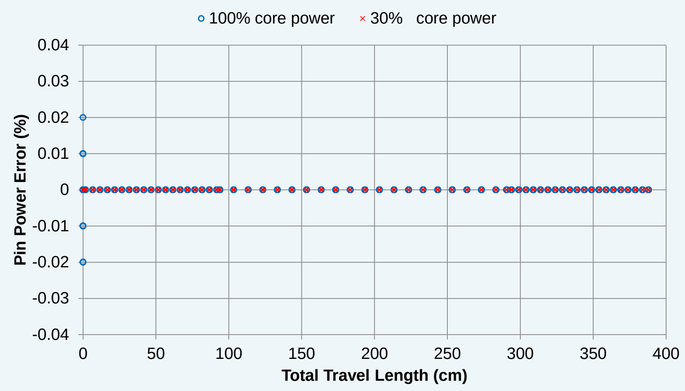

Fig. 6. Relationship between TTL and pin power error

Conclusion

Library of 3-D power distribution synthesis was generated for SCOMS in this study. From the result of MASTER code, the library data for 3-D power distribution synthesis were generated by using PREPCM3D code. The library test was performed by using PCM3D program that synthesized 3-D power distribution. Therefore, the synthesized library will be used as SCOMS library.