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Development of UCMS[1] for Analysis of Designed and Measured Core Power Distribution

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1. Introduction

In this study, reactor core loading patterns were determined by calculating and verifying the factors affecting peak power and important core safety variables were reconciled with their design criteria using a newly designed unified core management system.

Core loading patterns are designed for quadrant cores under the assumption that the power distribution of the reactor core is the same among symmetric fuel assemblies within the core. Actual core power distributions measured during core operation may differ slightly from their designed data. Reactor engineers monitor these differences between the designed and measured data by performing a surveillance procedure every month according to the technical specification requirements[Ref. 1].

It is difficult to monitor overall power distribution behavior throughout the assemblies using the current procedure because it requires the reactor engineer to compare the designed data with only the maximum value of the power peaking factor and the relative power density.

It is necessary to enhance this procedure to check the primary variables such as core power distribution, because long cycle operation, high burn-up, power up-rate, and improved fuel can change the environment in the core.

To achieve this goal, a web-based Unified Core Management System (UCMS) was developed. To build the UCMS, a database system was established using reactor design data such as that in the Nuclear Design Report (NDR) and automated core analysis codes for all light water reactor power plants[Ref. 5]. The UCMS is designed to help reactor engineers to monitor important core variables and core safety margins by comparing the measured core power distribution with designed data for each fuel assembly during the cycle operation in nuclear power plants.

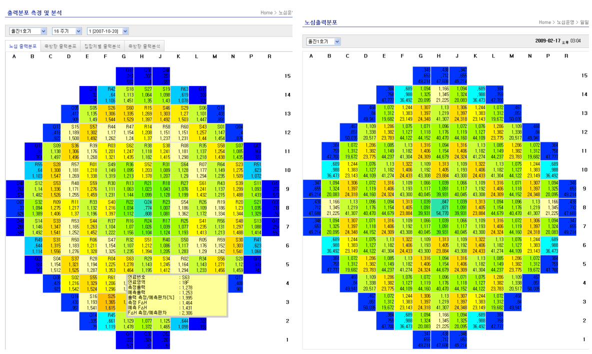
2. Core Power Distribution Analysis Applying the Unified Core Management System

To begin with, the 'Core Power Distribution Measurement and Analysis' procedure was performed at specific burn-up in the cycle operation while applying the UCMS to verify whether the core operated according to its designed core power distribution[Ref. 4]. The measured in-core neutron flux data was input into the system. Then, code input deck generation, running and output text processing were performed using the process automated in the system, and the analysis results were stored in the database (DB).

Conventional safety surveillance procedures require users to perform repetitive tasks due to the necessity for results extraction, editing, making tables and drawing graphs, because legacy core analysis code provides text-based results. Using the UCMS, however, reactor engineers are able to concentrate more time on making engineering judgments.

A database was compiled that contained major core variables such as the relative power densities in each fuel assembly, the power peaking factors in each fuel assembly, the axial power distribution, the Root Mean Square (RMS) error for axial power distribution, critical boron concentration and other factors. Then, a system was designed to perform a safety analysis of core power distribution based on this database.

3. Comparison of Designed and Measured Data for Core Power Distribution



Measured Data　　　　Designed Data

Fig. 1 Measured and Designed Data for Core Power Distribution

NDR data was linearly interpolated to measured specific burn-up and quadrant core data was expanded into full core data by rotating symmetry to compare the measured neutron flux power distribution by core analysis code (CECOR, INCORE) with designed power distribution by core design code (ROCS, ANC) at each burn-up step[Ref.2,3].

Fig. 1 shows a comparison of the measured and designed data for core power distribution by each code calculation at the same burn-up step.

The measured data in Fig. 1 displays information on fuel assembly ID, type, relative power density, power peaking factor, and the difference between the real measurement and that predicted by the code analysis with reference to the design data. Fig. 1 also offers a visualization of the

1 *UCMS : Unified Core Management System*

full core power distribution that is color-coded according to the power level in each fuel assembly. In this case, while overall core power distribution is symmetric, some fuel assemblies are asymmetric.

The designed data in Fig. 1 displays information on relative power density, power peaking factor and fuel burn-up in each fuel assembly at specific cycle burn-up, as well as a visualization of the full core power distribution that is color-coded according to the power level in each fuel assembly.

Using the UCMS, it was possible to verify asymmetric core power distribution during real cycle operation by comparison of the measured and designed data, and to verify a wave of asymmetric power distribution as burn-up occurred. It was also possible to verify an instance of reactor operation over the peak power levels specified in the NDR, as well as an asymmetric peak power distribution.

If this information regarding asymmetric fuel and power distribution is applied to the next cycle of core design, it will contribute to a greater safety margin through reduction of power peaking factors. The UCMS not only offers users detailed information on burn-up and on each type of fuel assembly, such as RPD, Fxy, Fq, Fr, Fz, ASI, and LHR, but the system also assists users in making more accurate engineering judgments through providing graphs of the trends of the core major variables that illustrate how those variables compare with design data; the system can provide these graphs by applying the accumulated data of core analysis code results from the beginning of the cycle to the present.

Below is an axial power distribution where the reactor height corresponds to an axial measurement point for comparison of the measured and designed data in terms of axial power shape. Fig. 2 is a graph comparing the measured axial power distribution with the axial power distribution specified in the NDR at specific burn-up.

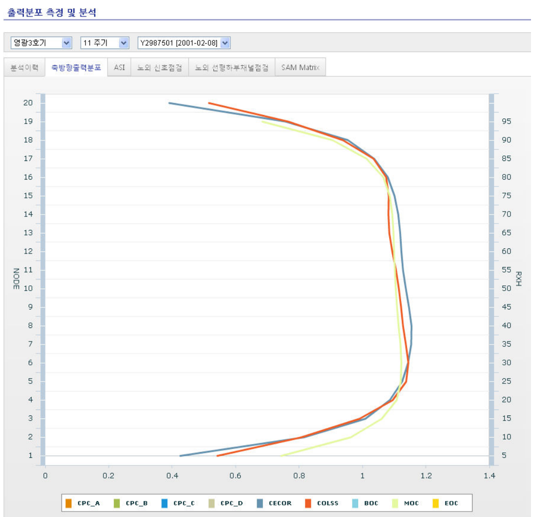


Fig. 2 Comparison of Measured and Designed Axial Power Shape

It was possible to verify a similar axial power shape in the measured and designed data by comparing the NDR axial power shape at the middle of the cycle to the results of analysis about CECOR, CPC and COLSS axial power distribution in the graph above.

4. Conclusion and Future Study

The UCMS was developed to monitor primary core variables and verify core safety margins by comparing and analyzing measured and designed data at the specific burn-up step. Using the UCMS, it was confirmed that the measured core power distribution at the tested plant was different from the designed core power distribution. If this result is reflected in the next cycle design at that plant, the plant operation margin will be ensured. Furthermore, end users will be able to make engineering judgments more quickly and easily by directly comparing design values with measured specific core information. Hereafter, the UCMS will be improved to be able to select the optimized loading pattern to align measured power distributions with designed power distributions.

Acknowledgements

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REFERENCES

[1] KHNP’s Core Management Procedures
[2] INCORE Code User’s Manual
[3] CECOR Code User’s Manual
[4] UCMS Engineering Workstation User’s Manual
[5] Nuclear Design Report (YGN Unit 3 Cycle 11 and UCN Unit 1 Cycle 16)