Innovative Neutron Flux Mapping System and Its Application to Kori #1 Unit

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This paper describes brief information about KEPRI's new contribution for the innovative flux mapping system(FMS), and retrofit experience obtained at Kori #1 unit including the performance of the system.

1. Motivation

The in-core neutron flux mapping system in a pressurized water reactor(PWR) power plant is designed to yield information on the neutron flux distribution at selected core locations by means of movable detectors. The flux mapping data are used to verify the reactor core design parameters, and to determine the fission power distribution in the core. Since the FMS provides important information related to plant safety, the power of the plant must be reduced or should be shutdown in case the function of the system is not available.

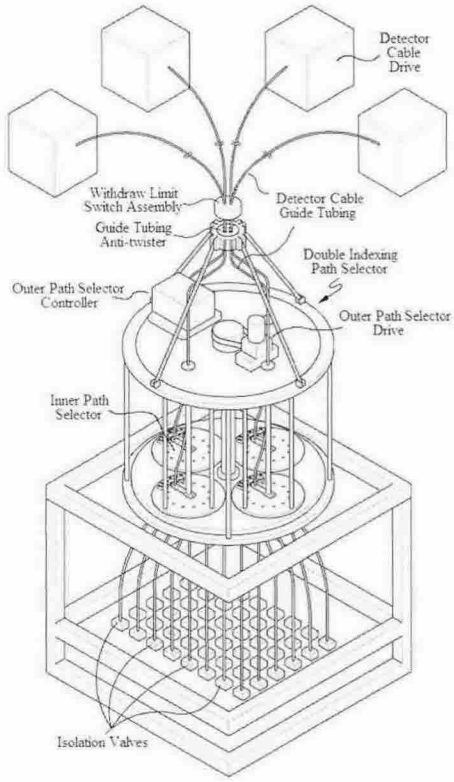

Fig. 1. FMS with Dips® architecture

2. Characteristics of new FMS

The PWR power plant equipped with a movable detector type neutron flux mapping system normally has thirty six to fifty thimbles depending on its power capacity, but typical flux mapping system has only four detector drives. So, multiple-path selectors are needed to route the detectors into all of the thimbles.

The conventional path transfer system is configured to have double layered architecture by allocating four independent path selectors at each layer. Four detector drives drive detector cables into their corresponding upper layer path selectors. Then the upper layer path selector selects one of four lower layer path selectors, or its detector storage path, or a calibration path so that the calibration path wye can receive any of the four detector from the upper layer path selectors. The calibration path provides means for cross calibration of detectors by routing each detector into a common thimble. Each lower layer path selector selects one of its quadrant thimble group.

As shown in Figure 1, on the other hand, Dips® (double indexing path selector) architecture that we newly propose is composed of four inner path selectors and an outer path selector. The inner path selectors are allocated evenly in a circular manner on the rotatable table of outer path selector which can be rotated 0 to 270 degrees at 90 degrees intervals. The upper path selectors in the conventional path selector architecture are eliminated by introducing the outer path selector. Since the Dips® has single layered architecture, the curvature of the detector guide tubing becomes larger, and the total length of the tubing becomes shorter than those of the conventional double layered architecture. So, the friction inflicted on the detector cable in the guide tubing does not cause any problems. Another advantage is with the small number of components the Dips® system has. Basically, it has five eighths of

The motivation of developing a new FMS in Korea Electric Power Research Institute (KEPRI) was to retrofit the old system at Kori #1 unit. The old FMS at Kori #1 unit had been deteriorated because of long-term operation longer than 25 years while the spare parts were obsolete. The major difficulty for maintaining the system was the radiation exposure to the maintenance personnel who was frequently dispatched to the detector drive system located at high radiation area. In addition, the frequent failure of expensive detector cables due to poor functionality of the system was another burden. In order to solve these problems, KEPRI has developed an innovative FMS including a detector drive system with a digital control system.

components in number compared with conventional one. For this reason, the Dips® becomes more reliable and easy enough to maintain. Due to the lower friction inflicted to the detector cable and the higher efficiency of the detector drive, the detector drive of Dips® FMS, compared with conventional ones, normally exerts two thirds of force to make the detector reach the top of fuel position. Moreover, the speed fluctuation of the detector during the flux mapping data gathering process is found to be as low as a standard deviation of only 0.1mm/second.

The conventional double layered path selector cannot satisfy functional requirements if one or more path selectors at lower layer do not work. This is because the transfer paths of the lower path selector are routed directly to their dedicated thimbles, and the failure of any one of lower path selectors results in dissatisfaction of accessing three quadrants of thimbles which is regulation requirement. However, the Dips® is free from these problems because any inner path selector can be rotated to substitute for the other bad thimble groups. Owing to such benefits of Dips® mechanism, the reliability of the detector drive system could improve five times higher than that of conventional systems in case the unit path selector experiences a trouble every three years as shown in Figure 2.

The programmable logic controller (PLC) based digital controller with Windows® based operator's console provides fully automated and user friendly operation and maintenance support means. The operator console is equipped with various kinds of utility functions which provide detailed information about system operating status.

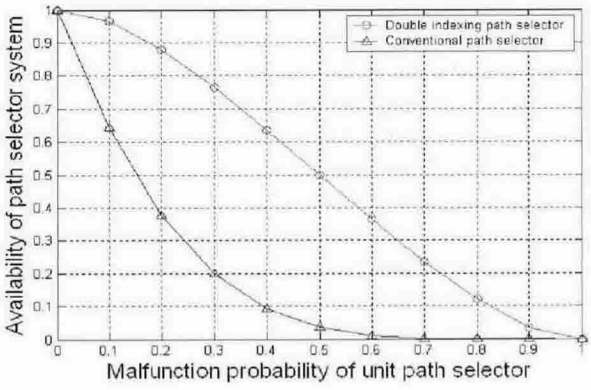

Fig. 2. Availability of path selector system with respect to probability of unit path selector failure

3. Retrofit of FMS in Kori #1 Unit

The developed FMS was installed in February 2003 at Kori #1 unit in Korea and served for one year successfully. The old FMS was replaced by the new system during the plant refueling outage period. All of the old system was removed except reactor containment vessel penetrating electric wire and cable which were reused. The replacement schedule was planed tightly not to extend the normal refueling outage period. The removal and installation processes took two and three days, respectively. After the replacement process was finished, a series of functional tests was performed for the driver and control systems, and the top and bottom limits of the each thimble were set for real operation. Figure 3 shows the distribution of neutron flux at 100% reactor power measured from four thimbles simultaneously by the Dips® FMS. It is formally reported from Kori unit 1 that 2,260 mRem of radiation exposure has been reduced in one year after the FMS was retrofitted.

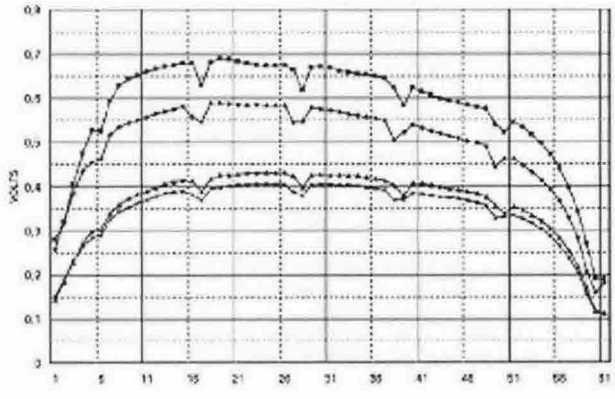

Fig. 3. Distribution of neutron flux at 100% reactor power