Uncertainty Analysis of MAPSSEL Vanadium Detector

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1. Introduction

A fixed in-core detector assembly design was developed as part of a joint program between the Korea Electric Power Research Institute (KEPRI) and Westinghouse Electric Company (W). The goal of the program was the development of an in-core detector assembly design capable of a longer useable lifetime than the standard Rh detectors used in existing systems, which can also provide power distribution measurement information input to the reactor protection system. The resulting in-core detector assembly is named MAPSSEL (**M**onitoring **A**nd **P**rotection **S**ignal **S**eparation **E**xtended **L**ife) to reflect its dual purpose[1]. The axial profile of the conventional Rh and the MAPSSEL detector element configuration is shown in Figure 1.

The key functional requirements of the MAPSSEL detector assembly are:

a. The detector should provide power peaking factor measurement uncertainties equivalent to the measurement uncertainties of the conventional Rh fixed in-core detector systems currently used in operating PWR plants.[2]

b. The detector is essentially non-depleting and can be used over many reload cycles.

c. The detector should respond promptly to changes in the fission power so it can be used to provide input to the reactor protection system.[3]

The detector element configuration of the MAPSSEL assembly design consists of six overlapping and sequentially increasing length V elements and three overlapping and sequentially increasing length Pt elements. The use of the overlapping and sequentially increasing length configuration eliminates any non-sensing detector emitter material in the core, so no background correction is needed. The V elements are used for 3D reactor power distribution measurements. The Pt elements provide the reactor power distribution information used by the reactor protection systems. In order for the MAPSSEL detector assembly design to replace the existing Rh detector design, the power distribution measurement uncertainty derived from the use of the V elements must be comparable to the Rh detector power distribution measurement uncertainty. The power distribution measurement uncertainty component corresponding to the use of the MAPSSEL V elements can be estimated prior to installation of MAPSSEL in-core detector assemblies in a power plant using the performance simulation methodology described below.

2. Simulation Methodology

The power distribution measurement uncertainty component associated with the use of the MAPSSEL V element configuration is evaluated using a simulation methodology, where pairs of ‘True’ and ‘Measured’ power distributions are analytically generated using a nuclear design methodology. A simulated 'measured detector current is obtained analytically from the ‘True’ power distribution. The ‘Measured’ power distribution is then calculated using the BEACON methodology from the simulated detector currents applied to a ‘Predicted’ core power distribution[4]. The ‘Predicted’ core power distribution is intentionally made to be different from the ‘True’ power distribution. The following conditions are used in generating ‘True’ and ‘Predicted’ power distribution pairs:

a. Burnup differences.
b. Control rod element assembly (CEA) position differences..
c. Reactor power level differences.
d. Xenon oscillations induced from asymmetric CEA insertion or core inlet temperature disturbances.

Each of the above conditions are evaluated at Beginning of Life (BOL), Middle of Life (MOL), and End of Life (EOL) core depletion conditions. The corrections to the ‘Predicted’ power distributions are performed at different levels of operable detectors and different detector element variability values.

The measurement uncertainty is defined by 95/95 upper tolerance limit from the percent deviations of detector-signal adjusted peaking factors from the ‘True’ peaking factors over high power density locations.

3. Conclusion

Comparison of the power peaking factor measurement uncertainty for the conventional Rh detector assembly and the MAPSSEL detector assembly is shown in Figure 2. It is seen that the MAPSSEL design provides accuracy at least as good as the typical Rh detector over the expected range of MAPSSEL detector sensitivity and operability variation. This demonstrates that the MAPSSEL Vanadium (V) detector design can safely replace the existing Rh detector design.

REFERENCES

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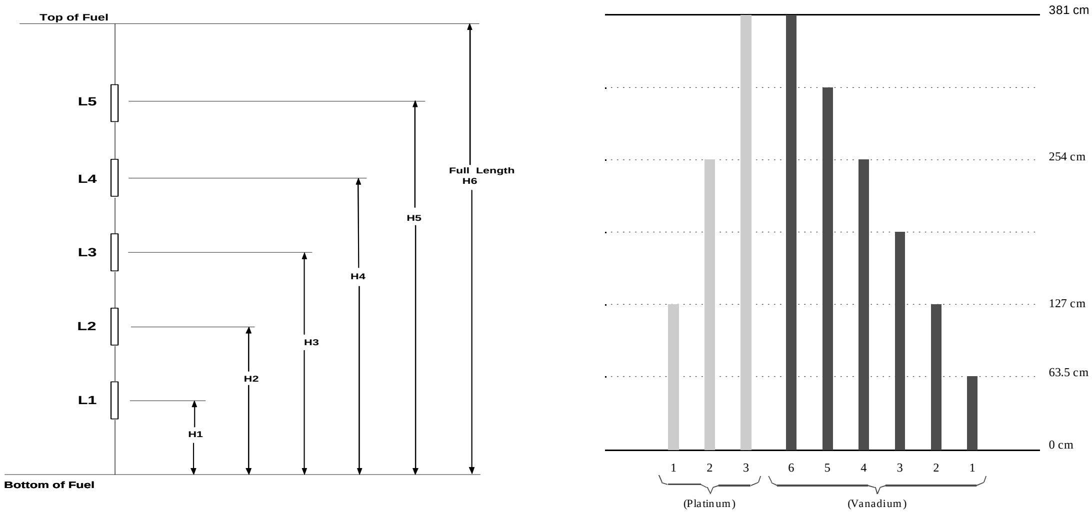

Figure 1 Typical Rhodium Detector Assembly and MAPSSEL Detector Assembly Detector Element Configuration

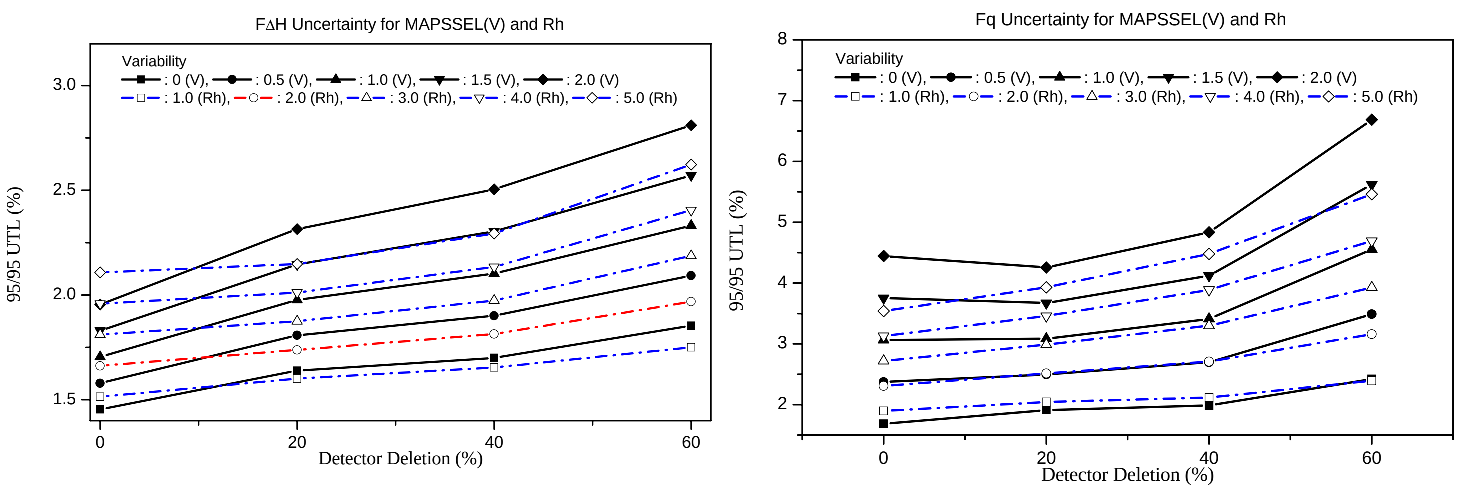

Figure 2. Total Peaking Factor Uncertainty versus Fraction of Inoperable Detectors for five-Element Rhodium and MAPSSEL Vanadium Detector Assemblies