Power feedback effects in the LEM code

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ABSTRACT – The nodal diffusion code LEM has been extended with the power feedback option. Thermohydraulic and neutronic coupling is covered with the Reactivity Coefficient Method. Presented are results of the code testing. Verification is done on the typical non-uprated and uprated NPP Krško reload cycles. Results show that the code fulfill objectives arising in the process of reactor core analysis.

1. Introduction

LEM (Laplace Eigenfunction nodal Method) [1,2,3] has been found to be very accurate and efficient method for the solution of the 2 and 3-dimensional multigroup neutron diffusion problems in rectangular geometry. It has been used for static design calculation of the PWR cores, performed with the CORD-2 package [4] as an alternative tool to the GNOMER [5] diffusion code. To assure verification capability of the LEM code in all design calculations, it has been recently extended with the possibility to cover power feedback effects.

Thermohydraulic and neutronic coupling is covered with the Reactivity Coefficient Method [6,7] which proved to be sufficiently accurate. Macroscopic neutron cross sections are modified on a nodal basis to take into account reactivity changes due to the following effects:

- Moderator temperature,
- Fuel temperature,
- Boron concentration,
- Xenon.

Apart from a correction to the neutron cross section affecting the reactivity, the effect of the different infinite medium neutron spectrum and leakage are taken into account as well.
2. Verification of the power feedback model

Accuracy and reliability of the LEM code in dynamic calculations is tested with the simulation of power operations. Starting with a Hot Zero Power (HZP) no Xe cross sections, Hot Full Power (HFP) core conditions are simulated. A typical non-uprated and uprated reload cycles of the NPP Krško were selected. Results of calculations (marked as LEM) are compared with results based on the standard sequence of calculation with the CORD-2 package (marked as CORD-2).

Comparison of the critical boron concentrations for the Beginning, Middle and End Of Cycle (BOC, MOC, EOC) conditions is shown in Table 1. Maximal difference is 15 ppm and lie well within standard 50 ppm review criteria.

Maximum and average difference in assembly power for the BOC, MOC and EOC can be found in Table 2. Maximum errors are less than 1.5% and average difference is less than 0.8%. Assemblywise HFP power and error distributions are presented in Figures 1 (non-uprated cycle) and 2 (uprated cycle).

Table 1: Comparison of the HFP critical boron concentrations at the BOC, MOC and EOC for the non-uprated and uprated cycle.

<table>
<thead>
<tr>
<th></th>
<th>Non-uprated</th>
<th></th>
<th>Uprated</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>BOC</td>
<td>1339</td>
<td>1337</td>
<td>-2</td>
<td>1358</td>
</tr>
<tr>
<td>MOC</td>
<td>653</td>
<td>657</td>
<td>+4</td>
<td>848</td>
</tr>
<tr>
<td>EOC</td>
<td>49</td>
<td>55</td>
<td>+6</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 2: Maximal and average difference in assembly power for the BOC, MOC and EOC (non-uprated, uprated cycle).

<table>
<thead>
<tr>
<th></th>
<th>Non-uprated</th>
<th></th>
<th>Uprated</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$\varepsilon_{P_{MAX}}$ [%]</td>
<td>$\varepsilon_{P_{AVE}}$ [%]</td>
<td>$\varepsilon_{P_{MAX}}$ [%]</td>
<td>$\varepsilon_{P_{AVE}}$ [%]</td>
</tr>
<tr>
<td>BOC</td>
<td>0.47</td>
<td>0.27</td>
<td>1.26</td>
<td>0.62</td>
</tr>
<tr>
<td>MOC</td>
<td>0.68</td>
<td>0.36</td>
<td>1.30</td>
<td>0.68</td>
</tr>
<tr>
<td>EOC</td>
<td>0.96</td>
<td>0.50</td>
<td>1.48</td>
<td>0.78</td>
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</table>
Figure 1: Comparison of the assemblywise power at the BOC, non-uprated cycle.
Figure 2: Comparison of the assemblywise power at the BOC, uprated cycle.
3. Conclusion

Power feedback modeling in the LEM code was found to be sufficiently accurate for the design calculations. Results of the IZP - HFP simulation on the NPP Krško non-uprated and uprated cycles show that the maximal assembly power errors are less than 1.5 %. Error in critical Boron concentration is less than 15 ppm. It is estimated that the accuracy of the code is 2 % in power distributions and 20 ppm in critical Boron concentrations.

References


