FURTHER DEVELOPMENT OF THE DYNAMIC CONTROL ASSEMBLIES WORTH MEASUREMENT METHOD FOR ADVANCED REACTIVITY COMPUTERS

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Abstract

The dynamic control assembly's worth measurement (DCAWM) technique is a quick method for validation of predicted control assembly's worth. The DCAWM utilize space-time corrections for the measured out of core ionization chamber readings calculated by DYN 3D computer code. The space-time correction arising from the prompt neutron density redistribution in the measured ionization chamber reading can be directly applied in the advanced reactivity computer. The second correction concerning the difference of spatial distribution of delayed neutrons can be calculated by simulation the measurement procedure by dynamic version of the DYN 3D code. In the paper some results of DCAWM applied for NPP Mochovce are presented.

1. Introduction

Usually boron dilution method is applied for control assembly (CA) reactivity worth measurement in VVER-440 reactors. The boron dilution method is time-consuming method due to small step control assembly position changes and slow boron acid concentration rate changes in the reactor coolant.

There was in [1], [2] published a dynamic method for control rod worth measurement in PWR reactors, which is much faster compared to boron dilution method. In this method the control rod position is continually changed and corrections are applied to measured detector signal due to 3D effects.

Similar method for CA´s reactivity worth measurement was published for VVER-440 reactors in [3]. The difference between the methods published in [2] and [3] is in applied corrections. In the method published in [3] only one correction is applied on reactivity computer results why in [2] two corrections are used. The first for redistribution of prompt neutrons due to 3D effects, this correction is applied to measured ionization chamber reading and the second is similar like in [3].

The method published in [3] was further developed like in [2]. The spatial correction for 3D effect suppression can be calculated by 3D static computer code and directly applied in advanced reactivity computer.

The paper contains results of DCAWM assessment applied for NPP Mochovce.

2. Theoretical background

A reactivity computer, that performs an inverse kinetic calculation from the time history of the detector signal, does reactivity measurement. The point reactor core model is used for the reactivity calculation. During the control group assemblies or single control assembly insertion to the reactor core, there are created strong 3D effect, where results lead to deviations from the point kinetic reactor model. Not accounting, these effect can lead to large errors in measured reactivity. The procedures described in [1], [2], [3] were proposed for evaluation this effect. As is the static spatial effect is caused by core environment change due to control assembly insertion, which leads to redistribution of the prompt neutrons. The second, the delayed neutron spatial distribution trailing behind the prompt neutrons causes the dynamic spatial effect. As is shown in analysis [2] the first effect is dominated.

The correction for the static spatial effect can be calculated by static 3D core simulator and detector response function as

$$SKOR_i(t) = \frac{DS_i(h)}{DS_i(h_o)} \qquad (1)$$

Where

$SKOR_i(h)$ - Static correction for CA position “h”

$DS_i(h), DS_i(h_o)$ - Simulated detector response in position “i” for CA insertion to position “h_o” and “h”

h_o - initial position of CA-s

The deviation of $SKOR_i(h)$ from one is a measure of spatial effect in detector position “i” for insertion of “CA-s” to “h”. The $SKOR_i$ is directly applied to measured ex-core detector signal by dividing the signal by $SKOR_i$.

The dynamic spatial correction due to dynamic spatial effect can be calculated by 3D-simulation of the detector signal as it measured in experiment (experiment simulation) and static reactivity calculation.

The dynamic spatial correction for CA´s position “h” and detector position “i”

$$DKOR_i(h) = \frac{\rho^{stat}(h)}{(reactor\ computer\ output\ using\ simulated\ detector\ signal\ corrected\ by\ SKOR_i(h)\ for\ CA's\ position\ "h")} \quad (2)$$

$$\rho(h) = DKOR_i(h)\ x\ (reactivity\ computer\ calculation\ otuput\ using\ measured\ signal\ of\ detector\ "i"\ corrected\ by\ SKOR_i(h)\ for\ CA's\ position\ "h") \quad (3)$$

Where

$\rho^{stat}(h)$ - Calculated static CA´s worth inserted to position "h" by 3D static code.

For static reactivity calculation, insertion process simulation and $SKOR_i$, $DKOR_i$ calculation the dynamic and static version of the DYN3D code was used.

The correction for static effect ca be calculated by 3D static core simulator and implemented in an advanced reactivity computer.

The correction for dynamic effect can be done posteriori after the experiment, by simulation the CA´s insertion process by dynamic version of DYN3D code.

3. Some results of DCAWM measurement simulation

For simulation of DCAWM measurement the 1-st core of 2-nd unit of Mochovce NPP was selected.

The simulation of core behavior in the course of 6-th CA´s group insertion the dynamic version of DYN3D code was used.

The fast neutron density needed for detector signal correction was calculated by static version DYN3D code. The detector signal was established by using the fast neutron density calculated by dynamic and static version of DYN3D code and detector response functions as it is mentioned in [2] and [3].

The initial position of 6-th group of CA´s was 225 cm from the core bottom (critical state, zero power). From this position the CA´s were inserted to 50 cm a then withdrawn to the initial position as is in Fig. 3.1 The insertion rate is 2 cm/s.

The detector signals were calculated for detector positions 1, 2, 3 round the core Fig. 3.2 (the detector centre is in mid plane of the core) doe to detector and core symmetry.

The dependence of $SKOR_i$ on CA´s insertion is in Fig 3.3 and time dependent version for the given rod insertion process (Fig. 1) on Fig. 3.4.

The reactivity computer output for detector position 1, 2 and 3 from not-corrected and corrected detector signal $SKOR_i$ together with static reactivity is on Fig. 3.5.

From Fig. 3.5 it can be seen that after applying the static correction on simulated detector signal the reactivity computer output results scatter is acceptable and the dynamic correction is close to one, and practically no dynamic correction may be applied, when the CA´s are in final position.

For illustration of the viability of DCAWM the first phase of rod ejection experiment on 2-nd unit of Mochovce NPP performed during the reactor start-up was reevaluated. The starting position of 6-th CA´s group was 196 cm and the final position after inspection 50 cm. The detector signal for evaluation was used from position 8 (which is equivalent wit position 2).

The measured CA´s worth between the position 196 → 75 is as follows

Method of evaluation	$\Delta\rho[\%]$
DCAWM from row detector signal position 2	-1.07
DCAWM	-1.11
Boron dilution experiment	-1.04

The results presented in [3] and in this paper confirm the possibility of utilization DCAWM on VVER type reactors. Also the calculated $SKOR_i$ can be implemented in advanced reactivity computer, so that approximately the some results can be achieved as from boron dilution experiment even by neglecting the dynamic correction.

Conclusions

The DCAWM method was successfully tested on VVER-440 reactors. The advanced reactivity computers allows applying directly the recalculated $SKOR_i$ and results are comparable with boron dilution measurements and methodology as it was presented also in [3].

References

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[2] Y.A. Chao, D.M. Campman, D.J. Hill, L.R. Grofmyer: Dynamic Rod Worth Measurement, Nuclear Technology, Vol. 132, December 2000, p. 403-412

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Fig. 3.1 Time dependence of 6-th group position

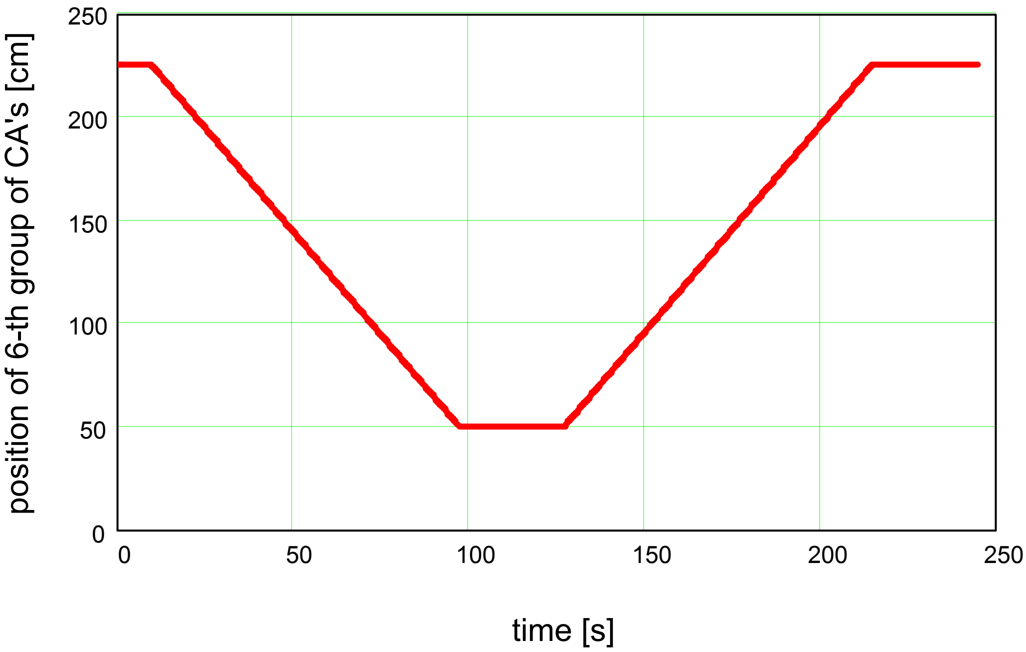

Fig. 3.2 Neutron detector position round the core

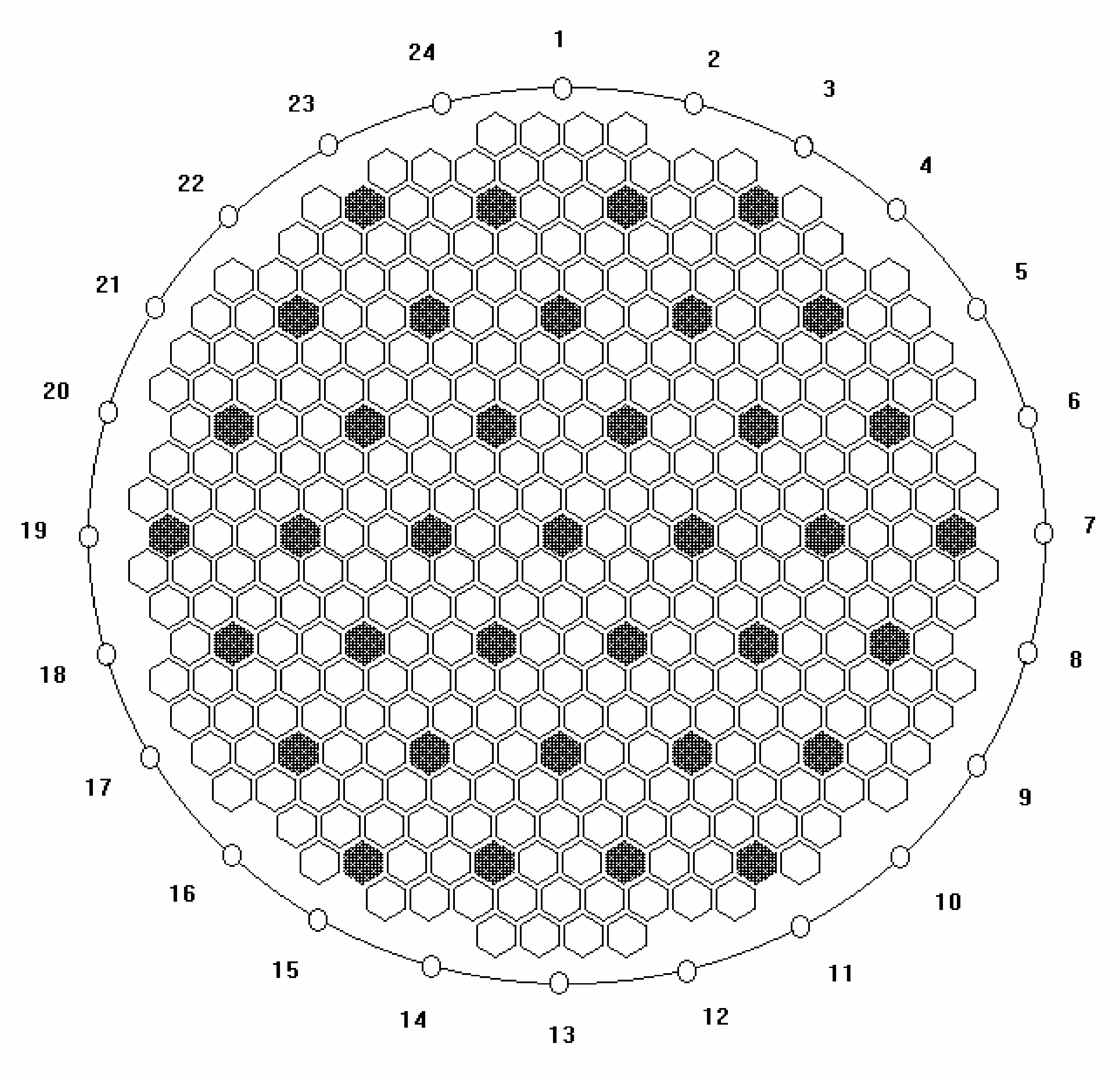

Fig. 3.3 $SKOR_i(h)$ dependence on 6-th group of CA's insertion

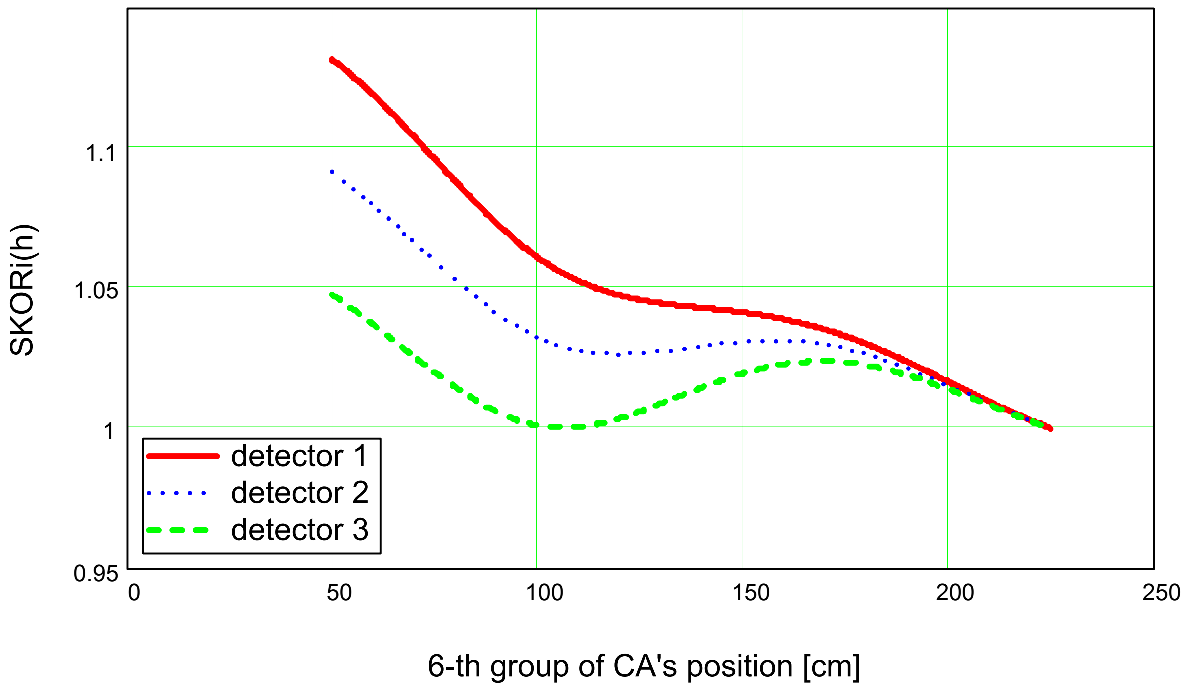

Fig. 3.4 Time dependence of $SKOR_i(t)$

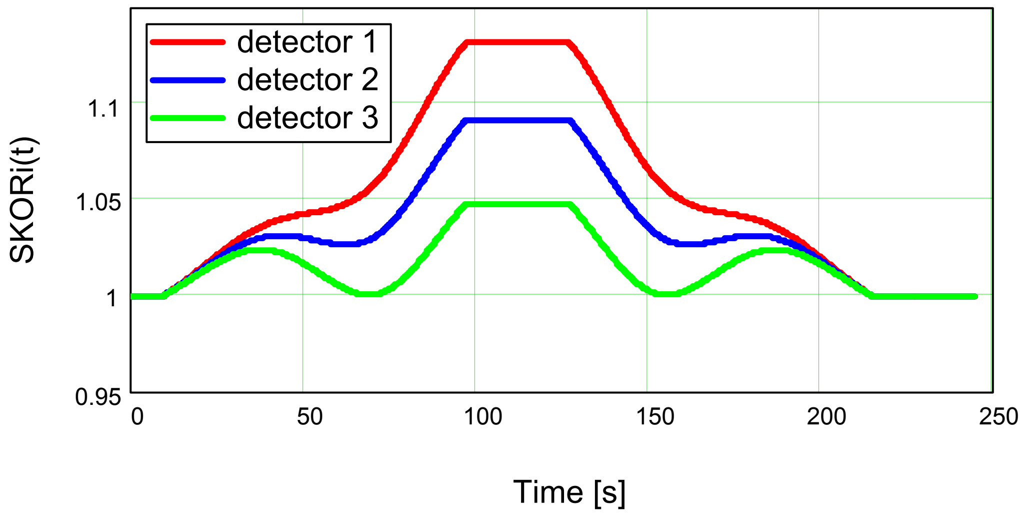

Fig. 3.5 Time dependence of reactivity computer output in the course of CA's movement