Neutron Lifetimes behavior analysis considering the Two-Region Kinetic Model in the IPEN/MB-01 Reactor

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Abstract. This is a complementary work about the behavior analysis of the neutron lifetimes that was developed in the IPEN/MB-01 nuclear reactor facility. The macroscopic neutron noise technique was experimentally employed using pulse mode detectors for two stages of control rods insertion, where a total of twenty levels of subcriticality have been carried out. It was also considered that the neutron reflector density was treated as an additional group of delayed neutrons, being a sophisticated approach in the two-region kinetic theoretical model.

Keywords: Reflected Reactors; Reactor Noise; Spectral Densities; Neutron Lifetimes.
PACS: 28.50.Dr

INTRODUCTION

Recently some experiments were performed in the IPEN/MB-01 nuclear reactor with the intention to determine experimentally the coupling kinetic parameters and the neutron lifetimes. The preliminary results [1] showed that more subcritical levels were needed to describe the behavior profile of the neutron lifetimes. Furthermore, the theoretical Auto Power Spectral Densities (APSD) derived by point kinetic equations [2], that take the reflector effect into account [3,4], presented some inconsistent results. This is due to a high correlation among the parameters derived from the non-linear curve fit of the experimental data, characterizing it as an over parameterized function.

Therefore, the purpose of this work is to complement the studies already performed by the IPEN/MB-01 nuclear reactor researchers, applying a new simplified theoretical two region model developed by Hugo van Dam [5] to improve the understanding of the nuclear reflected reactor. The basis of this model consists in utilize the reactivity of the system in the two-region kinetic equations instead of the multiplication factor, which distinguishes itself of the previous kinetic model used in other works [1,6] by its simplicity and low correlation among the parameters.

XXXVI Brazilian Workshop on Nuclear Physics
AIP Conf. Proc. 1625, 93-96 (2014); doi: 10.1063/1.4901770

The experimental data were obtained through neutron noise analysis in the frequency domain (spectral densities) and the neutron lifetimes were obtained as a result of the experimental data fitting through the application of the least squares method.

EXPERIMENTAL PROCEDURE

Twenty subcriticality levels were considered in this work and divided in two stages. The first stage consists of simultaneous movement of the control banks BC1 and BC2 in steps of 2.5% of insertion. Both control banks initiated in the position of 93% withdrawn and finished in the 45.5% withdrawn. For this case, the reactivity ranged from about 0 up to -3500 pcm.

For the second stage of the experiment, only the control rod BC1 was inserted to obtain the subcritical states. Considering the control rod BC2 fixed in the position of 88.56% withdrawn, it was possible to insert BC1 from the initial position of 100% up to the last position of 5% withdrawn. This procedure could allow the changing on the reactivity worth from 0 up to -3000pcm.

For the whole set of experiments the core configuration was 26x24 fuel rods instead the standard configuration of 28x26 fuel rods. This new configuration provides practically zero excess of reactivity, and thus the criticality can be reached with all the control rods withdrawn. In this way it is possible to achieve a large range of subcriticality levels. In order to improve the counting statistics in deeply subcritical states and to ensure a reasonable neutron flux in subcritical states, an additional neutron source of 100 mCi was placed on the east face of the core in the middle of the active region, 4.30 cm to the first line of fuel rods. The neutron detector was placed on the west face in the reflector region.

The neutron signals are acquired using two gas detectors, which present different sensitivities for neutron counting. The detectors were employed depending on the subcritical level of the system. A BF_3 detector (Low sensibility) for low and moderate levels of subcriticality, and a ^3He (High sensitivity) detector for high levels of subcriticality.

In the first stage, for the reactivity range between 0 up to -1568 pcm was used the BF_3 detector, while the ^3He detector was employed in the reactivity range between -2076 pcm up to -3770 pcm. In the second stage, the BF_3 was employed in the range of 0 up to -883 pcm and for the reactivity range of -1278 up to -2855 pcm was used the the ^3He detector.

Through the acquired neutron signals the Auto Power Spectral Density (APSD) was obtained using a Multichannel Scaler (MCS-PCI) attached in a desktop computer by a PCI Local Bus standard. The MSC records the counting rate of events in a given time (dwell time), and the APSD is obtained by a FFT algorithm using the LabView software.

The parameters studied in this work, the neutron generation time and the decay constant of the reflector, Λ and λ_7 respectively, were derived by a least squares fitting of the experimental APSD's through the theoretical model of the Hugo van Dam. More details about the spectral densities can be found in Ref. 7.

RESULTS

Table 1 shows the results for the twenty subcritical configurations. The decay constant of the reflector uncertainty is due only to the fitting procedure and the neutron generation time uncertainty is derived trough the general error propagation formula [8].

TABLE 1. Neutron Generation Time (Λ) and Decay Constant of the Reflector (λ_7) obtained through the Hugo van Dam model

Stage 1			**Stage 2**		
Bank Position (% withdrawn)	**Λ (10^{-6}s)**	**λ_7 (s^{-1})**	**Bank Position (% withdrawn)**	**Λ (10^{-6}s)**	**λ_7 (s^{-1})**
93	30.63 ± 2.56	3000 ± 23	100	30.58 ± 1.47	2997 ± 12
90.5	30.71 ± 2.30	3000 ± 22	95	30.57 ± 1.99	3011 ± 17
88	30.52 ± 2.34	3000 ± 23	90	30.51 ± 1.85	3012 ± 19
85.5	30.47 ± 2.12	3000 ± 22	85	30.35 ± 1.75	3012 ± 19
83	29.87 ± 2.24	3000 ± 24	80	29.94 ± 1.41	3012 ± 18
80.5	29.58 ± 2.23	3000 ± 25	75	30.07 ± 0.75	3011 ± 9
78	28.57 ± 2.27	2999 ± 27	70	29.69 ± 0.82	3011 ± 12
75.5	29.41 ± 1.95	3000 ± 29	65	29.44 ± 0.80	3011 ± 13
73	28.70 ± 1.03	3000 ± 18	60	28.86 ± 0.94	3015 ± 15
70.5	28.33 ± 1.13	3000 ± 19	55	27.78 ± 0.73	3011 ± 23
68	30.19 ± 1.14	2999 ± 23	50	26.17 ± 0.62	3011 ± 23
65.5	27.42 ± 1.09	2999 ± 23	45	25.09 ± 0.55	3011 ± 24
63	26.99 ± 0.99	2999 ± 24	40	26.78 ± 0.36	3011 ± 10
60.5	26.73 ± 1.15	2999 ± 26	35	26.23 ± 0.36	3011 ± 10
58	26.19 ± 1.09	2999 ± 29	30	25.93 ± 0.43	3011 ± 13
55.5	25.86 ± 1.17	2999 ± 25	25	25.37 ± 0.40	3011 ± 12
53	25.04 ± 0.50	2999 ± 20	20	25.26 ± 0.41	3011 ± 13
50.5	24.36 ± 0.44	2999 ± 19	15	25.13 ± 0.42	3011 ± 14
48	23.69 ± 0.44	3000 ± 21	10	24.67 ± 0.46	3011 ± 16
45.5	23.13 ± 0.52	3000 ± 27	5	24.57 ± 0.45	3011 ± 16

As can be seen, the studied parameters presented the same behavior for both stages, in the sense that the neutron generation time decreases with the increase of the subcriticality, while the decay constant of the reflector remains basically unchanged. Moreover, the results for the neutron generation time behavior obtained for the IPEN/MB-01 reactor is in agreement with the work of Hanson and Diamond [9].

CONCLUSIONS

The experiment for the determination of the reflector kinetic parameters and the neutron lifetimes of the IPEN/MB-01 reactor was successfully performed. The uncertainties of the kinetic parameters are consistent, indicating the quality of the measurements.

This work was very important to show that through the Two-Region kinetic model developed by Hugo van Dam is possible to determine the behavior of the kinetic parameters for subcritical systems. Besides, this work gives additional information concerning a previous work, where only a few subcritical levels were employed in the analysis.

The results of this work will also help to understand the impact of the neutron lifetimes and the reflector kinetic parameters on the reactivity system calculation.

ACKNOWLEDGMENTS

The authors are grateful to Seung Min Lee at IPEN for lending some experimental data and for the financial support given by CAPES, which made this research possible.

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