Improving the Performance of the Power Monitoring Channel in Tehran Research Reactor (TRR)

Mohsen Ahmadnia
Department of Electrical Engineering, Hakim Sabzevari University
Sabzevar, Iran
m.ahmadnia@hsu.ac.ir

ABSTARCT: *In this work, the fission chamber detector with 5 MW of power was tested in different locations of Tehran Research Reactor pool. If the detector was located at the distance of 1 meter from the eastern edge of the reactor and at the height of about 1.4 meters from the floor, it was the best location for detector counting but due to the different placements and displacements in western part of the reactor, it was not possible unfortunately. The dead time for 3 MW of power had been 1.67% which was the best result in comparison with Monte Carlo Code.*

Keywords: Linear Behavior, Dead Time, Multichannel Analyzer (MCA), Feed Preamplifier

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1. Introduction

Two important criteria for power measurement in nuclear reactors are redundancy and diversity. This holds true both in power and research reactors. Other criteria such as accuracy, reliability and speed in response are also of major concern. Tehran Research Reactor (TRR) is originally has been equipped with four channels, namely, a fission chamber (FC), a compensated ionization chamber (CIC), and two uncompensated ionization chambers (UIC). In order to improve the power measuring system, two more channels have also been considered for implementation in recent years. One of these channels is based on O16 (n, p) N16 reaction which is considerably important due to the short half-life of N16 (about 7 s). In 1976, J. Laving, presented a method for monitoring power distribution in a nuclear reactor by a motion detector inside the core of it. The other channel, suitable Fission chamber used in the reactor is the core of each work area. Chamber walls are covered with enriched Uranium for more ionization process. These small fission chamber walls and electrodes are made of aluminum and its working voltage is between 200 to 800 volts. Argon gas is usually selected as the internal gas of fission chamber and is forced under the pressure of several atmospheres.

2. Basic theory of fission chamber (FC)

Fission chamber is suitable to be used in core of each work area in reactor. Chamber walls are covered with enriched Uranium to expand the ionization process. This small kind of fission chamber's walls and electrodes are made of aluminum and its working voltage is between 200 to 800 volts. Argon gas is usually selected as the internal gas of fission chamber and is forced under the pressure of several atmospheres. High pressure prevents the fission products to exceed over the thickness of the light detector. Progressive destruction of the materials sensitive to neutrons is a radical problem in long term use of inside core neutron detectors. For example a fission chamber which uses U -235, loses its sensitivity to 50% after receiving the cumulative neutron flux equivalent to $n/cm^2.s\ 10^{21} \times 7/1$. One way of reducing the harmful effects of neutron in below detectors, is using fertile and fissionable materials for synthetic coatings in sensitive to neutron places of the chamber. Using this new generation of chambers will lead the fertile isotopes to change into fissionable nuclei in order to prevent the damage of the fissionable materials in main cover of the chamber. Taking advantage of this method, the long-term response of fission chambers will develop to a great extent. For example the sensitivity of fission chamber, based U -238 and Pu -239 will change to only 5 ± % after receiving the cumulative neutron flux equivalent to $n/cm^2.s10^{21}\times 8/4$. Similar results have been obtained for fission chamber based Uranium 234 and 235(Knoll, 2000).

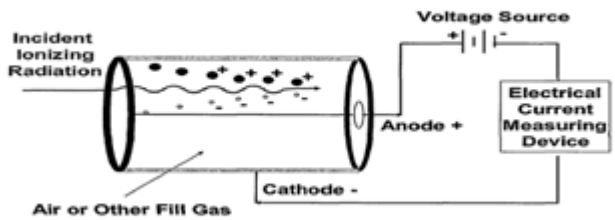

Figure 1. An example of a gas detector

3. Experimental setup

Fission chambers are used for counting the number of thermal neutrons. There is a direct relation between the thermal neutrons and the total number of neutrons and it is directly related to the power of reactors. In this work, the number of thermal neutrons at different levels of reactor power will be recorded by fission chamber detector. For this purpose, at different times of turning on and off the reactor that the power is changed at different levels, we could measure the number of thermal neutrons and the purpose of this action is to find the suitable calibration coefficient and this coefficient is found by conforming the amount of counting to the related power. We are about to find the probable changes of counting in a fixed power during operating time of reactor in a week (the power with a constant value) by recording the counting and also we determine to find the reasons of

Figure 2. Devices NT-124 (MCA)

occurring such changes (because in case of occurring such changes, we may witness some errors in measuring the power by this method), we should find the reason of occurring such probable changes and try to correct them. At the end of the process, we should design a suitable electronic system to be able to monitor the power of reactor in kilowatt, according to the counted neutrons.

We used a detector FC with lining U -235, a set NT -124, containing (a multichannel analyzer with resolution capability of 1000 channel, amplifier and a power supply with high voltage) for counting the neutrons and collecting the spectrum of a detector.

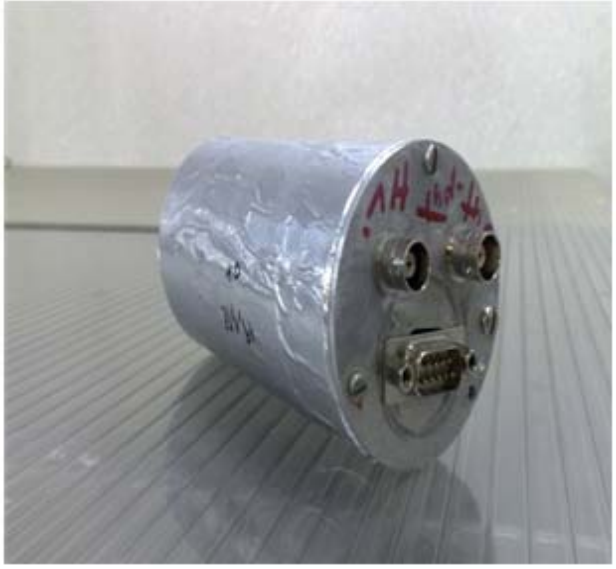

Figure 3. Preamplifier

In this work, MCA is directly connected to the computer with a signal cable RG 58, and samplings are recorded by the aid of MCA-NT software. The spectra of samples including spectra of gamma and neutron are saved in computer. Then the APTEC software, enabled us to measure the area of under spectra of gamma and neutron and this indicates the number of gammas and neutrons.

Figure 4. An example of spectroscopy in laboratory environment

Then, we placed the fission chamber within an aluminum enclosure (Figure 5) downward vertically in the water pool. After that, we measured the spectra of gamma and neutron.

Figure 5. Aluminum housing and wrapping it around the reactor

We placed the detector in a cylindrical aluminum enclosure with 80 cm length, that the lower part is about 50 cm long, with inner diameter of 4 cm, and outer diameter of 5 cm that has occupied 27. 94 cm of this enclosure and the outer diameter of FC is 25.4 mm, and approximately 20 cm connecting cable is made of RG58 which connects the detector to the preamplifier. The amplifier with the length of 15 cm and outer diameter of 6 cm is located at the primary part of the chamber. The primary part of the enclosure is 30 cm long, with inner diameter of 3 cm and outer diameter of 8 cm. The two cable amplifier RG 58 and a preamplifier power cable are plugged to multichannel analyzer system. A USB cable is plugged to the portable computer from the multichannel analyzer system that sends the information to the computer after analyzing at the multichannel system. The length of each cable is 20 cm. After the placement within the enclosure, the cables were passed from the steel tube of length 6.6 meters; the detector and preamplifier were connected to multichannel analyzer system.

4. Results and discussion

Power (MW)	Gross	Live Time (sec)	CPS
1	6467	60	107.7833
2	12252	56	207.661
3	17765	59	301.1017
4	22807	59	386.5593
5	27115	59	459.5763

Table 1. Experimental data obtained at a distance of 1.2 meters from the reactor core east

Detector (FC) is kept at a distance of 1.2 meters from the eastern edge of the pool and at least 1 meter above the bottom raised with the pool by the crane. As it shown in the table (1) by increasing of reactor power up to 5 MW, the counting of Gross is raised whit the specific coefficient a factor which determined the certitude of neutron detector (FC), since the experimental data obtained by log count the Gross column, only neutrons counted from channel 90 to 1,000 in software. APTEC is considered as shown in Figure (6), the reactor power of 3 MW is (Live time oval number (1)) 59 seconds shows and (Gross oval number (3)) is the number 17765. If we want to declare the CPS to declare that how much detector had counting during one second, we should obtain the percentage of Gross to live time and the result is shown in the CPS column of the table1. One noteworthy points of

the figure (6) (Dead Oval (2)) which is distinguished by the green color, that it is very lower than 1.67. It means that the signal from the preamplifier with the MCA ample opportunity analysis neutron counting and probability of error is very low and this is a very good achievement.

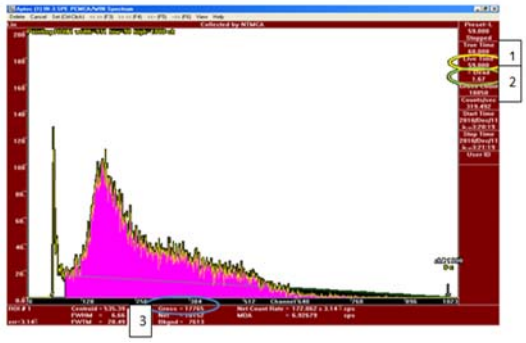

Figure 6. Example of counting neutrons in the reactor core east a distance of 1.2 meters using software APTEC

Figure (6) is good example of the Measuring range at the distance of 1.2 m from east of core of Tehran research reactor. No noise and X-ray was observed and the volume of the Gamma is ray much lower than thermal neutrons.

The Figure (6) is given by using Excel software. The horizontal axis is related to the Power of reactor which is shown from lower exponent to upper. The vertical axis of the slightly CPS is shown for each specified power of (FC).

Row	Per Particle	Source Power	Reactor Power (W)	Result	MCNP (Count)	Exp. (Count)	Error%
1	-12E 1.20	90062259000	+0.4E 1.00	1080.7471	1081	794	36.11425
2	-12E 1.20	90062259000	+0.4E 5.00	5403.7355	5404	7146	24.38097
3	-12E 1.20	90062259000	+0.5E 2.00	21614.9422	21615	28914	25.24403
4	-12E 1.20	90062259000	+0.5E 2.00	54037.3554	54037	49105	10.04451
5	-12E 1.20	90062259000	+0.6E 1.00	108074.7108	108075	142840	24.33862
6	-12E 1.20	90062259000	+0.6E 1.50	162112.0662	162112	209868	22.75522
7	-12E 1.20	90062259000	+0.6E 2.00	216149.4216	216149	271090	20.26655
8	-12E 1.20	90062259000	+0.6E 2.50	270186.7770	270187	330121	18.15523
9	-12E 1.20	90062259000	+0.6E 3.00	324224.1324	324224	396396	18.20701
10	-12E 1.20	90062259000	+0.6E 3.50	378261.4878	378261	442511	14.5193
11	-12E 1.20	90062259000	+0.6E 4.00	432298.8432	432299	498640	13.30442
12	-12E 1.20	90062259000	+0.6E 4.50	486336.1986	486336	540847	10.07878
13	-12E 1.20	90062259000	+0.6E 5	540373.5540	540374	583575	7.402895

Table 2. MCNP calculations have been compared with actual data

Before choosing the location of the detector and according to the certificate of fission chamber (FC) and checking different statues around the core we are reached to the conclusion that the detector at a distance of 1 m east of core and a height of at least one meter from the bottom of the pool is the best place for counting Log count. It is because detector does not have reached the saturation limit and it can still continue for about 6000 counts per second.

Table (2) data obtained in there actor MCNP software data are given with regard to this information, Figure(7) observed the

experimental sample and is shown by the red line and blue line reactor core which is simulated with MCNP software.

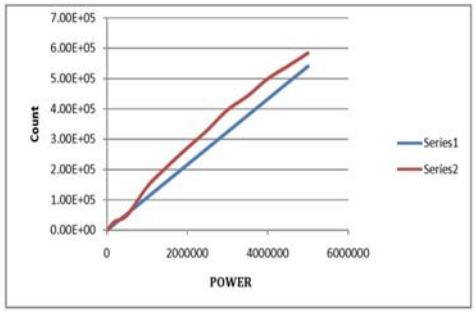

Figure 7. Comparison of experimental samples with MCNP software

5. Conclusion

In increasing and decreasing trends in power the device is loyal, which means the device creates the same response in the term of sweep to the any specific power.

In the term of stability of the device (no changes without any reason) at the time of testing (about several days) we can see that the device has good stability. By simulating system behavior in different situations and comparing the results with experimental data any significant changes did not observed. In all practical simulation of the devices there are too many factors that can led to different results. For example, in the use of Software MCNP if want to have the result with high accuracy and in compliance with experimental data we should not ignore even the smallest errors. However, in some cases, software modeling capability is limited. However, after the final installation of the display in the control room, the instrument displays the Schiff base stability throughout the entire reactor (about a week) which will demonstrate.

If the detector is located at a distance of 1m from the eastern edge of the reactor core at a height of about 1.4 meters from the floor of the pool is considered to be the best place for counting detector.

However, due to lack of permission of the operating group of the reactor for replacement of the device with this analogy that it might create some obstacle for operating group to have access to the area we could not assemble the device in the aforementioned location so we would have the best accuracy result regarding to neutron counting.

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