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INSERTION OF REACTIVITY (RIA) WITHOUT SCRAM IN THE REACTOR CORE IEA-R1 USING CODE PARET

Urias F. Alves[1], Lazara S. Castrillo [2] and Fernando A. Lima[3]

[1] Universidade de Pernambuco-UPE-POLI
Mestrado em Tecnologia da Energia
Rua Benfica, 455
50720-001 Recife,PE, Brazil
uefalves@upe.gov.br

[2] Universidade de Pernambuco-UPE-POLI
Mestrado em Tecnologia da Energia
Rua Benfica, 455
50720-001 Recife,PE, Brazil
lazara.castrillo@upe.br

[3] Centro Regional de Energia Nuclear (CRCN-NE/CNEN –PE)
Av. Professor Luis Freire
05508-000 Recife, PE, Brazil
falima@cnen.gov.br

ABSTRACT

The modeling and analysis thermo hydraulics of a research reactor with MTR type fuel elements - Material Testing Reactor- was performed using the code PARET (Program for the Analysis of Reactor Transients) when in the system some external event is introduced that changed the reactivity in the reactor core. Transients of Reactivity Insertion of 0.5 , 1.5 and 2.0$/ 0.7s in the brazilian reactor IEA-R1 will be presented, and will be shown under what conditions it is possible to ensure the safe operation of its nucleus.

1. INTRODUCTION

In the operation of a nuclear reactor research is necessary to know with precision the burning of nuclear fuel, the spatial and temporal distribution of neutron flux and also determine the factors that affect the profile of the reactivity of the core. This is to do avoid possible design basis accidents (DBA) or those accidents with low probability of occurrence but that could causes serious damage to the core. Particularly, for the study of reactivity initiated accidents is necessary to consider two types of phenomenology: reactivities rapidly inserted, such as those due to temperature variations; and reactivities slowly or continually inserted, due to changes in the isotopic composition of the fuel and / or the presence of poisons. in the other hand, for research reactors there are two categories of accidents occurring for very short times [1]:

1. Reactivity Insertion Accidents (RIAs);
2. Loss of flow accident (LOFA).

Reactivity is a fundamental quantity that expresses the deviation of the reactor criticality, ie expresses the imbalance between the neutrons number that fleeing, the number of neutrons that are absorbed and the number of neutrons that appear due to nuclear fission. To guarantee to safety and the integrity of core in conditions of accidents, the monitoring of the reactivity can be accomplished using computer codes or data coming from the instrumentation and control system.

With it exposed, using the predictive and conservative code for RIAs, PARET -Program for the Analysis of Reactor Transients-, in this work were analyzed responses neutronics and thermo hydraulics when a externally is inserted reactivity in the research reactor IEA-R1, located at IPEN - USP / SP.

2. PARET – VALIDATION

The PARET code is intended for analysis of the reactivity accidents at research reactors with fuel with cylindrical or plate geometry and their respective cooling channel. The mathematical model was written in FORTRAN language for simulate up to four channels and each region can be represented with its own energy production, flow rate of coolant and hydraulic parameters. Each of these regions can be further subdivided into a maximum of 20 axial nodes. For each of those regions, a representative channel consist of a fuel rod surrounded by an equivalent coolant cell.

The PARET code permit to select heat transfer and flow instability modes, and includes a table of decay heat power based on the ANS curve for fission product decay heat. The code also provides a simulation of control rate insertion rod reactivity and delayed time settings. The feedback reactivities are computed together with the thermal-hydraulics calculations. The fuel temperature is calculated from a radial one dimensional heat conduction equation. The inserted reactivity is introduced as a function of time, while the feedback reactivity is calculated from the change of thermal-hydraulics in the reactor by: Doppler effect, void effect, Coolant temperature effect, effect of fuel cladding thermal expansion [2].

Many kinetics experiments were performed in the 50s and 60s to investigate reactivity accidents. The most known experiment are the called Special Power Excursion Test -SPERT [3]. The SPERT and IAEA– Generic reactors are used as international benchmark experiments [4, 5]. The experimental data reported in the open literature for these cores were used to check the operation of inserting reactivity in this work. Experimental data of IAE-R1 core were also used to check and reproduce their physical and geometric data, and soon after were simulated the reactivities inserted with rate of 0.5, 1.5 and 2.0 $ / 0.7 s, without SCRAM action. All numerical simulations were performed only for the hotter channel, divided into 21 nodes and 7 nodes radial axial. This channel has more probability to produce bubble and pressure pulses. The fuel plate (MTR) of the reactors it was divided into two regions: the fuel and metal sheath covering the fuel. Each reactor was modeled with its characteristic peak factor. The peak factor provides the ratio of the local heat flux and heat flux in the core medium.

2.1. Validation of the Reactor IAEA.

The IAEA is a generic reactor of 10 MW of power whose purpose is represents the features of most pool reactors that exist worldwide. This core is cooled and moderated by light water circulating forcibly downward. The main operating conditions thermo hydraulic and neutronic core is shown in [5]. The experimental axial distribution of the peak factor is introduced externally to PARET code with a numerical table. This is showing in the figure 1.

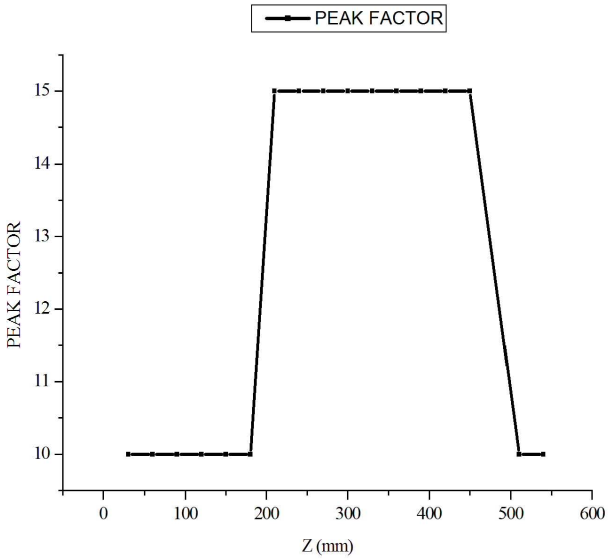

Figure 1: Peak Factor, IAEA reactor [5].

The accident simulated and verified, consisted of a reactivity inserted of 1.5$/0.5s, flow rate of 134.0 kg /m^{2}s, pressure 1.7. 10^5 Pa and the inlet temperature of the refrigerant 38^{o}C, figure 2.

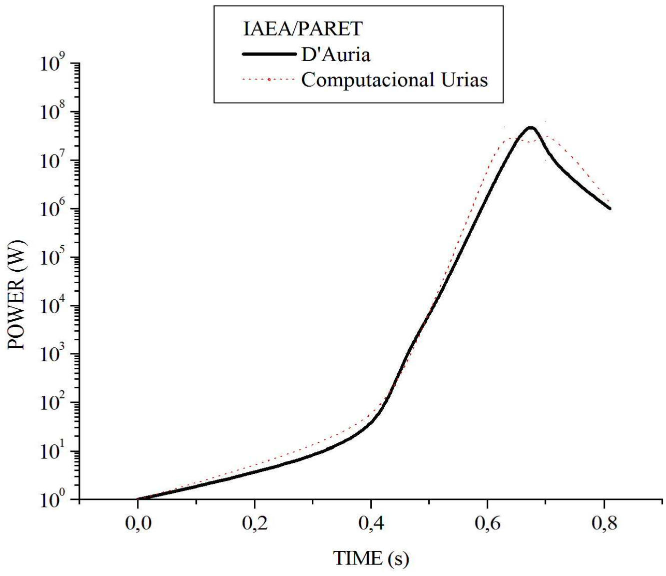

Figure 2: Validation of the power profile with IAEA generic reactor [6].

In this comparison three aspects are important to analyze in the figures: the shape, the pulse width and the power. It was found that both results have excellent numerical agreement and that the transitional profiles are in coincidence. The inserted reactivity of 1.5$/0.5s causes an increase in power that reaches a peak power of 10^2 MW in approximately 0.8 seconds. A further observation of the figure is that this increase is divided into two intervals with different slopes: a first increase was reached to 250 W/s; and the other hand, the second increase was reached in 333 MW/s in 0.3 seconds.

3. RESULTS AND DISCUSSION OF THE INSERTION OF REATIVITY IN THE CORE IEA-R1

Nuclear reactors experience jumps in temperature when increasing the neutron flux generated by an increase in reactivity and this analysis is important because the rate of insertion of reactivity determines the stable period the reactor, which in turn defines the growth the rate of power. The accident was analyzed for three inserted reactivities, 0.5, 1.5 and 2.0 $/0.7 s in the absence of the action of the shutdown system. Figure 3 shows the ramps of the reactivity externally inserted at the core of IAE-R1.

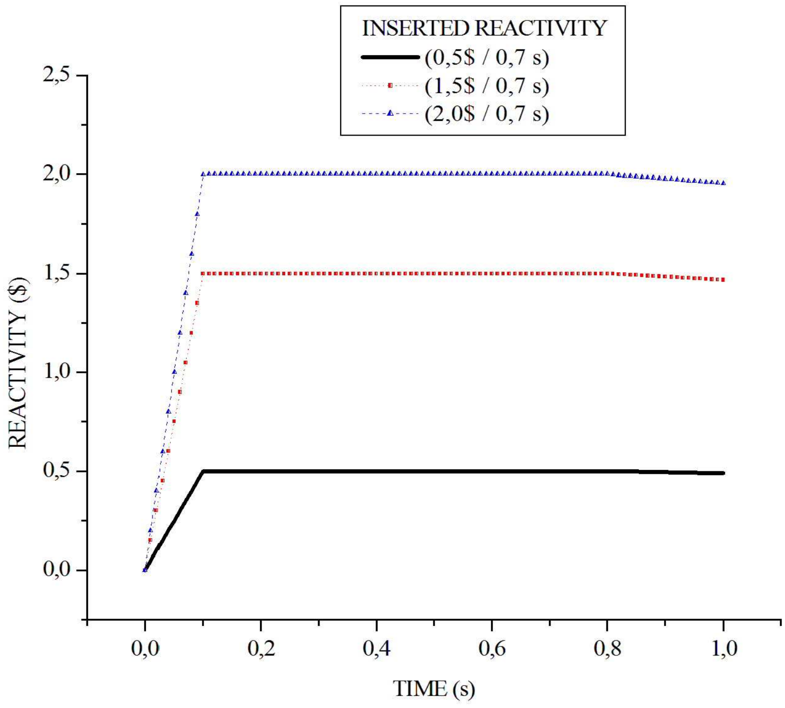

Figure 3: Reactivity externally inserted IAE-R1.

More details about the configuration of the IAE-R1 are found in [8]. The values of ramps of reactivity insertion used in this work follow the recommendation the reference [9].

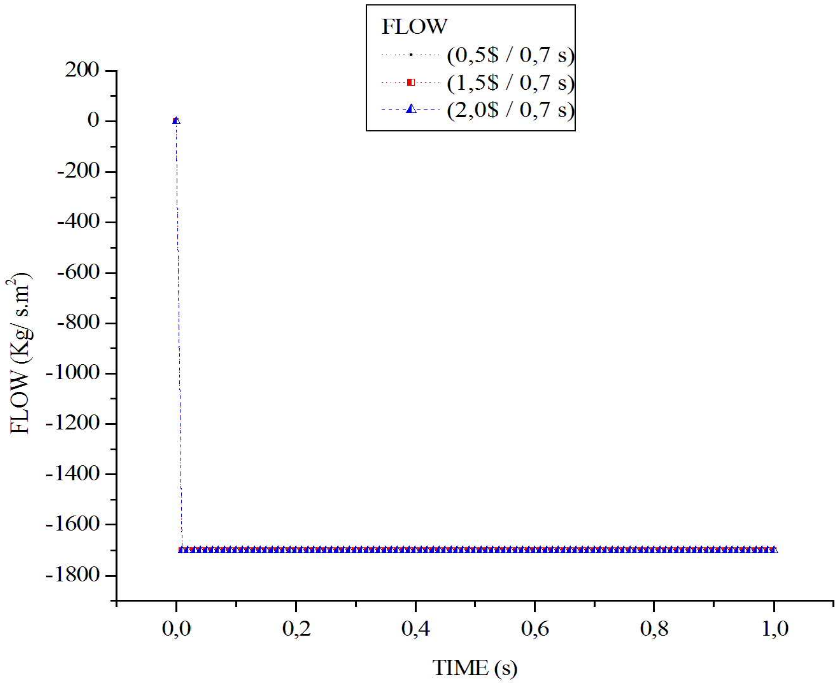

Figure 4: Transient of the inlet mass velocity.

In this transient, the pump was simulated with constant flow rate of 1700 kg /m² s and downward, as shown in Figure 4 above. The result of the reactivity compensated, due to effects the temperatures of the fuel and moderator simulated with the PARET are show in figure 5

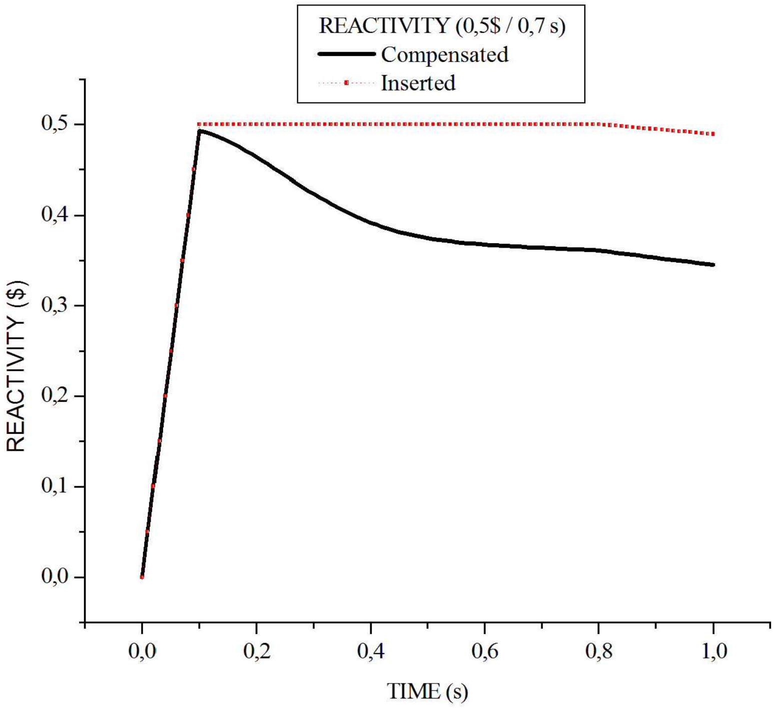

Figure 5: Transient of the reactivity of $ 0.5 / 0.7s and externally inserted.

As the inserted reactivities was low, the power excursion was finished in a few seconds and the auto regulation was initiated. The transient of the figure 5 show also the compensated reactivity due to negative effects of the temperatures.

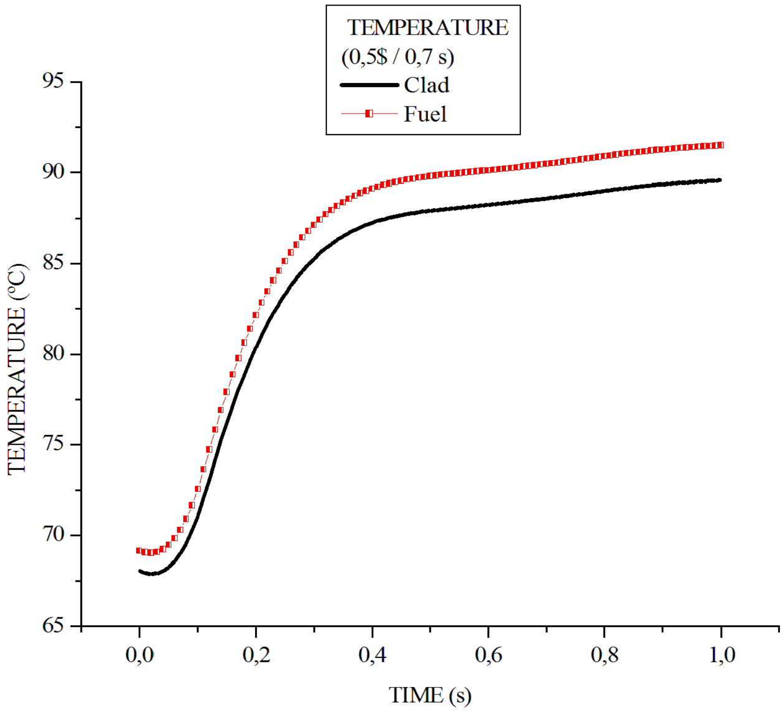

Figure 6: Transient of Temperature for $ 0.5 / 0.7s inserted externally.

The differences in the heat capacities produce fuel temperature more high than the moderator temperature. In this case, the amount of reactivity inserted does not cause fusion of the fuel (3120 K). The most value reached is the 363, 15 K and therefore is not considered a severe accident. However, this reactivity causes an increase of ~ 89% in the temperature of the fuel and clad in just 1 second and 25% and the coolant.

Figure 7 show the comparison of the behavior of power versus time when externally reactivities inserted are of 0.5 $, 1.5$ and 2.0$ in 0.7 s. In the figure, it can be noted that when the reactivity was of 0.5 $, there was a small variation of the power in 0.11 seconds, reaching 9.17 watts slightly. In the other hand, in the numerical curves of 1.5 $ and 2.0 $ there is a presence of the three oscillating shorts peaks that characterizing power pulses. In this case the first peak is of 177 watts, at 0.11 seconds for 1.5$ inserted, while for the reactivity of 2.0 $, is first reached a peak the 236 watts in a shorter time of 0.09 seconds.

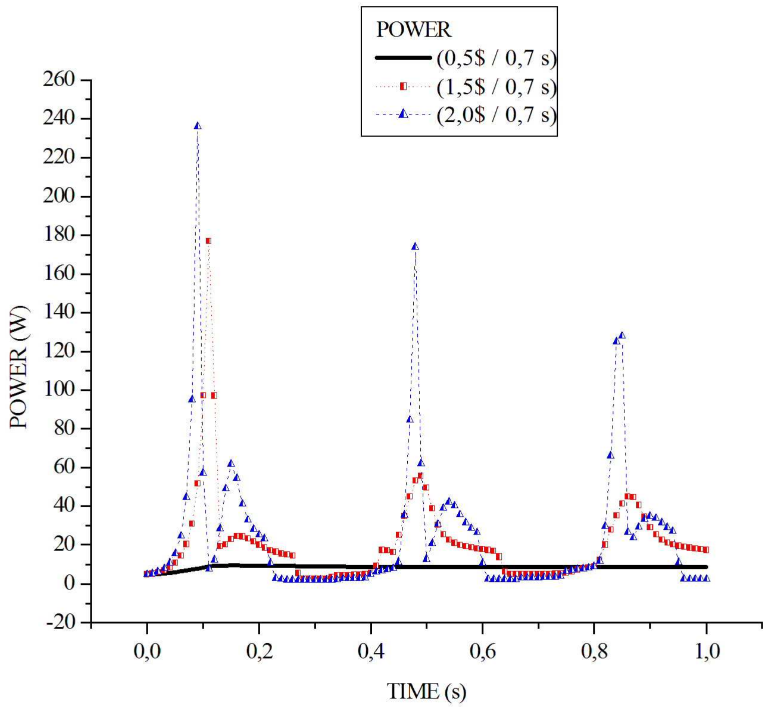

Figure 7: Power vs time for reactivities inserted.

4. CONCLUSIONS

A computational and parametric study was conducted using a conservative and simplified code, the PARET. As seen in the comparison made with the generic reactor IAEA, this code is able to produce results with consistency. It was therefore chosen to discuss the phenomenology of a hypothetical reactivity accident (RIA) in the hottest channel of the research reactor IEA-R1 and interpret the influence of externally inserted reactivity in thermo hydraulic parameters and response reactivity compensated or feedback. The transient for the reactor Brazilian showed that reactivity of 0.5$ inserted externally was self compensated, however, from a reactivity of $ 1.5 is possible to obtain generated power pulses in very short intervals of time.

Therefore higher values of reactivity can create scenarios of severe accidents that will produce: failure of cladding, releasing gas and / or steam formation in core. For reasons of safety, the lack of experimental data inhibits other numerical experiments can be performed to a full understanding of these accidents to high levels of reactivity.

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