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RELAP5 Code Simulation of the Angra2 Pressurizer Surge Line Accident

Gaianê Sabundjian[1], Rafael Radé Pacheco[2], Thadeu das Neves Conti[3], Ana Cecília de Souza Lima[4] e Andrea Sanches Del Pozzo[5]

[1]*gdjian@ipen.br*, [2]*rafaelrade@gmail.com*, [3]*tnconti@yahoo.com.br*
[4]*aclima@ipen.br*,[5]*andreasdpz@ipen.br*,
Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN) Av. Professor Lineu Prestes, 2242 CEP: 05508-000 São Paulo – SP - Brazil

1. Introduction

Angra2 is a Pressurized Water Reactors (PWR) built by Siemens-KWU (now Areva NPP), it is located at the Central Nuclear Almirante Álvaro Alberto in Angra dos Reis, Rio de Janeiro, Brazil. It achieved full power operation in 2001 with 1,350MWe. Angra2 has four pumps to control of water flow, four loops with two ECCS (Emergency Core Cooling System) for each loop (one Hot and one Cold ECCS) [1].
In this paper is analyzed a Medium Break Loss-of-Coolant Accident (MBLOCA) at the pressurizer surge line of Angra2. The event is simulated by RELAP5/MOD3.2.gama code [2]. This accident is a guillotine-type break and represents a both side rupture of 437 cm². This is an accident described in chapter 15 of the Final Safety Analysis Report and this work is part of the study being carried out in conjunction with CNEN to verify the results of the FSAR.

2. Methodology

The RELAP5 code was developed by the Idaho National Laboratory. This code was originally designed for the analysis of thermal hydraulic transients in PWR. The RELAP5 can model the primary and secondary cooling systems of experimental facilities and of Nuclear Reactors with geometric details. The program uses the non-homogeneous non-equilibrium two-fluid model, and considers the conservation equations of mass, momentum and energy for the liquid and gas phases. One-dimensional model is used to treat the fluid flow and the heat conduction in the structures; however, in some special cases such as the cross flow in the reactor core and the rewetting region in flooding model, the two-dimensional model is used [2].
For the simulation of an accident or transient with RELAP5 the first step is the elaboration of the nodalization of the hydrodynamic components of the installation under study, which should be modeled by means of the geometric representation closest to reality. The initial and boundary conditions used in this simulation are in agreement with the Final Safety Analysis Report of Angra2 (FSAR-A2) [1]. The actuation set points of ECCS are given as input data for RELAP5 code [2].

3. Results and Discussion

The accident analyzed is a guillotine break in the pipeline of the surge line that connects the pressurizer to the hot leg of primary circuit 20 of the Angra2 reactor. The accident starts after 100 seconds of the steady state simulation time, the other circuits remain intact, and the event is simulated up to 1100 sec.
Table I provides a summary of the analyzed accident, the temporal sequence of operation and evaluation of Angra2 nuclear reactor ECCS performance. According to some results provided by RELAP5 and FSAR-A2, it was possible to observe the differences related to onset time of some phenomena.

Table I: Guillotine MBLOCA accident temporal sequence.

EVENTS	TIME (s)	
	RELAP5	RFAS-A2
Break initiation	100	100
Reactor trip from RCS pressure (p_{RCS} < 132 bar): → turbine trip, loss of offsite power reactor coolant pump trip.	100.5	100.5
100 K/h secondary-side cooldown (p_{RCS} < 132 bar and p_{cont} > 1,03 bar)	100.5	100.5
ECCS criteria met (p_{RCS} < 110 bar and p_{cont} > 1,03 bar)	104.5	105.1
Safety injection pumps start (High pressure pump)	140.0	137.6
Accumulator injection starts	275.0	371.0
Safety injection pumps start (low pressure pump)	302.0	396.0
Hot channel recovered	400.0	450.0
Cold-leg accumulators isolated (500 s after ECCS criteria signal)	604.5	605.1
The end of Simulation_	1100.0	1100.0

Fig. 1 shows the pressures in the primary and secondary loops to RELAP5 and FSAR-A2. Can to be notes that to pressures of secondary loops data are very similar. It is noted that the depressurization of the primary is approximately equal in the first 50 seconds after the accident, and then it is faster in the simulation of MBLOCA by RELAP5 than FSAR-A2 one. After 400 seconds the pressures of primary are similar to RELAP5 and FSAR-A2. The ECCS system operates in function of the primary pressure, therefor the ECCS to RELAP5 code simulation is faster than FSAR-A2 one.

Fig. 2 shows the mass flow in the lines of ECCS loops 10 and 20 to RELAP5 and FSAR-A2. Both (RELAP5 and FSAR-A2) high pressure pumps of the Hot ECCS start at about the same time and have similar data until 275 seconds. Then, in RELAP5 accumulator injection starts, then Hot and Cold ECCS mass flow rate are higher than FSAR-A2 one. It is noted that FSAR-A2 accumulator injection starts at 371 seconds, then Hot and Cold ECCS flow mass hate are similar for all systems until end of the simulation.

Fig. 3 shows void fraction at **3/4** of the hot channel of the core of Angra2. It is noted that at 104 seconds, that is, 4 seconds after the accident, the void fraction in the reactor core is no longer null, and increases rapidly due to the depressurization of the primary circuit. It can be seen that there is only steam in the core for a short time, but due to the smooth operation of the reactor SREN systems and good cooling of the core, after 375 seconds of simulation there is only liquid water in the hot channel at 3/4 from the top of the Angra2 reactor core. The hot channel is flooded after 400 seconds of RELAP5 simulation. There are no FSAR-A2 core void fraction data.

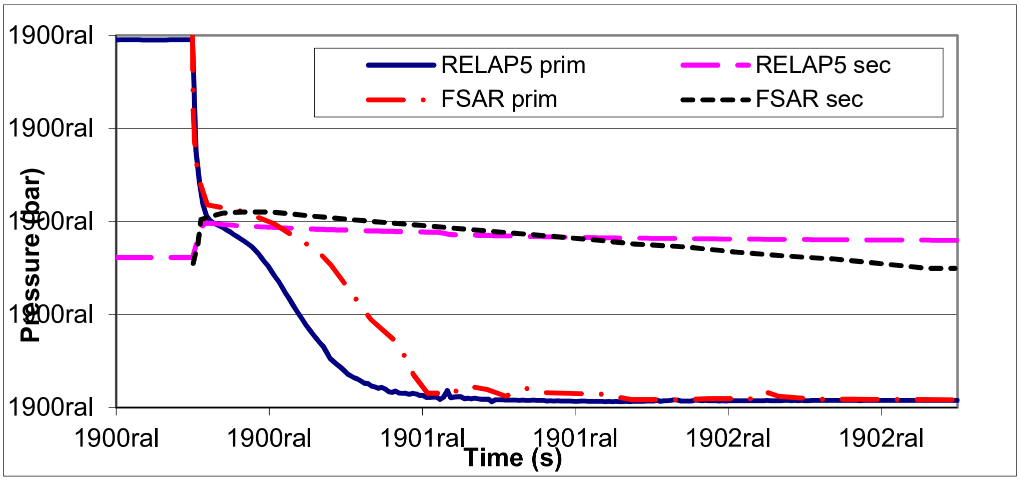

Figure 1: Pressure in the primary and secondary loops of Angra2.

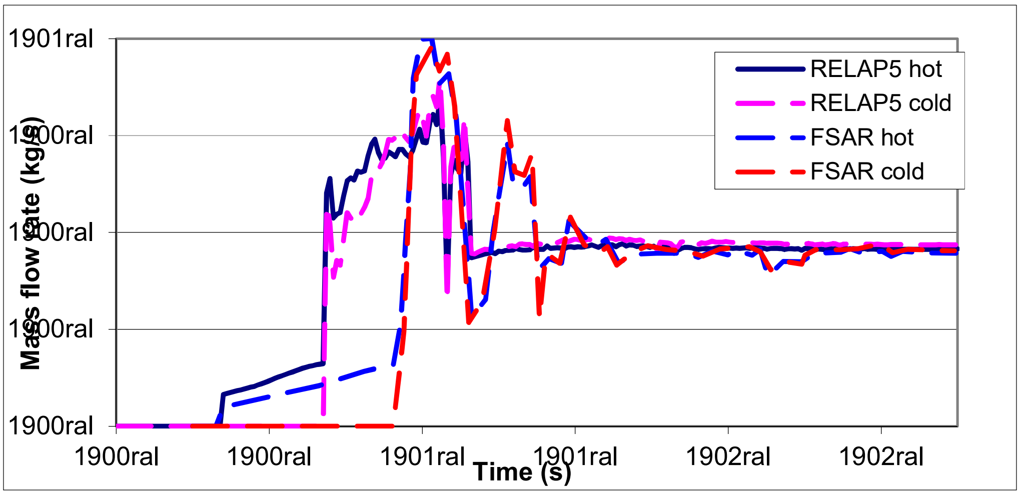

Figure 2: Mass flow in the lines of ECCS – Loops 10 and 20.

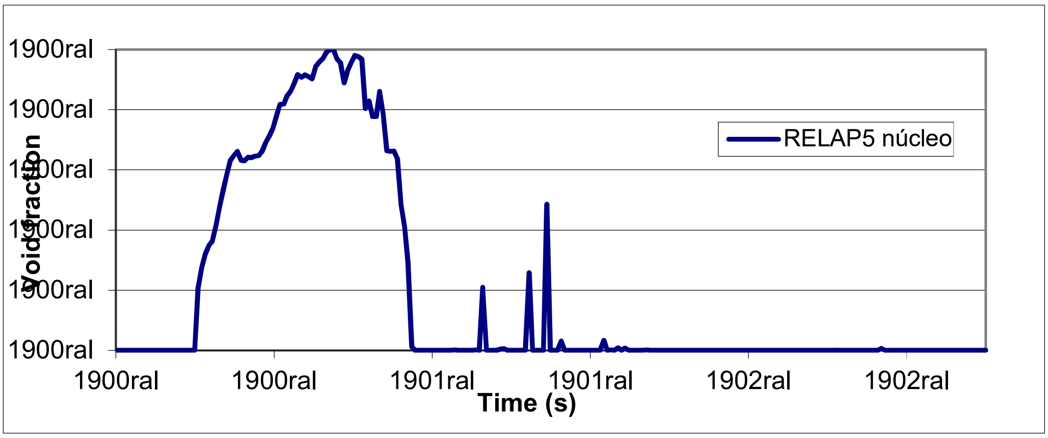

Figure 3: Void fraction to hot channel core of Angra2.

Fig. 4 shows cladding temperature at **3/4** of the hot channel of the core of Angra2 nuclear plant to RELAP5 simulation and FSAR-A2. Between 250 and 280 seconds there are oscillations in the hot rod core cladding temperature to RELAP5 simulation. The FSAR-A2 analyses is more conservative, because its temperatures data are higher than RELAP5 one.

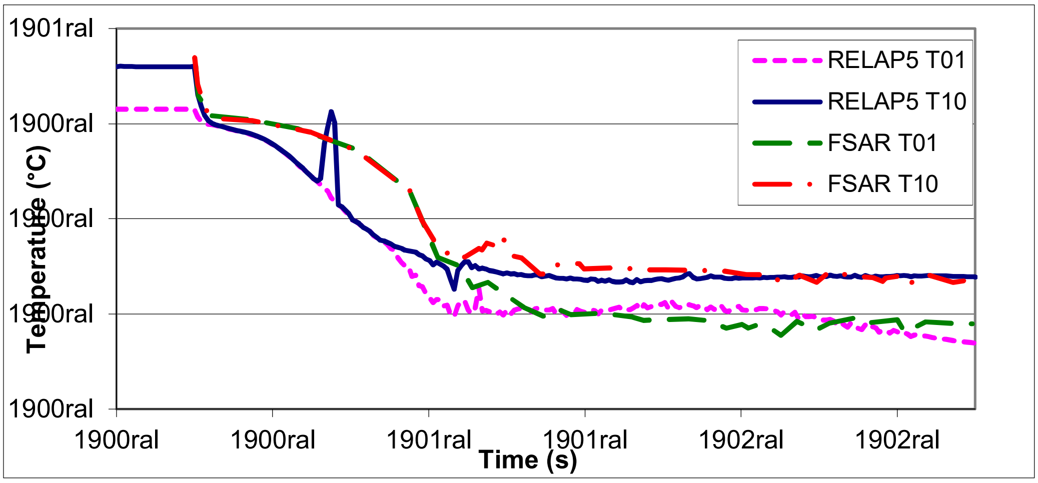

Figure 4: Hot rod cladding temperature of Angra2 core.

4. Conclusions

Can be notes that in this MBLOCA RELAP5 code simulation, the primary pressure decreases faster than FSAR-A2 one. How the ECCS system operates in function of the primary pressure, therefor the ECCS to RELAP5 code simulation is fast than FSAR-A2 one. And the evaluation of the most important variables in this accident with FSAR-A2, when compared to their RELAP5 code simulation data one, showed that in this accident analysis FSAR-A2 was more conservative than the RELAP5 code.

Results presented in this paper showed that the actuation logics of the Angra2 Reactor Protection System (RPS) and the Emergency Core Cooling System (ECCS) used in this simulation worked correctly, maintaining integrity of Angra2 reactor core, with acceptable temperatures throughout the event, and lower than steady state simulation.

Acknowledgements

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