PRELIMINARY TRANSIENT ANALYSIS FOR THE IRIS REACTOR PRESSURIZER WITH RELAP5/Mod3.3 CODE

Sabundjian[1], G.; Andrade[1], D. A. de; Baptista Filho[1], Benedito Dias; Palmieri[2], E. T.
[1]CEN/IPEN - Travessa R, 400 – Cidade Universitária
CEP 05508-900 – São Paulo – SP – Brazil
Phone: +55-11-3816 9165 ext. 259/263/262, Fax: +55-11-3816 9423, E-mail: gdjian@ipen.br
[2]CNEN/CDTN - R. Prof. Mário Werneck, S/N
Cidade Universitária – Pampulha
Caixa Postal 941 – Belo Horizonte – MG – Brazil
Phone: +55-11-499 3125, E-mail: etp@cdtn.br

Abstract - The International Reactor Innovative and Secure (IRIS) concept is being developed by an international consortium led by Westinghouse Electric Company. The pressurizer design and transient analysis are under the responsibility of Brazil as part of an agreement established with Westinghouse. The IRIS pressurizer is housed within the vessel head. Its configuration is quite different from that of conventional pressurizers. A specific nodalization for RELAP5/Mod3.3 code was developed to reproduce the main phenomena involved within this component. The objective of this work is to check the control logic actuation as well as to describe the nodalization scheme proposed for the thermal-hydraulics analyses of the IRIS pressurizer. Few results are presented. Only the model of the pressurizer is considered. Boundary conditions as well as controls are supplied. The analyses performed provided relevant information to the project task. Although the nodalization is still in development, the results showed to be very consistent.

I. INTRODUCTION

One of the most notable characteristics of IRIS, the International Reactor Innovative and Secure [Grgic et. al., 2002], is the integrated design of the primary system, with eight steam generators, eight spool pumps and pressurizer located inside the vessel, thus without any large vessel penetration. The IRIS concept is being developed by an international consortium led by Westinghouse Electric Company.

The IRIS pressurizer is housed within the vessel head. Its saturated water layer is separated from the reactor water by a plate that resembles an “inverted hat.” Its configuration is quite different from that of conventional pressurizers and a specific nodalization for RELAP5/Mod3.3 code [NUREG/CR-5535 Report, 1995] had to be developed to reproduce the main phenomena involved within this component. This work has the objective of describing one of the nodalization schemes proposed for the thermal-hydraulics analyses of the IRIS pressurizer.

The positioning of the steam generators in a peripheral annulus for easy maintenance and for core refueling without first removing the steam generators results in a comparatively large diameter and tall reactor vessel. The reactor vessel, the automatic depressurization system and suppression pools are within a spherical containment. The power rating for the reactor ranges from 100 MW (e) to 300 MW (e). The IRIS has been projected with two types of fuel: the first uses uranium oxide with enrichment 5% and the second uses MOX – mix uranium and plutonium oxides. This integral reactor vessel makes it possible to reduce containment size. Making the IRIS cost more competitive. IRIS is being designed to enhance reactor safety, and therefore a key aspect of the IRIS program is the development of the safety and containment systems. These systems are being designed to maximize containment integrity, prevent uncover core following postulated accidents, minimize the probability and consequences of severe accidents, and provide a significant simplification. Figure 1 illustrates this concept.

II. IRIS PRESSURIZER NODALIZATION

In order to study some transients involving the pressurizer a detailed nodalization of the pressurizer [Andrade et. al., 2003] was developed for RELAP5/Mod3.3 code, as shown in Figure 2 and Table I. Pressurizer was divided into two axial parts to better represent the flow path (up and down). Heaters are located in the lower part. Pressurizer is composed by components 131, 132, 133, 134 and 135. Component type and divisions are presented in Figure 2. Calculation was based on 37 guide rods, 90 heater rods and 48 instrumentation rods. In present version the diameter of the guide tubes is 0.1143 m, heaters diameter is 0.0316 m and instrumentation diameter is 0.0381 m. There are 10 heat structures in the model including 2 heater groups. The head of the vessel is assumed with constant thickness of 0.133 m. It is insulated on the outer side as well as on all other outer parts of the vessel.

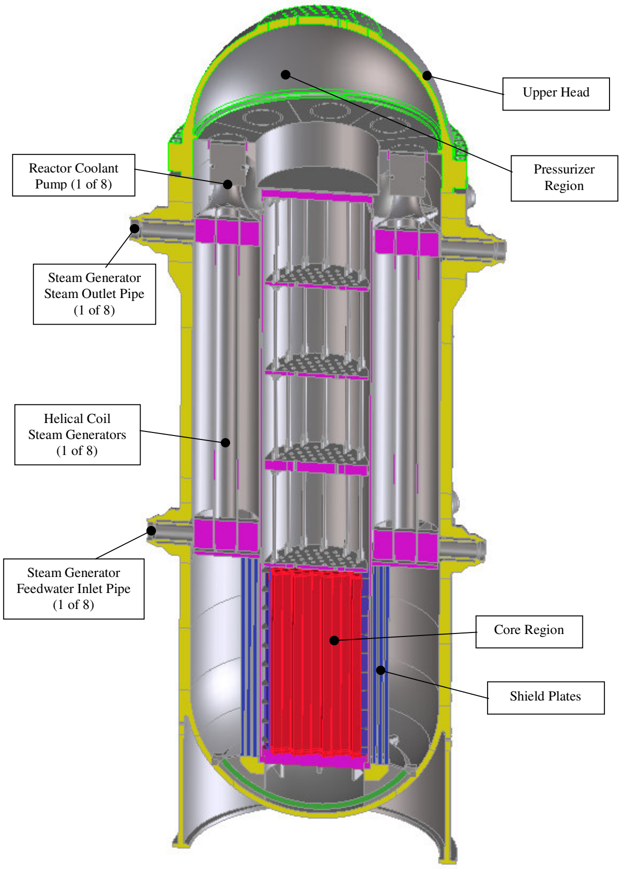

Fig. 1. IRIS Vessel 3D view

Relief and Safety valves are represented by control volumes 985 and 987. Valve 902 represents an artificial level control of the pressurizer. Control volumes 901, 986 and 988 are considered as time dependent volumes and represent ambient conditions for pressure and temperature.

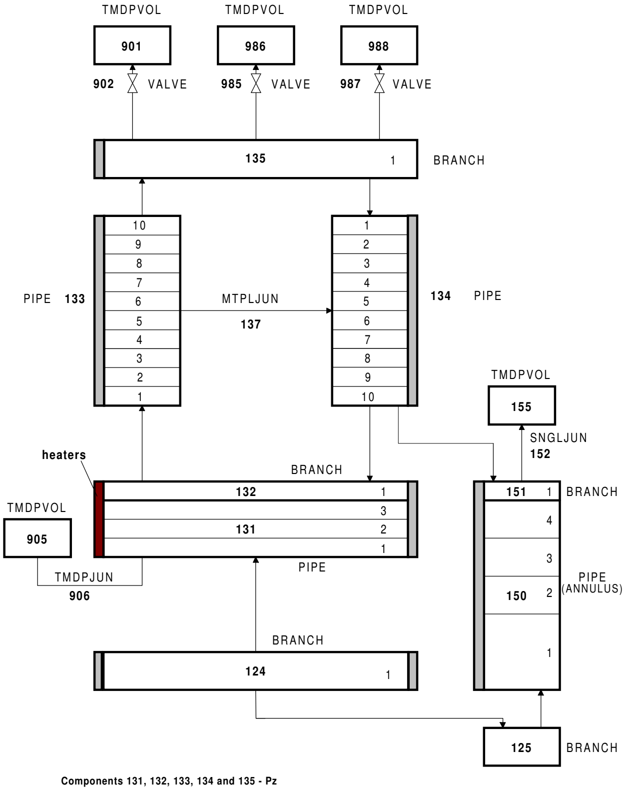

Fig. 2. Pressurizer Nodalization

Components 905 and 155 provide the boundary conditions of the plant in steady state. Component 124 represents the top part of the riser, components 125, 150 and 151 represent part of the upper downcomer.

TABLE I

HYDRODYNAMIC VOLUMES USED IN SIMULATIONS – RELAP5

Part of the Plant	Hydraulic Region	Component number	Component
	Pressurizer	131,133,134	PIPE
Pressurizer		132,135	BRANCH
	Relief Valve	985	VALVE
	Safety Valve	987	VALVE
Vessel	Riser	124	BRANCH
	Upper downcomer	125,151	BRANCH
		150	ANNULUS
Boundary Condition Components	Auxiliary components	155,901,905,901,986,988	TMDPVOL
	Auxiliary valve	902	VALVE
	Auxiliary junctions	152	SNGLJUN
		906	TMDPJUN

III. PRESSURIZER TRANSIENT SIMULATION

Transients analyzed in this paper aim at the verification of the correct logic actuation.

The first transient analyzed was the case of an over pressure in the pressurizer causing the opening of the relief and safety valves. The second transient analyzed was the temperature drop in the pressurizer causing the heater bank control actuation. Nodalization presented in Figure 2 was used in both cases. Hypothetical boundary conditions, however, are provided for each transient, only to check the control logic.

Relief and Safety valves opening setpoints are respectively 16.1 e 17.23 MPa.

The number of control rods, instrumentation guides, and heater rods are 37, 48 and 90, respectively, Table II.

TABLE II

ROD GUIDES, HEATER AND INSTRUMENTATION QUANTITY

Parameter	Value
Rod guide tubes No.	37
Heater rods No.	90
Instrumentation tubes No.	48

The total amount of heaters was organized in two banks, one with 30 and another with 60 heater tubes. The actuation curves for these banks are shown in Figure 3. The first is proportional-integral and the backup presents a step curve.

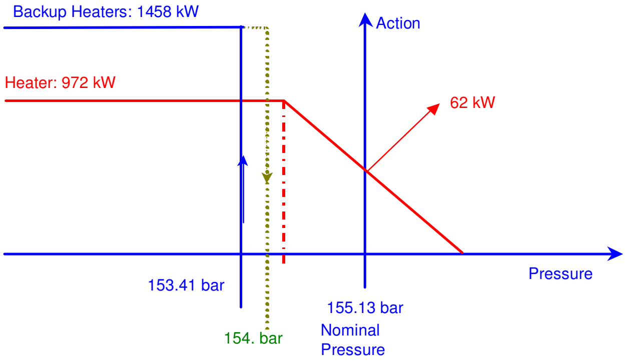

Fig. 3. Heaters Control Diagram

The first transient consists basically of an accident causing an overpressure in the pressurizer, which is imposed through hypothetical boundary conditions in the component 155, Figure 2. Consequently it is expected that the valve control actuates to reach the project operational conditions.

In order to check the correct logic for the heater banks a second transient is considered. This transient consists of a hypothetical forced drop of pressure in the pressurizer through the boundary conditions established in the component 155.

For both cases, It was simulated 100 s of steady state.

IV. RESULTS

In this section are presented the results for the transients proposed previously.

Figure 4 shows the behavior of the relief and safety valves for the overpressure transient in the pressurizer. The relief valve actuated when the pressure reached 16.1 MPa, however with the increase of pressure imposed by the boundary condition, it was not enough, causing the actuation of the safety valve. We can observe the correct actuation of both valves.

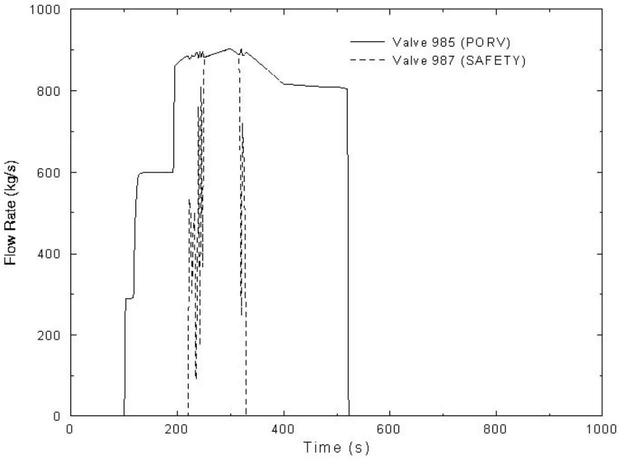

Fig. 4. Valve flow

Pressure in the top of the pressurizer is shown in Figure 5. This behavior is coincident with the valve opening as expected. Although the relief valve has closed at 522s, the pressure keeps dropping until 600s reaching a new steady state condition due to the boundary conditions imposed.

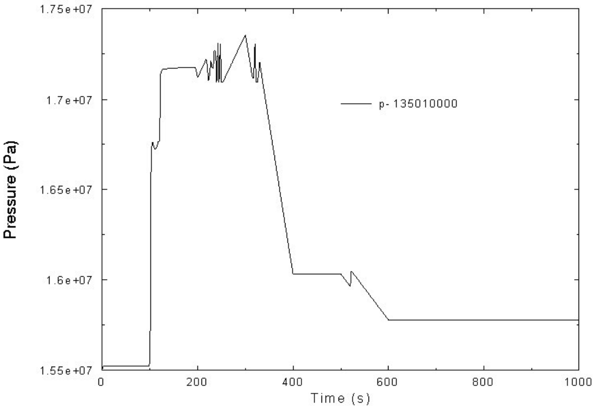

Fig. 5. Pressure in the top part of pressurizer

Results for the second transient, i.e., a drop of pressure or temperature in the pressurizer is presented in next two figures.

Figure 6 shows the heaters power behavior for this accident. Both banks actuate in the beginning of the transient and remain in their maximum value (972 and 1458 KW) until the operational conditions are restored.

Figure 7 shows the pressure behavior in the pressurizer for the transient. We can note that the pressure in the pressurizer diminishes during the accident and due to the actuation of the heaters, a new value for the pressure is reached for the operational conditions. Since the pressurizer is considered isolated, the pressure reached a new operational value after the accident. However, this behavior would be different if the accident was analyzed for the complete plant. Pressure would reach the project value since other systems would interpose changing the pressure field.

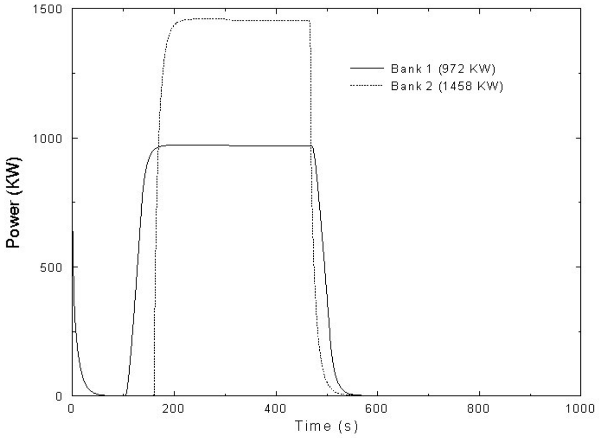

Fig. 6. Heater actuation

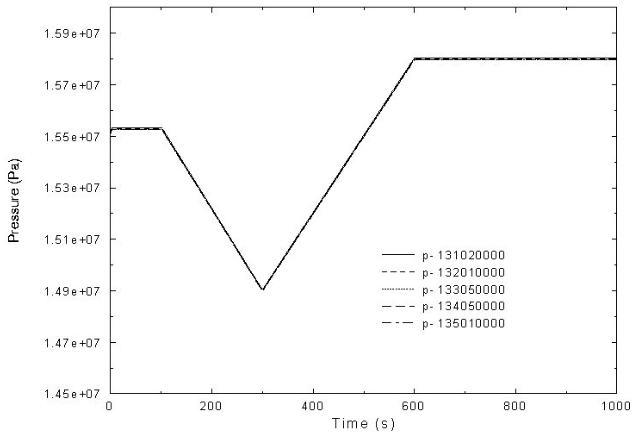

Fig. 7. Pressure behavior in the Pressurizer

The pressurizer level is presented for the second transient in Figure 8. Note that the level is varying with heaters actuation tending to reach its original level. Figure 9 illustrates this behavior through the vapor fraction curves.

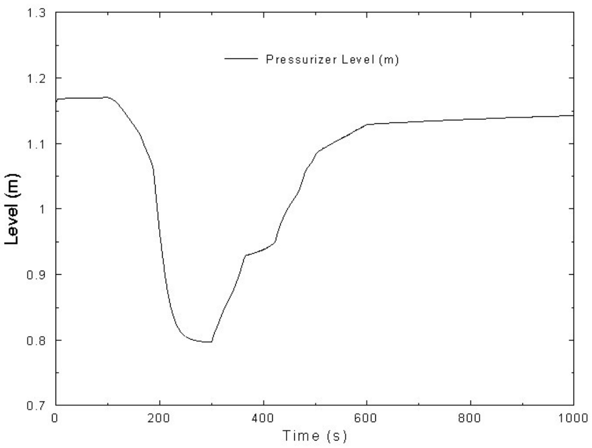

Fig. 8. Pressurizer level

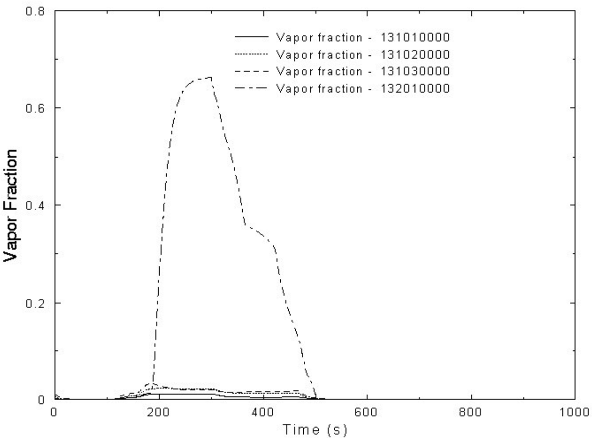

Fig. 9. Vapor fraction in the heaters region

V. CONCLUSIONS

According to the results presented in the previous item we can conclude that the nodalization for the isolated pressurizer, developed in this paper, is proper to simulate transients involving control logic actuation for the pressurizer. Results showed to be satisfactory since the control associated with pressurizer worked correctly.

Next activities related to the development of the complete nodalization will be based on this work. The objective is to implement the isolated pressurizer model to the complete plant nodalization of IRIS reactor. However, nodalization must be qualified for steady and transient state as well.

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