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SIMULATION OF IRIS TRANSIENTS WITH RELAP5

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ABSTRACT

IRIS - International Reactor Innovative and Secure, is an integral pressurized water nuclear reactor that is being designed to bridge the gap of options for new improved reactors before generation IV reactors are available. In order to support a safer operation and therefore a higher availability it was envisaged a surveillance system that would alert the operators for transients that might be occurring. A system based in neural networks using Self-Organizing Maps is being developed to achieve this goal. Such development requires the evolution of several thermo-hydraulic parameters representing different possible states of operation: steady states, slow and fast transients of small and large amplitudes and accident conditions. This paper presents simulations of IRIS with RELAP5 carried out with the goal of achieving the evolutions of those parameters required for the development of the system. It is also described the main points of the represented control system and its effects in the obtained results.

1. INTRODUCTION

IRIS - International Reactor Innovative and Secure [1], is an integral pressurized water nuclear reactor that is being designed to bridge the gap of options for new improved reactors before generation IV reactors are available. In order to support a safer operation and therefore a higher availability it was envisaged a surveillance system that would alert the operators for transients that might be occurring. A system based in neural networks using Self-Organizing Maps is being developed to achieve this goal [2].

The development of a System of Identification and Classification of Transients – SICT for a nuclear reactor demands thermo-hydraulic data corresponding to most possible operational conditions of the reactor in order to train the system to recognize these states. In case of IRIS reactor, which is still a project, there is no operational data available, and even for existing reactors there is not data available for all accidental conditions. Therefore, one option to fill this lack of information is to use data from simulations of the reactor under all envisaged conditions.

For the current status of development of such a system for IRIS, it has been used data obtained from simulations of IRIS with the well known RELAP5 code [3]. The basic model of IRIS for RELAP5 was developed by the University of Zagreb [4] for the study of IRIS behavior in some transients, mainly those related to its preliminary safety analysis. This model does not contain a fully updated reactor control system but it is assumed that it can provide information about the operational behavior with an approximation credible enough to be used for the training of SICT. If better simulation results become available, this new information can easily replace the current ones in the training processes.

2. SIMULATION MATRIX

The IRIS simulations with RELAP5 initially planned to form the basic data base for supplying training data for SICT covered steady state conditions, power increase and decrease in steps and in ramps as well as abnormal conditions or accidents. Table 1 presents the 48 simulations programmed to be run and provide information for the artificial neural network.

Table 1. Matrix of Simulations

Class: Steady State		**Class: Step Down 10% (Initial Power →Final Power)**		**Class: Step Up 10% (Initial Power →Final Power)**	
1	100%	11	100% → 90%	19	100% → 105%
2	90%	12	90% → 80%	20	90% → 100%
3	80%	13	80% → 70%	21	80% → 90%
4	70%	14	70% → 60%	22	70% → 80%
5	60%	15	60% → 50%	23	60% → 70%
6	50%	16	50% → 40%	24	50% → 60%
7	40%	17	40% → 30%	25	40% → 50%
8	30%	18	30% → 20%	26	30% → 40%
9	20%			27	20% → 30%
10	105%				
Class: Ramp Down 10% (Initial Power →Final Power)		**Class: Ramp Up 10% (Initial Power →Final Power)**		**Class: Abnormal Conditions / Accidents**	
28	100% → 90%	36	100% → 105%	45	100% →Step -50%
29	90% → 80%	37	90% → 100%	46	Safety Valve Opening
30	80% → 70%	38	80% → 90%	47	Loss of Coolant Accident/Small Break
31	70% → 60%	39	70% → 80%	48	100% (SCRAM)
32	60% → 50%	40	60% → 70%		
33	50% → 40%	41	50% → 60%		
34	40% → 30%	42	40% → 50%		
35	30% → 20%	43	30% → 40%		
		44	20% → 30%		

The approach to run these cases starts with initially obtaining a simulation of a steady state at full power – 100%. This was achieved with a run until 10000s. This first run, case 1 in Table 1, defines the nodalization and the control system that will be used in all other cases. The other cases are run as a RESTART of a previous one, for example, case 28 is run as a RESTART from time 10000s of case 1 and it is also run 10000s generating the steady state at 90% - case 2, which by its turn can be used to run cases 12, 20, 29 or 37.

This approach shows that if in any phase a case presents an inconsistence, which requires a change in the model, it is necessary to start again the chain process from the beginning, i.e., from case 1.

3. SIMULATION OF IRIS WITH RELAP5

The simulation of IRIS with RELAP5 is basically the same that was used previously [5] and consists of around 3000 thermo-hydraulic components, i.e., volumes and junctions. Fig. 1 presents a scheme of IRIS integral reactor, with the main components in its vessel and a sketch of its nodalization.

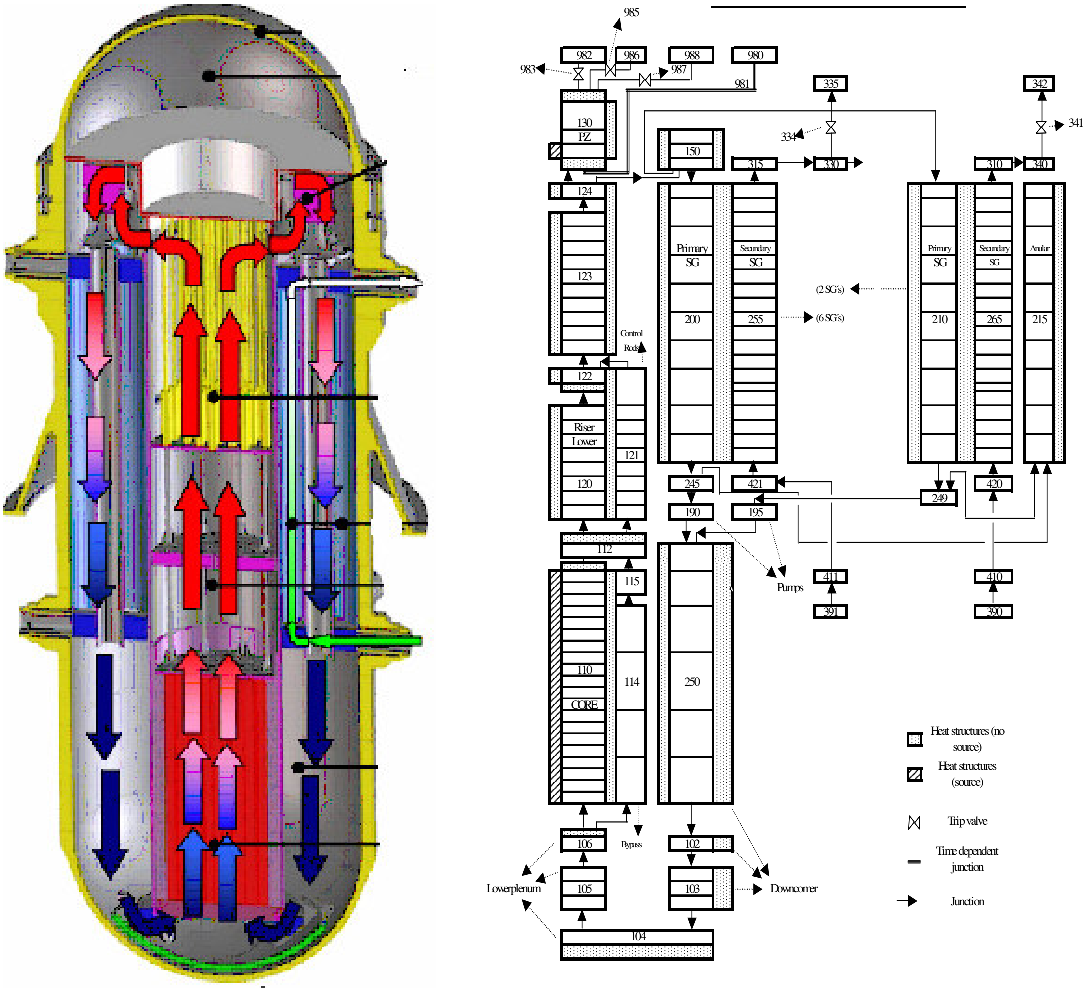

Figure 1. Main components of IRIS within the vessel and their RELAP5 nodalization

Besides the nodalization, the boundary conditions used in the model were also kept as those described in the just cited previous study.

The original control system of IRIS simulation with RELAP5 led to unnatural oscillations in some cases, which provoked and abrupt failure of the calculations before reaching the final specified time step. A sample of such behavior is illustrated in Fig. 2 and 3 with pressures from case 28.

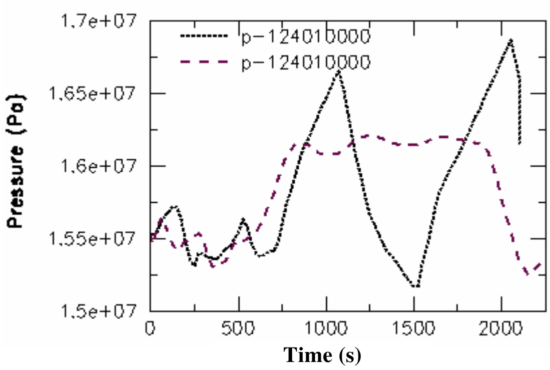

Figure 2. Pressure in secondary circuit

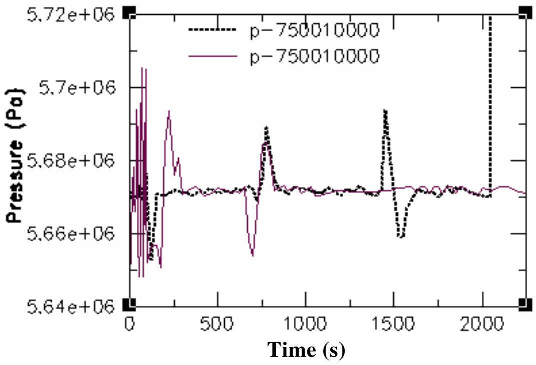

Figure 3. Pressure in primary circuit

After extensive search for the reasons of this abnormal behavior and of similar situations that appeared in other cases, the identified causes relied in components of the control system. As mentioned in the introduction this model was developed for safety analysis and was not very refined one. Two main changes were introduced in this system.

The control rod speed was detected to be too high at low temperature error. The rod speed of RELAP5 table 153 was changed from the values represented by the dashed line in Fig. 4 to the values of the solid line. The rod speed curve for the whole range of temperature error is presented in Fig. 5.

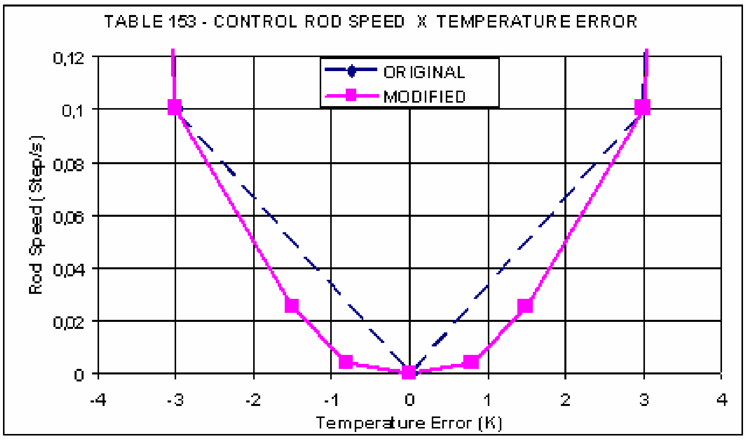

Figure 4. Control rod speed at low temperature error

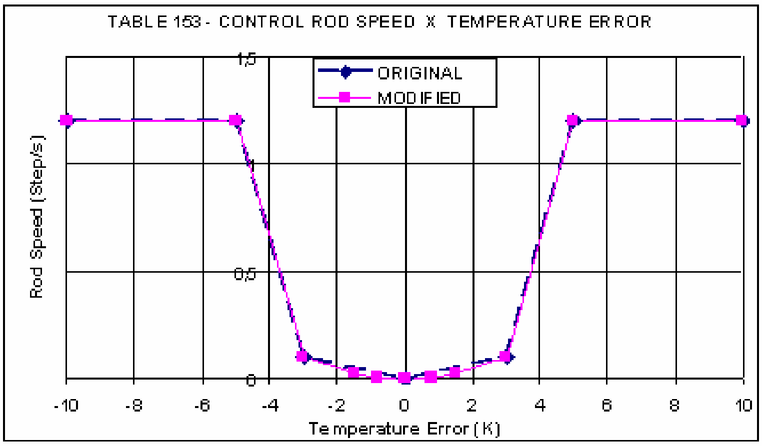

Figure 5. Control rod speed for the whole temperature error range

Another observed point was the very high influence of the opening of the turbine admission valve at low aperture, as shown in Fig. 6. This caused strong flow oscillations in the secondary side of the reactor. As this is in reality a typical behavior of valves the solution here was to introduce a lag of 1s in the control of the valve.

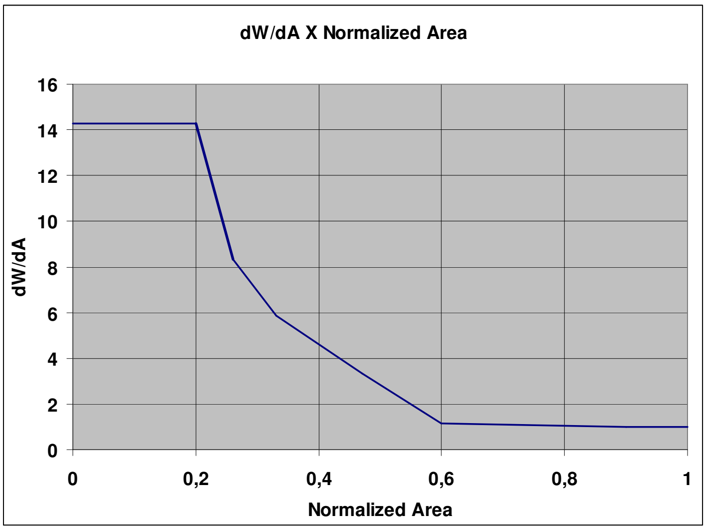

Figure 6. Influence of valve area on the flow variation

4. CURRENT RESULTS

After introducing the changes in the control system all cases of steady state and power change in step and ramp, i.e., cases 1 to 45 could be run successfully. Fig. 7 and 8 show the evolution of same parameters and case shown in Fig. 2 and 3, but run with the updated model.

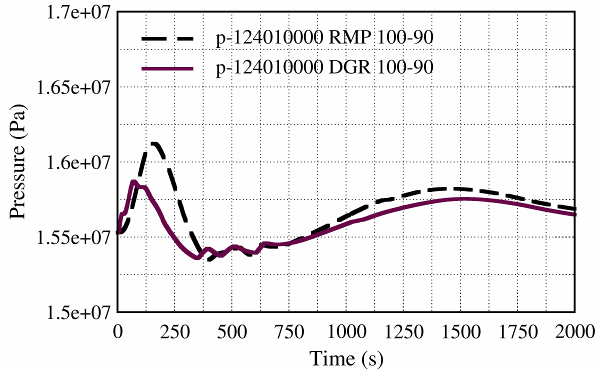

Figure 7. Pressure in secondary circuit

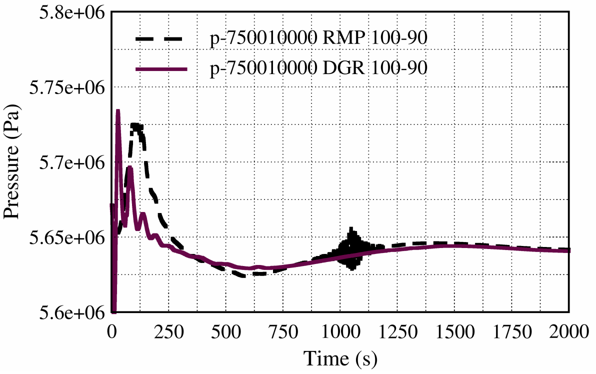

Figure 8. Pressure in primary circuit

Cases 46 to 48 that demand different preparation of inputs were not yet run. However, once they are the kind of cases for which the model was originally developed and considering also the stability shown in processing all the other cases it is not expected any problem with these cases.

5. CONCLUSIONS

After several changes in the modeled control system it was achieved a stable version. Using this version it was possible to run all steady state and power change cases. The results of these runs are stored in order to be used in the training of SICT.

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