Развитие на ASTEC V1.2 rev1 код за ВВЕР-1000 реактори/ събитие пълно обезточване

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Evolution of ASTEC V1.2 rev1 code for VVER-1000 reactors/ SBO sequence

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Abstract

Този доклад представя сравнение между пресмятания на тежки аварии за ВВЕР1000 реактори с ASTEC код за събитие пълно обезточване с отворен предпазен клапан на компенсатора на обема и без интервенция на хидроакумулаторите.

Целта на представения анализ е да представи подобренията на актуализираната версия (ASTEC v1.2 rev1) по отношение на ASTEC V1.1 p2: промени в кода, подобрения на входни данни. Подобни несъответствия ще бъдат изучени и, според случая, предложения за подобрения на ASTEC ще бъдат направени.

Introduction

The reference power plant for this analysis is the VVER-1000/V320. This type of reactor is a pressurized water reactor that produces 3000 MW thermal power and generates 1000 MW electric power.

The VVER-1000/V320 design includes four primary coolant loops, each including one main coolant pump and a horizontal steam generator. The behaviour of the horizontal steam generators is very different compared to the western type (vertical) steam generators. Steam generators play a very important role in the safe and reliable operation of VVER power plants. They are supplied by two different feedwater systems. Each system consists of turbine-driven pumps and piping connecting the feedwater line at four different locations in each steam generator. They determine the thermal-hydraulic responses of the primary coolant system during operational and accident transient.

Initial Conditions

The initial conditions as modelled in the input decks of different version of ASTEC code (ASTEC V1.2 rev1 & ASTEC V1.1 p2) are listed in the following table (Table1):

Parameters	Design Value	ASTEC Value
Core power, MW	3000	3000
Primary pressure, MPa	15.7	15.7
Average coolant temperature at reactor outlet, °C	320.15	320.55
Maximum coolant temperature at reactor inlet, °C	290.0	290.35
Mass flow rate through one loop, kg/s	4400.0	4363.1
Pressure in SG, MPa	6.27	6.418

Pressure in MSH, MPa	6.08	6.38
SEMPELL1 opening pressure, MPa	18.11	18.11
SEMPELL1 closing pressure, MPa	16.67	-
SEMPELL2,3 opening pressure, MPa	18.6	18.6
SEMPELL2,3 closing pressure, MPa	17.07	-
Steam mass flow rate through SG, kg/s	408	409.6

Table 1: Initial plant conditions

Results

The modules which have been taken into account are CESAR, DIVA, SOPHAEROS and CPA [4] and therefore the analysis is orientated to the in-vessel phase of the accident.

The sequence of the main events during Station Blackout with PRZ Relief Valves (SEMPELL) stuck open and without hydroaccumulators intervention, as estimated by the two versions of ASTEC, is presented in Table2.

No	Event	ASTEC V1.2 rev1 Time, s	ASTEC V1.1 p2 Time, s
1	Initiating event- SBO	0.0	0.0
2	Reactor scram	0.0	0.0
3	Feedwater terminated	0.0	0.0
4	MCPs are switched off	0.0	0.0
5	Turbine stop valves (TSVs) are closed	0.0	0.0
6	Open of the PRZ relief valve (SEMPELL)	8 049.0	9 078.0
7	Start of DIVA module	9 846.0	10 965.0
8	Beginning of oxidation	9 847.0	10 966.0
9	First total core uncovery	10 481.0	12 618.0
10	Start of FP release from fuel pallets	10 701.0	13 201.0
11	First corium slump	12 150.0	12 618.0
12	Lower head vessel failure	27 899.0	33 625.0

Table 2: SBO sequence- Main events

The comparison of main events from the table above shows that the new ASTEC v1.2rev1 version predicts earlier core degradation with a first total core uncovery (and consequent vessel failure) roughly occurring about two hours earlier than in ASTEC v1.1-p2. This is due to the code source modifications concern CESAR and DIVA modules of ASTEC code. CESAR describes the Reactor Coolant System two-phase thermalthydraulics, while DIVA module describes in-vessel core degradation [2].

Different trends for five main plant parameters for both ASTEC code versions (ASTEC V1.2 rev1 & ASTEC V1.1 p2) have been compared. In the onset of the accident the main coolant pump and secondary side feedwater stop and the decay heat is removed from the core due to natural recirculation. The primary pressure decreases essentially because of the decreasing of the decay heat (see Figure 1 and 2). In the mean time heat is transferred to the secondary side and removed through "steam dump" to the atmosphere. The secondary pressure oscillates between the opening and closing pressure thresholds of the SDA (Steam Dump to Atmosphere). As a consequence, primary pressure is also oscillating according to the secondary pressure behaviour. This process continues until secondary side heat sink depletion and the core decay heat causes a gradual increase of primary coolant temperature and pressure followed by the opening of PRZ Relief Valves and leakage of primary coolant to containment (through the relief tank) – see Figure 5 and 6. There is almost 1 000s time difference in the opening of PRZ Relief Valves for two versions of ASTEC code

(ASTEC V1.2 revl & ASTEC V1.1 p2). Probably this could be due to the code source modifications concerning CESAR module.

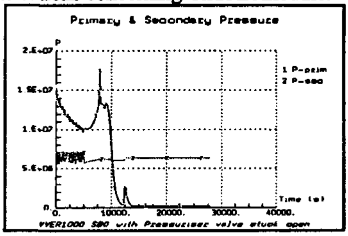

Figure 1ASTEC v1.2 revl Primary and Secondary Pressure

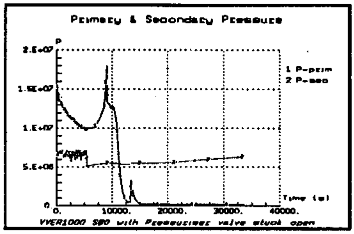

Figure 2 ASTEC v1.1-p2 Primary and Secondary Pressure

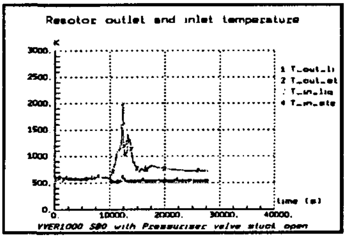

Figure 3 ASTEC v1.2revl Reactor Outlet and Inlet temperature

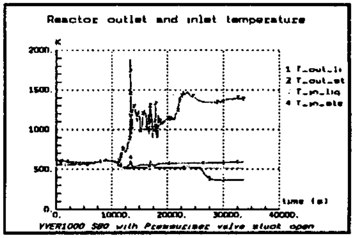

Figure 4 ASTEC v1.1-p2 Reactor Outlet and Inlet temperature

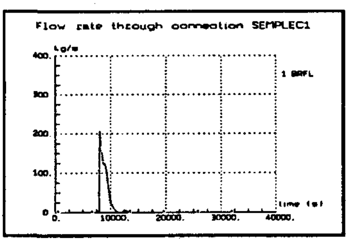

Figure 5 ASTEC v1.2revlFlow rate through PRZ relief valve

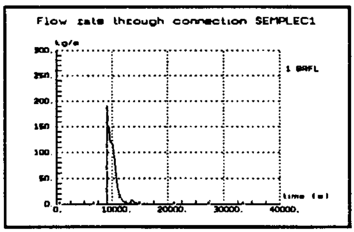

Figure 6 ASTEC v1.1-p2 Flow rate through PRZ relief valve

PRZ Relief Valves opening leads to the depressurization of the core. This is followed by increasing of fuel temperature which leads to begging of the oxidation process by steam. As a consequence there is material relocation: radial and axial movement of a mixture of molten and solid masses within or along the rods in the core and slumping into the lower plenum [3]. Figure 9 and 10 presents the Corium Masses in the Lower Plenum for both versions of ASTEC code. It should be noticed here that there are differences in the corium configuration in the Lower plenum predicted by both versions of ASTEC code. ASTEC v1.2revl predicts larger amount melted metal and pool, while ASTEC v1.1-p2 – melted metal and debris. The two ASTEC codes (ASTEC V1.2 revl & ASTEC V1.1 p2) predict a big corium slump in Lower plenum approximately at the same time (about 15 000s after initiating of the accident), which leads to slight increase of Primary Pressure (see Figure 1 and 2).

Figure 7 and 8 presents the Fission Products cumulated mass through PRZ relief valve during the severe accident sequence calculated by SOPHAEROS module. The main Fission Products taken into account are xenon (Xe), caesium (Cs), iodine (I), krypton (Kr), lead (Pb) and tellurium (Te). There is difference in the amounts of Fission Products leakage from the primary circuit to the containment for both versions of ASTEC code: ASTEC 1.2rev1 version predicts mainly leakage of xenon and krypton, while ASTEC 1.1-p2 version mainly xenon and caesium.

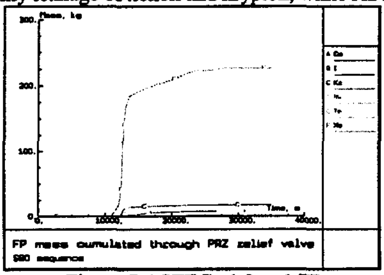

Figure 7 ASTEC v1.2rev1 FP mass cumulated through PRZ relief valve

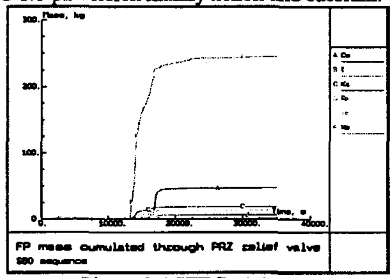

Figure 8 ASTEC v1.1-p2 FP mass cumulated through PRZ relief valve

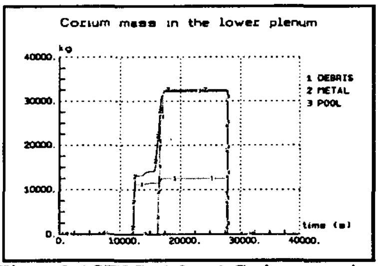

Figure 9 ASTEC v1.2rev1 Corium mass in Lower Plenum

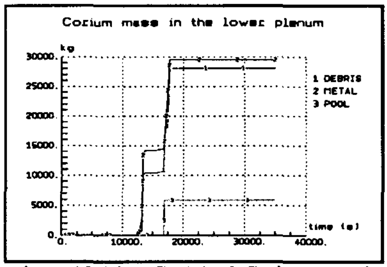

Figure 10 ASTEC v1.1-p2 Corium mass in Lower Plenum

Conclusion

This analysis for Station Blackout sequence with PRZ Relief Valves (SEMPELL) stuck open and without hydroaccumulators intervention performed with different ASTEC code versions (ASTEC V1.2 rev1 & ASTEC V1.1 p2) shows evolutions of the calculation of the update new version with respect to ASTEC V1.1 p2. Main progress concerns the code source modification for core degradations models. This is one of the requirements for sufficient validation of ASTEC code to predict and cover the main physical phenomena during a NPP severe accident sequence.

References

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[2] ASTEC-V1/DOC/02-04, Description of thermal hydraulic models of DIVA Technical note RSN/DRS/SEMAR 02/31 S. Pignet

[3] ASTEC-V1/DOC/04-12, Modeling of the lower plenum in DIVA module Technical note IRSN/DPAM/SEMCA2004/23G. Guillard

[4] Input deck for VVER 1000, Released CD, June 2004

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