**ENERGY FORUM 2006**

**VVER 1000 Station Blackout Sequence Calculations by the Computer Code ASTEC**

Пресмятане на събитие пълно обезточване за реактор ВВЕР 1000 с помощта на компютърния код ASTEC

Polina Tusheva\(^1\)\(^2\), Boris Kalchev\(^2\), Dimitar Dimov\(^2\),
Jordanka Georgieva\(^3\), Pavlin Groudev\(^3\), Antoaneta Stefanova\(^3\),
Roberto Passalacqua\(^4\)

1- Technical University of Sofia- PhD Student, 2- Energy Institute JSC, Sofia, Bulgaria
3- Bulgarian Academy of Sciences, Sofia, Bulgaria
4- PhD fellow of the University of Pisa, Pisa, Italy

В този доклад се представля оценката на компютърния код ASTEC v1.2rl като се разглежда съмълниране на събитие пълно обезточване. Анализът е направен за реактори тип ВВЕР1000/В320. Направен е сравнителен анализ на получените резултати с референтен компютърния код за тежки аварии- MELCOR 1.8.5. Изследването е направено в рамките на проект SARNET (по 6-та Рамкова програма Euratom).

**Summary**

This paper deals with an assessment of ASTEC v1.2rl code in the simulation of station blackout sequence. The reference power plant for this analysis is a VVER-1000/V320 (e.g. Units 5&6 at Kozloduy NPP). A comparative analyses with MELCOR 1.8.5 severe accident code will be discussed.

This investigation has been performed in the framework of the SARNET project (under the Euratom 6th framework program) by the FoBA Us group (Forum of Bulgarian ASTEC users). The ASTEC v1.2rl code version here used is the one released in December 2005 by the French IRSN (Institut de Radioprotection et de Sécurité Nucléaire) and the German GRS (Gesellschaft für Anlagen- und Reaktorsicherheit mbH).

**Introduction**

The reference power plant for this analysis is the VVER 1000 of Units 5 and 6 of the Kozloduy NPP. This plant is a VVER 1000 Model V320 pressurized water reactor with 3000MW thermal power and 1000MW electric power.

The VVER 1000/V320 consists of four primary coolant loops, each including one main coolant pump and a horizontal steam generator. The behaviour of horizontal steam generators is very different in comparison to western types which are vertical SGs. The Steam Generators have a very important role for safety and reliability of VVER nuclear power plants. The steam generators are fed 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 conditions.

A reference input file, reviewed and approved by the ASTEC maintenance team in CEA, for VVER-1000/V320 plants, has been used as a basis for the ASTEC calculations here performed. The input file developed for SBO sequences includes the ASTEC v1.2 modules CESAR, DIVA and CPA.

**Initial conditions**

In the table below (Table 1) are shown the initial plant conditions, modelled both in ASTEC and MELCOR.
Parameters | Design Value | ASTEC v1.2 Value | MELCOR 1.8.5 Value  
--- | --- | --- | ---  
Core power, MW | 3000 | 3000 | 3000  
Primary pressure, MPa | 15.7 | 15.7 | 15.64  
Average coolant temperature at reactor outlet, °C | 320.15 | 320.55 | 320.4  
Maximum coolant temperature at reactor inlet, °C | 290.0 | 290.35 | 290.1  
Mass flow rate through one loop, kg/s | 4400.0 | 4363.1 | 4406.0  
Pressure in SG, MPa | 6.27 | 6.418 | 6.31  
Pressure in MSH, MPa | 6.08 | 6.38 | 6.13  
SEMPPELL1 opening pressure, MPa | 18.11 | 18.11 | 18.11  
SEMPPELL1 closing pressure, MPa | 16.67 | - | -  
SEMPPELL2,3 opening pressure, MPa | 18.6 | 18.6 | 18.6  
SEMPPELL2,3 closing pressure, MPa | 17.07 | - | -  
Steam mass flow rate through SG, kg/s | 408 | 409.6 | 406  

Table 1 Initial plant conditions

Boundary conditions

The analyses have been performed assuming a station blackout with simultaneous loss of HPIS, LPIS (ECCSs) and EFWS. In addition, immediately after the initiating event, the main circulation pumps are assumed to stop. The main assumptions of the sequence are listed below:
1/ 0s- station blackout, reactor scram, stop of pumps;
2/ 0s- turbine isolation;
3/ 0s- loss of FWSGs (feed water to steam generators);
4/ spray system and hydroaccumulators are not available.
It should be said that this investigation is limited to the “in-vessel” phase of the sequence; therefore the effect of sprays on containment atmosphere has not been studied.

Results and discussion

The VVER-1000 reference input file, reviewed and approved by the ASTEC maintenance team during a mission of the FOBAUs Group to Cadarache on September 2005, has been modified in order to model a Station Blackout (SBO) scenario. For example, the modelling of the pressurizer relief valves (SEMPPELL), and their connections to the containment, has been added in order to model the primary system depressurization (in this calculation only the modelling of stuck-open PRZ valves will be discussed). The DIVA module is assumed to start when either the void fraction in the core vessel or the fuel temperature reach a threshold value.
The SBO calculations have been performed with the new ASTEC v1.2 version of the integral severe accident code ASTEC. The results have been compared to the reference computer code MELCOR 1.8.5.
The ASTEC v1.2 calculation for a SBO sequence has been performed for a total “problem time” of 8.3 hrs (about 30000 s) therefore it focuses only on the “in-vessel phase” of the accident (up to the lower-head vessel failure which occurs at 24121 s).

| No | Event | ASTEC v1.2 Time, s | MELCOR 1.8.5 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  

67
The comparison of main events, from the table above, shows that the new ASTEC v1.2 version predicts an earlier core degradation with a first total core uncovery (and consequent vessel failure) roughly occurring about one hour earlier than in MELCOR 1.8.5.

In figures below ASTEC v1.2 predictions are compared to MELCOR trends (Figures 1 to 10). After the accident-initiating event, the main pumps stop and the decay heat is removed from the core because of natural recirculation. Heat is transferred to the secondary side and removed via "steam dump" to the atmosphere. The secondary side feedwater also stops, therefore the secondary side water inventory is continuously decreasing and when the secondary side heat sink is depleted (at about 5000 s for ASTEC) 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).

At the onset of the accident the primary pressure essentially decreases because of the decreasing of the decay heat. ASTEC and MELCOR show a very similar behaviour (figures 1 and 2). 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. It must be noticed that the mass flow rate through the PRZ valves is much larger in the ASTEC calculations because of the essentially single-phase (liquid) flow rate (compare figures 5 and 6) through the PRZ valves. Figures 9 and 10 show the total hydrogen mass released during core degradation. ASTEC predicts a lower release of hydrogen (~325kg) whilst MELCOR a larger one (~460kg).

| 6 | Start of DIVA module | 9502.0 | - |
| 7 | Beginning of oxidation | 9503.0 | 11655.0 |
| 8 | First total core uncovery | 10125.1 | 13580.0 |
| 9 | Start of FP release from fuel pallets | 11118.0 | 12640.0 |
| 10 | First corium slump | 11812.0 | 14180.0 |
| 11 | Lower head vessel failure | 24121.0 | 27800.0 |

Table 2 Main events
Conclusion

Station Blackout with fully open PRZ relief valves without any active and passive safety system (e.g. hydroaccumulators) have been investigated in a severe accident scenario for a VVER-1000 with the ASTEC v1.2 code. ASTEC predictions have been studied for the in-vessel phase of the accident and compared to those of MELCOR. As a whole the results predicted by ASTEC and MELCOR are coherent. ASTEC and MELCOR codes exhibit the larger differences in the core degradation predictions. ASTEC predicts faster (than in MELCOR) core degradation.

For future calculations on validation of ASTEC code the SBO sequence will be extended to the ex-vessel phase of the accident.

References

[1] SBLOCA ASTEC Calculations for VVERs 1000 & (30&40mm-SBLOCAs) Comparison with MELCOR First Progress meeting of the ASTEC Topic 21-24 February 2005, Kohn (GIRS), FoBAUs Group
[2] ASTEC-V1/DOC/02-04, Description of thermal hydraulic models of DIVA Technical note RSN/DRS/SEMAR 02/31 S. Pigne