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GENERIC BOILING WATER REACTOR (BWR) SIMULATION MODEL IN APROS 6 - TEST SIMULATIONS

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1 INTRODUCTION

This document consists of the results of five test cases simulated with a generic BWR Apros simulation model. The model is described in report "Generic Boiling Water Reactor (BWR) Simulation Model in Apros 6", FNS-382515. The test cases were used to ensure the functionality of the model. The results can be further used as a baseline for comparison with new simulation results if some modifications are made to the model.

The test cases are presented in the second chapter and the test results in the third chapter. The simulation queues for all the test cases are included in the generic BWR model package. Software version Apros 6 Nuclear 6.03.23 was used in the test simulations (solver: AprosNuclearCont3D, compatible with: 5.11.08).

2 TEST CASES

Five different transients were simulated as test cases. The test cases were:

1. Manual reactor scram
2. Closing of steam line valves
3. Steam line break
4. Feed water line break
5. Reactor power decrease to 90 %

The test cases are described below.

2.1 Manual reactor scram

In the beginning of the transient a steady state initial condition is loaded. After 10 seconds the simulation time step is decreased to 5 ms and manual reactor scram is initiated. After 20 s of transient simulation the simulation time step is increased to 10 ms. Total simulation time is 100 s.

Manual reactor scram is initiated by signal 516SS1SIGN. This leads to normal scram operations of e.g. running down the main circulation pumps and moving the control/scram rods into the core. Turbine trip is triggered automatically 10 s after the scram.

The simulation queue for this case is:

```
load_ic Initial Condition 0
modi OUTPUT1_IS01 IO_FILE_NAME reactor_scram.dat
do 10
set sicudt 0.005
set simadt 0.005
modi 516SS1SIGN VALUE T
do 20
set simadt 0.01
do 70
```

2.2 Closing of steam line valves

In the beginning of the transient a steady state initial condition is loaded. After 10 seconds the simulation time step is decreased to 5 ms and the closing of the steam line valves is initiated. After 20 s of transient simulation the simulation time step is increased to 10 ms. Total simulation time is 100 s.

The closing signal of the steam line valves 311VCLMANS closes the main steam line inner and outer isolation valves 311V1-V4 and 311V5-V8. This causes a significant increase in the reactor pressure and power which leads to reactor scram.

The simulation queue for this case is:

```
load_ic Initial Condition 0
modi OUTPUT1_IS01 IO_FILE_NAME steam_valves_close.dat
```

```
do 10
set sicudt 0.005
set simadt 0.005
modi 311VCLMANS VALUE T
do 20
set simadt 0.01
do 70
```

2.3 Steam line break

In the beginning of the transient a steady state initial condition is loaded. After 10 seconds the simulation time step is decreased to 5 ms and a steam line break is initiated. After 20 s of transient simulation the simulation time step is increased to 10 ms. Total simulation time is 100 s.

Steam line break signal 311BREAKOPENS initiates a guillotine break in the main steam line. Valves 311BRKVLV1 and 311BRKVLV2 are opened and valve 311BRKVLV0 between them is closed to separate the two ends of the ruptured pipeline. This transient leads to reactor scram by reactor containment supervisory signal 516-I.

The simulation queue for this case is:

```
load_ic Initial Condition 0
modi OUTPUT1_IS01 IO_FILE_NAME steam_line_break.dat
do 10
set sicudt 0.005
set simadt 0.005
modi 311BREAKOPENS VALUE T
do 20
set simadt 0.01
do 70
```

2.4 Feed water line break

In the beginning of the transient a steady state initial condition is loaded. After 10 seconds the simulation time step is decreased to 5 ms and a feed water line break is initiated. After 20 s of transient simulation the simulation time step is increased to 10 ms. Total simulation time is 100 s.

Feed water line break signal 445BRKOPENS opens break valve 445-BRKVLV. The break valve is located in the feed water line outside of the containment. Feed water line inner isolation valves 312V1 and 312V2 are closed by the break signal. The break leads also to reactor scram by feed water line rupture supervisory signal 516-M.

The simulation queue for this case is:

```
load_ic Initial Condition 0
modi OUTPUT1_IS01 IO_FILE_NAME feed_water_break.dat
do 10
set sicudt 0.005
set simadt 0.005
modi 445BRKOPENS VALUE T
```

```
do 20
set simadt 0.01
do 70
```

2.5 Reactor power decrease to 90 %

In the beginning of the transient a steady state initial condition is loaded. After 10 seconds the simulation time step is decreased to 10 ms and reactor power set point is set to 90 %. Total simulation time is 300 s.

Reactor power set point 535NFLUXSP is an input signal for 535 reactor power control system. The rotation speed of the main circulation pumps 313P1-P6 is decreased by the automation to reach the new power set point.

The simulation queue for this case is:

```
load_ic Initial Condition 0
modi OUTPUT1_IS01 IO_FILE_NAME reactor_power_decrease.dat
do 10
set sicudt 0.01
set simadt 0.01
modi 535NFLUXSP SP_VALUE 0.9
do 290
```

3 TEST RESULTS

3.1 Manual reactor scram

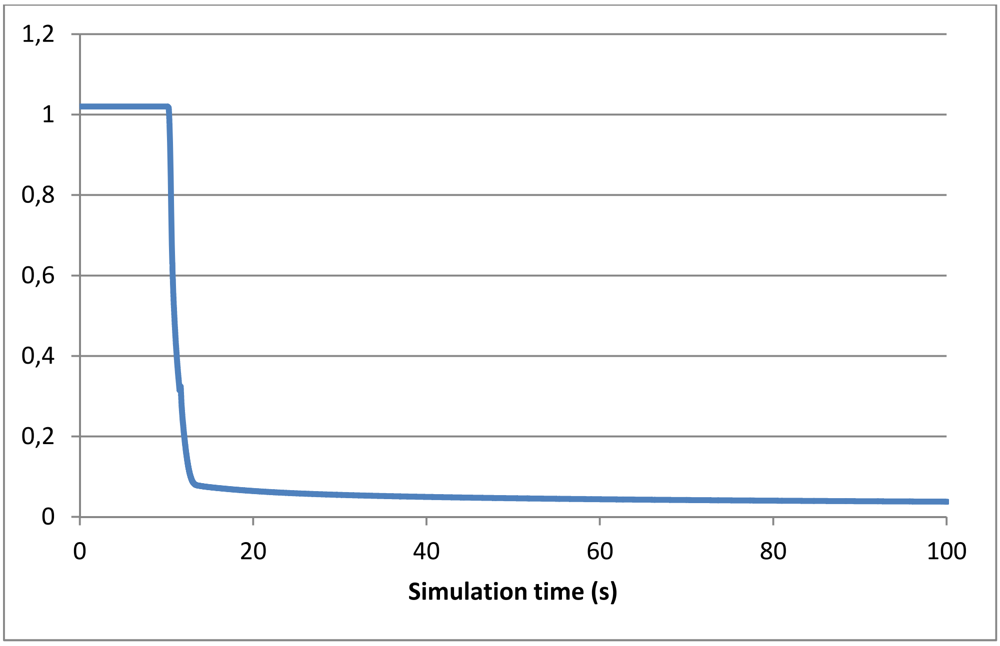

Figure 3.1-1. Reactor power (%).

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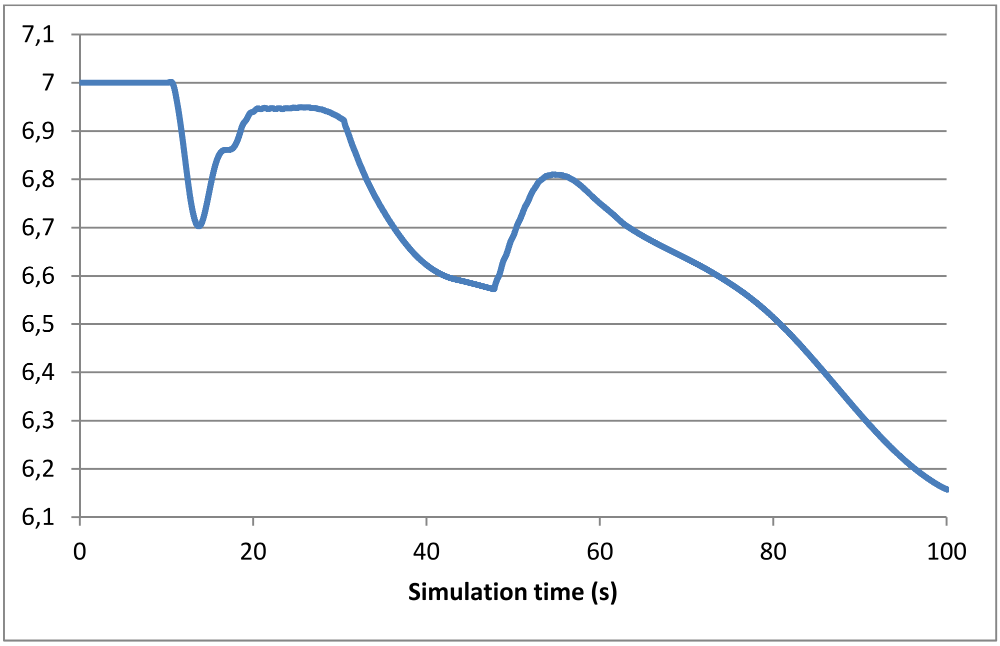

Figure 3.1-2. Reactor pressure vessel (RPV) steam dome pressure (MPa).

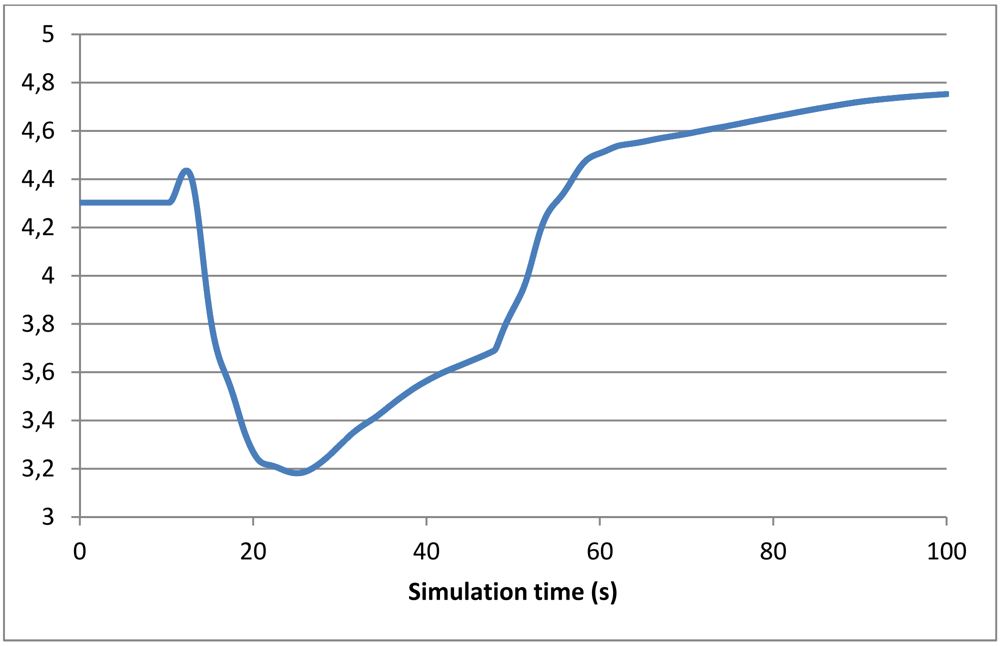

Figure 3.1-3. RPV fine collapsed level (m).

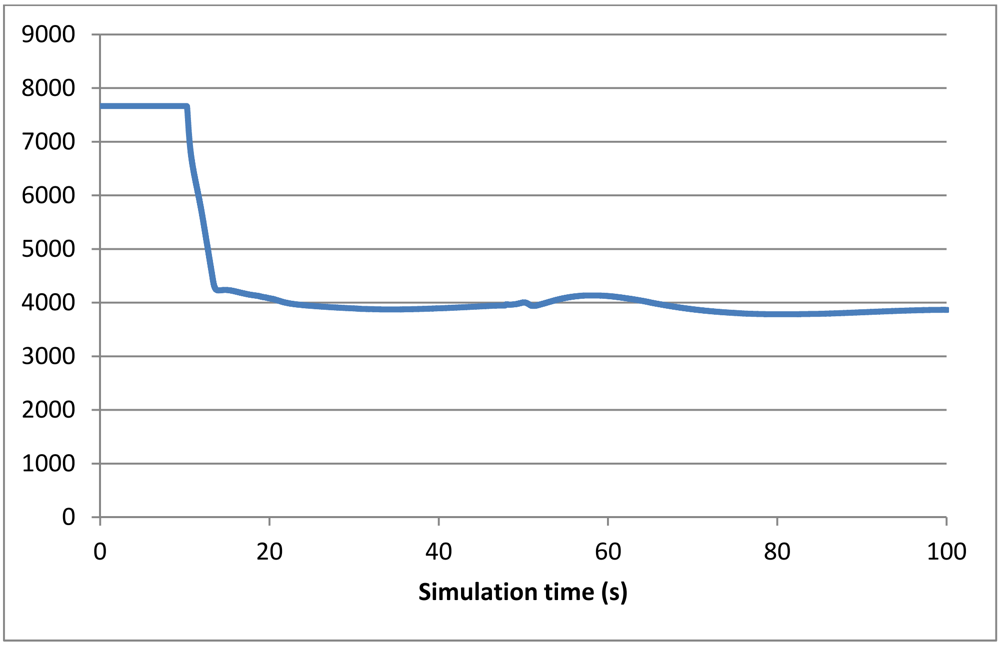

Figure 3.1-4. Main circulation flow (kg/s).

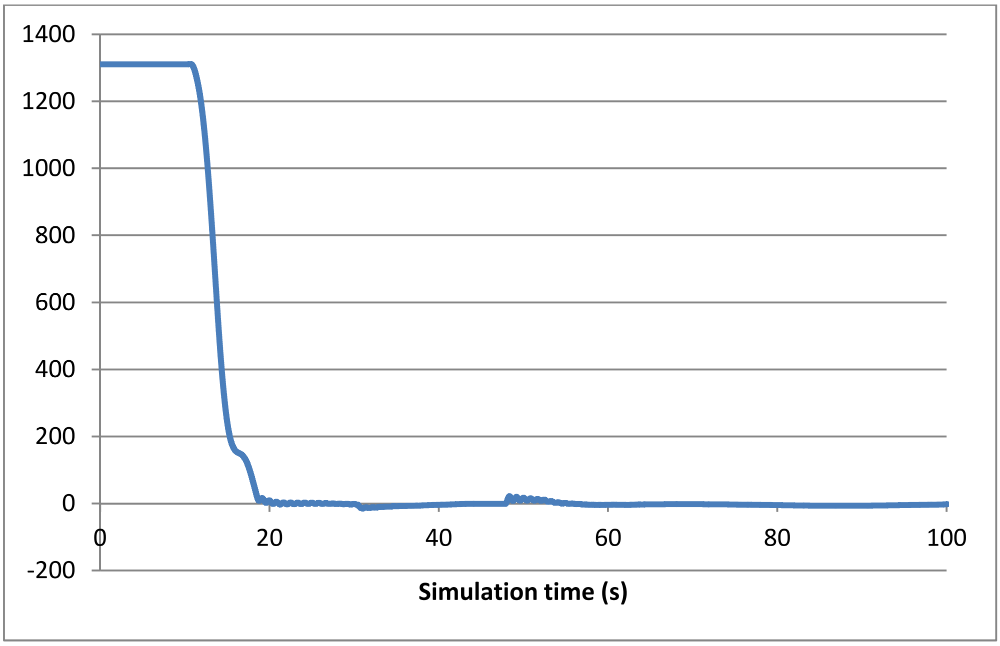

Figure 3.1-5. Main steam flow (kg/s).

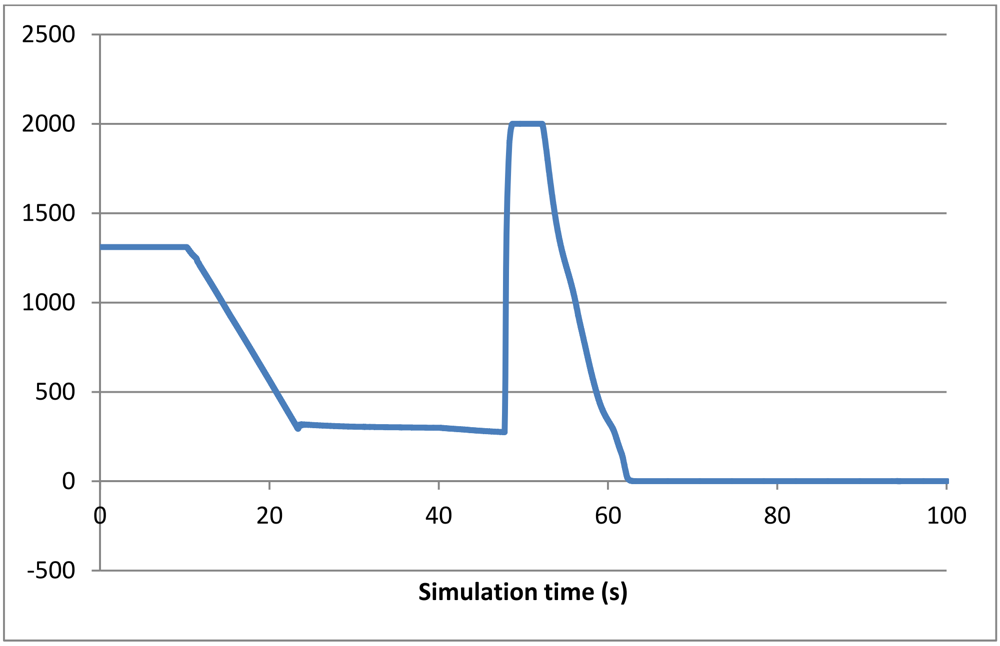

Figure 3.1-6. Feed water flow (kg/s).

3.2 Closing of steam line valves

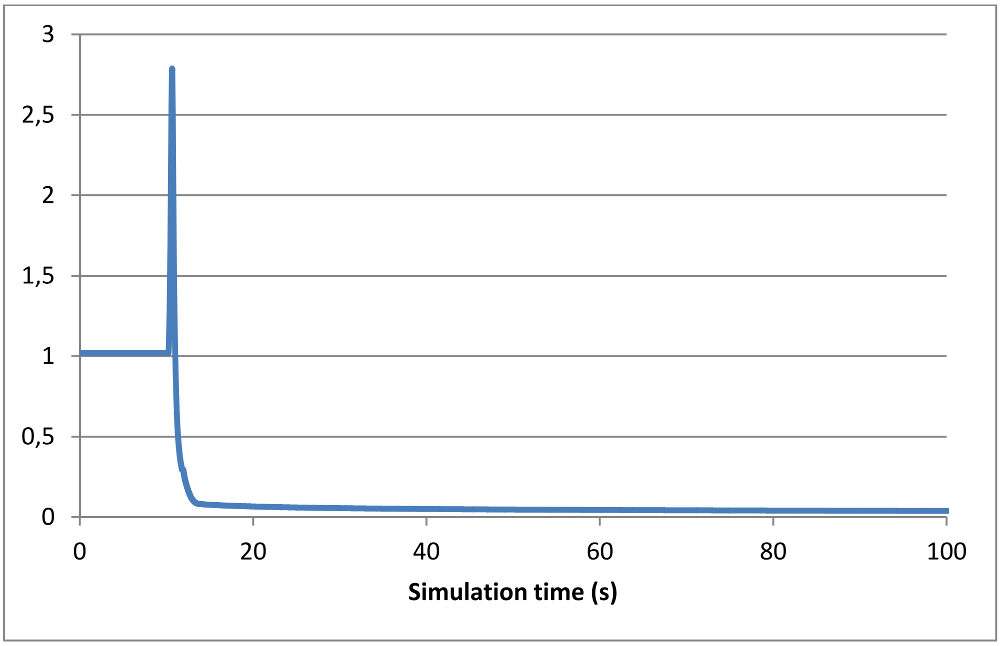

Figure 3.2-1. Reactor power (%).

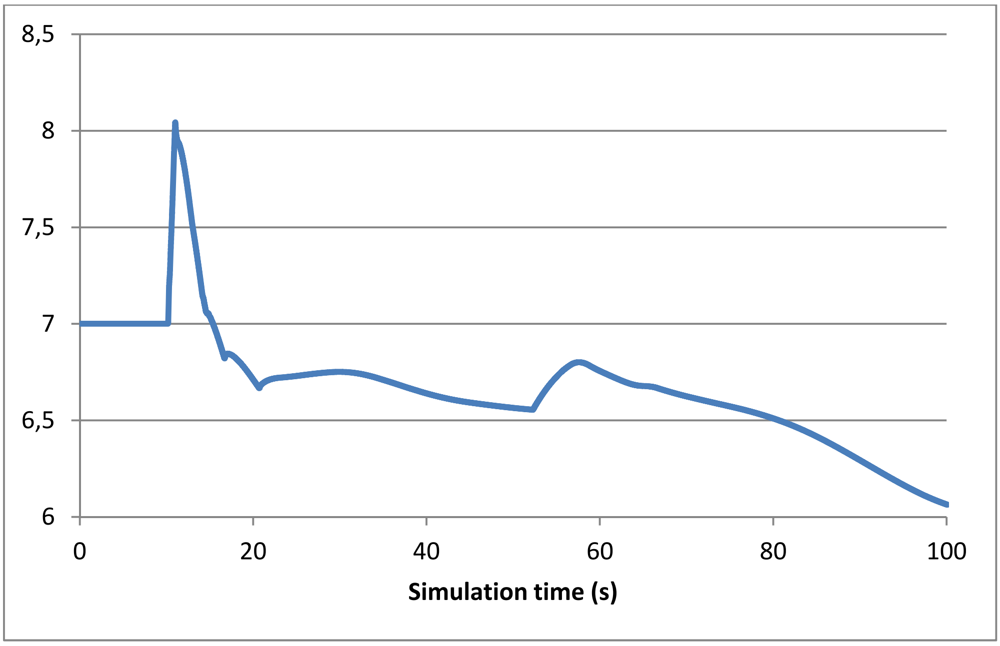

Figure 3.2-2. Reactor pressure vessel (RPV) steam dome pressure (MPa).

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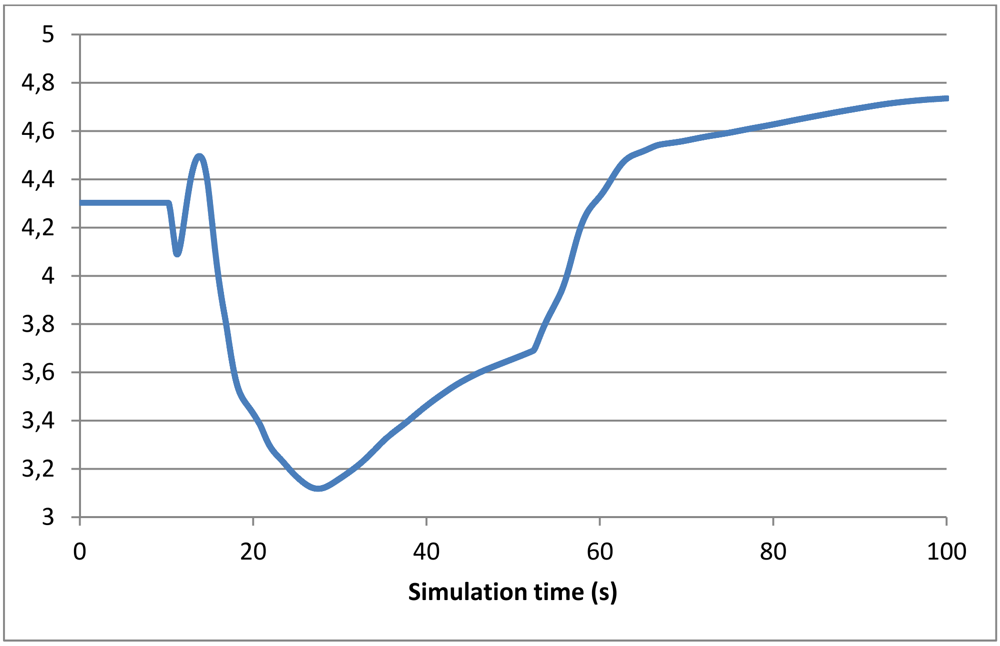

Figure 3.2-3. RPV fine collapsed level (m).

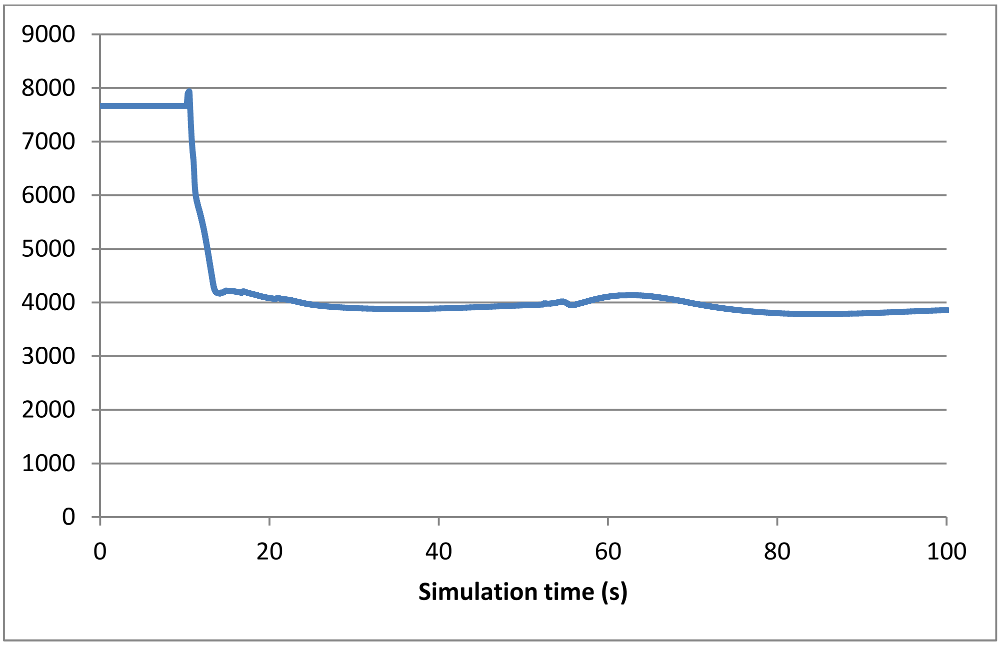

Figure 3.2-4. Main circulation flow (kg/s).

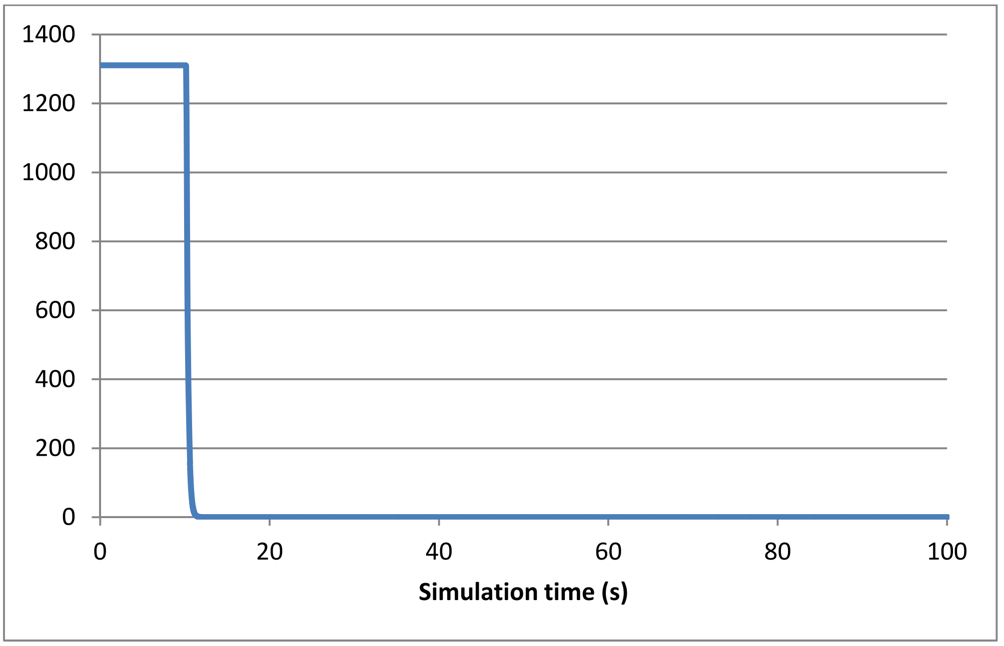

Figure 3.2-5. Main steam flow (kg/s).

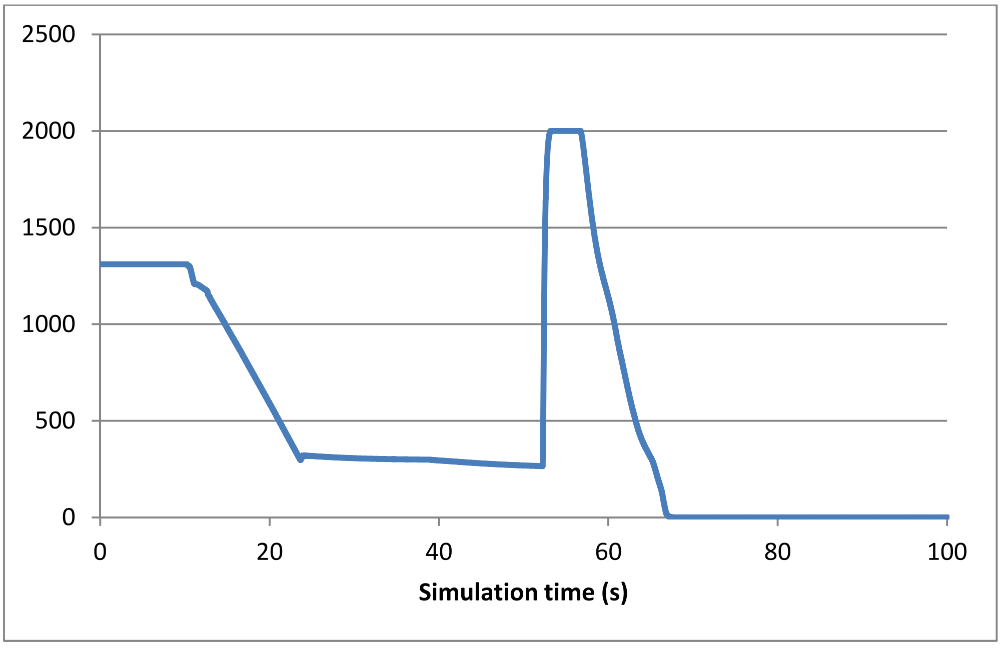

Figure 3.2-6. Feed water flow (kg/s).

3.3 Steam line break

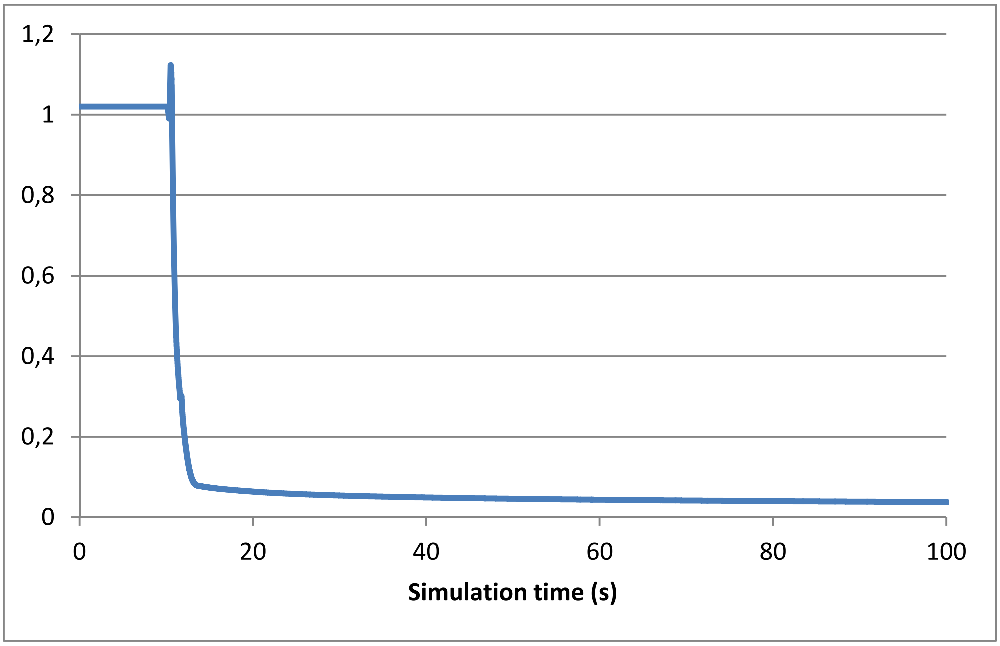

Figure 3.3-1. Reactor power (%).

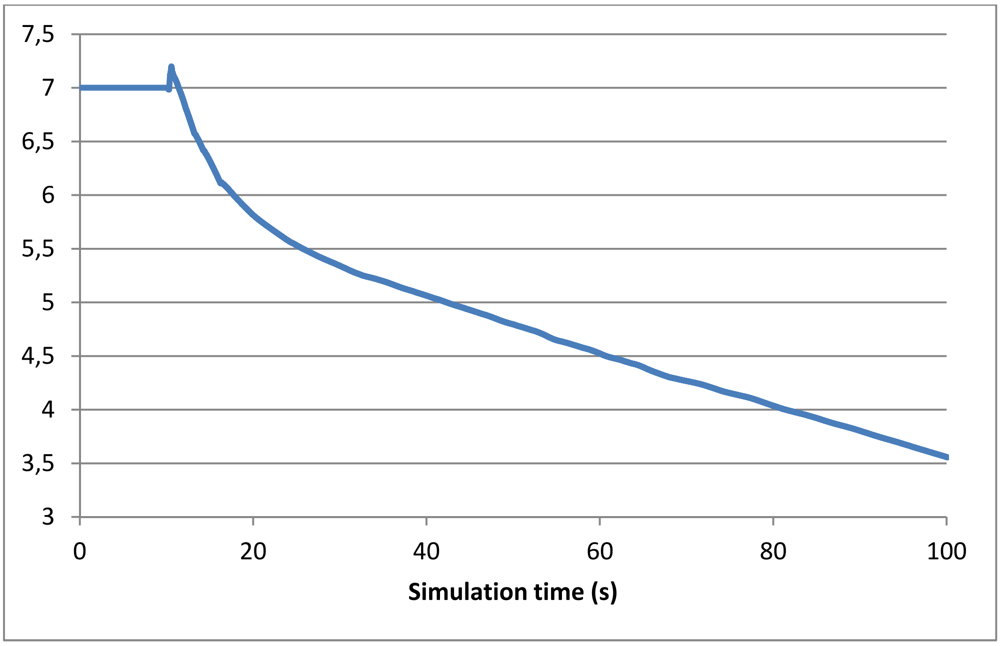

Figure 3.3-2. Reactor pressure vessel (RPV) steam dome pressure (MPa).

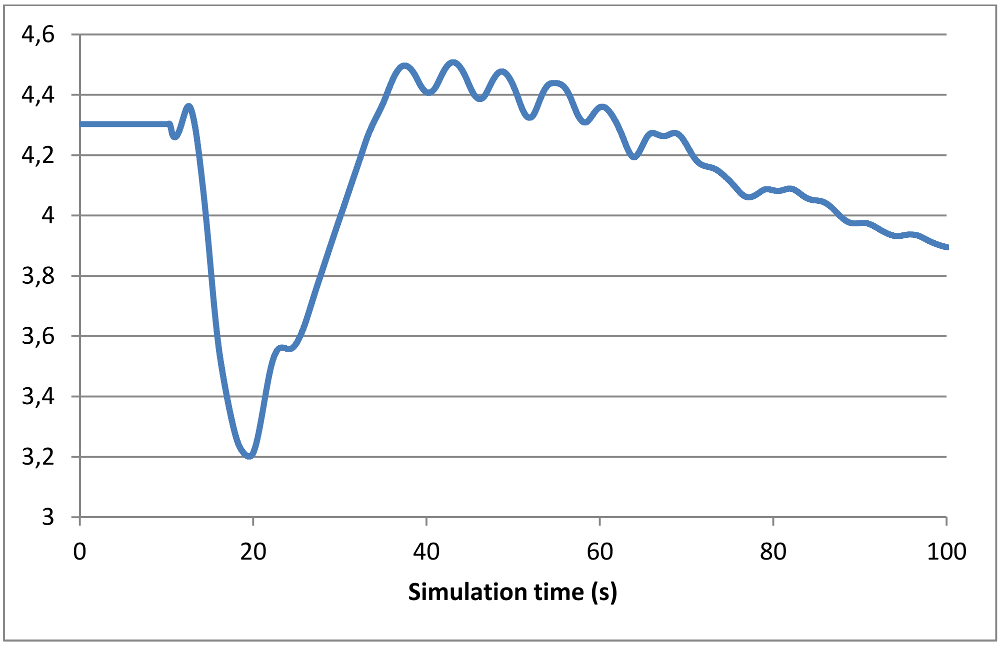

Figure 3.3-3. RPV fine collapsed level (m).

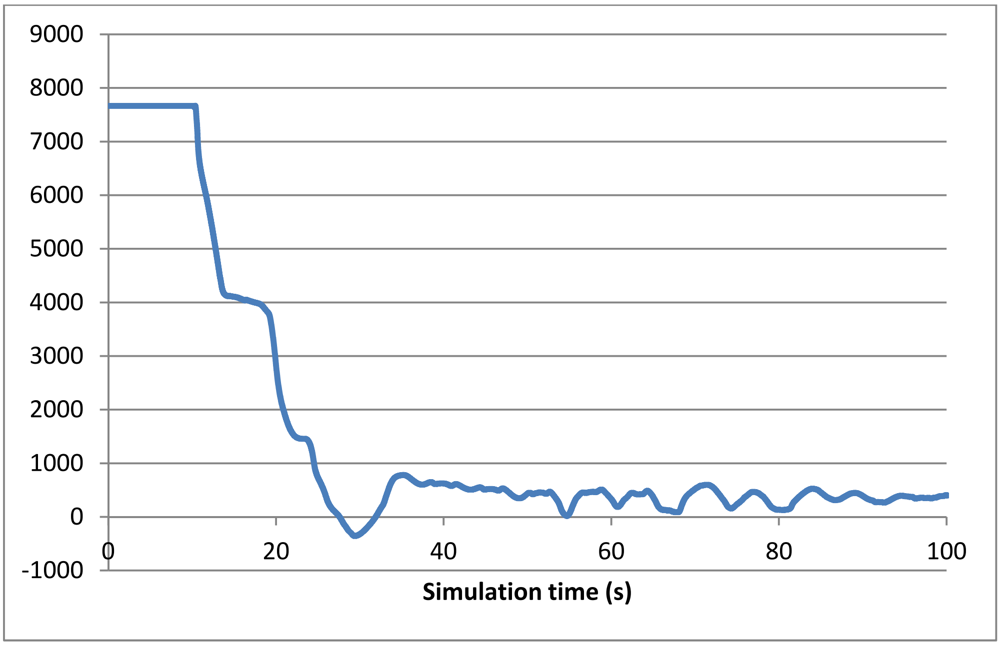

Figure 3.3-4. Main circulation flow (kg/s).

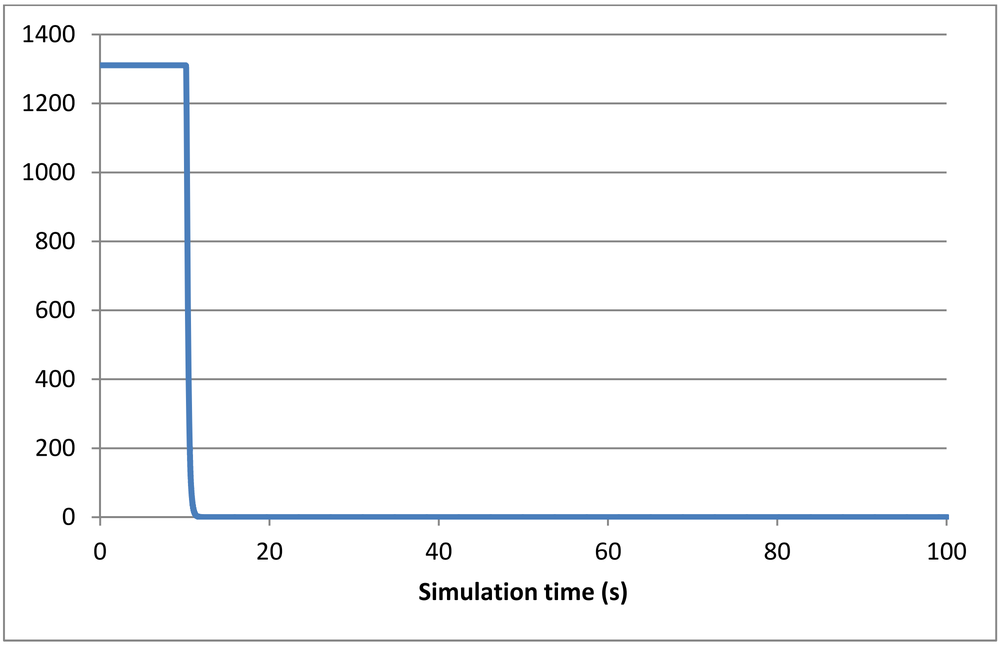

Figure 3.3-5. Main steam flow (kg/s).

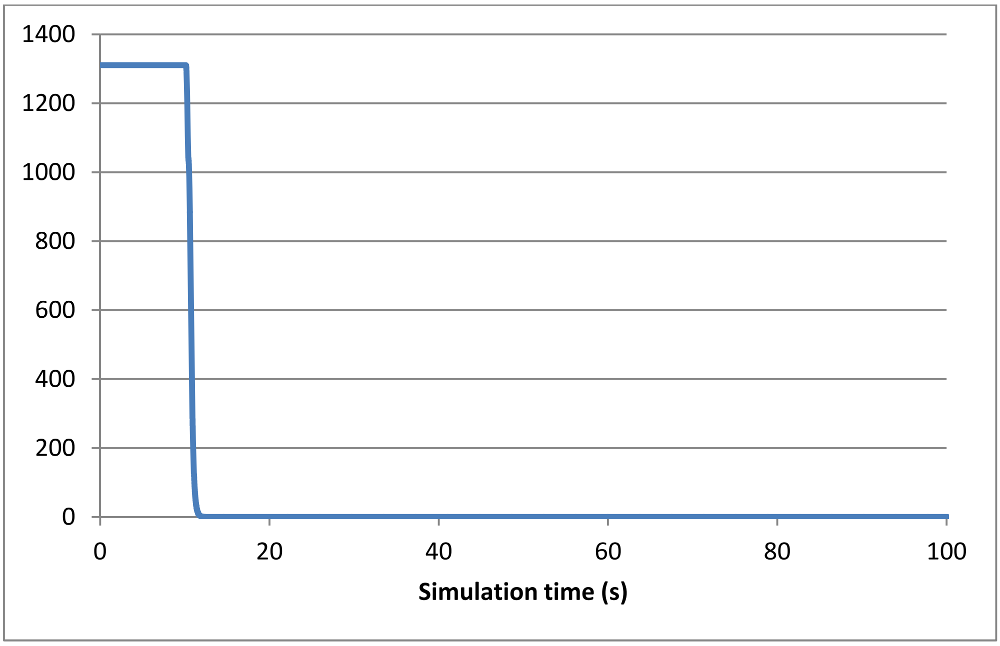

Figure 3.3-6. Feed water flow (kg/s).

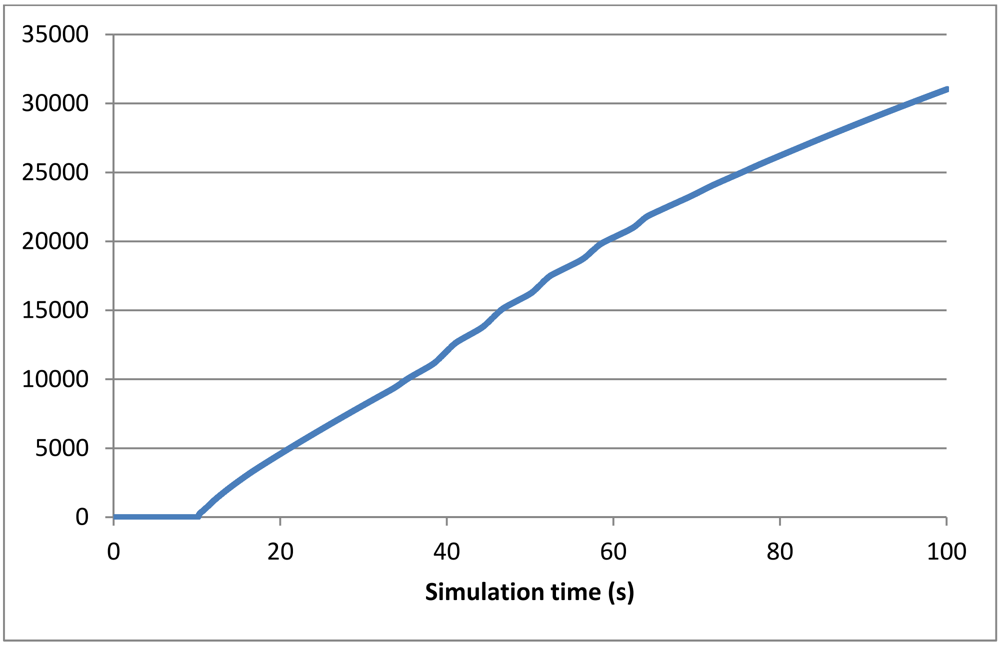

Figure 3.3-7. Integrated steam line break flow (kg).

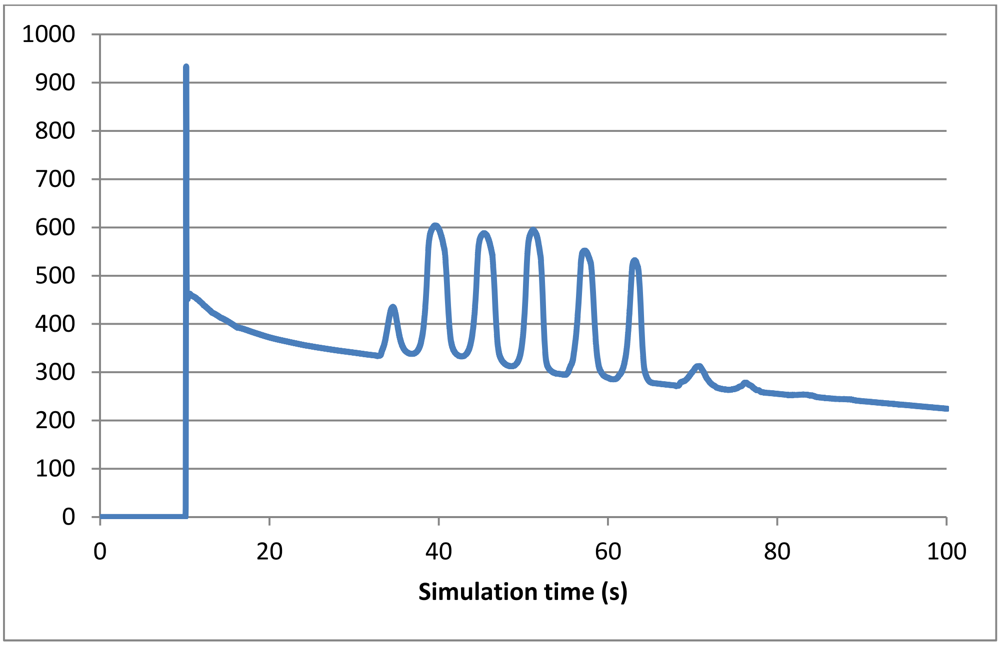

Figure 3.3-8. Primary steam line break flow (kg/s).

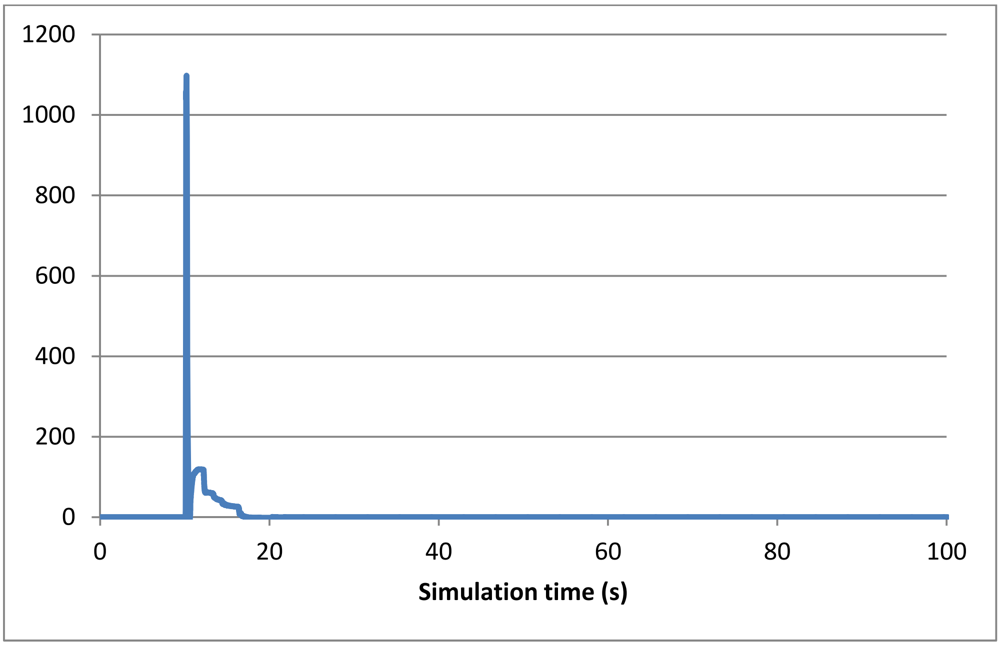

Figure 3.3-9. Secondary steam line break flow (kg/s).

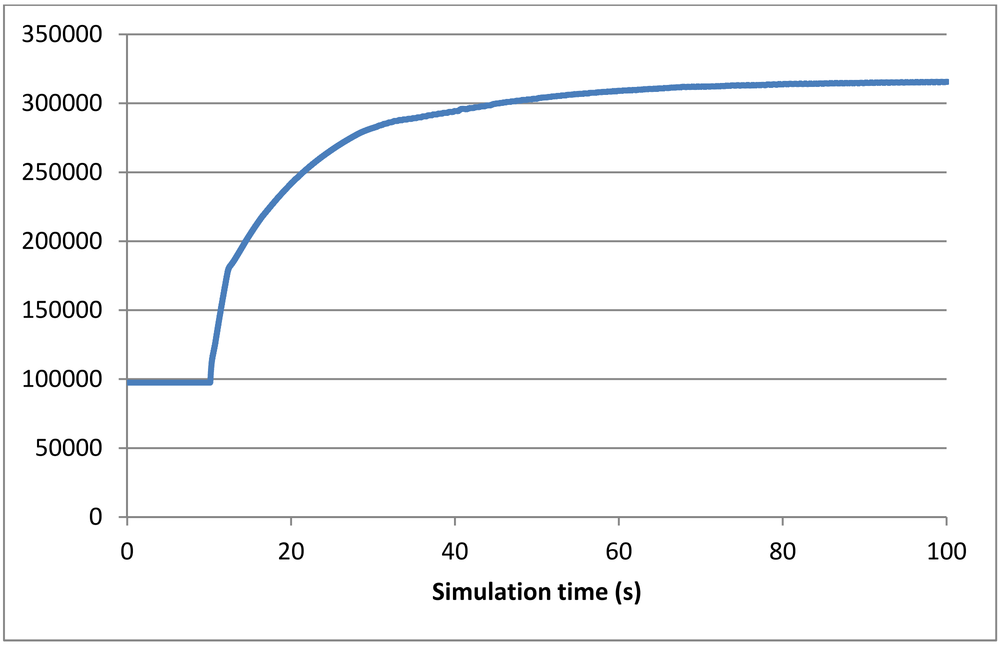

Figure 3.3-10. Containment drywell pressure (Pa).

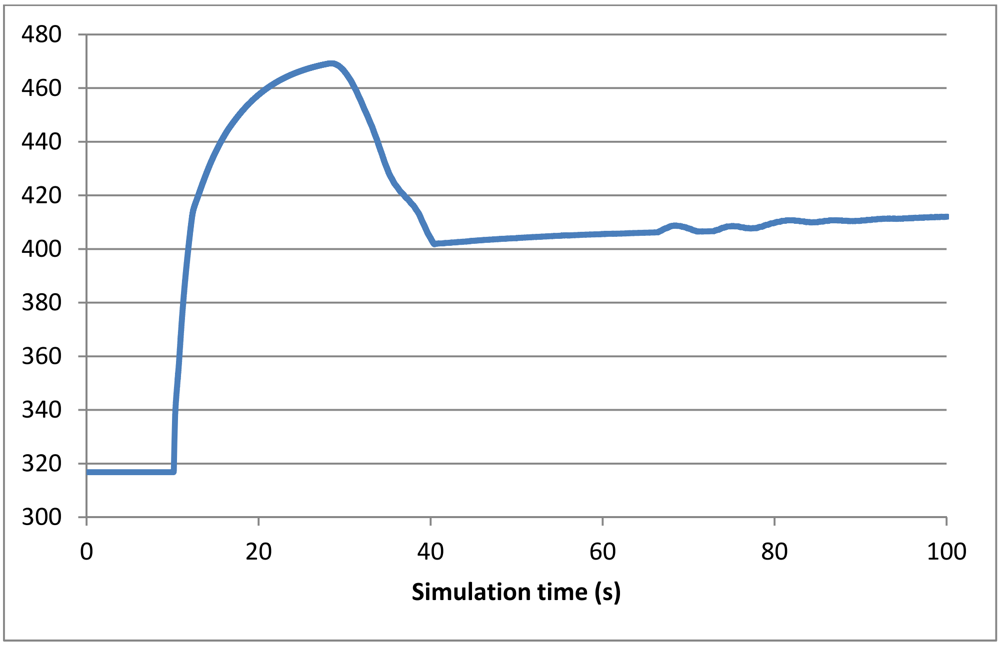

Figure 3.3-11. Gas temperature in the containment drywell (K).

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3.4 Feed water line break

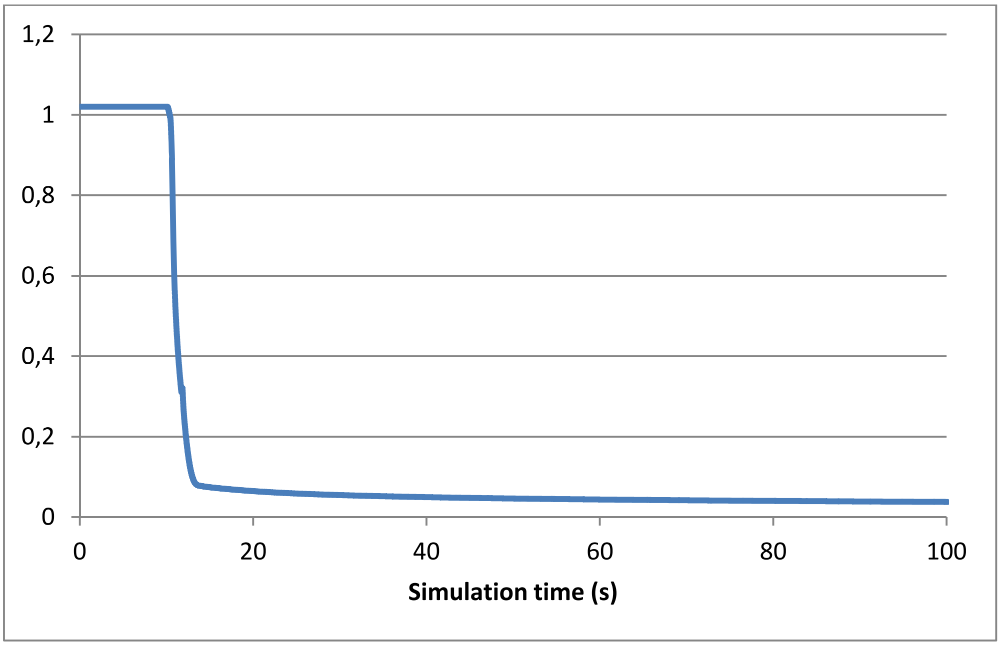

Figure 3.4-1. Reactor power (%).

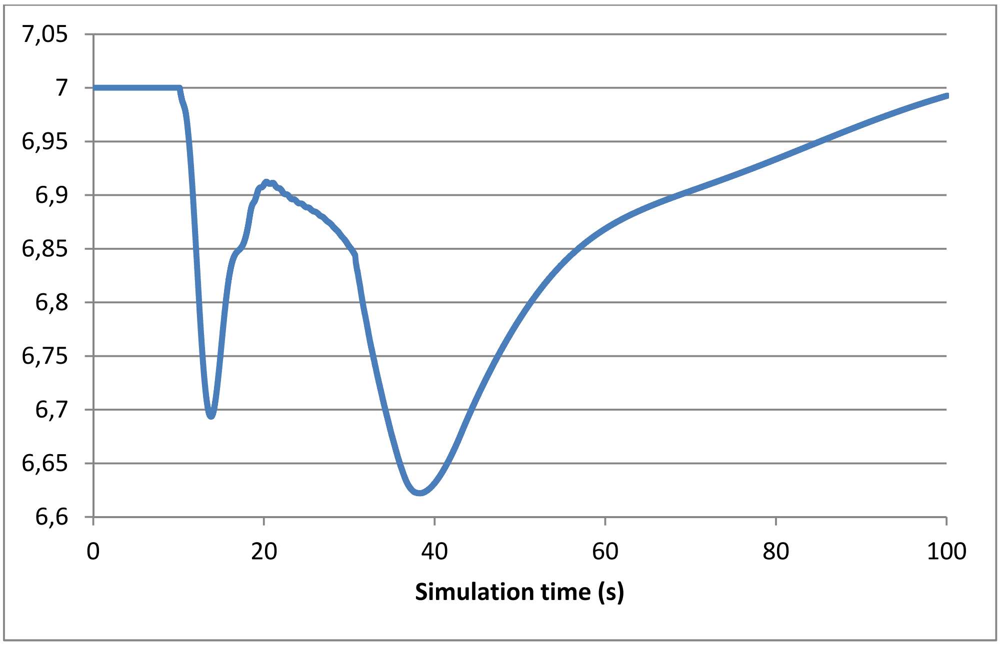

Figure 3.4-2. Reactor pressure vessel (RPV) steam dome pressure (MPa).

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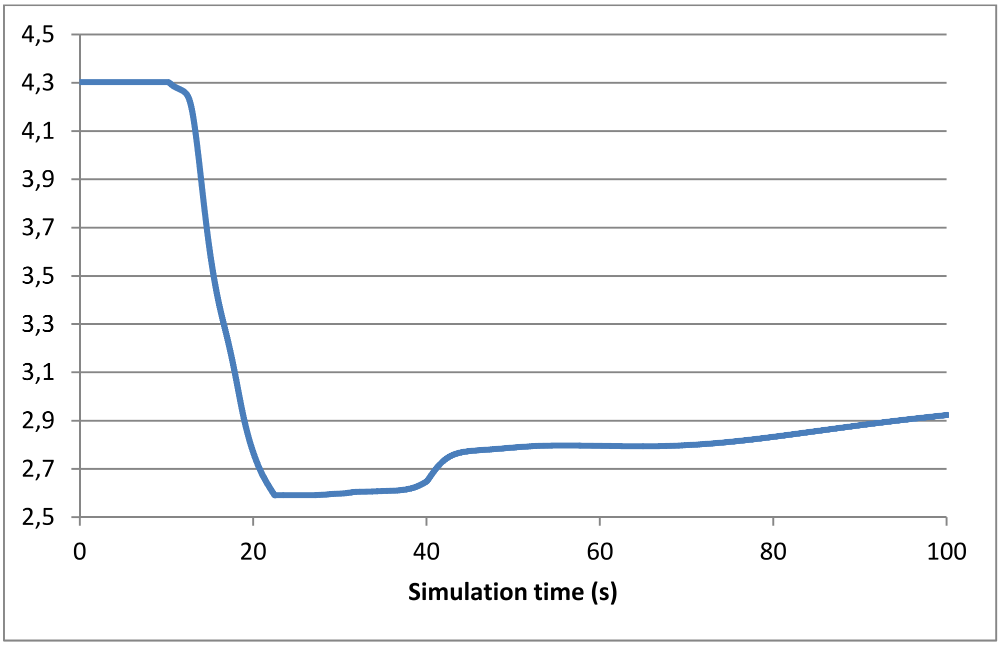

Figure 3.4-3. RPV fine collapsed level (m).

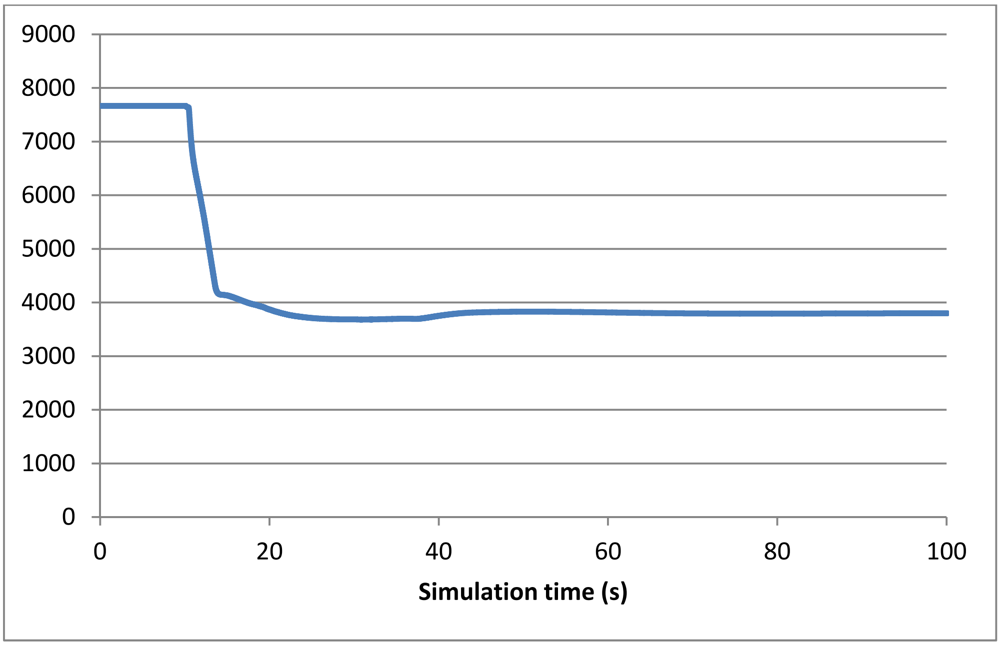

Figure 3.4-4. Main circulation flow (kg/s).

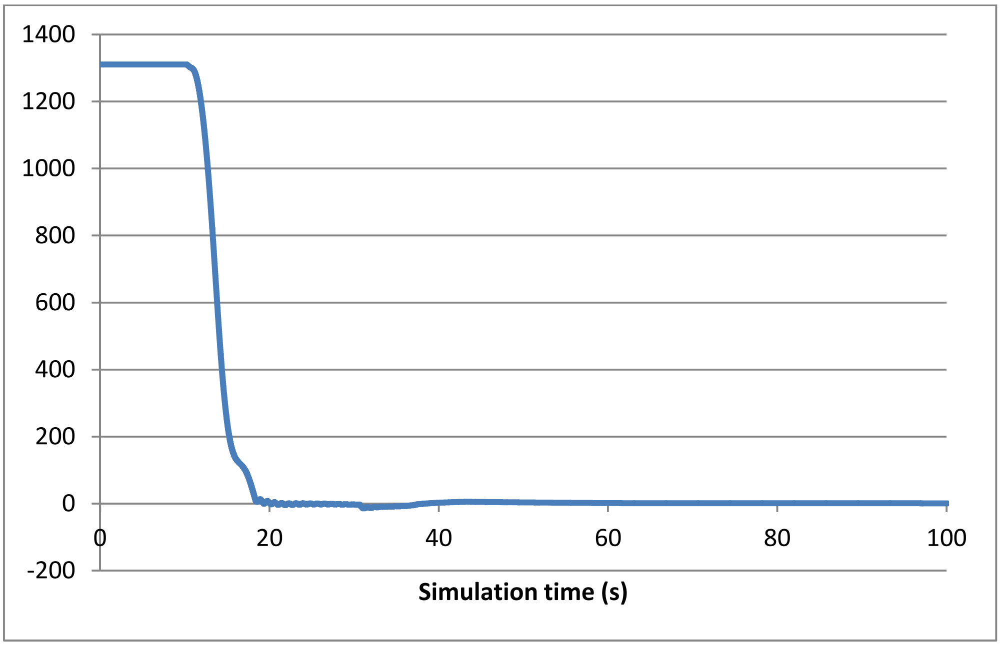

Figure 3.4-5. Main steam flow (kg/s).

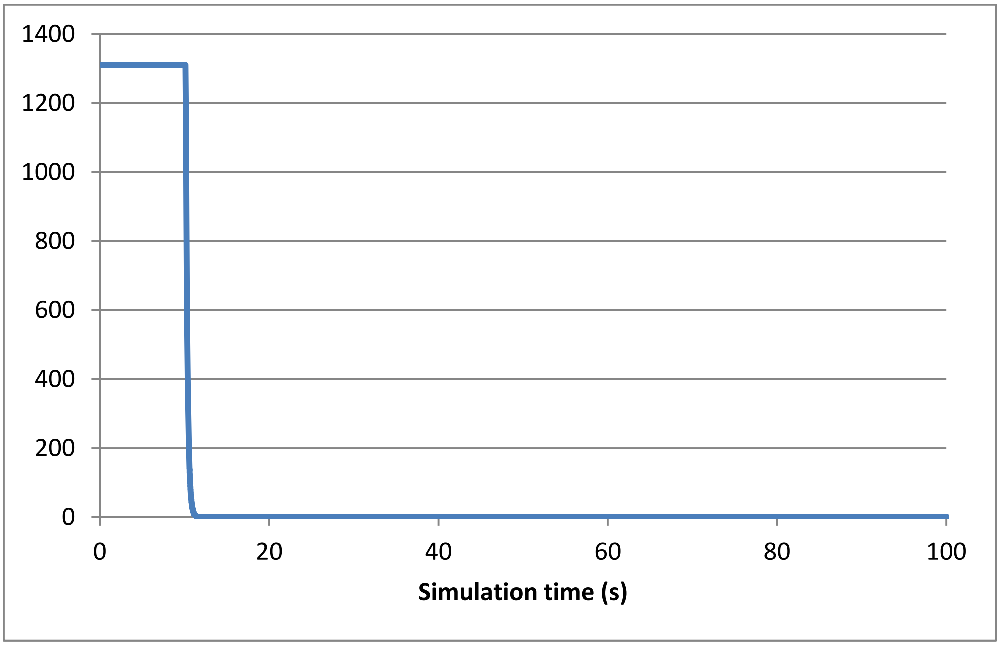

Figure 3.4-6. Feed water flow (kg/s).

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3.5 Reactor power decrease to 90 %

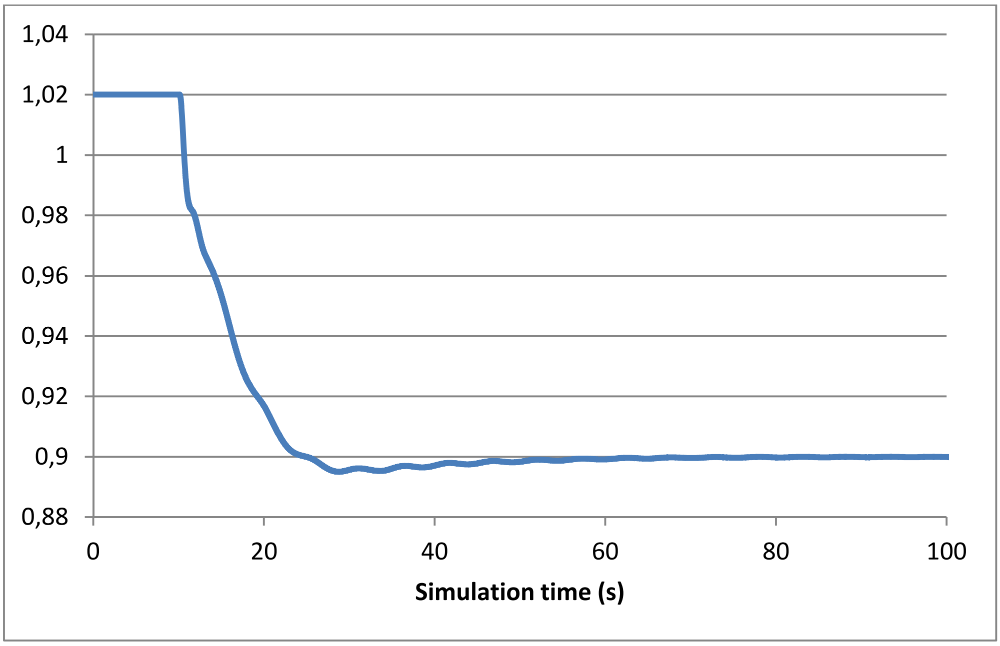

Figure 3.5-1. Reactor power (%).

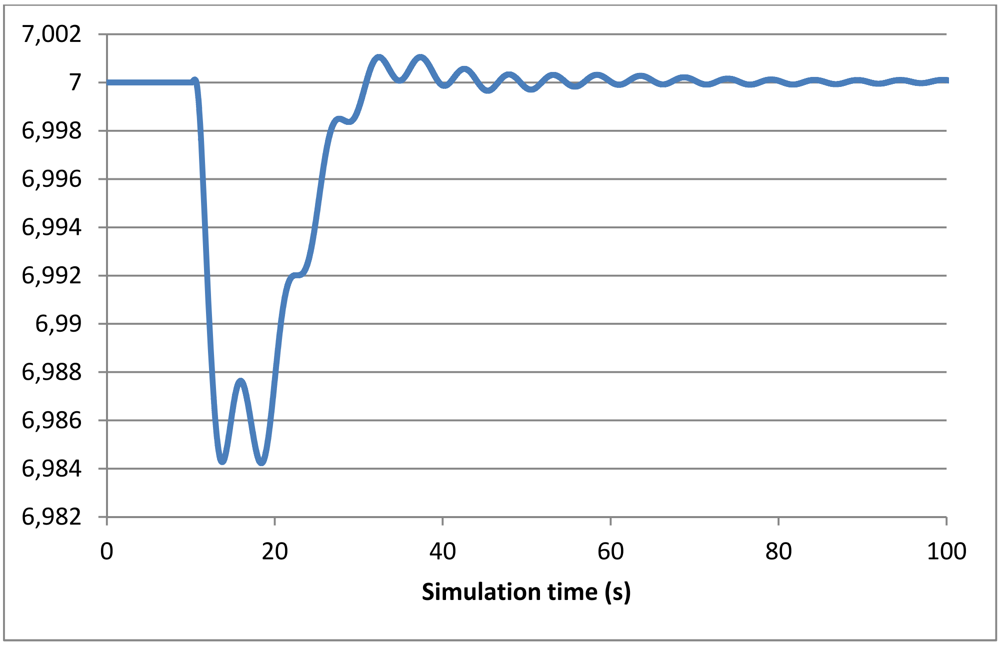

Figure 3.5-2. Reactor pressure vessel (RPV) steam dome pressure (MPa).

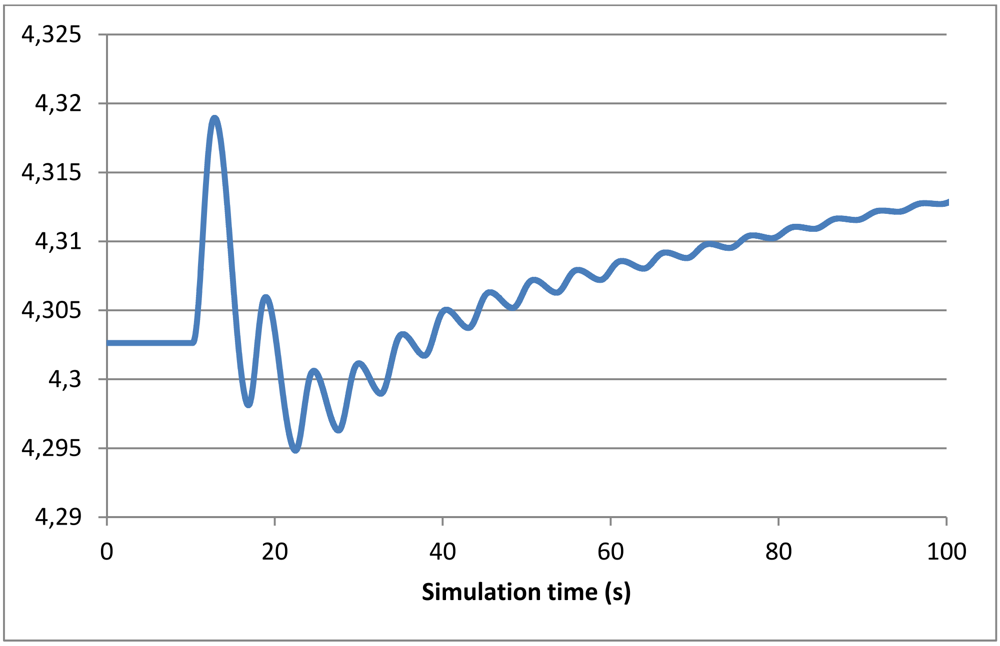

Figure 3.5-3. RPV fine collapsed level (m).

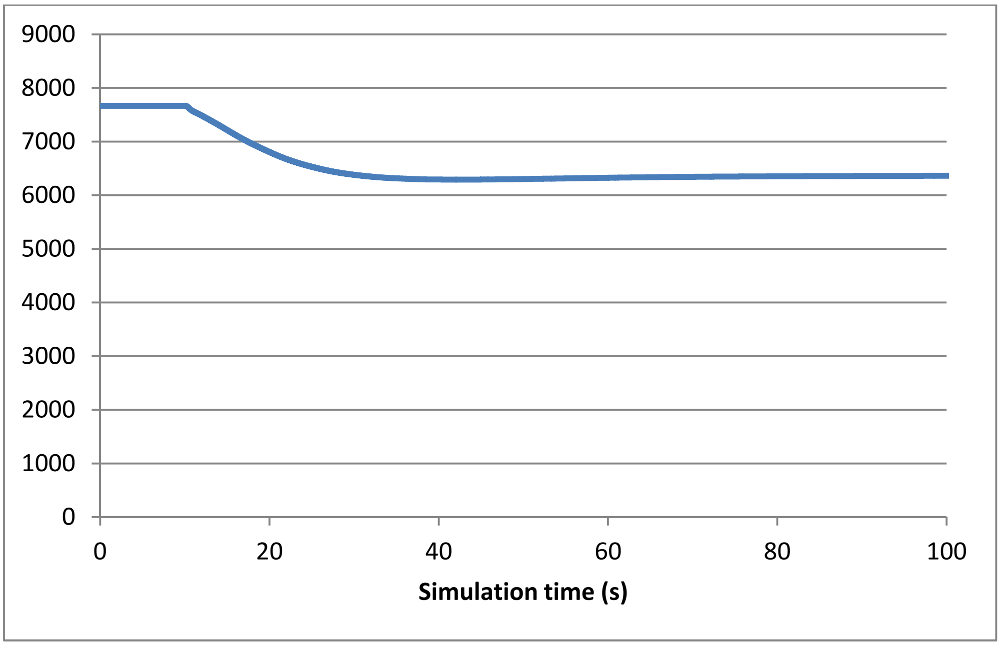

Figure 3.5-4. Main circulation flow (kg/s).

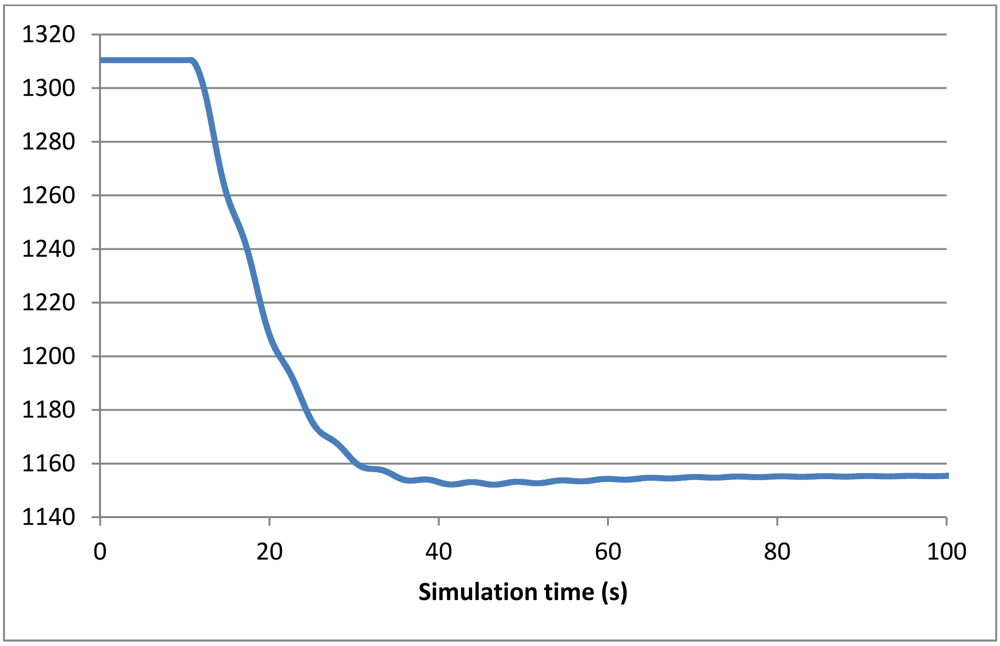

Figure 3.5-5. Main steam flow (kg/s).

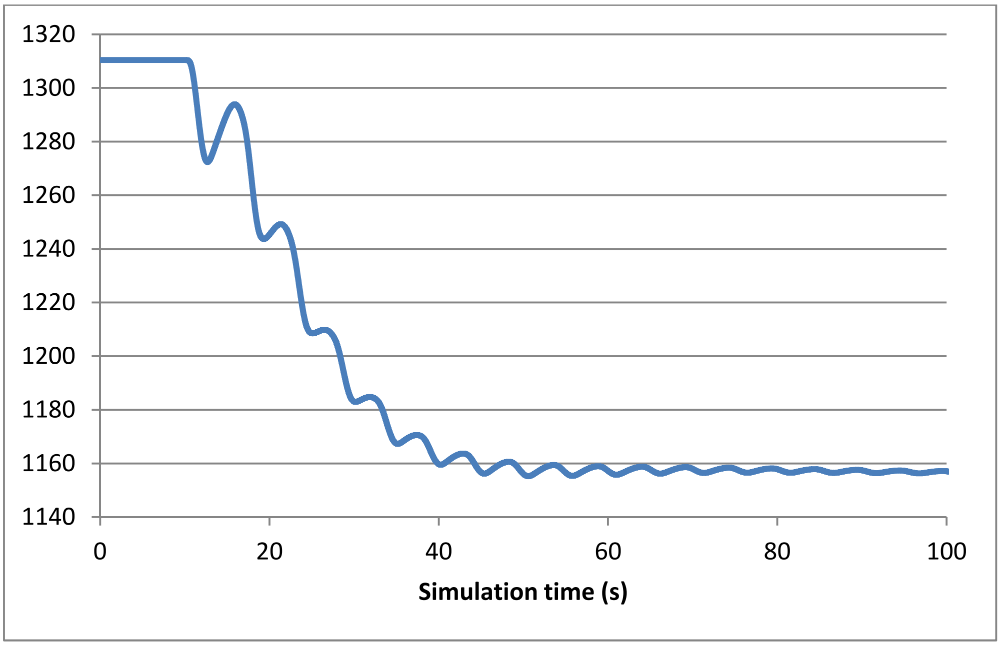

Figure 3.5-6. Feed water flow (kg/s).