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Preliminary main steam line break calculations with HEXTRAN/SMABRE utilising the sensitivity analysis tool

Authors: Elina Syrjälahti

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Summary

This report is a short summary of the work done during the spring 2008 in the TRICOT project task 1.3 concerning the uncertainty and sensitivity analysis of the reactor dynamics codes.

Some minor changes have been made to the previously developed sensitivity analysis tool.

Earlier main steam line break analyses have shown that the largest break is not necessarily the most unfavourable scenario, because in addition to the leak flow, also the functioning of safety systems influences to the progress of accident. For example the functioning of the main circulation pumps may have a remarkable effect. For that reason arise an idea to apply the sensitivity analysis tool to the searching of the most unfavourable main steam line break scenario. In this report preliminary studies have been summarized.

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Signatures Elina Syrjälahti Elina Syrjälahti Research Scientist	Signatures Anitta Hämäläinen Anitta Hämäläinen Team Leader	Signatures Timo Vanttola Timo Vanttola Technology Manager

VTT's contact address

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1 Introduction

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Some minor changes have been made to the previously developed sensitivity analysis tool.

Earlier main steam line break analyses have shown, that largest break is not necessarily the most unfavourable [3] scenario, because in addition to the leak flow, also the functioning of safety systems influences to the progress of accident. For example the functioning of the reactor coolant pumps may have a remarkable effect. For that reason arose an idea to apply the sensitivity analysis tool to the searching of the most unfavourable main steam line break scenario. In this report preliminary studies have been summarized.

2 Main steam line break

The sensitivity analysis tool [1] was applied to the main steam line break accident. Instead of extensive uncertainty analysis with several input parameters, the idea was to search for the worst leak size in main steam line break accident. At first phase the only varied parameter was the size of the leak.

The modelled plant was the VVER-440 type. The coupled code HEXTRAN/SMABRE was used in the analysis. The used model was based on the Loviisa plant model, but it included some conservative assumptions. There are also some deficiencies in modelling of the signals. Thus it does not exactly describe the real Loviisa plant.

The size of the leak varied from 50% to 400%. Leak sizes from 50% to 263 % indicate the break in one steam line. Leak sizes greater than 263 % indicate that there is a double-ended guillotine leak (200%) in one steam line and that leak damages also the next steam line. Due to the location of steam lines, it was assumed that the broken steam lines are connected to different turbines.

The leaks were modelled in SMABRE with valves (card 21) instead of a break card (card 24), because only one break card is allowed, and in this case several separate leaks were needed. [2]

Valves out from the circuit are located in nodes 1721, 1722 and 1752. The Moody model is used in these valves. Opening and closing of valves is controlled with time options, parameter TVALOP and TVALCL [2]. Other parameters of the valve card have such values that they do not have an effect on functioning of the valves. The time needed for the opening and closing of a valve is the same as the used time-step so that behaviour of a valve is similar than with a break card.

At the initial state, these three valves are closed. Besides these, there is a valve in the junction between nodes 1721 and 1722. This valve is fully open at the initial state.

If the break is less than 200%, only the valve in the node 1722 is opened. The flow area of the valve is (leak size (%) * 0.14725m^2). If the break is from 200% to 263 %, two valves are opened: one in the node 1722, another in the node 1721. The flow area of one valve is (0.5*leak size (%)*0.14725 m^2). In this case also the valve in junction between nodes 1721 and 1722 is closed; otherwise that valve is always fully opened. If the break is more than 263 %, the valve in the node 1722 is fully opened (flow area 2*0.14725 m^2) and the similar node 1752 in another loop is opened, the flow area is ((leak size-200%)*0.14725 m^2).

3 Changes in the sensitivity analysis tool

Some options were added to the subroutine xgenerb2.pl to model leak sizes and opening times of valves.

To avoid interrupt of analysis by allowing working without continuous interactive user connection to unix computers, the script *~rea/ua/Srun/sensla2.pl* was divided to two parts. When the split scrip is used, the user has to run first the script *~rea/ua/Srun/sensla_prep.pl* that performs the interactive part of the original script, i.e. asks used codes, files and what parts of the analysis are made. The script writes a short input file for the script *sensla_batch.pl*. Sensla_batch.pl performs the dynamic code runs, calculates the sensitivity measures etc. If the user wants to interrupt the interactive connection to unix-computers, the script can be run with the command "*at now ~rea/ua/Srun/sensla_batch.pl*". If the script is run with the command at, comments that are normally printed on the terminal are sent to file /var/spool/mail. Thus progress of the analysis cannot be seen from the terminal. With the unix command ls latest files can be seen and thus the user can check the progress of the analysis.

Due to time constraints a complete testing of the new, split scripts has not been done yet. Thus it is possible that in some situations the split scripts do not work properly. Thus the original script sensla2.pl has been kept. At least in normal 3D-analysis the split scripts seem to work properly.

The sensitivity analysis of output variables is added also to TRAB-1D calculations. Only input parameters of 3D-calculation are included to the analysis and results in directories *Irun*/HCvari1* are analysed. Other variations in TRAB-1D input are not included to the analysis, when rank correlation coefficients are calculated. Similar files with rcc-values, minimum maximum and upper and lower limits are written than in analysis of 3D-calculations. Running numbering of calculated channels is in name of the file, i.e. Results/rcc_1_ch1_funtim_dat.dat means first variable in TRAB-1D output of first calculated channel. In the file *minmax_slave.txt* is summary that tells, in which run minimum and maximum values of each TRAB-1D output variable are achieved.

4 Results

In first calculations the leak size was the only varied parameter. The consequences are dependent on the size of the leak. In the following figures the leaks are grouped to four groups, <100%, 100-150%, 150-200%, 200-263% and 263-400% (leak in two steam lines). Total leaks can be seen in Figure 1. Leaks consist mainly from steam, only in break sizes 150-263 % there is temporary water leak within ten seconds of opening of break. Maximum values of water leak are approximately 500 kg/s.

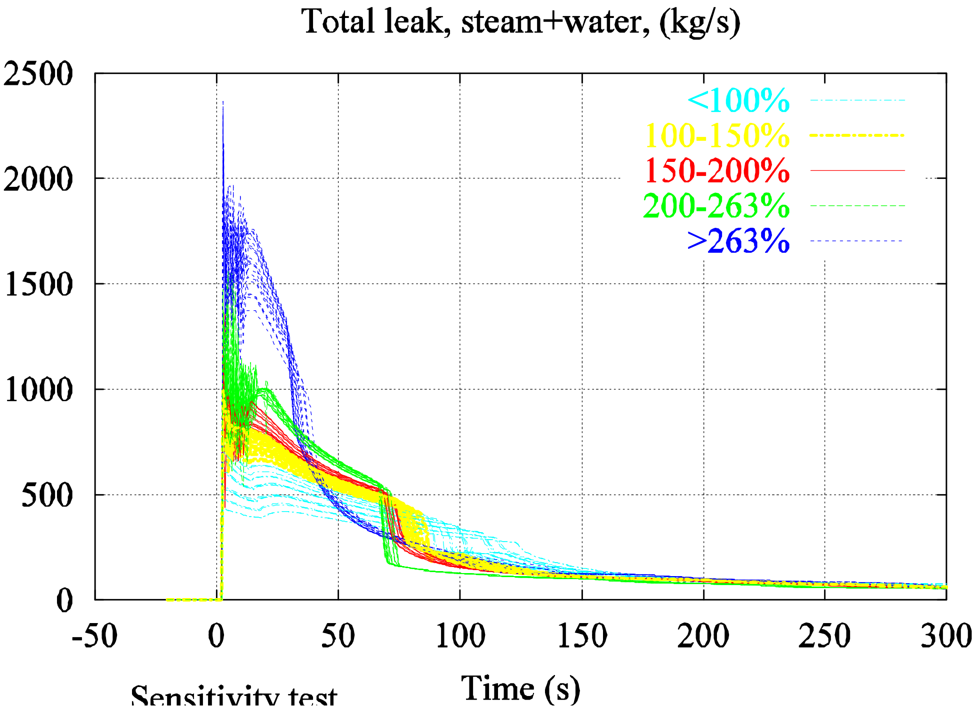

Figure 1: Total leak from secondary side.

If there are two breaks in different steam lines, liquid level measurement of steam generator 5 was assumed to work properly. Thus main circulation pump of loop 5 trips. That leads to lower core mass flow (Figure 2) and also lower increase of fission power (Figure 3). The level measurement of steam generator 2 was assumed to be damaged in the all cases.

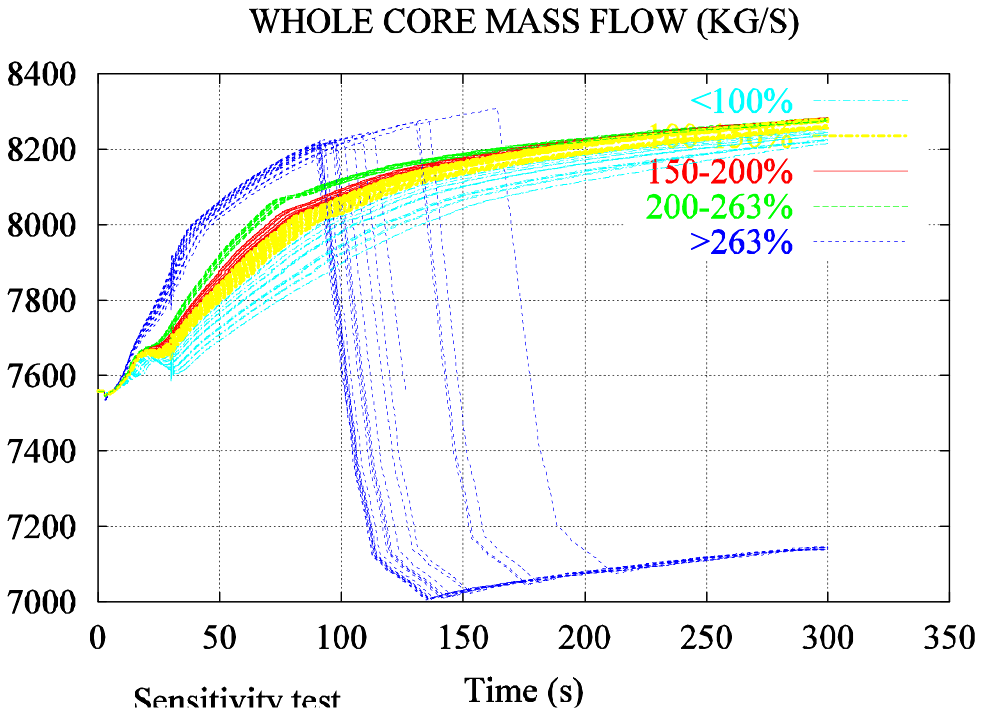

Figure 2: Mass flow at core inlet.

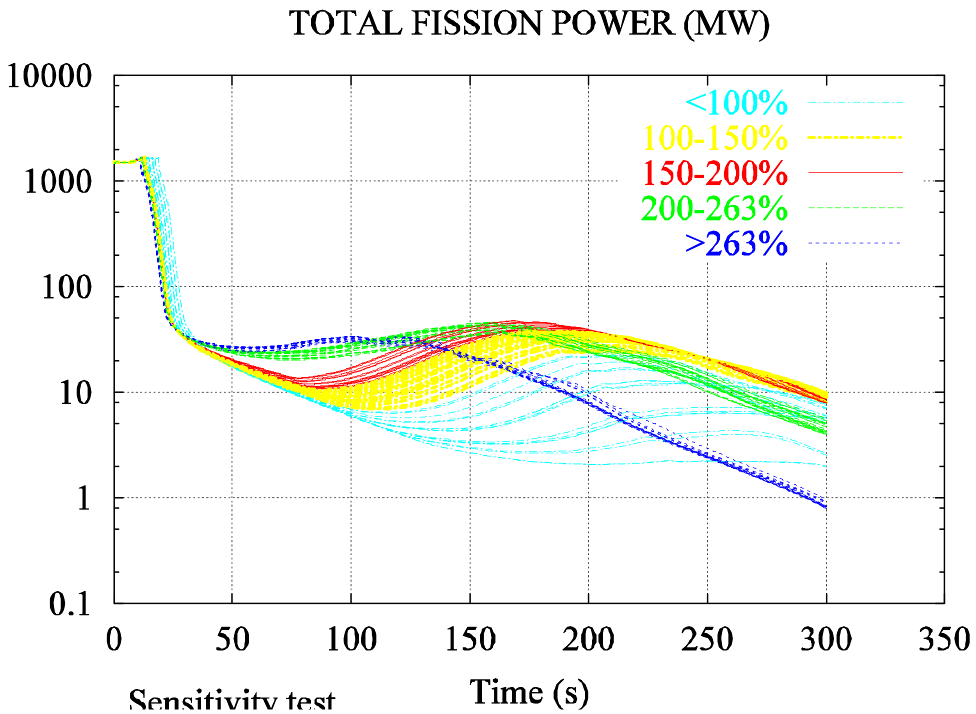

Figure 3: Total fission power, only leak size varied.

Calculations were repeated with the assumption that level measurement in the steam generator of damaged loops may fail or work properly. Functioning of the level measurements has an effect on the behaviour of the main circulation pumps and the injection of emergency feed waters. For these calculations, signals were modified so that pressure drop below 30 bars in one steam header will cause reactor trip. In first calculations only steam header connected to turbine SA50 was modelled. However, due to the error in SMABRE input, reactor trip was in these calculations initiated already at the beginning of the coupled calculation. Even then some results are shown in this report. Case 2 refers to these calculations.

Leak out from the break is in Figure 4. Steam and water flows are very similar to case 1. In total mass flow to the core (Figure 5) and core inlet temperature (Figure 6) effect of steam generator level measurements can be seen. If level measurement fails, main circulation pump does not trip. Mass flow remains at higher level and temperature of coolant is lower. If main coolant pump is switched off, also coolant temperature rises. In the scenarios with break in two steam lines even three set of curves can be seen. That is because level measurement may damage only in one damaged loop or in both damaged loops or it can work properly in all steam generators. Number of curves in each set is very small, so in recalculations the number of the simulations with two damaged steam lines should be increased.

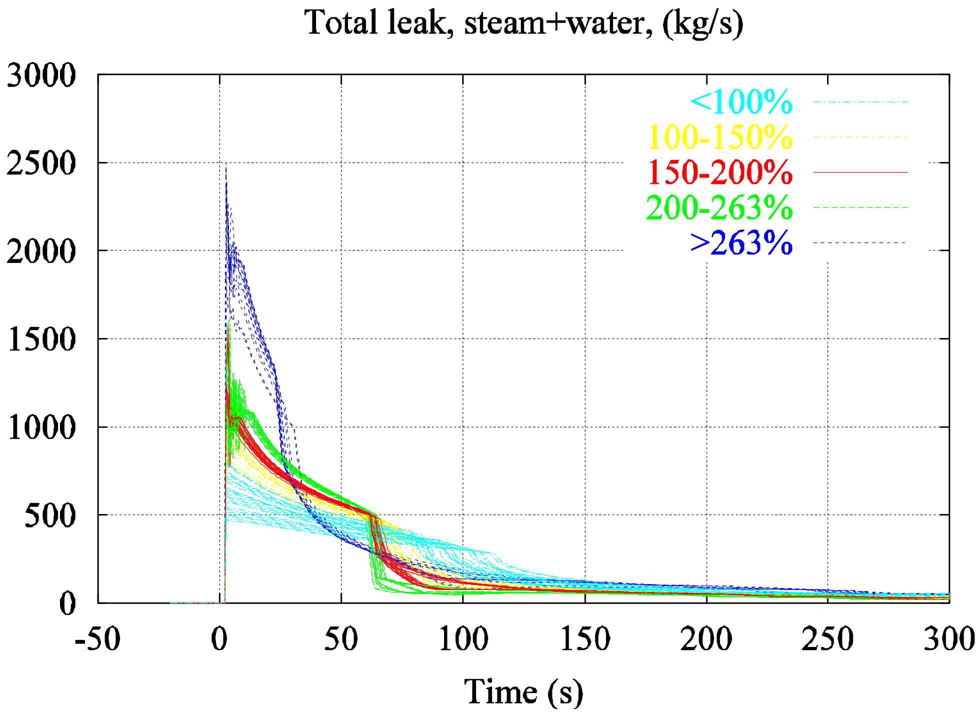

Figure 4: Total leak from secondary side.

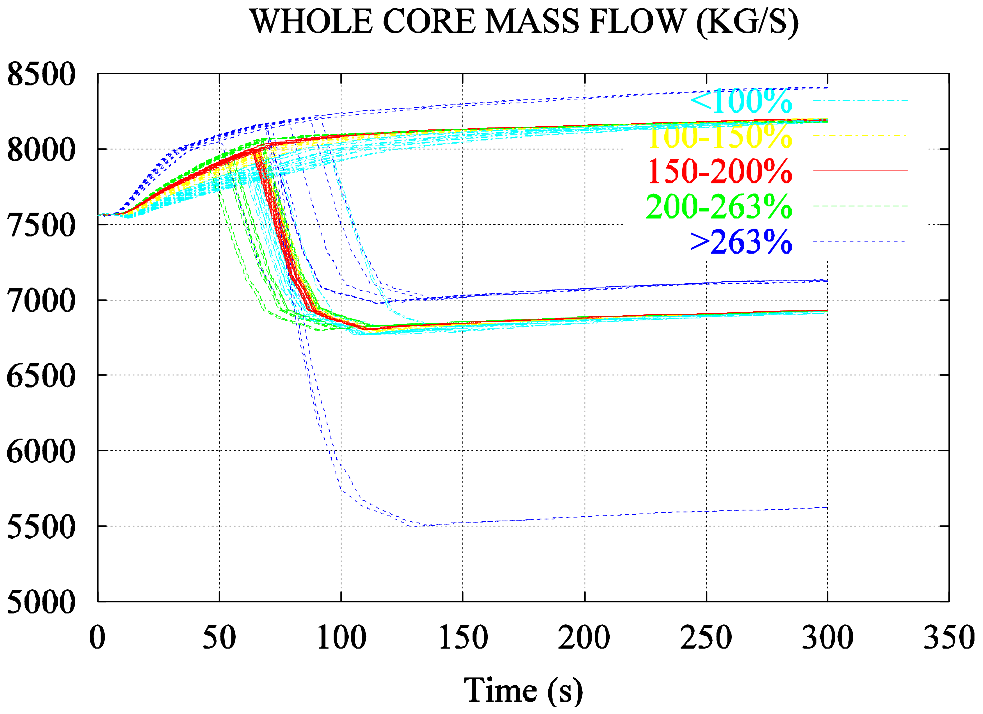

Figure 5: Mass flow to the reactor core.

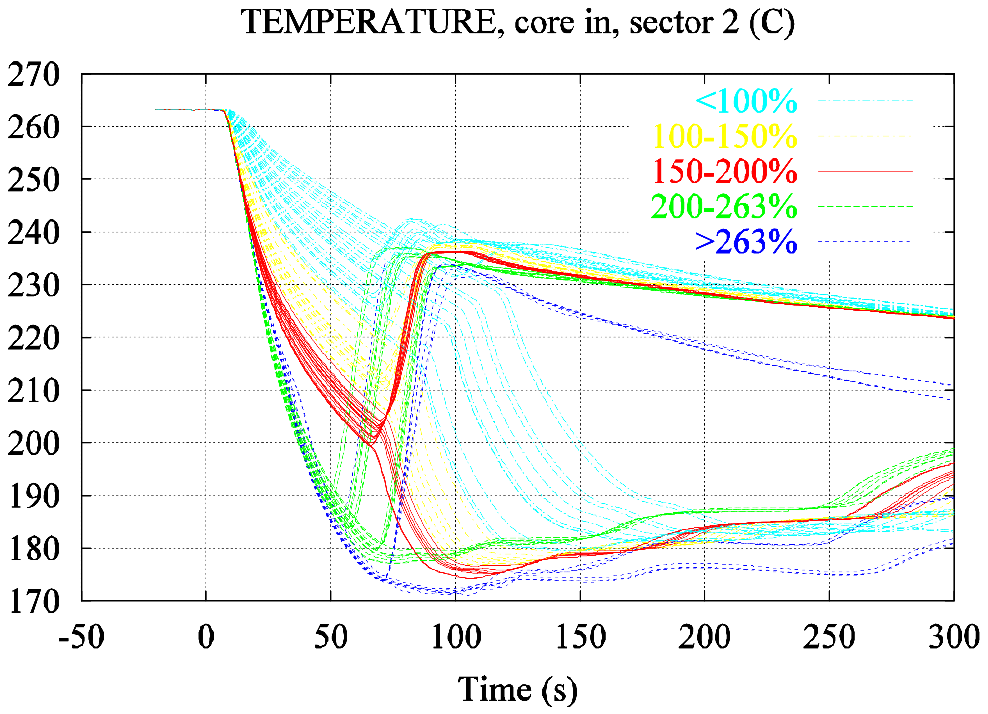

Figure 6: Temperature at core inlet, sector 2.

5 Summary

Preliminary main steam line break calculations have been made with VVER-440 plant model. In first simulation set the leak size was the only varied parameter. The leak size was assumed to vary from 50% to 400 %, values above 263 % meaning scenario, in which leak in one steam line damages neighbouring steam line. In the second simulation set also failing of level measurement of steam generator in the damaged loop may occur.

The distribution of the leak sizes should be revised, because now the range is quite wide and when other uncertainties have included, it is possible that calculated cases do not cover all needed scenarios. Either the leak size distribution can be modified or the number of calculated cases can be increased. Especially in the latter case the extent of printout should be checked.

Modelling of signals in SMABRE input should be checked. There are some deficiencies, because with existing SMABRE plant model there have been only few calculations, in which two different steam lines are damaged.

Calculations should be made also using other initial power levels than full power 1500MW.

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