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Ämne: **Activity Plan "RASTEP – Using Bayesian Belief Network (BBN) Modelling for Rapid Source Term Prediction"**	

1. BACKGROUND AND SCOPE

Development of tools for use in the fast, online event or accident diagnosis and subsequent radiological source term forecasting at nuclear power plants is increasingly desired by off-site emergency planning and response personnel. Availability of such analytical tools would enhance the efficiency in preparing accident response options, and online implementations would be invaluable in quickly predicting likely offsite consequences and result in a more appropriate off-site response.

Large uncertainties are inherent in severe accident situations at nuclear power plants. In trying to model severe accident sequences a mixture of probabilistic and deterministic approaches are typically used. Thus probabilistic safety assessment (PSA) models are used for creating an over-all logical model representing the reaction of the plant to various challenges, and identifying critical event sequences leading to unacceptable radioactive releases. Deterministic analyses are used to determine critical aspects related to physical phenomena during progression of a severe accident, to the time and composition of releases, etc.

The proposed activity aims at providing a basis for improving off-site emergency management by developing a computerized source term prediction tool. The suggested name of the tool is RASTEP (Rapid Source Term Prediction). RASTEP will use Bayesian belief networks (BBN) to model severe accident progression in a nuclear power plant. The output will be a set of possible source terms with associated probabilities. RASTEP will consist of two fundamentally different parts, i.e., a BBN model used to predict plant states and release paths, and a source term definition part used to characterise the source term (height, composition, amount, timing).

The BBN model is based on prior information from the plant PSA model which is iteratively updated based on plant observables. Source term definition and severe accident progression uses information from deterministic severe accident analysis tools, e.g., MAAP. The tool shall interface with commonly used off-site dose calculation tools, e.g., LENA and/or ARGOS. The approach chosen aims at facilitating decision making in a situation with incomplete or partly contradictive information.

The work will be partly based on a pilot project performed in 2001-2005 within the EU project STERPS, which was part of the EU framework programmes 5 and 6[1, 2]. Nordic participation in the EU project was through the Royal Institute of Technology in Stockholm (KTH), with Wiktor Frid (professor at KTH at the time; now at SSM) as project manager, with the participation of Scandpower (Michael Knochenhauer), and extensive in-kind participation from OKG. Information exchange with some of the partners in the EU project is planned to be included in the NKS activity.

As input of plant information via automatic signal transfer is one option, the NKS project will include the issue of signal validation. Also, as the source term prediction part of the tool is crucial and separate from the BBN part, the possibility to integrate a deterministic source term prediction code will be explored.

During 2008 and early 2009, SSM has sponsored a pro-project with the aim to make a feasibility study for the RASTEP project based on experiences from the EU project. The pre-project included information exchange with a reference group with utility representatives as well as with further developments made by the German Gesellschaft für Reaktorsicherheit (GRS), also a former participant from the EU STERPS project.

2. DESCRIPTION OF ACTIVITY SUB-STEPS

A number of sub-steps have been defined and will be performed over the two project years. This will be further detailed in the initial detailed project planning.

2.1 Definition of User Interface

In a computer based decision support tool intended for use during severe accident conditions, relevant and easily used user interfaces will be important. This includes both input interfaces (creation of model, running of model) and output interfaces, including interface with LENA/ARGOS, ADAM, etc.

2.2 Definition of BBN Functionality

The pre-project has already resulted in a proposal for a radical re-composition of the BBN structure suggested in the EU STERPS project, see Figure 2-1, which also gives a good view of the general lay-out of a BBN. Other aspects of BBN modeling are the identification of relevant PSA information (prior information) and of relevant observables. Finally, the definition of a relevant and defendable set of conditional probabilities related to BBN nodes has proved to be a major challenge, and will need to be further explored.

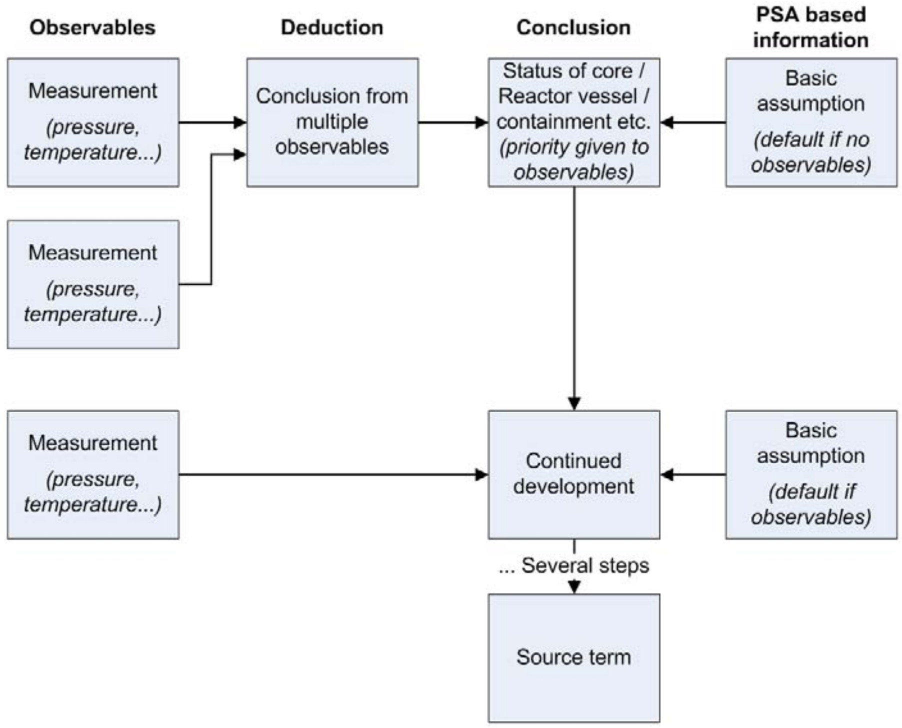

Figure 2-1 RASTEP – Suggested basic structure of BBN model

2.3 Source Term Definitions

The STERPS pilot project based source term definition on a complex excel spread-sheet model including a set of pre-calculated source terms, which were associated with various end states of the BBN. This proved to work well in some cases, but was often perceived to be too inflexible.

This sub-step includes the exploration of various approaches, including the improvement of the functionality of the STERPS simplified spreadsheet approach, but also looking at more sophisticated approaches, such as interfacing RASTEP with a deterministic source term prediction code, e.g., MELCOR, MAAP or ADAM. Such codes would use as input the characteristics of the accident initiator and the availability of various systems, and calculate the various phenomenological outcomes and their resulting radiological source terms for the alternative scenarios (with different probabilities).

2.4 Signal Validation

A critical aspect affecting the uncertainty in the estimates of a rapid source term prediction tool is the availability of correct measurement information from the monitored plant. This involves the validation of plant measurements (pressures, temperatures, ...) at the starting point and during accident progression to update the predictions of the BBN models. Research on signal validation techniques for on-line instrument channel monitoring has been a central activity at IFE and at the Halden Reactor Project for the past fifteen years, where techniques and tools have been developed and tested in numerous applications, e.g., [3].

The typical application of these techniques has been during normal operation for the on-line monitoring of the calibration status of instrumentation. A research challenge in the proposed project would be to investigate the applicability of these techniques to severe accident situation.

2.5 Application to Plants

The basic part of the application of RASTEP involves development of generic BBN models for Swedish BWR:s and PWR:s, followed by specific plant applications:

- Generic BWR model followed by specific plant application
- Generic PWR model followed by specific plant application
- Performance of demonstration exercise

2.6 Dissemination of Results

The following dissemination of results is anticipated during 2010:

- Conference paper and presentation at PSAM 10 *Probabilistic Safety Assessment and Management*; Seattle, USA; May 2010 (paper accepted)
- A project seminar will be held in late 2010.
- NKS report.
- Presentation at NKS-R/B mini seminar (if held during the year)

3. PROJECT ORGANISATION

The SSM project manager is Wiktor Frid. NKS activity leader and Relcon Scandpower project manager will be Michael Knochenhauer. Expertise on signal validation will be provided by IFE Halden. In addition, the activity will include expertise related to PSA, severe accident analysis and programming (BBN, Netica, source term characterisation, input and output interface, LENA/ARGOS interfaces).

End users will be represented through a reference group, including experts in severe accident analysis and emergency preparedness from SSM and the Swedish utilities (Forsmark, Ringhals and Oskarshamn). Information exchange will be organised with some of the previous STERPS partners, e.g., GRS in Germany and NRG-Arnhem in the Netherlands.

4. REFERENCES

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3. P.F. Fantoni, M. Hoffmann, R. Shankar, E.L. Davis, ” On-line monitoring of instrument channel performance in nuclear power plant using PEANO”, Progress in Nuclear Energy, Volume 43, Issues 1-4, 2003, Pages 83-89.