GRS Source Term Prognosis Software FaSTPro: Recent Developments and Improvements (EXTENDED ABSTRACT)

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Extended Abstract:
In the event of a severe accident in a nuclear power plant (NPP), when airborne radioactive particles may be released to the environment (so-called source term), emergency disaster control authorities need to take measures early enough for being able to protect the public. Computerized analytical tools to guide and assist the plant crisis team or an external emergency team for estimating the source term form radionuclide releases can be helpful and time saving in such events. In case of a severe accident, information about the expected source term should be timely transmitted to the authorities via data transmission or ready-made forms to make suitable forecasts of the radiological situation, e.g., with the German decision support system RODOS (*R*ealtime *O*nline *D*ecision *S*upport *S*ystem) developed by the Institute for Nuclear and Energy Technologies (IKET) [1] [2].

Results from plant specific probabilistic safety analysis (PSA) up to Level 2 are available for most NPPs from Periodic Safety Reviews (PSRs), including source terms of potential accident sequences and their corresponding probabilities. Bayesian Belief Networks (BBNs) [3] can be used to combine existing PSA results and actual plant related observations in the control room during a severe accident [4]. The underlying Level 2 PSA represents the basis of the calculations. This level of knowledge is updated with the information available to the analyst concerning the status of the plant. In addition, the underlying PSA probabilities for the occurrence of source terms are adjusted according to actual observations made in the main control room [4] [5]. The result of this combination is an improved and more accurate prediction of the probabilities for accident sequences to be expected in case of a severe accident.

For core melt accidents, the GRS tool FaSTPro (*Fa*st *S*ource *T*erm *Pro*gnosis) allows for predicting and transmitting source terms for different scenarios using pre-calculated source terms calculated with MELCOR and plant specific Level 2 PSA data.

Keywords: Bayesian Belief Network, Level 2 Probabilistic Safety Assessment, source term

1. INTRODUCTION

Emergency disaster control authorities must timely initiate procedures to ensure the protection of the public in case of a severe accident in a nuclear power plant (NPP). Common procedures start either from rather simple recommendations to stay indoors or to take iodine tablets and range up to a complete evacuation of the areas around the NPP which are most probably affected by releases of radionuclides. In the longterm, even a resettlement of the people living around the NPP could be necessary [6] [5]. The procedures or measures are selected based on the expected release scenarios and depend on the time of contamination spread over the area and the amount of radioactive substances. The spreading depends on the weather conditions at the time of the releases and the source term [6].

The source term contains two types of information, the amount of radioactive material which is expected to be released and the progression of time of the releases during the accident. The source term is used as input for dispersion codes such as ARTM (*A*tmospheric *R*adionuclide *T*ransport *M*odel) [6] . This allows a prediction of the distribution of radioactive substances for given weather conditions. The necessary data of the weather forecast are quite easily accessible, whereas the source term prediction is the result of a complex calculation which can be done only by few experts with sufficient knowledge about the details of the plant and its current state during the accident. In Germany, the operator is responsible for determining the source term in the course of an accident and forward it to the authorities in charge [7].

2. THE GRS SOURCE TERM PREDICTION SOFTWARE FASTPRO

A schematic overview of the methodological concept of FaSTPro is presented in Figure 1 [4, 5, 8, 9, 10]. In FaSTPro, the observations of the user are merged and compared to the result of the Level 2 PSA. This allows calculating the corresponding probability distributions of the different accident scenarios. If the deductions from the observations contradict to those from the PSA, the observations and measurements of the current plant state have a higher weight in the calculations. If, on the one hand, the containment pressure is low according to the PSA but, on the other hand, the user observes a high pressure the high pressure represents the basis for the further calculation.

FaSTPro asks the user by multiple-choice questions about the status of the plant prior to the source term prediction calculation. The given answers are combined with the underlying Level 2 PSA results for the NPP to generate a result by means of a synthesis of both concepts [4, 5, 8, 9, 10]. The general user interface (GUI) of FaSTPro is built with modular windows. One of the modular windows is used to ask the user multiple-choice questions. The user must answer these questions and revise the answers if new and/or additional information about the status of the plant becomes available. The software architecture allows to dismiss questions (by giving the answer “unknown”) and to change the previously given answers at any time [4]. Another module shows the probabilities of different results after FaSTPro has performed the calculation. Possible results are the calculated occurrence probability of the hazard state or the corresponding probabilities of core and/or fuel damage states, or the final source terms of the release categories which are based on the underlying PSA.

The source terms are the most important results for the prediction of the release of radioactive material into the environment and are visualized in another module of the GUI. In FaSTPro, the source terms have mostly been derived from extensive accident simulations performed with the deterministic integral severe accident code MELCOR [8, 9, 10]. However, it is also possible to use data from other (integral) codes. The user has the possibility to choose between different data export formats for the calculated data sets (including the source term prediction). A final report of all calculation results is available either in a printable form (pdf-format) or as an data input set for the decision support system RODOS program (XML-format).

3. OVERVIEW OF CURRENT DEVELOPMENTS

FaSTPro has been extensively developed and enhanced over almost one decade [4, 5, 8, 9, 10]. As an example of the recent developments, it is no longer limited to power operation states but is also applicable to scenarios with severe accidents for shutdown states of PWR type NPPs [5] [11]. Moreover, a FaSTPro version for potential releases from spent fuel pools (SFPs) has been developed [8, 10].

Currently, there is a FaSTPro version under development that is applicable to a whole nuclear site. It considers external events, e.g., flooding or high winds, which may influence the safety or integrity of several buildings containing radioactive materials or of different units collocated at the same site. This FaSTPro version will allow to analyze the potential source terms of different radioactive sources at the site during a severe accident, e.g., different reactor units, spent fuel pools, tanks in the auxiliary building, spent fuel pool storage casks and nuclear waste storage facility, and generates a combined source term for the entire site.

In addition, a new FaSTPro version is under development for the current EPR (*E*uropean *P*resurzed *R*eactor) design. This version will include the effects of new technologies of this specific Generation 3+ NPP like a core catcher that is implemented to mitigate accidents. This FaSTPro version uses publicly published data from the Level 2 PSA of the manufacturer.

FaSTPro is a Python-based tool and has been updated from Python version 2.7 to Python version 3.7. This update has been done as FaSTPro is currently about to become a feature in the GRS software ATLASneo. ATLASneo is a tool to plot thermal hydaulic caluclation results. This will also simplify the necessary future update to the current Python version 3.11 (currently under development for ATLASneo). ATLASneo reduces the FaSTPro program structure to its basic features, as e.g., the session save or load functionality is then just part of the embedding ATLASneo framework.

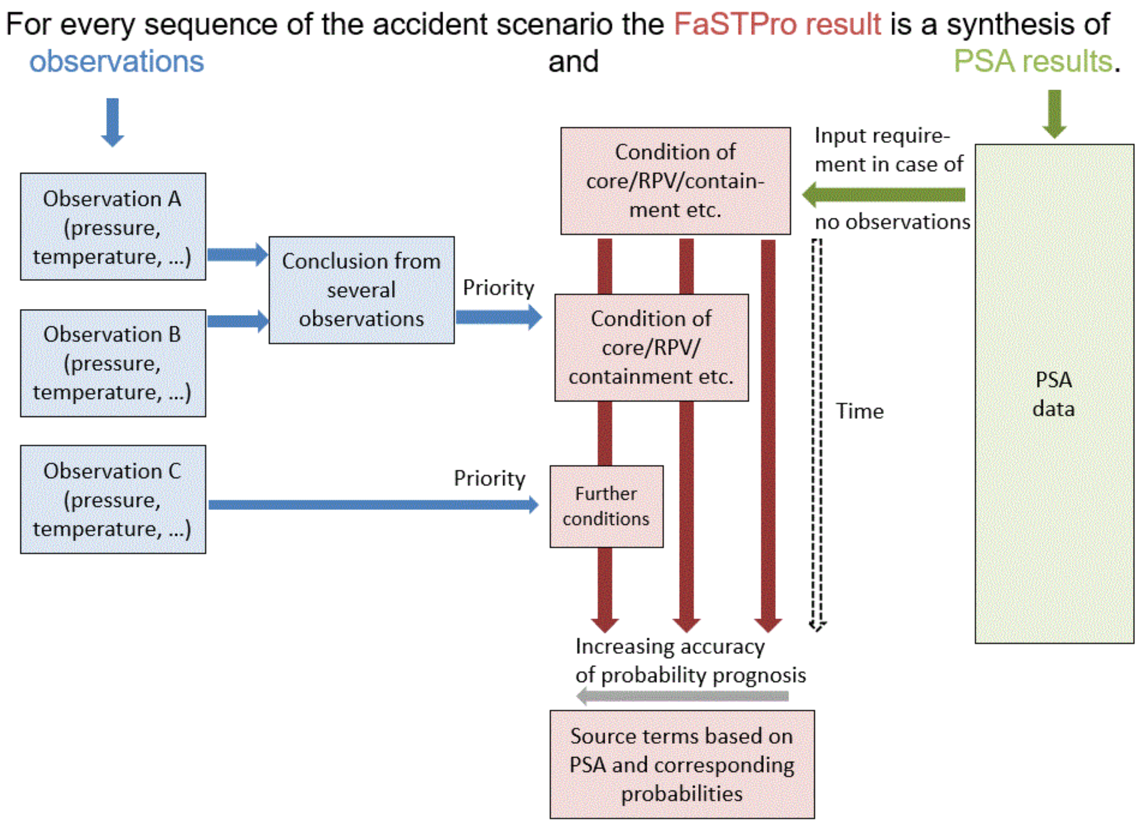

Figure 1. Combining information in FaSTPro: observations (left, blue) and Level 2 PSA (right, green), results in a prediction of source terms (middle, red) (from Hage [5])

Another field of research is the PSA Level 2 to Level 3 source term characterization and grouping in the frame of FaSTPro. Characteristics for source term categories with relevance for Level 3 PSA are e.g., the point in time of the release (early/late release), the amount of release (large/small release) or the type of the scenario (intact/non-intact containment (bypass)) [12]. In future research activities it will be beneficial to review the direct or indirect integration of suitable source terms characteristics in FaSTPro, e.g., in the GUI, or in the prepared XML form for RODOS.

4. CONCLUSION

The source term prediction tool FaSTPro is based on a synthesis of two inputs. On the one hand, probabilistic data (originating from a Level 2 PSA or from plausible expert estimations) and, on the other hand, the current plant status with information about the status provided by the main control room. The enhanced and extended versions of the GRS analysis tool FaSTPro, which are currently under development, will allow for a prognosis of the release of radionuclides also for EPR reactors and for a whole nuclear site (eith multiple reactor units and/or radionuclide sources collocated at the same site). In this enhanced form it will improve the plant and site external emergency preparedness e.g., at crisis centers.

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