DOSE PROJECTION USING DISPERSION MODELS

Borut Breznik[1], Marija Zlata Božnar[2], Primož Mlakar[2], Gianni Tinarelli[3]
[1]Krško Nuclear Power Plant, Vrbina 12, Krško, Slovenia
[2]AMES d.o.o., Jamova 39, Ljubljana, Slovenia
[3]ARIANET s.r.l., Via Gilino, 9, 20128 Milano, Italy

INTRODUCTION

The dose projection is a tool for decision making in case of nuclear emergency situation. In the paper the dose projection software will be presented developed for Krško NPP located in Slovenia. This software can be used for quick emergency evaluation in the case of hypothetical pressurised water reactor accident and for emergency exercises.

The software is developed to estimate reactor core damage, status of fission products barriers, potential releases, atmospheric dispersion and finally the dose calculation.

The intention was to use all the available automatic on-line measurements of the radiological monitors in the NPP, meteorological monitors in the surrounding and a modern atmospheric dispersion model capable of accurate calculations in the complex orography which is characterised for the Plant location. It is also important that the software is written in a user friendly way, automated as much as possible and made on a widely used Windows platform for the PCs.

The program should provide dose projection in early stage of the accident (first hours) for distances of few kilometres from the NPP. The results are available for the 25 km by 25 km area that includes the Krsko basin and some nearby laying hills and valleys. The results should support a decision of emergency team in the NPP about evacuation or sheltering in the environment already in early phase of the accident.

At present the software uses only simple Gaussian air pollution dispersion model. For this year the replacement of the Gaussian model is planned with numerical Lagrangean model “Spray”.

Since the software is intended to be used for severe accident scenarios, it should be also expected, that the on-line meteorological and radiological parameters will not be completely available at all possible stages. For this cases the alternative possibilities are included, that require less or no measurements. The selection of this alternatives is based on operators judgements according to the last available data. Reduction of information certainly decrease the accuracy of the result.

MEASUREMENTS AND SOFTWARE MODULES

Main program modules should automatically according to the on-line measurements or based on an operator decision determine the following: source term, core damage, fission products radioactivity, release source term and critical exposure pathways for an early phase of the release.

The atmospheric dispersion module should give an accurate view of pollutants propagation in the atmosphere. The numerical Lagrangean particle model Spray uses the meteorological data as a result of a 3D model Minerve. It uses half hour averaged on-line measurements from one SODAR, one high meteorological tower and several ground level meteorological stations.

Finally, dose modelling is dealing only with two exposure pathways: radiation from the cloud and internal exposure due to inhalation of contaminated air, recognised as critical in the emergency situation. For this two pathways the modelling is more reliable than in other pathways scenarios.

AIR POLLUTION DISPERSION CALCULATION MODULE

To simulate the dispersion from the Krsko Power Plant emissions, a mass-consistent three dimensional wind field over complex terrain is firstly reconstructed using the MINERVE6 model (Desiato et al., 1998).

This code is mainly based on an objective analysis scheme in terrain-following (sigma) coordinates, used to perform an initial interpolation of sparse ground-level and upper-air SODAR data available over the computational domain, and a final divergence-free adjustment. This method is particularly suitable for real-time applications, assuring a good compromise between the quality of the generated fields and the response time, in presence of a well designed measuring network. Within the MINERVE6 code, also temperature fields are computed via a 3D Cressman analysis scheme, again based on ground-level and upper-air data available from the local network.

Three dimensional wind and temperature fields are then passed to the SURFPRO code, suitable to calculate turbulence scale parameters based on standard parameterisations (Van Ulden and Holtslag, 1985), taking into account the horizontal terrain inhomogeneities through the use of a land-use horizontal field.

All the information coming from the meteorological codes is then passed to the SPRAY3 stochastic Lagrangian particle dispersion model (Tinarelli et al. 1994). This code is based on the formulation developed by Thomson (Thomson, 1987) allowing the simulation of the dispersion in non-stationary conditions from continuous or discontinuous sources of whatever structure, taking into account complex conditions such as the presence of complex terrain and the related meteorological inhomogeneities. The entire modelling system is routinely invoked on half hourly basis using the present available data, in order to produce a field of dilution coefficients from the power plant emission, starting from the conditions generated at the end of the previous run.

RADIOACTIVITY OF THE CORE

The assessment of the accident starts with the determination of the source term.

The activities of the radionuclides are derived by ORIGEN computer code for a few fuel burn-ups. To have a practical and quick calculation of instantaneous radioactivity the following approach was selected:

Precalculated values of steady activities for three burn-ups were provided for the selected nuclides based on the results of the ORIGEN code. Steady radioactivity levels for power operation can be easily interpolated for all other fuel burn-ups.

The variation of the activity during start-up and following power transients is calculated continuously by the software module using the following algorithm:

$$A_{t2} = A_{02}\exp(-\lambda_2 t) + (P/P_0)\,A_{r2}\,(1 - \exp(-\lambda_2 t)) + (\lambda_2 / (\lambda_2-\lambda_1))(A_{01} - (P/P_0)\,A_{r1})(\exp(-\lambda_1 t) - \exp(-\lambda_2 t))$$

where index 1 means parent and 2 daughter nuclide, A_{t2} is instantaneous activity of the nuclide at time t, A_0 is initial activity before power change, A_r is steady activity at full power, λ is decay constant, P/P_0 is normalised power and t is time.

The module runs automatically and provides up-date of the activities in the core every half hour or in the case of reactor power transient.

RADIOLOGICAL IMPORTANCE OF THE SOURCE TERM

To select the radionuclides of interest, relative radiological importance was examined by implementation of dose index. The dose index was defined as follows: applicable dose conversion factor multiplied by available radionuclide activity to be released. The noble gasses source term causes the external dose only, but with higher fraction of volatiles (such as iodine and caesium) major contribution has the effective dose due to inhalation. The assumption of one hour exposure to total source term of noble gases and one hour inhalation of volatiles provides the comparison of external dose and committed dose. For dose index, dose conversion factors for adults were used from the IAEA reference [1994] and inhalation of $1 m^3$ air.

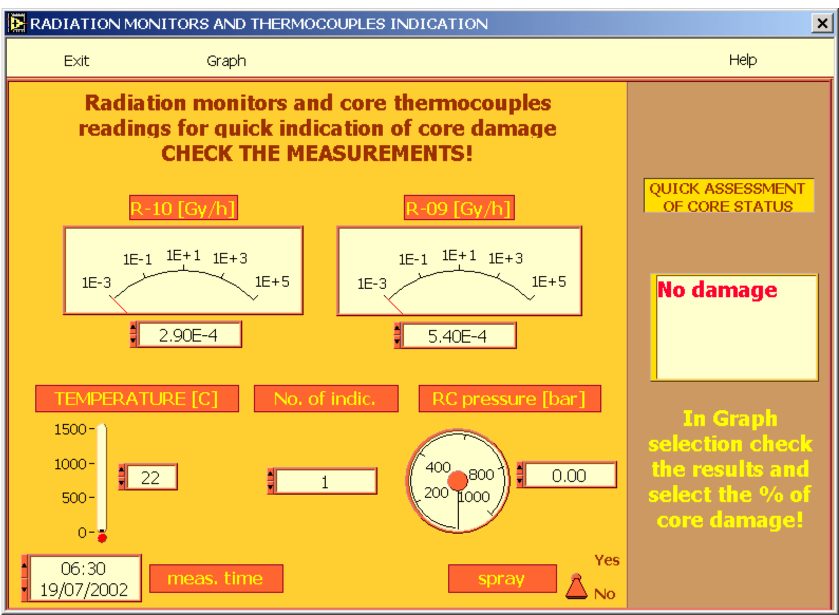


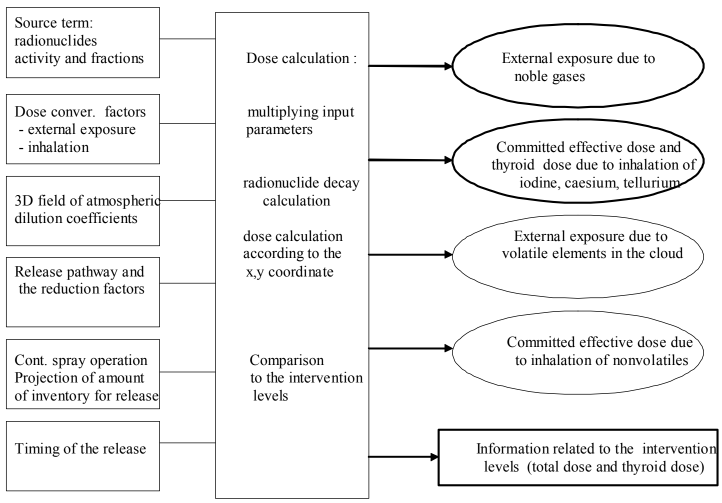
Figure 1. On line measured data determine the status of the core status.

THE ASSESMENT OF THE CORE DAMAGE

Radiation and consequent decay heat of fission products are physical phenomena which initiate core damage. Indicators of core damage and overheating are for example core thermocouples, water level measurement in the reactor vessel, and containment radiation monitors. The assessment module has some of the relevant data on-line, but the assessment is accomplished by verification procedure included within this module.

DOSE PROJECTION

The procedure of dose projection can be summarised as shown on the diagram below. It has been mentioned that in an early phase of the accident the following exposure pathways were selected: radiation from the cloud and internal exposure due to inhalation of contaminated air.



CONCLUSION

The described dose projection and its software implementation provide more accurate initial source term activity determination than most usual applications. The core damage assessment is based on quick indications provided by the plant instrumentation. User can define release pathway and selects its reduction factor. Advanced 3D numerical air pollution dispersion modelling ensure currently most reliable calculation of the atmospheric dispersion for local situation. The exposure pathways which are foreseen in the projection are external radiation from the cloud and inhalation.

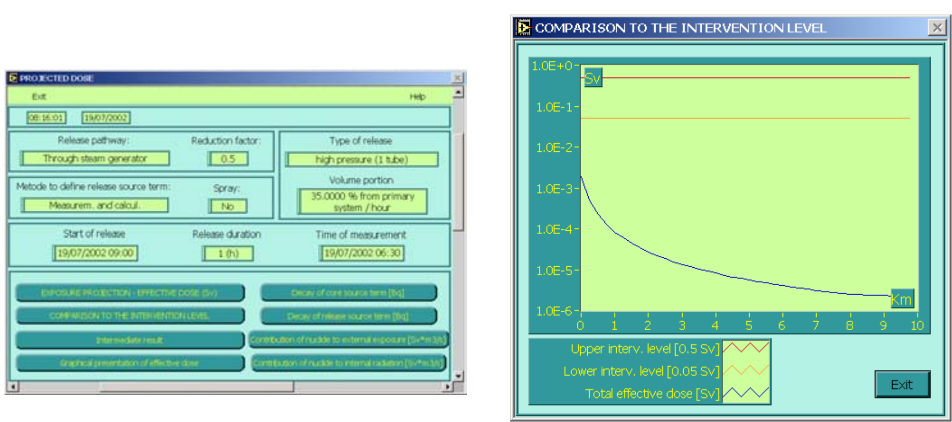


Figure 2. Results presentation.

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