Development of a DSS to Assist Nuclear Authorities in the Early Phase Emergency Management in a Potential NPP Accident[1]

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Summary:

Emergency engineering and management developed as an important inter-disciplinary activity with special economic, managerial and social implications in case of accidents or disasters. Nuclear accidents, in particular, are rare and special events with a broad spectrum of potential scenarios and in case of occurrence they would have to be treated with competence and determination in order to reduce consequences and public risks.

At ETHZ expertise has been developed during the Polyproject on "Risk and Safety of Technical Systems" in the field of developing Decision Support Systems (DSS) for emergency preparedness and planning (e.g. ETH-NUKERISK, ETH-RISK MONITOR, ETH-CHEMRISK). Co-operation with Swiss national nuclear authorities (HSK) was active during the whole period of research and development within the above project (1991-1995).

At the present stage, a continuation of the above research is proposed in view of extending the current practice in the field of risk management and emergency engineering and management. Adaptation of response technical manuals to the case of Swiss nuclear power should be of importance and relevance for early phase nuclear power plants emergencies. The work would deal with integrating existing on-line monitoring systems for NPPs with in-field monitoring following early phase accident phase with knowledge obtained from plant specific PSA level I and II studies in view of assisting emergency managers and decision maker in the early phase of a nuclear accident. A Knowledge and Decision Support System (DSS) would be designed and developed in order to integrate various aspects related to emergency preparation and mitigation actions.

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1. Introduction

An emergency is the chain of events[4], or any part of it, IF the system in question cannot be brought back to normal operation or stable conditions by normal routine or planned procedures only. Although response and emergency share the same time axis, all steps in the response should be practically initiated as soon as an event initiator would clearly manifest itself. The capacity of an emergency response system to act is reflective of an on-line emergency preparedness and management.

- In the content of this work emergency engineering and management is defined as a body of methodologies, methods, tools and applications in order to deal efficiently with emergency preparedness, mitigation and management of accidents.
- Special interest was paid lately for on-line linking of monitoring installations (e.g. nuclear generation unit) with emergency co-ordination centres in view of rapid detection and assessment of possible deviations in plant operational behaviour (AMPA system).
- On line monitoring of NPPs assists in identifying early warnings regarding initiating accidents and their potential consequences for a NPP. Information regarding plant monitoring could lead to making adequate decisons for emergency preparedness and management for a given NPP.
- PSA studies contain information and data to assist the plant diagnosis and the potential evolution to unsafe operation. Level I and II, PSA has the potential to be more integrated into emergency engineering and management practice for NPPs.
- *Early Phase Emergency* deals with a series of issues which have to be gradually solved and eventually integrated, namely: i) diagnosis of incidents or accidents in accordance with initiating events or specific behaviour of the installation, ii) using monitoring procedures to enhance specific knowledge about installation and its operational trajectory; on-line monitoring as well as off-line plant monitoring are of importance in this process; iii) evaluation of safety performances by using PSA level I and II studies which are to be more intensively used for highlighting deviations from normal operation and potential accident sequences; iv) use of GIS systems in order to represent and handle accident propagation sequences into complex terrain and real environmental conditions; v) use of adequate consequence assessment models to deal with emergency multi-criteria decisions, namely evacuation, relocation, depending on most probable evolution of the accident, weather conditions etc. These aspects should be integrated into a comprehensive DSS in order to assist the emergency decision making process.
- In case of potential nuclear accidents, communication procedures at the local level (commune) should be assisted by actions relevant to the given accidental situation.
- In developing the emergency DSS, specific legal responsibilities of HSK should be included in all the procedural steps.

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[4] e.g. event initiator, event sequences or scenarios, disruption, release, hazard vectors, environmental alternations such as asset depreciation and health effects

2. *Scientific and Technical Information for Emergency Management*

2.1 Basic Aspects

- The present research is dealing with the early phase of a potential nuclear accident and takes into consideration the HSK legal responsibilities.
- The work would include adequate processing of information in case of accidental emergencies by means of on-line monitoring of various NPPs located in Switzerland and, when possible, the off-line monitoring (outside the NPPs direct environment). Information generated by monitoring activities would be processed and integrated, by means of expert rules, in the overall structure of the decision making process and various emergency procedures and rules (radiation alert, evacuation). Results from expert judgement are to be included in computerised *knowledge tables* associated to the diagnosis process. PSA results, mainly from the level I and II, are going to be integrated into the overall procedural rules associated with the specialised DSS for emergency management. This process would provide better know how (PSA based, identification and exploration of a variety of potential accident sequences, safety indicators and accident branching points) together with the identification and use of time management sequences for accident mitigation, sensitivity analysis for uncertainty evaluation, etc.
- Timing of accidents together with bypass failure or leak situations or late containment failure (more than one day) or other similar events should be included when designing DSS for severe accident management.
- Interactions between pre-accident conditions and phases and various plant operational states in combination with the "outside" plant events are to be integrated in a comprehensive strategy for NPPs emergency management.
- The overall integration of various issues regarding the emergency status of an NPP would represent an important element of design for the DSS. The use of computer tools in prevention, preparation and mitigation of accidents represents the current trend in emergency engineering and management. The use of computerised *Knowledge Base and DSS tools would facilitate* technical assistance and practical decisons in dealing with complex situations in case of a potential nuclear accidents.
- The current trend (including Switzerland) is to design on-line DSSs, with specific tasks to be carried out in case of emergency, namely:
    - screening the operational performance of the power plant (e.g. on-line monitoring) as well as environmental aspects which could give relevant information on the operational status of the NPP;
    - evaluating emergency scenario and present information to the appropriate user or decision maker;
    - making diagnosis related to the state of the plant in relation to the emergency status;
    - keep records on monitoring activities and signal deviations from normal operational status;

- advice on a proper decision regarding emergency actions in the early phase of a nuclear accident.

The present research would have to address all the problems presented above in a comprehensive and integrated manner, highlighting issues of practical interest in all phases of emergency activities due to potential nuclear accidental situations. Special attention would be given to understanding and finally including the technical specificity of various Swiss NPPs. The study would start with one specific NPP and others would follow.

2.2. Relevance of the Present Research

At the present time there are activities in Switzerland regarding on-line monitoring of various NPPs, for identifying deviations from the normal operational status of the specified installations. The results of this approach should be integrated and harmonised with technical and organisational information needed for emergency management. This would lead to increasing the efficiency of activities (when information is complex and multivectorial) and would create a proper framework for adopting rules for calling emergency actions (e.g. radiation alert, general alert, warning) .

In order to assist the emergency preparedness activities, knowledge should be additionally provided by proper use of PSA studies. The new rules for calling emergency actions have to have a simple and robust structure; this would assist structuring various phases of the emergency process (mainly the early phase activities).

The envisaged research is aiming at creating an enhanced methodology and to design procedures in order to assist early phase emergency preparedness and management based on a variety of information, logical rules, expert judgement and legal constraints (e.g. the legal truth).

For the Swiss NPPs, consideration should be given to decreasing risk by improving various strategies regarding emergency preparedness and mitigation. New approaches in the field of emergency engineering and management (use of expert systems and the logic of accident development) are going to be used. To assist emergency procedures for NPPs, information from the existing on-line monitoring systems would be highly incorporated into the proposed decision support tool. The work would consider integrating technical and environmental aspects (including meteorological issues), terrain complexity - all information in the content of early phase of a nuclear accident. Modern *GIS features* would be included and integrated into a comprehensive DSS structure. Soft and friendly interfaces would be introduced and integrated in the overall structure of DSS. The final product should be a DSS, designed for assisting the decision making proccess in case of nuclear emergency,.at the communal and cantonal levels.

2.3 State of the Art

Emergency engineering and management recently included a large body of activities due to the needs to dealing with potential large scale natural and technical disasters. An international professional society, TIMEC, is actively engaged in promoting research and applications related to emergency engineering. The international conferences recently organised by TIEMEC (Florida, 1994 and Nice, 1995) shown a large theoretical and practical interest in

developing DSS for emergency preparedness and planning assisting a large number of potential accidents (e.g. chemical, nuclear installations or the transportation of dangerous goods).

The Response Technical Manual of USNRC has been intensively used for training specialists assisting potential nuclear accidents emergencies. Recently the manual has been updated for diverse conditions and aimed for a larger international applicability.

A number of decision support systems were developed by ETHZ, by the principal investigator of this proposal, within the Polyproject on "Risk and Safety of Technical Systems" e.g. *ETH-NUKERISK, ETH-CHEMRISK, ETH-RISKMONITOR* (1991-1995), as well as by NAZ for late phase risk assessment of a potential nuclear accident.

Swiss specific PSA studies for NPPs are available (level I, II and III); information from these studies are not yet integrated in the practice of emergency preparedness and planning. Advanced information technology as well as telecommunication facilities are already envisaged for assisting specific applications related to emergency. Lessons learned from the management of large scale natural disasters show the need for a proper integration of DSSs as well as telecommunication technology towards efficient and *in-time actions*.

2.4. Project Description

- *A full review of the potential use of in-plant monitoring and off-line monitoring* should be considered jointly with their integration into a set of rules, knowledge and expert judgement procedures *fully assisting the decision making process prior or during an accident*. Procedures should be considered for different NPPs currently operating in Switzerland.
- *Rules and procedures should be constructed from PSA studies* and a proper integration into advanced emergency emergency DSS should be finally implemented.
- A coherent set of rules based on PSA studies and operational practice should be designed, in order to comply with the „legal truth" in Switzerland for calling various emergency actions.
- Integration of the accident scenario presentation with early phase accident development by using *GIS* oriented *technology* by taking into account the terrain complexity as well as meteorological aspects specific for emergency situations (under specific Swiss conditions and NPP site specific information). Interfaces are to be organised, designed and implemented at all levels of this project.
- Develop and implement a conceptual design for interfaces with *adequate communication and transmission systems*, currently in use in Switzerland (at the plant level, communication with authorities as well as with the public, when possible and necessary).
- Create friendly interface facilities to interact with various categories of decision makers in accordance with the development of the accident and the specific environmental conditions.
- Develop procedures and facilities to *exercise and train personnel* for emergency situations (create specialised databases using features of multimedia technology); develop rapid assessment tools for assisting in-field emergency decision and actions.

- This project will not develop any PSA type studies. It will rather use in an extensive and comprehensive manner, with high efficiency, the set of knowledge, data, information and major findings generated from the Swiss NPPs PSA studies. Similarly, information and the structure of AMPA and STAR would be integrated to the extend needed within the framework of this project .

2.5 Goals and Objectives of the Project

The overall goal and associated objectives of the present work is to *design, develop and realise a Knowledge and DSS* in order to assist the decision making process in case of potential nuclear emergency situations, by:

- including information from the *on-line and off-line monitoring*;
- including *GIS features* in the overall structure of the DSS;
- including *rules and procedures* currently in practical use at HSK as well as the level of the existing Swiss NPPs.
- explore further research issues related to the topic of emergency engineering and management by using *intelligent systems and communication technology*.

This project should assist in designing and implementing the modern concepts in emergency engineering and management, mainly by monitoring procedures, Probabilistic Safety Assessment studies, expert judgement and elicitation, knowledge processing and their integration into a comprehensive emergency Knowledge and DSS and Manual for assessment and assisting decisions in case of potential major nuclear accidents. *The project should assist the appropiate Swiss authorities in designing an initial version of a Response Technical Manual* (with specific application to the Swiss NPPs) by using information and knowledge from existing plant specific PSA level I, II and III studies as well as from accident consequence assessment models.The legal truth should always be considered and finally integrated in the structure of the overall project and its independent modules. *Expert systems type of products should be developed, tested and implemented in the phase one of the present work, for assisting the training activities.*

The role of supporting systems in severe accident management/emergency situations are:

i) considering the inherent complexity of severe accidents, computerised supporting is requested to:

- monitor accident progression;
- predict possible events and timing;
- provide guidance for plant staff;
- evaluate the efectiveness of specific strategies.

ii) utilise PSA results, aimed to develop a supporting system for severe accident management/emergency management.

The utilisation of PSA results in the present project would have to go through the following steps for designing an overall procedure:

- prepare and design the structure of a specialised database: from PSA documents and from information materials on severe accident management;
- build database to be further computerised by using a professional database package;
- adopt monitoring systems for relevant parameters or processes under investigation, by identifying the accident progressing path as well as the most probable and the most desirable paths on a specific severe accident scenario;
- extract suitable guidances to direct accident progression to most desirable path (e.g. PSA-based and safety objective tree-based as a complementary tool);
- subsequently monitor the effectiveness of actions, if taken.

The *databases should be designed to contain*, among others, the following types of information:

i) PSA results (e.g. definition of plant damage states, definition of containment event tree top events and the tree topology, conditional branch probabilities, phenomenological fault tree structures and logical dependencies, state frequencies of specific undesired events as well as off-site consequences);

ii) system characteristics (available features and strategies for severe accident management);

iii) safety objective trees (e.g. prevention of core damage, prevention of containment failure, mitigation of fission product release);

iv) severe accident management guides (e.g. generic and plant-specific information).

Plant damage state (PDS) identification deals with i) the description of the state of plant onset of core damage, determines configuration of e.g. containment event tree, includes containment safeguard and cavitiy conditions, ii) the estimation of PDS parameters (define PDS by combination of possible values) and iii) PDS reduction by deletion of meaningless combinations by rules and deletion by screening of very infrequent sequence (e.g. 10^{-10}).

In ***phase two*** of this project attention will be given to assist the decision makers for implementing real site and specific emergency situations.

Final product of this research consist of a set of knowledge bases and data bases fully integrated into a specialised *Knowledge and Decison Support System* designed to assist the emergency preparedness and planning processes due to potential accidental situations at NPPs in Switzerland.

Supporting tools (e.g. Knowledge and Decision Support Systems) are essential in severe accident management and emergency preparedness and management, considering both the phenomenological complexity and the variety of possible scenarios. PSA results and on-line monitoring information and data can provide ways to identify appropiate actions at given situation. State-oriented approach using safety objective trees provides an alternative method to support severe accident management and emergency tasks. It is important to highlight that

supporting systems (e.g. data bases, knowledge bases, DSS) are subject to full validation to be implemented.

3.Needs for the Project

Phase one of the project would devote to i) emergency management and planning state of the art investigation and ii) designing of rules for accident identification/propagation and emergency preparedness based, among things, on plant specific PSA studies and expert elicitation, on-line monitoring by use of the existing AMPA system.

Activities are going to be related to the development of specialised databases and knowledge bases requested by the project and development and implementation of advanced intelligent systems for emergency planning and management.

This project is regarded as *highly interdisciplinary* and requires a strong co-ordination and harmonization of various tasks/subtasks and resources which are going to be considered along the whole period of work.

Firstly, the project would concentrate on considering a concrete program of work for identifying various potential contributions from the field of PSA, on-line monitoring, operation experience and associated knowledge availability, influence of meteorological situations in accident propagation and management and their later integration.

Secondly, a simplified version (pilot model) of the above descriebed Knowledge and Decision Support System would be conceptualised, designed and experimented.

Finally, a more advanced prototype would be considered for further testing, implementation and for training purposes.

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