DECISION SUPPORT SYSTEMS AND EXPERT SYSTEMS FOR RISK AND SAFETY ANALYSIS

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During the last 1-2 years, rapid developments have occurred in the development of decision support systems and expert systems to aid in decision making related to risk and safety of industrial plants. These activities are most noteworthy in the nuclear industry where numerous systems are under development with implementation often being made on personal computers. An overview of some of these developments is provided, and an example of one recently developed decision support system is given. This example deals with CADET, a system developed to aid the U.S. Nuclear Regulatory Commission in making decisions related to the topical issue of source terms resulting from degraded core accidents in light water reactors. The paper concludes with some comments on the likely directions of future developments in decision support systems and expert systems to aid in the management of risk and safety in industrial plants.

Keywords: Decision support systems, expert systems, risk analysis, safety analysis, radioactive source terms.

INTRODUCTION

During the past 10 years or so, there has been a great deal of activity and much progress in the field of expert systems(1). This is a subdiscipline of artificial intelligence. Expert systems are computer programs that encode the knowledge of an expert in some specific area and make it available to people who do not have this expertise. Most frequently this knowledge is needed when some decision must be taken. A related type of computer program is a decision support system. As a rule, such systems do not encode knowledge but rather provide assistance in some form to a decision maker, often in an interactive way on a personal computer. For example, assistance may be provided in the form of a data base and help in its use. Alternatively, assistance may simply be in the form of help in structuring the problem.(2)

Expert systems are usually employed when a problem has certain characteristics. For example, problems that involve the choice of one or more possible alternative decisions are well suited for expert systems as are problems for which there is no well established underlying theory but rather just a body of knowledge as in many branches of medicine. Indeed, one of the earliest applications of expert systems was in the field of medical diagnosis.

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Expert systems are particularly useful where there is a shortage of experts. This was true for one of the other early applications of expert systems in the field of oil-well log interpretation. Also, expert systems are useful where noisy data is present. The use of so-called fuzzy logic in expert systems for such cases is particularly helpful.(3)

Decision support systems are also helpful under the same circumstances as expert systems but may have a wider range of application in that they seek to provide assistance with problem solving rather than actually to provide the solutions to problems.

Problem solving in the fields of risk and safety management has many of the characteristics well-suited for expert system and decision support system applications. Often several alternative solutions are available; and, in general, there is a body of knowledge or set of standards rather than a comprehensive underlying theory on which decisions are made. Also, there is usually a shortage of experts and almost invariably the data used in decisions are noisy. Applications of decision support systems and expert systems in the fields of risk and safety include their use in decision making, safety analysis, operator training, process control, monitoring system compliance with standards, and inspection and maintenance.

Recently, in the United States, applications have been made in several of these areas. Most activity has taken place in the nuclear industry where there is now a wide variety of ongoing projects, and some systems are becoming available. Much of this activity has taken place in just the last 2 years or so.

This paper provides an overview of these developments and provides an example of a decision support system called CADET recently developed at Battelle's Columbus Division for the U.S. Nuclear Regulatory Commission to provide assistance in decision making on matters related to radioactive source terms from light water reactors during degraded core accidents. Some conclusions are also drawn on possible future developments in the use of expert systems and decision support systems in risk and safety management.

DISCUSSION

Decision support systems and expert systems are being developed to assist in many different aspects of nuclear plant power generation. Applications range over design, construction, fuel scheduling, operator aids in reactor control, fault detection and diagnosis, failure analysis, maintenance, monitoring compliance with licensing requirements, and operator training. Developments in these areas were described at the First International American Nuclear Society Topical Meeting on Computer Applications for Nuclear Power Plant Operation and Control(4) and the Second Electric Power Research Institute Workshop on Artificial Intelligence Application to Nuclear Power(5), both held in 1985.

Applications are also being made in areas more directly related to plant risk and safety. Some of the key developments are briefly described here.

In the area of assistance with risk analyses, a system called SQUIMP has been developed for event tree sequence importance calculations.(6)

SQUIMP provides for prompted data entry, generic expansion and on-line pruning of the event trees, Boolean reductions, and importance factor selection. It is intended for applications in the context of probabilistic risk assessment (PRA).

Systems to assist in accident management have also been developed. CEALMON is a rule-based emergency action level (EAL) monitor implemented on an IBM-PC.[7] It helps to automate EAL classification procedures in a real-time processing environment. The rule base includes the logic of current EAL tables and higher-level rules the resolve ambiguities and data conflicts, identify false alarms, and draw inferences in the event of missing data. A system called RSAS has recently been developed to assess the status of a reactor system during an accident and recommend corrective actions to reactor operators.[8] RSAS performs data consolidation and consistency checks, monitors safety setpoints, and determines diagnostic hypotheses related to core damage and containment releases. It was designed for use in the U.S. NRC operations center.

Two systems have been developed recently to present PRA information and results. PRISM is a plant risk status information management program implemented on an IBM-PC.[9] It provides plant-specific risk data and looks at the contributions of safety systems, support systems, and components to plant risk. It is intended for use by individuals who are not necessarily familiar with probabilistic risk assessment. CADET provides information on radionuclide source terms from degraded core accidents.[10] It was developed to provide assistance to U.S. NRC management and staff in decision making on issues related to source terms. CADET is described more fully in the next section.

AN EXAMPLE - CADET

Introduction

CADET was developed for the U.S. Nuclear Regulatory Commission by Battelle's Columbus Division as a user-friendly information and knowledge-based decision support system that provides information on radionuclide source terms to the environment from light water reactors during degraded core accidents.[10] The computer code is implemented on IBM Personal Computers.

CADET was developed to achieve several objectives:

- to consolidate the pertinent facts relating to source terms from the large amount of information data, and research results that have accumulated over the years,
- to incorporate expert opinion as needed to properly interpret the facts, and
- to aid a decision maker faced with decisions on issues related to source terms.

The information a decision maker needs is often scattered in various reports, is not in a suitable form, is not easy to comprehend, or does not appear relevant. Even when relevant information has been found, there is uncertainty whether it has been properly interpreted. Often an expert's opinion is needed in addition to the data. The decision maker then turns to a technical expert. It would be preferable if some form of self-help were available to the decision maker. CADET has been developed to fill this need for decisions related to radionuclide source terms.

Description of CADET

CADET is a menu-driven, interactive program. The menu available is shown in Figure 1. Inexperienced users can gain a feel for the code from menu item 1, "Data Base Description". It provides information on the plants and accident sequences contained in the data base. Also available is the list of radionuclides used in the source term analyses and the types of off-site consequence measures that can be used by the code to estimate the ex-plant consequences of accidents.

1. Data base description
2. Plant descriptions
3. Accident sequence descriptions
4. Source terms, consequences, and risk
5. Alternative containment failure modes
6. Plant design modifications
7. Data comparisons
8. Data base searches

FIGURE 1. CADET MENU

Menu items 2 and 3 are also useful for inexperienced users. Item 2, "Plant Descriptions", provides the principal features for each plant in the data base. Such information as nominal power, operating pressure and temperature, and engineered safety feature characteristics is included. Item 3, "Accident Sequence Descriptions", provides information that defines each accident sequence in the data base. This includes key events and their times of occurrence, the containment pressure and temperature histories during the accident, and the masses of combustible and noncombustible gases in the containment as a function of time. The probability of each sequence is also indicated using data from external sources.

Menu item 4, "Source Terms, Consequences, and Risk", is the principal part of CADET. For a particular plant and accident sequence, the user can select several options:

a) the distribution of radionuclides within the plant at the end of the accident,

b) the quantities of radionuclides released to the environment,

c) the ex-plant consequences resulting from the release of radionuclides to the environment, or

d) an estimate of the risk posed by the accident.

Ex-plant consequences are calculated from the source terms using a simple algorithm for a standard set of geographic, demographic, and weather conditions. Risk estimates are calculated by combining the consequence estimates with accident sequence and containment failure mode probabilities provided in CADET's database.

Menu items 5 and 6 provide the capability to perform some sensitivity calculations. Item 5, "Alternative Containment Failure Modes" allows the user to examine the impacts on source terms if the timing of containment failure were to change or if the leak rate from containment were different. Item 6, "Plant Design Modifications", allows the effects of filtered venting of containment to be examined.

Menu item 7, "Data Comparisons", allows source term data collected from different sources for the same or similar plants and accident sequences to be compared. Menu item 8, "Data Base Searches", provides a capability to search the data base for plants and accident sequences with the highest or lowest source terms or with source terms higher or lower than a threshold value input to the code by the user.

CADET answers questions about all plants and accident sequences analyzed in the report BMI-2104.(11) This is the principal source of data for CADET. Much of the data used or generated by CADET can be displayed graphically.

Uses of CADET

This is the first time that a large body of information on radionuclide source terms has been collected in one place and made readily available through an interactive computer code on a personal computer. It is also available at a time when a large amount of new data on this topic has become available and just before the U.S. Nuclear Regulatory Commission will attempt to use the data to revise regulations based on old and outdated source term assumptions. As this decision making process moves forward, it is anticipated that CADET will be used by NRC management and staff as a resource that will significantly reduce the effort involved.

It is also expected that CADET will become a part of a larger piece of software called the Source Term Integrator (STI) on which work has already begun. The STI will act as a focal point for a software tool that will provide access to various elements important to the use of source term and risk data in ensuring the safety of operating reactors. Other elements will include modules to assist in accident sequence definition, the use of uncertainty data, the incorporation of data from the systems analysis part of a probabilistic assessment, and the automatic execution of large computer codes to generate new source term information employing input data decks prepared using expert systems.

CONCLUSIONS

This paper has provided an overview of some expert systems and decision support systems being developed and used in risk and safety management, primarily of nuclear plants. A computer code called CADET that operates on an IBM Personal Computer was described as an example of a decision support system. It provides assistance in decisions that involve information on radionuclide source terms from light water reactors during degraded core accidents.

A great deal of activity is presently underway, much being motivated by commercial interests of software developers. We are now at the point where credible systems have been developed and are being used. However, a shakedown period is clearly ahead as the real capabilities and the potential of these systems are better understood through actual demonstration and use.

Much of the recent development effort has been stimulated by the introduction and increasing availability of personal computers. Clearly, this trend will continue for the forseeable future. Indeed, without the stimulus of personal computers that provide for on-the-desk assistance on command, it is unlikely that many of the developments described in this paper would have occurred.

Expert systems and decision support systems are beginning to be used in other industries in the U.S. in areas relevant to safety and risk. The use of expert systems in process control has received some attention. Personal computers are being used to assist in safety analysis at chemical plants to predict the dispersion of hazardous materials in the event of a release. Their use with expert systems is not far behind.

There is a variety of ways in which expert systems and decision support systems can be expected to be used in risk and safety management. For example, as analyst aids to help in selecting appropriate analysis techniques, to assist in conducting analyses such as HAZOPs, and to assist in preparing data for computer code analyses such as gas dispersion calculations. In the data area, they can be used to provide guidance in the collection, analysis, and use of data on, for example, component failures. These systems can also help in training analysts through interactive tutorials. They can also help with such safety-related plant operations as maintenance and inspection, for example, by providing guidance with inspection schedules and requirements, or by providing assistance in the interpretation of the results of diagnostic tests.

Efforts have already begun on a number of these applications. Many more are likely to follow in this rapidly developing field.

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