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USING MARS TO ASSIST IN MANAGING A SEVERE ACCIDENT

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ABSTRACT

During an accident, information about the current and possible future states of the plant provides guidance for accident managers in evaluating which actions should be taken. However, depending upon the nature of the accident and the stress levels imposed on the plant staff responding to the accident the current and future plant assessments may be very difficult or nearly impossible to perform without supplemental training and/or appropriate tools. The MAAP Accident Response System (MARS)[1,2,3] has been developed as a calculational aid to assist the responsible accident management individuals. Specifically MARS provides additional insights on the current and possible future states of the plant during an accident including the influence of operator actions. In addition to serving as a calculational aid, the MARS software can be an effective means for providing supplemental training.

The MARS software uses engineering calculations to perform an integral assessment of the plant status including a consistency assessment of the available instrumentation. In addition, it uses the Modular Accident Analysis Program (MAAP)[4] to provide near term predictions of the plant response if corrective actions are taken. This paper will discuss the types of information that are beneficial to the accident manager and how MARS addresses each. The MARS calculational functions include: instrumentation, validation and simulation, projected operator response based on the EOPs, as well as estimated timing and magnitude of in-plant and off-site radiation dose releases. Each of these items is influential in the management of a severe accident.

INTRODUCTION

There are numerous and complex details involved in the understanding and managing of a severe accident. With the very stressful situation imposed on the plant operators and accident management, it is imperative that adequate training and reliable supplemental tools are available to assist the accident management personnel. The MAAP Accident Response System (MARS) was developed to assist the plant operators and accident managers both for training on and use during an accident.

The MARS software uses actual (or simulated) plant data to assess the current state and to predict potential future states of the plant experiencing the accident. The MARS operational mode for assessing the current plant status is called TRACKER. The MARS operational mode for determining potential future plant states is called PREDICTOR and can be used to provide a near term projection (runs much faster than real time) of the plant response at any time during the accident. The information generated by MARS is intended to supplement the information available to those individuals response for making decisions. This includes:

1) Instrumentation Validation including Consistency Checks,

2) Projected Operator Response based on the EOPs, and

3) Estimating Timing and Magnitude of In-Plant and Off-site Radiation Dose Releases.

Descriptions of the other information available from MARS can be found in the MARS references listed at the end of this paper.

INFORMATION BENEFICIAL TO THE ACCIDENT MANAGERS

The information which is beneficial to the accident managers likely depends on the accident sequence and the status of the barriers for fission product release and for movement of core debris. However, the basic type of information the accident managers would like to know consists of:

a) Can I trust all the plant instrumentation readings?

b) Based upon the current state of the plant, what will be the plant status in the short & long term if the operators follow their EOPs properly?

c) At what time during this accident could I expect to have a release of radiation and where would this likely occur?

Based upon the responses to these three questions, additional questions arise which probe for more details. For example if the response to the first question, "Can I trust all the plant instrumentation readings?", is "NO", the next question is what instrumentation can I trust. A systematic approach to validating the available plant instrumentation through an integral consistency check helps address this concern. In addition, obtaining representative values for those signals which do not pass the validation criteria, can be beneficial for the accident manager. Likewise, the response to the other two questions will require additional details to determine and support the response.

INSTRUMENTATION VALIDATION & SIMULATION

The ability to successfully manage a nuclear plant during normal and accident conditions, relies upon the use of plant instrumentation readings. The primary purpose of plant instrumentation is to:

1) Effectively operate the plant,
2) Monitor plant status,
3) Deduce problematic plant conditions, and
4) Provide the entrance conditions and guidance for normal, abnormal or emergency operating procedures.

Under normal and accident conditions, the interpretation and use of plant instrumentation must always consider the possibility of faulty or non-representative readings. The probability of successfully detecting and addressing faulty or non-representative instrumentation during normal operation is higher than doing so under accident conditions. This paper focuses on the instrumentation assessment under accident conditions.

Assessing whether plant instrumentation readings are representative of the current plant situation is crucial to the successful management of an accident. Relying on instrumentation readings which do not represent the current state of the plant (i.e., instrumentation malfunction, off-scale, etc.) may result in inappropriate operator actions. Thus, basic information about the confidence level which should be placed on instrumentation readings will greatly assist the accident managers. In addition, the ability to determine representative values for instrumentation which does not pass the validation process, can provide additional information to the accident managers. The MARS software addresses both of these instrumentation issues, validation and simulation.

The validation of plant instrumentation can be broken down into two steps: 1) process all of the available plant data and 2) perform a consistency check of the processed plant data. Following each step of the validation process, a higher confidence level for the individual instrumentation readings results.

The development of methods to process plant instrumentation signals has been studied since the early 1980's.[5] The instrumentation validation processing phase can be summarized as:

1) Perform a comparison check among a set of redundant measurements of one process variable.

2) Discount those variables which are off-scale.

3) Question those instruments which remain at mid-range.

4) Question measurements which are "flat", i.e., no change.

Once the instrumentation processing phase is complete, a higher confidence level can be placed on those variables which have passed the screening criteria. Following this screening, the number of plant data which exit the processing phase may be reduced from what entered. For instance some variables may have been discounted for one reason or another. In addition, even though a comparison check of redundant variables is performed, the resulting value may not be representative of the actual plant condition. For these two reasons a consistency check of the data is required.

The consistency evaluation performs an integral assessment of the processed plant instrumentation readings to assure that each reading is representative. Plant instrumentation consistency evaluations can basically be performed by either using previous knowledge (i.e. data look-up tables, etc.) or by dynamically simulating the conditions. The MARS software uses the latter method, dynamic simulation, to perform its consistency check of the plant instrumentation.

One of the primary shortcomings of using previous knowledge to perform a plant instrumentation consistency check is that it uses previous knowledge to perform its assessment. Previous knowledge means that the same or similar type of accident (and corresponding instrumentation readings) must exist in the data base. With the large uncertainty associated with the accident progression, including the incorporation of operator actions, the generation of a representative data base is very challenging.

The MARS software uses engineering calculations, based upon changes in mass and energy, to dynamically assess the consistency between individual instruments and sets of plant data. To illustrate how MARS performs a consistency check on individual instruments, we will assume that we have valid instrumentation readings for all of the variables in a plant except for the core power which passes through the validation processing phase but is not representative of the actual core power. Information about the control rod status, the primary system pressure, the MSIV status, and the dynamic mass and energy balances performed by MARS on the reactor coolant system, the steam generators (PWRs) and the containment would alert the accident manager and then determine a representative value.

The MARS modeling of consistency between individual sets of plant data can be illustrated by assuming the plant instrumentation readings are reported every 60 seconds with all of the plant instrumentation readings being valid. However, during several of the 60 second intervals a primary system injection system could be turned on and off resulting in an increase in the primary system water level with no indication of system actuation from the plant instrumentation. In this case, the instrumentation is representative, but due to the data reporting interval the accident managers could be misled. Based upon the MARS dynamic mass and energy calculations, the accident manager would be alerted of a likely system actuation that is not reported in the plant data set. In addition, the MARS tracking simulation would be re-initialized with this insight to better represent the plant.

The generation of simulated plant data is another of the MARS features to assist in obtaining representative plant instrumentation readings. MARS tracks the plant behavior using thermal-hydraulic evaluations similar to the MAAP codes. Through this technique, values for plant instrumentation reading which either were discounted, missing, or not available can be approximated. For instance, for a containment where hydrogen combustion is a concern, MARS provides information to assist in evaluating this concern including providing representative values with realistic uncertainties for the concentrations of hydrogen, steam, carbon monoxide, nitrogen, etc.

The ability to (1) determine which plant instrumentation values are valid, (2) provide representative values for those variables which are not valid, and (3) create representative values for variables which are difficult to obtain can greatly benefit the accident manager. The MARS software incorporated each of these features.

CURRENT AND FUTURE PLANT STATES

The ability to mechanistically assess the current and predict the future plant states would greatly aid the accident managers in making their decisions. By using the validated set of plant data, as described above, the accident managers will have available representative sets of current and past plant histories. This information can be used to assess the plant conditions. However, due to the complexities of an accident and the stress levels of those managing the accident, a fundamental understanding of the current and future plant states may by challenging to determine. Add to this the response of the operators and the challenge expands. With: the complex details involved in an accident evaluation, the advances in the understanding of severe accident phenomena and the advances in the computer hardware field, a computer software tool is a natural candidate for assisting the accident managers.

MARS was developed as an accident management tool to provide insights to the current and future plant states. MARS has been benchmarked against both real transients[6] and numerous simulated accidents and has been found to be in good agreement in determining both the current (MARS - Tracker mode) and future (MARS - Predictor mode) plant conditions.

The MARS Tracker mode of operation uses the validated plant instrumentation readings (as described above) and engineering calculations to update the plant specific MAAP model to the specific accident sequence based on the plant data and initialize the MAAP code. The MAAP code is used to determine the thermal-hydraulic and fission product response of the plant during accident conditions. Once MAAP has been initialized by MARS, the evolving set of plant data is used to assess how well the thermal-hydraulic model can track the dynamic plant behavior. Internal calculations are performed to assure MARS is following the plant behavior. When adjustments are necessary, such as the size of a break in the primary system, the Tracker evaluates and makes such changes. Once MARS is successfully tracking the validated plant data, numerous insights are available to the accident manager including: the type of accident occurring, the potential root cause of the accident, the current status of the fuel and vessel, the containment conditions, system status along with values for several thousand thermal-hydraulic and fission product parameters.

The Mars Predictor mode of operation uses the conditions established by the Tracker as its basis for performing faster than real time predictions of the future plant state. The Predictors allow for operator actions based upon the Emergency Operating Procedures (EOPs), Accident Management (AM) guidelines, or other possible actions to be incorporated into the predictions. The modeling of the operator responses is handled by user input and is performed by the MAAP Operator Model (MOM) software. Since the Predictors execute several times faster than real-time (even on the slowest 386 PCs), the accident managers can gain insights into the potential future plant states well before the operators would be required to take action.

TIMING AND MAGNITUDE OF RADIATION RELEASE

A determination of when the various fission product barriers have been breached, can help guide the accident manager decisions. The fission product barriers include: Clad, Fuel, Vessel and Containment. The expected timing and magnitude of the releases, should the accident continue in the current manner, can benefit the accident managers in estimating what actions could be taken and how much time is available to implement the action.

The MARS Predictor (as discussed above) calculate the thermal-hydraulic and fission product response of the plant assuming various operator actions. Included in the Predictors is the ability to use the calculated fission product response to determine the radiation dose and dose rates within and outside the plant.[7,8] With this capability, access to the various plant regions can be determined. In addition, the magnitude of the release of radiation can be estimated.

SUMMARY

The managing of and training on severe accidents can be greatly enhanced through the use of supplemental tools. The basic information that the supplemental tools should address to assist the accident manager would answer the questions:

a) Can I trust the plant instrumentation readings?

b) Based upon the current state of the plant, what will be the plant status in the short and long term if the operators follow their EOPs properly?

c) At what time during this accident could I expect to have a release of radiation and where would this likely occur?

The MARS software, as discussed in this paper, effectively addresses each of these issues.

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