DEVELOPMENT OF THE EMERGENCY RESPONSE SUPPORT SYSTEM IN JAPAN

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ABSTRACT

The Emergency Response Support System (ERSS) is set up to support the activity of the Ministry of International Trade and Industry (MITI) in case of emergency in a commercial nuclear power plant in Japan. The ERSS provides MITI with effective technical information by linking the MITI computer system with those in nuclear power plants. The development of the ERSS started in FY 1987 and is scheduled to end in FY 1995. The ERSS consists of five subsystems: the Information Processing System, the Diagnosis/Prediction System, the Analytical Prediction System, the Large Display System and the Transmitted Plant Parameters Simulation System. In the prototype all subsystems are installed in the computer room of Nuclear Power Engineering Corporation (NUPEC) whereas in the practical system the Information Processing System (Information Collection Module) and the Large Display System are installed in the MITI Decision Making Room. The other difference between the prototype and the practical system is that the simulated data are produced by the Transmitted Plant Parameters Simulation System and are used in the former in stead of the real plant information used in the latter.

INTRODUCTION

After the accident occurred at Chernobyl in April 1986, the Nuclear Safety Commission of Japan pointed out the importance of improving the practicality of various emergency measures in its investigative report on the accident published in May 1987. In response, the Ministry of International Trade and Industry (MITI) studied the action that the government of Japan, local self-governing bodies, and utility companies should take in an emergency; the roles of MITI and utilities and their specific actions; judgment of emergency situations and their classification; and the Emergency Response Support System (ERSS).

The role of MITI in an emergency situation at a nuclear power station is to grasp the plant situation accurately, to predict if the situation could become worse or not, and to evaluate the effect of radioactive material released on the environment around the plant site. The objective of the ERSS is to supply information relating to the above items to MITI personnel and to support their activity during an emergency situation of a nuclear power plant.

On the basis of the studies MITI entrusted the Nuclear Power Engineering Corporation (NUPEC) with the development of ERSS. The NUPEC decided to adopt a two-steps development plan: the first step (FY 1987 - FY 1992) is devoted to develop the ERSS prototype and the second (FY 1993 - FY 1995) to attain its practicality.

In the design of the ERSS the system is presumed to be activated in the event of "the design basis accidents (DBA)" (e.g., loss of coolant accident), "situations more serious than DBA" (e.g., severe accidents), etc. at a commercial nuclear power plant (light water reactor type) in Japan. According to the decision of the utility, plant parameters of an affected plant are transmitted to the ERSS from the plant site in the case of an emergency.

In the succeeding parts of this paper the explanation of the practical system is first given in the aspect of its completion and then the prototype is described from the view point of the differences between two systems.

CONSTITUTION OF THE ERSS

Figure 1 shows the fundamental constitution of the ERSS. The main processing part of the ERSS consists of five subsystems: the Information Processing System, the Diagnosis/Prediction System, the Analytical Prediction System, the Large Display

System and the Transmitted Plant Parameters Simulation System. In the NUPEC Operation Room are installed the main processing parts with the exception of the Information Processing System (Information Collection Module) and the Large Display System, which are installed in the MITI Decision Making Room.

The plant parameters are first transmitted to MITI and then transferred to NUPEC. The information from the plant is automatically displayed on the Large Display System before it is processed at the NUPEC Operation Room. Besides the above on-line information some information will be informed through off-line devices (telephone, facsimile, etc.). These are manually input to the ERSS at the Decision Making Room.

Main results obtained by the Diagnosis/Prediction System and the Analytical Prediction System are shown on the Large Display System through the Information Processing System. If required, the detailed results of these subsystems can be seen at the Decision Making Room through engineering workstations (EWS).

The Transmitted Plant Parameters Simulation System is installed for the purpose of emergency drills.

THE INFORMATION PROCESSING SYSTEM

The Information Processing System is divided into two modules: Information Collection Module and Information Control Module. The former module is installed in the MITI Decision Making Room and is in charge of functions such as data acceptance, transmission and archives. The latter module is in the NUPEC Operation Room and is in charge of managing other subsystems.

The numbers of plant parameters transmitted from a plant are about 70 for BWR and 100 for PWR. These parameters are selected from the following points of view:

- Usefulness of parameters in specified accident sequences which are studied in the probabilistic safety assessment (PSA),
- Requirements from the Diagnosis/Prediction System and the Analytical Prediction System.

The plant parameters are transmitted once per minute through the Packet Switched Network of the Nippon Telegraph and Telephone Corp. (NTT).

THE DIAGNOSIS/PREDICTION SYSTEM

Constitution of the Diagnosis/Prediction System

The Diagnosis/Prediction System is an artificial intelligence (AI) system which is constructed on a real-time expert shell "G2". As shown in Figure 2, two inference systems are included in the subsystem. The #1 inference system is operated in real time mode immediately after the plant parameters are transmitted from the plant site. The #2 inference system is usually in standby mode and is operated in catch-up mode when off-line data are manually input. The #2 system is also used for executing the "what-if-study".

The #2 inference system can run faster than the #1 inference system. When the #2 system catches up with the #1 system the processed data in the #2 system are transferred after synchronization is established.

Functions of the Diagnosis/Prediction System

The objective of the Diagnosis/Prediction System is to offer information on the present plant situation and the prediction of the future plant state by applying the artificial intelligence technology.

Because an accident scenario cannot be known for an unprecedented accident the symptom-based inference is adopted first and the scenario-based inference is employed as an auxiliary mean. The following 13 functions are the basic functions of the Diagnosis/Prediction System:

((Event Identification))

- Initial Event Judgment
  The cause of an accident is assumed and identified. Clarifying the cause deepens the understanding of the accident situation at hand and increases confidence in determining countermeasures.
- Accident Scenario Identification
  In addition to the initial event, the accident scenario is identified in the real-time way.

((Plant Situation Determination))

- State of Safety Functions Determination
  The status of the following four safety functions is determined: reactivity control, core cooling, decay heat removal, and containment vessel soundness.
- Radioactivity Barrier State Comprehension

The soundness of the core, reactor pressure vessel, and containment vessel is determined from the point of view of radioactivity barriers.

((Emergency Situation Judgment))

- Convergence/Progress of Accident Determination

  Information is provided for determining whether the accident will be put down or expanded.
- Emergency Action Level Judgment

  Information is provided for determining the level of the emergency (classified into four levels).

((Countermeasure Determination))

- Judgment of Operations Influencing Radioactive Release

  The feasibility of plant operations which lead to radioactivity release is determined.
- Judgment of Necessity to Notify Related Agencies of the Accident

  Information is provided for judging whether related agencies should be consulted or not.

((Plant State Prediction))

- Prediction of Accident Progress Based on the Knowledge Data Base

  On the basis of the knowledge data base on plant behavior, qualitative and quantitative information is provided for predicting whether the accident will cease or escalate.
- Prediction of Accident Progress Based on Simple Simulation

  Prediction capability of the ERSS is reinforced by adding a simplified physical model analysis to the AI process.

((Radioactive Material Prediction))

- Prediction of Released Amount of Radioactive Material

  Quantity of released radioactivity is estimated by using the data of the core fission product inventory and its fractions.
- Prediction of Dose Rate around the Plant Site

  The quantity of the released fission products on the surrounding area is evaluated by using a simple exposure-effect evaluation code.

((Emergency Situation Transition))

- Prediction of Changes in an Emergency Situation

  Transition in the emergency action level is predicted from the results of the plant state prediction.

Knowledge Data Base

The functions of the subsystem can be attained by comparing the transmitted plant parameters with the previously collected knowledge-based data, which are mainly extracted from the "PSA Levels 1 and 2" studies.

For this purpose many kinds of severe accidents were analyzed by the MAAP (Modular Accident Analysis Program) code. The comparison of these analyses with those by other severe accident analysis codes (e.g., MELCOR, THALES/ART, etc.) shows that the MAAP analyses are generally acceptable to the ERSS.

THE ANALYTICAL PREDICTION SYSTEM

The purpose of the Analytical Prediction System (APS) is to supplement the prediction functions of the Diagnosis/ Prediction System. The main part of APS consists of a sophisticated version of the MAAP code and can be started at any moment of the transition of the accident by inputting the plant parameters transferred from the plant (Initiation Mode).

In a short duration after the start of the APS its output is compared with the plant parameters in the duration. If a considerable deviation is detected, the start condition of the APS is modified by inputting the latest plant parameters at the end of the duration and/or by modifying a system parameter (e.g., a size of breakage in the case of LOCA) (Tracking Mode). When the deviation is regarded permissible the APS is ready for the prediction and can be run at the request of users (Prediction Mode).

The following is information provided by the APS which is considered to be useful for precise comprehension of the plant situation.

((Event Information))

- Possibility of core exposure and its predicted time
- Possibility of hydrogen generation and its predicted time
- Possibility of change in core shape and its predicted time
- Possibility of reactor vessel breakage and its predicted time
- Possibility of containment vessel breakage and its predicted time

((Quantitative Information))

- Coolant pressure, temperature, etc.
- Core cooling condition (amount of coolant, fuel temperature, etc.)
- Core damage condition (Zr-water reaction, fuel

melting, etc.)

- Debris cooling condition (water quantity in lower plenum, debris temperature, etc.)
- Explosion/deflagration (hydrogen generation, concrete reaction, etc.)
- Effect on environment (fission product distribution in plant, fission product release to environment).

THE LARGE DISPLAY SYSTEM

The Large Display System in the MITI Decision Making Room consists of four 58" display units (arranged in 2x2) and peripheral equipment. Figure 3 shows an example of the screen layout for a BWR plant. A similar layout is also prepared for PWR. The right-hand side of the screen shows plant site information whereas the left-hand side shows diagnosis/prediction information.

The name of an affected plant and its scram time are indicated in the upper part of the upper right-hand side quarter. The plant system status (e.g., remarkable phenomena and machinery status in the plant) is shown in the second part and the environmental parameters (e.g., meteorological parameters and readings of radiation monitoring posts) are shown in the third part. The lower right-hand side quarter is a changeable window and shows main plant parameters and their trend graphs by menu selection. The menu buttons appear at the bottom of the quarter.

The initiating event, accident scenario and emergency action level are estimated by the Diagnosis/Prediction System and indicated at the top of the upper left-hand side quarter. The remaining part of the quarter shows the inference results of the radioactivity barrier and the status of safety functions. Messages relating to the prediction of accident progress are sequentially shown in this quarter. The lower left-hand side quarter is a changeable window and shows information from the Diagnosis/Prediction System and the Analytical Prediction System. In Figure 3 the quarter shows a network expression for predicting accident progression. The menu buttons appear at the lower part of the quarter. The bottom of the quarter is a window relating messages on the ERSS computer system status.

THE TRANSMITTED PLANT PARAMETERS SIMULATION SYSTEM

The Transmitted Plant Parameters Simulation System is installed mainly for the purpose of accident drills. The subsystem simulates the plant parameters which will be transmitted from a plant in a real situation. The main part of the simulated data is produced by converting the MAAP results. Some of the simulated data (e.g., meteorological data) are newly created and added in order to complete the simulation.

The frequency of producing the simulated data is one minute by the analogy of the frequency of transmitting the actual plant parameters.

THE ERSS PROTOTYPE

As explained before, the prototype of the ERSS has been completed in FY 1992. Almost all functions of the practical system are realized in the prototype. The major difference between the practical system and the prototype is that the former is separately installed in MITI and NUPEC whereas the latter is only in NUPEC. The other differences are as follows.

- In stead of actual plants the following typical BWR and PWR plants are considered as reference plants in the prototype.

  BWR: 800MWe MARK-I BWR-4 plant
  PWR: 1100MWe improved and standardized 4-loop plant

  These plants were selected because of the abundant PSA data available in them.
- In stead of actual plant parameters the simulated data produced by The Transmitted Plant Parameters Simulation System are used.
- The numbers of simulated plant parameters for the typical BWR and PWR plants are:

BWR	on-line	62
	off-line	6
PWR	on-line	94
	off-line	7

- The Large Display System is simulated by using four 19" display units arranged in 2x2.

ACKNOWLEDGMENT

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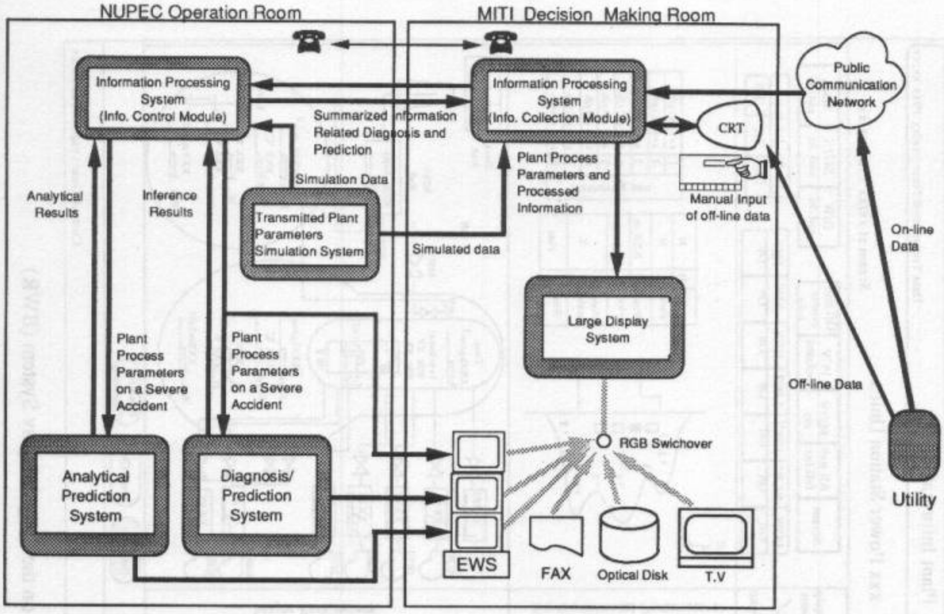

Figure 1. Constitution of the ERSS Practical System

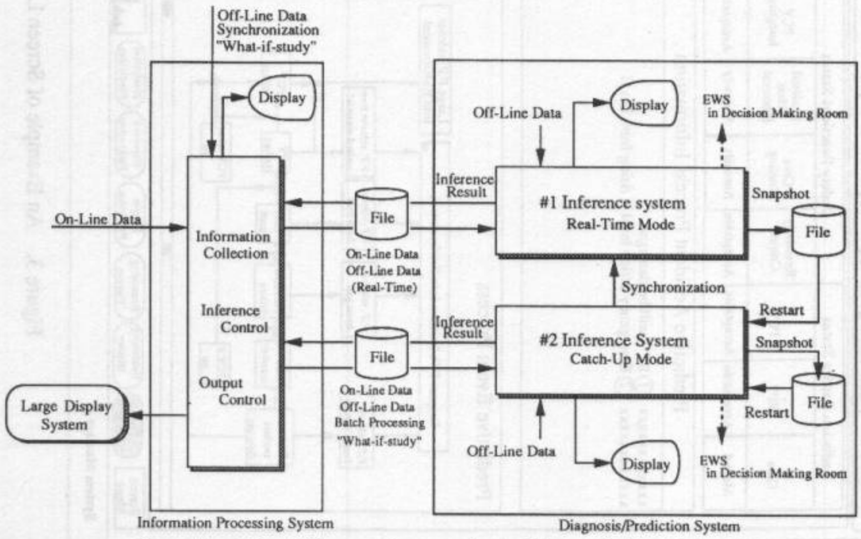

Figure 2. Two Inference Systems in the Diagnosis/Prediction System

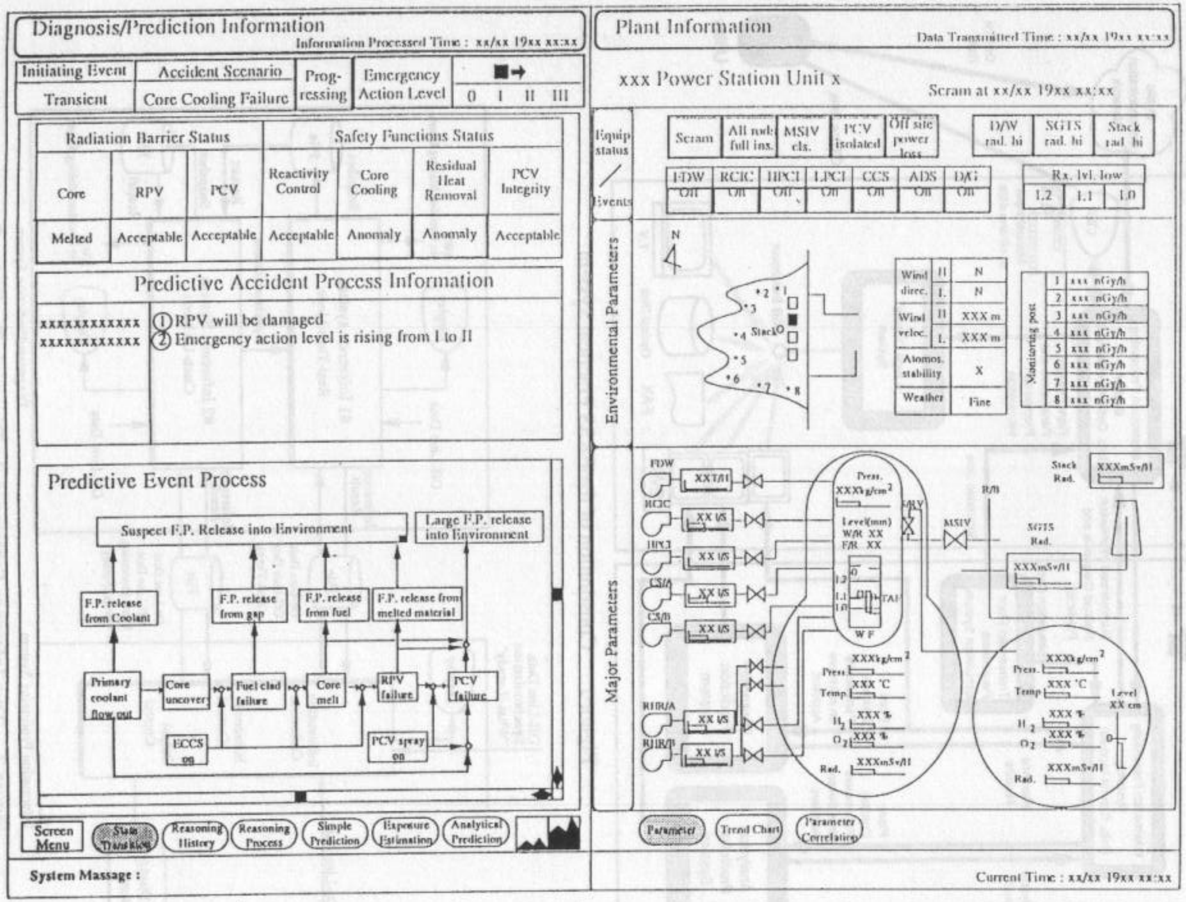

Figure 3. An Example of Screen Layout on the Large Display System (BWR)