# Safety Performance Improvement for Nuclear Power Plants Utilizing THOMAS

Won June Kim, Jung Uk Ryu, Kune Y. Suh*
*PHILOSOPHIA, Inc., San 56-1 Sillim-dong, Gwanak-gu, Seoul, 151-742, Korea*
** kysuh@philosophia.co.kr*

## 1. Introduction

THOMAS (Thermal Hydraulics Online Monitoring Advisory System) is equipped with a couple of salient features compared with existing monitoring systems. The first has to do with the three-dimensional (3D) visualization technique to support the nuclear power plant (NPP) operators and personnel using the virtual reality (VR) [1] technology. VR depicts an environment simulated by a computer. Most of the VR environments primarily include visual experiences, displayed either on a monitor or though special stereoscopic goggles. Users can often interactively manipulate a VR environment [2], either through standard input devices like a keyboard, or through specially designed devices like a cybergloves. Additional devices were not applied the in THOMAS. The visualized model file is brought to the VR space from the computer-aided design (CAD) tool. In the VR space, using mapping, the component color is changed with linked value of the safety variables. Operators thus can easily recognize the plant condition. This is related with the human factor engineering. The second is the function of decision making using the influence diagram logic. The influence diagram logic is based on the total probability and Bayesian theory. The accident modeling is rooted in the emergency operating procedure (EOP). The final goal of this system is, in the accident situation, to present a success path to the operator for the recovery of the NPP system. At the current developing level, the database signals THOMAS. In other words, a spectrum of system analysis codes provides the safety parameter values to the database, which are subsequently supplied to THOMAS through the network.

## 2. Advisory Monitoring System

THOMAS is not the whole monitoring system, but an advisory system examining typically 76 variables. Therefore, its main functions include only the reactor coolant system (RCS) and the emergency core cooling system (ECCS). Variables are selected partly by the thermal hydraulic system code analysis and partly by the expert's advice. As shown in Figure 1, the main server has two key functions. The first is the data supporting module which handles the input and output of operation data from PDAS (Plant Data Acquisition System). Another is the GUI (Graphic User Interface) module which transmits the rendered result of the 3D object from the main server to the operator's computer.

The main network system of THOMAS comprises the TCP/IP internal protocol. A memory sharing method is accompanied. The hardware framework is rather simple compared with the commercial monitoring system. Two workstation computers are placed near the PDAS of main monitoring system server. One functions as the main server of THOMAS, whereas the other performs as the backup server. The several client computers are set in the main control room of the NPP for the operator. The multiport bridge switching hub then connects the server with the client.

The central merit of the THOMAS system has to do with convenience in the installation and expansion from the system design point of view.

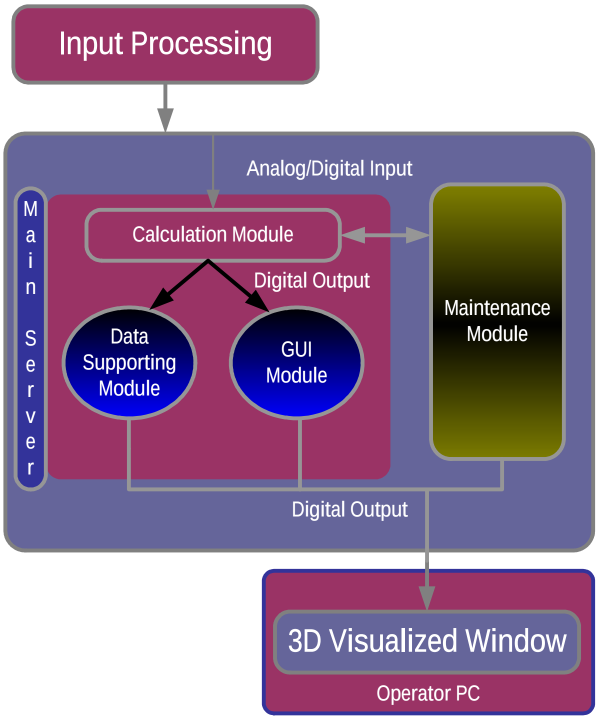


Figure 1. THOMAS design concept

## 3. 3D Visualized Window

Recent developments in the VR, CAD and computer graphics technology have led to much more efficacious methods of disseminating a wide variety of information beyond and above the form of text. Generally, humans can much more readily adsorb the information in the form of pictures and movies rather than text. The multimedia conference and military training in the VR space are good examples of applications. [3] Text is no longer effective enough to pass on the information at large. The 3D visualization technology appears to be the answer to dealing with the complicated system such as the NPP monitoring system. [4] In response to changing environment a 3D visualized window has been adopted in THOMAS. The 3D visualized window module displays the critical safety parameters of the RCS using the 3D object technique. In this module the safety parameters from the DBMS (Database Management System) are demonstrated in color or flickering. In addition, THOMAS helps the operators preview the accident sequence using the 3D animation. The total number of supported sequence animation is 26 spanning from a small-break loss-of-coolant accident (SBLOCA) to a turbine trip. One can navigate through and freely rotate the 3D object in the 3D visualized window. This free view capability brought not only the advantage of the effective data arrangement but also the effect of centralization of eyes.

The visualized window module includes the two-dimensional (2D) module as well as the 3D module. In other words, the 2D graph is used to confirm the trend of each and every safety parameter. At the moment, previous 20 point and present values are drawn for selected safety parameters in the XY plane. Also, if the guideline exists for each parameter, it is expressed in the same graph.

## 4. Accident Prediction Function

The accident model in this module is based on EOP with its decision making algorithm of influence diagram whose network consists of nodes and arcs as illustrated in Figure 2 [5]. The node has information and condition of the dependency. The nodes are grouped into four types according to their functions: decision, chance, diagnosis and value. The arc is a line with a direction of information and condition.

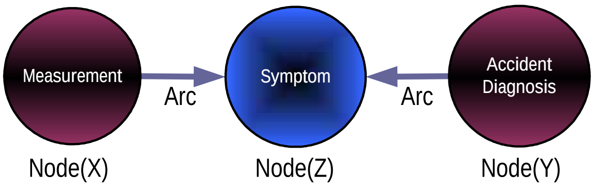


Figure 2. Conceptual structure of influence diagram

The total probability and Bayesian theory are used for the quantity calculation of the influence diagram. First, the measurement node is absorbed into the symptom node by calculating the total probability given the probabilistic safety assessment (PSA) data of the sensor. The Bayesian theory is then utilized to reverse the direction of the arc. Last, the total probability theory is used once more to determine the accident which most coincides with the given symptom.

At the moment users can select only three types of symptom: increase, decrease and changeless given the safety parameters. However, it is difficult to apply this method to NPP because each symptom of the accident may as well rapidly change during a short period of time. For example, during a steam generator tube rupture (SGTR) accident, the steam generator pressure is perturbed. It is thus important to choose the baseline for type of symptom. In this work the baseline is selected pursuant to the result given by the system codes such as RELAP and RETRAN. The experts' opinions may also serve as one of the methods for selecting the baseline.

## 5. Conclusion

THOMAS has a 3D visualized window and accident prediction function as the NPP advisory monitoring system. The two modules have a mutual dependency because the latter module predicts the accident and corresponding symptom is checked with the former. The current effort concentrates on development of prototype which connects the database with the 3D objects and models the accident by applying the influence diagram for SGTR and SBLOCA.

Future work will focus on expansion and commercial application of the THOMAS prototype. The expansion includes not only modeling the accident but also adding the support functions for user friendliness. On the other hand, the commercial approach relates to licensbility of the prototype. To this end, verification and validation of THOMAS is in progress backed up by system codes and experts' opinion. THOMAS is expected to drastically change the environment of the NPP monitoring system.

## ACKNOWLEDGMENTS

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