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Development of an Integrated Knowledge-base and its Management Tool for Computerized Alarm Processing System

Gyunyoung Heo, Seong Soo Choi, Han Gon Kim, and Soon Heung Chang

Department of Nuclear Engineering
Korea Advanced Institute of Science and Technology
373-1 Kusung-dong, Yusong-gu
Taejon, Korea 305-701

Abstract

For a long time, a number of alarm processing techniques have been researched to reduce the number of actuated alarms for operators to deal with effectively during the abnormal as well as the normal conditions. However, the strategy that the only systems with a few clear technologies should be used as a part of an alarm annunciation system has been adopted considering the effectiveness and the reliability in actual alarm processing systems. Therefore, alarm processing systems have difficult knowledge-base maintenance problems and limited expansion or enhancement defects. To solve these shortcomings, the integrated knowledge-base which can express the general information related to all the alarm processing techniques is proposed and its management tool, Knowledge Input Tool for Alarm (KIT-A) which can handle the data of the knowledge-base efficiently is developed. Since the integrated knowledge-base with KIT-A can manipulate all the alarm information without the modification of alarm processing system itself, it is expected to considerably advance the overall capability of maintenance and enhancement of the alarm processing systems.

I. Introduction

In a nuclear power plant (NPP), it has been the top goal to limit the release of radioactive materials. Among the principles to achieve this goal, the roles of alarm annunciation systems are getting more important especially after the TMI accident. The key point is to reduce the number of alarms that do not need operators' attention and to report the alarms that are prioritized according to their importance. As a result of the researches, the general methodology of alarm processing system design which is composed of four steps [1] - alarm source, logic, operating sequence, and displays - and many alarm processing techniques which can actuate the important alarms that are indispensable to controlling the plant in each step - elimination, suppression, and prioritization - have been proposed.

By the way, although many techniques have been developed, the practical methods that are applicable to real alarm processing systems are not sufficient. The general reason may be because of the effectiveness and reliability of processing methods and the difficulty of the construction of the integrated knowledge-base that includes general techniques. Because of these facts, an alarm processing system has kept its own specific knowledge-base. Such a system, however, may cause the following demerits: In view of data-interchange, a standardized format of knowledge-base is more useful than the special format that is adopted in a specific system dependently. And an alarm processing system itself must be changed because it has all the alarm processing techniques by itself to apply new processing techniques to a current alarm processing system or to modify the conventional one installed previously. These experiences have shown that there is a need for the generic tool for configuring more intelligent alarm systems where various alarm handling techniques can be integrated. So the OECD Halden Reactor Project has developed the Computerized Alarm System Toolbox (COAST) [2].

In this paper, the development strategies of the integrated alarm processing knowledge-base to supplement these problems are proposed and the generic management tool that is developed to satisfy these strategies is demonstrated.

II. Development Strategies of Integrated Alarm Processing Knowledge-base

II. 1. Overall Concept of Integrated Knowledge-base

The ultimate goal of the integrated knowledge-base is to provide the capability to manipulate all the alarm processing techniques by establishing the standardized format and to operate this knowledge-base independently.

The schematic concept of the integrated knowledge-base is shown in Fig. 1. Because the integrated knowledge-base can include all kinds of alarm processing techniques and handle them, the information management is very flexible. In addition, the integrated knowledge-base with the validated alarm processing kernel can be an 'add-on' module to conventional alarm processing systems in NPPs or even other industries. In this approach, there are the following merits:

- It is possible to easily construct and modify the knowledge-base. So development time and efforts will be reduced and the flexibility will be higher.
- It is easy to understand the contents of knowledge-base because of its standardized format. So the reliability of knowledge-base will be enhanced.
- It is possible to reuse the knowledge-base independently from the alarm processing system.

II. 2. Integration of Alarm Elimination/Suppression Techniques

There is some difference between meaning of elimination and that of suppression. That is, an eliminated alarm is considered as a non-alarm and not presented to the operator. On the other side, a suppressed alarm is presented with operators' request. But their structure is very similar each other. Thus it is possible to integrate the elimination and the suppression techniques together by the same principle. To achieve this, the re-classification of the conventional alarm elimination/suppression techniques has been done from the data item checking point of view. Because there are some techniques for which their boundary are not definitely separate, the classification of techniques is re-accomplished with being based on the methodology itself of the techniques [3-5]. From this analysis, the following data items are identified:

- Alarm Name

  : This is the target alarm to be eliminated/suppressed.
- Alarm Elimination/Suppression Technique Name

  : This is the name of the alarm elimination/suppression technique by which the alarm is eliminated/suppressed. Because one alarm may be related to many elimination/suppression techniques, it is necessary to identify which technique is the cause of alarm processing.

- Check Time

  : This is the time interval to which the alarm elimination/suppression is applied. The check time consists of an initial check time and a final check time.

- Alarm Elimination/Suppression Logic

  : This is the condition that is applied to eliminate/suppress specific alarms. The simple syntax-directed definitions of the alarm elimination/suppression logic are follows;

  expr → *expr* **OR** *term* | *term*

  term → *term* **AND** *factor* | *factor*

  factor → (*expr*) | signal name | alarm name | event name

  | **TRUE** (keyword meaning always suppression)

The relation of these four data items is shown in Fig. 2. To develop the processing kernel of the elimination/suppression, an alarm elimination/suppression rule is analyzed as follows:

FROM *Initial Check Time* **TO** *Final Check Time*

IF *Alarm Elimination/Suppression Logic* = **TRUE**

THEN *Actuated Alarm* is suppressed.

Table 1 shows the conventional alarm elimination/suppression techniques analyzed and the results of the application of the alarm suppression rule.

II. 3. Integration of Alarm Prioritization Techniques

There are few known methodologies in prioritization techniques unlike elimination/suppression techniques. So the static and the dynamic prioritization techniques using prioritization logic matrix [6] is incorporated.

Because the prioritization technique needs the physical information of the plant, it is necessary to construct the plant hierarchy as shown in Fig. 3. In this methodology, system-level prioritization uses the dynamic prioritization technique and the other level one uses the static prioritization technique. As a result, the final priority can be represented by the prioritization logic matrix that is made by logical combination of each prioritization principles according to the operational modes. If an individual alarm belongs to two components or more, the conservative priority should be selected. The individual alarms in the integrated knowledge-base have the final priority in each operational mode that is calculated by the prioritization logic matrix. In this case, each alarm has both static and dynamic properties.

III. Development of the Management Tool for Operation of Integrated Knowledge-base

The management tool is a kind of the generic tool that can make the integrated knowledge-base available in alarm processing kernels. The management tool needs the following functional requirements:

- The management tool can create the knowledge-base that can be accessed by the alarm processing system. And the knowledge-base should be operated independently from the alarm processing system.
- The management tool can handle all the information related to the alarm processing techniques.
- The management tool should have the capability of defining the hierarchy and properties of the plant for

the alarm prioritization.

- A syntax checking function should be incorporated to guarantee the reliability of all the information.

In this study, the management tool which satisfies the above functional requirements, Knowledge Input Tool for Alarm (KIT-A) is developed. The function hierarchy of KIT-A is shown in Fig. 4. Functional level 1, 2, and 3 are used for the construction of the integrated knowledge-base related to the alarm prioritization. KIT-A makes a knowledge-base with the inputted properties and the prioritization logic matrix that is included in itself. Functional level 4 is used for the alarm elimination/suppression. In KIT-A, new elimination/suppression techniques can be defined and the general ones related to alarm elimination/suppression can be operated. In addition, for the conventional elimination/suppression techniques whose methodologies are known, the specific windows with the typical data items can make the construction of knowledge-base much easier. KIT-A provides the methods to manipulate all the alarm processing information through syntax- and graphic-based editor. So KIT-A can reduce the errors from the complex tasks and can input the information quickly. In each level, inputted information is checked and is reported to a user if there is something wrong through the syntax checking module of KIT-A. KIT-A creates the integrated knowledge-base in ASCII format using its interior database management system. Fig. 5 illustrates a display of KIT-A.

IV. Results and Conclusions

The concept of the integrated alarm processing knowledge-base is proposed to have the reliability and performance of alarm processing systems enhanced. The integrated knowledge-base can be an actual alarm annunciation system in NPPs or other industries because it can represent all the information related to alarm processing regardless of systems. In fact, the various alarm processing techniques are generalized appropriately to the integrated knowledge-base. And KIT-A is developed to handle the integrated knowledge-base and is designed towards the reduction of a user's errors using the syntax- and graphic-based editor. The integrated knowledge-base with KIT-A can be used as a generic system for computerized alarm processing systems in a general plant.

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Table 1. The application of alarm elimination/suppression rule to conventional alarm processing techniques

Alarm Elimination/Suppression Techniques	Check Time		Alarm Elimination/Suppression Logic
	FROM	TO	
• Status Indicator Separation	A moment of an alarm actuation	A moment of an alarm clearing	▪ Always suppression
• Causality-based Method			▪ Direct precursor
• Multi-setpoint Intrarelationship			▪ Level precursor
• Mode Dependency Method			▪ Specific mode
• Event-oriented Method			▪ Specific event
• State Dependency Method			▪ Specific state
• Time Delayed Method		A preset time	▪ Always suppression

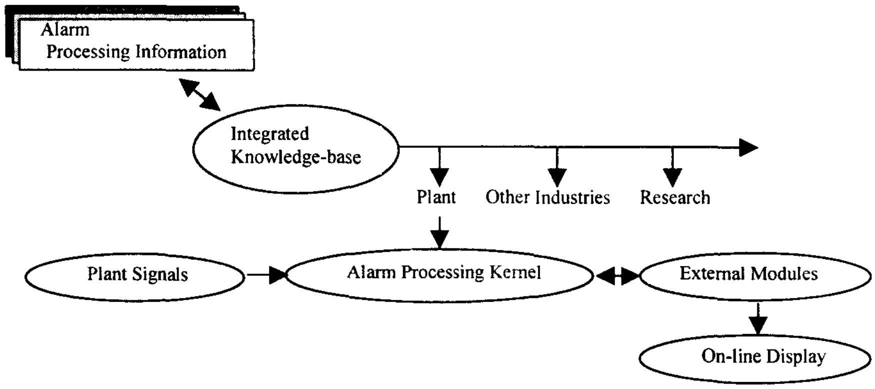

Fig. 1. The schematic concept of the integrated alarm processing knowledge-base

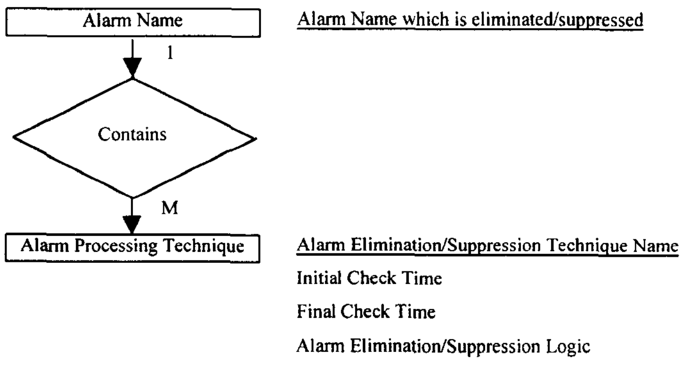

Fig. 2. The entity-relation diagram for the alarm elimination/suppression information

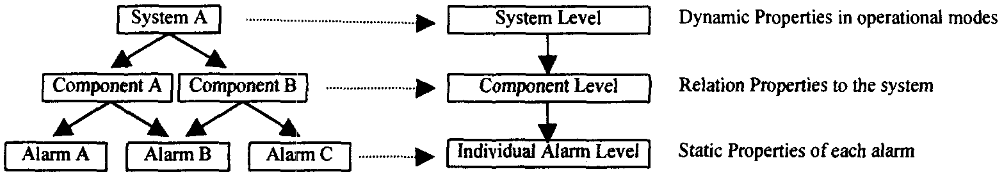

Fig. 3. The plant hierarchy for the alarm prioritization

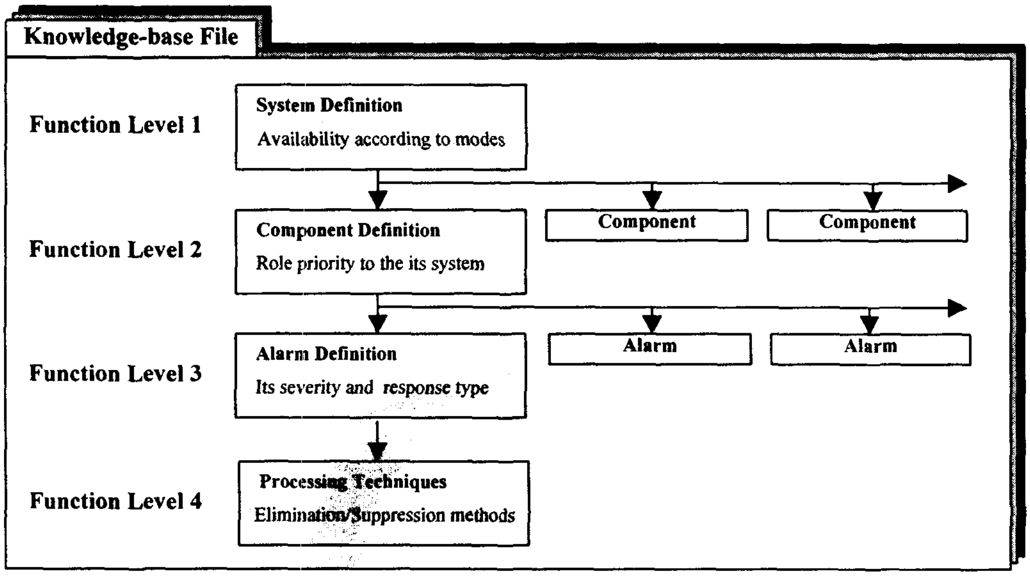

Fig. 4. The functional hierarchy of KIT-A

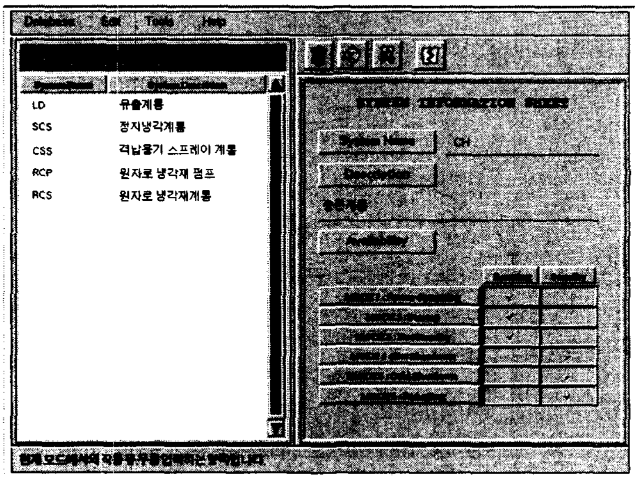

Fig. 5. The main display of KIT-A