Introduction

This Technical Information (TI) introduces the background on how Yokogawa devised a new alarm management concept, “CAMS” - Consolidated Alarm Management System, as well as an overview and the scope of realization in CAMS for HIS, the first CAMS-based product, to customers who are:

- up against alarm flooding;
- considering rationalization of alarms;
- considering integration of distributed alarm systems;
- considering the enhancement of DCS’s alarm monitoring functions;
- not satisfied with the current practices of alarm rationalization or improvements

References


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CONTENTS

1. Backgrounds on How YOKOGAWA Devised CAMS Concept ............. 1-1
   1.1 Alarm Flooding May Cause Plant Accidents ................................. 1-1
   1.2 Causes and Solutions to Alarm Flooding ................................. 1-1
   1.3 EEMUA Publication No.191 Alarms Systems ............................... 1-2
   1.4 EEMUA Issues ............................................................................. 1-3
   1.5 Changes in Ways of Thinking ...................................................... 1-4
   1.6 Target Users and Expansion of Scope of Application .................. 1-4

2. CAMS Concept ............................................................................. 2-1
   2.1 The Basic Concept - Three Consolidation Items ......................... 2-1
   2.2 Implementing Real-time Alarm & Event Monitoring .................... 2-3

3. CAMS for HIS ............................................................................. 3-1
   3.1 Alarm Processing and Configurator Functions ............................ 3-2
   3.2 Real-time Alarm & Event Monitoring (Message Monitor) Functions ... 3-4
1. Backgrounds on How YOKOGAWA Devised CAMS Concept

1.1 Alarm Flooding May Cause Plant Accidents

Health & Safety Executive (HSE), a British agency, and other expert groups investigated disasters that occurred in various industrial plants in the 1990’s. They found that a part of these accidents were caused by operators who overlooked important alarms or made erroneous judgment because of alarm flooding. Direct and indirect losses incurred from accidents are sometimes so great that they may be a question of life or death for a company; therefore, every company involved in the industrial automation industry has to consider countermeasures against alarm flooding.

1.2 Causes and Solutions to Alarm Flooding

Alarm flooding is the condition where many alarms appear continuously and monitoring panels are filled with alarm messages. Alarm flooding occurs by one or combination of the following factors.

Increment of the Number and Types of Alarm

- The number and types of standard alarms increased remarkably since the advent of the DCS in the 1970's.
- A variety of instruments broadcast alarms – e.g. field instruments, SCADA, DCS systems, safety instrumented systems, asset management systems, MES systems, ERP systems, etc.
- Along with the progress of the integration of the plant information, operators have to deal with more alarms.
- Advanced alarms such as predictive alarms and diagnostic alarms were added for operators to respond more quickly and appropriately.

Expanding the Monitoring Range

Operators began to monitor a part of the following alarms.

- System alarms from field instruments and safety instrumented systems for safe operation of the plants;
- Alarms from relevant instrumentation and from upstream and downstream of the plants for efficiency in operation;
- Alarms from production management systems for prompt and flexible operation.
Lack of Alarm Management

• The rules to "define alarms with thorough considerations" have become obsolete now, while alarm setting units were used to create alarms in the age of panel instrumentations,

• In the batch process plants, alarms are designed and managed (changes of alarm set value and on/off mode of the unnecessary alarms by each operation mode) based on TPO (Time, Place and Occasion). This practice is not common in continuous process plants.

Lack of Functions and Performances in Alarm Systems

• The current alarm systems do not have sufficient functionalities and performances to support and implement rationalized alarm management such as to define alarms with thorough considerations and to buzz alarms in accordance with TPO.

• Operators become less skilled when the ratio of automation has increased and skilled operators retired of the age. Moreover, current alarm messages do not indicate the root causes of the alarms or how to solve the alarms, e.g., "tank level low," that prevent operators to respond immediately.

• Even the skilled operators can respond only to the limited number of alarms on the spot. However, the current alarm systems do not have the ways to reduce the operator loadings when it exceeds the operator’s capacity.

From the above reasons, it is necessary to adopt new alarm systems to rationalize alarms to expand the operators' scope of operation and monitoring while the number and varieties of alarms increase, yet it is important to secure the safety operations of the plants.

1.3 EEMUA Publication No. 191 Alarms Systems

Under these circumstances, the Engineering Equipment and Materials Users Association (hereafter abbreviated as EEMUA) issued a publication No. 191 Alarm Systems in 1999. EEMUA is a guideline to design, management and procurement of an ideal alarm system written by major multinational companies in the petroleum, gas, chemical, and power industries. Here described the EEMUA's approach to the alarm rationalization, which are quite fundamental as described in the paragraphs earlier in the chapter.

• Define only good alarms in compliance with the standards as follows;
  - Relevant (appropriate)
  - Unique (not redundant)
  - Timely (neither too prompt nor too late to be dealt with)
  - Prioritized (indicates priority of alarms to the operators)
  - Understandable (includes brief and easy-to-understand messages)
  - Diagnostic (specifies problem)
  - Advisory (indicates how to deal with the alarms)
  - Focusing (concentrates on the prioritized alarms)
Among the defined alarms, only necessary alarms are issued based on the TPO by suppressing the following examples;
- Multiple alarms generated from a single process (e.g. “High” alarm in “High-High” alarm)
- Alarms from out of service plant units
- Unnecessary alarms based on the operation mode (e.g. start-up and shutdown operations, normal operation, recipe changeover)
- Chattering alarms

In other words, EEMUA takes an approach to cutting off the source of alarm flooding problems under thorough controls so that unnecessary alarms are not defined or appeared. This idea of EEMUA has been adopted by the companies which took part in creating of the guidelines and widely spread into the industries in the early 2000’s. The introduction of EEMUA guidelines brought successful results to those companies that made investments on purchasing the new alarm systems with enhanced alarm design and management functions and on engineering for rationalization of alarms.

1.4 EEMUA Issues

A company has to review all the existing alarms in order to “implement a drastic rationalization of alarms based on the EEMUA guidelines in an existing plant to reduce alarm flooding.” For instance, if there are 10,000 tags in the plant, it means the company has to repeat 40,000 times of work to review four types of alarm - the high-high limit, high limit, low limit, and low-low limit. Moreover, it is an enormous work to do trying to manage those 40,000 alarms by TPO. Alarm rationalization based on the EEMUA guidelines should be phased in over a long period of time and it requires long-term investment and work. Because this is a top-down improvement, the commitment from the management is indispensable. If the continuous support from management is not available, there is a risk of terminating the alarm rationalization incomplete.

Alarm rationalization based on the EEMUA guidelines is essential and the most desirable approach; however, it takes a long period of time until projects are completed. During the transition period, it is the main issue how to reduce the risk of causing accidents by alarm flooding.
1.5 Changes in Ways of Thinking

Yokogawa concluded the solutions to the EEMUA guideline is as follows.

- The ultimate goal is for operators to monitor only necessary alarms at the right time.
- If only necessary alarms are informed to the operators at the right time, even though many unnecessary alarms are still generated, it can be treated as there is no alarm flooding.
- This idea is quite reasonable when considering the latest environment for industrial process control where various kinds of systems generate variety of alarms. If operators who receive and monitor alarms can decide the necessity of each alarm among different systems with different alarm design and management functions, it is more practical to reduce alarm flooding in shorter period of time.
- It will be appreciated, in the future, if a new alarm management system is provided with both an essential approach based on the EEMUA guidelines and an operator-initiated practical approach.
- This is suitable for current situations of the plants where the integration of information is in progress.

It sounds easy when the results are shown, but it is difficult to be the first one to come up with the new idea.

1.6 Target Users and Expansion of the Scope of Application

The article 1.5 described ideal situations of a future alarm management system, specifically about an operator’s real-time alarm monitoring. However, alarms (and events) occurring in plants have been used in various ways by many users.

Table: Examples of Users and Applications of Alarms & Events

<table>
<thead>
<tr>
<th>Applicable A&amp;E</th>
<th>Real-time A&amp;E (Combination of Real-time A&amp;E and Evacuated SOE)</th>
<th>Historical A&amp;E (Combination of Real-time A&amp;E and Evacuated SOE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Users</td>
<td>Real-time Monitoring</td>
<td>Offline Check</td>
</tr>
<tr>
<td>Operator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shift Manager</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production Staff</td>
<td></td>
<td></td>
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<tr>
<td>Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Services by System Vendors</td>
<td></td>
<td></td>
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<tr>
<td>Relevant Plant Operators</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Integrating the above information, the ideal solutions to the alarm management system can be described as below:
In the current plants where the integration of information is in progress, it is very effective if all the relevant users use only necessary alarms & events at the most suitable timing and depending on the purpose of usage among all those alarms & events generated.

This fundamental design concept is summarized as the “Consolidated Alarm Management System (CAMS) Concept” and the details are described in the following sections.
2. CAMS Concept

2.1. The Basic Concepts – Three Consolidation Items

“C” for CAMS (Consolidated Alarm Management System) stands for “Consolidation” and it represents three things. And these three consolidations form the center of the CAMS concept.

1. Consolidated Acquisition of Alarms & Events, such as:
   • Real-time alarms & events
   • Sequence of Events (SOE) saved at shutdown

2. Consolidated Storage of Alarms & Events, such as:
   • Real-time alarms & events
   • Sequence of Events (SOE) saved at shutdown
   • Alarms & events generated by a new alarm management system

3. Consolidate Management of Various Applications that uses Alarms & Events, such as:
   • Real-time alarm & event monitoring (online monitoring)
   • Historical alarm & event viewer (offline viewer)
   • Alarm configurator (alarm design function)
   • Alarm KPI report (alarm system enhancement)
   • Alarm & event analysis (operation and shutdown analysis)
   • Alarm set value change management (e.g. threshold changes and alarm suppression by operators)
The basic design concept of CAMS is as shown below:

Figure: Basic Design Concept of CAMS
2.2 Implementing Real-time Alarm & Event Monitoring

This section describes how to implement real-time monitoring by operators.

A new alarm processing and display system is required to let operators monitor only necessary alarms at the right time by extracting the ones they need in reference to EEMUA approach. The following chart describes the concept in order of the alarm processing procedures.

### Alarm generators

- **Acquisition:** Acquiring all available A&E online real-time
- **Normalization:** Removing dialect or mismatch of information
- **Re-classification:** Excluding false alarms or false events
- **Alarm prioritization:** Prioritizing alarms based on purpose & consequence
- **Grouping:** Excluding redundant alarms
- **Suppression:** Excluding nuisance alarms
- **Filtering:** Extracting necessary alarms
- **Sorting:** Sorting alarms based on urgency or importance
- **Eclipsing:** Integrating repeated alarm in a single line
- **Shelving:** Moving unnecessary alarms to the shelf temporarily
- **Load shedding:** Activating predefined filter automatically

Figure: New Alarm Processing and Display System

### Alarm Processing Functions

** Acquisition of Alarms & Events **

Operators are to acquire all the alarms & events for monitoring online and real-time. The corresponding communication interfaces are as follows;

- DCS Control Bus Communication
- OPC Alarms & Events
- FTP
- Serial Port
- Manual Inputs
Normalization of Alarms & Events

Acquired alarms & events are normalized in order to eliminate the differences in descriptions and levels;

• Standardizing the notation of alarms & events, e.g. High, HI, and H+.
• Standardizing alarm priorities uniquely defined for each system.
• Standardizing plant hierarchy uniquely defined for each system.
• Adopting UTC time stamp (if it is not done)

Re-Classification of Alarms & Events

Segregating events out of all the acquired alarms and re-classifies them as the events. Similarly, alarms are re-classified as the alarms out of all the acquired events.

Alarm Prioritization

Deciding the priority of alarms quantitatively and defining only necessary alarms by the purpose and consequences of the alarms. This is a support function for alarm designing suggested by the EEMUA guidelines.

Detailed Registration of Alarms & Events (Additions of Identifiers)

Operators can add unique identifiers to monitor only the necessary alarms at the right time by selecting the information. Samples of the identifiers are as shown below:

• Purpose of Alarm Monitoring
  Defining purposes of alarm monitoring on the view points of safety, environment and economy enables sorting of alarms objectively.

• Alarm Applications
  Defining alarms based on applications such as operations, maintenance, productions planning, etc. to sort alarms later.

• Operation Mode to be Monitored
  Unnecessary alarms can be eliminated from monitoring target by defining operation modes that must be monitored; such as start-up, normal operation, load changes, recipe changes and shut-down. As for “start-up” identifier, zero (0) is defined as unnecessary alarms and one (1) is for alarms to be monitored. In this way, during the start-up period, operators can only respond to the alarms that shows the value of one (1).

• Time to Respond
  Defining the time allowed for responding to the alarms such as 15 minutes, 30 minutes or one hour, and by using the message sorting function on the monitoring window, alarms are shown in the order to be treated first.
Detailed Registration of Alarms & Events (Addition of Value-added Information)

By adding value-added information enables operators to respond to alarms & events quickly and accurately. It is suggested to have multiple and different layers of value-added information by the operators’ role-basis (e.g. board, field or shift manager). Followings are the samples of the value-added information.

- Assumed causes of alarms
- Operators’ Required Actions (in accordance with the listing orders)
- Operators Actions taken to the same alarms occurred previously
- Information to be monitored simultaneously (graphics, trends, etc. It is convenient if a link is provided.)
- A link to reference documents (e.g. SOP, Maintenance Manuals)

Grouping Identical Alarms

In the EEMUA definition, “grouping” is the function to inform alarms in a bundle when the alarms lead to the results (e.g. the outcome may become out of standard quality) even the types and causes of alarms are different. This function has already been achieved with CENTUM CS 3000 in the name of a representative alarm function. However, the new architecture incorporates a function to delete unnecessary duplication to be informed to operators when completely identical alarms are generated during the same period of time by multiple systems.

Suppression of Unnecessary Alarms

Deleting unnecessary alarms for operators from monitoring targets, such as;

- Alarms generated from out of service units
- Chained alarms

Functions on Monitoring Display Side

Filtering

Messages are filtered according to the predefined identifiers (e.g. user name, plant hierarchy, alarm types, alarm priorities) as well as by new identifiers (e.g. alarm monitoring purposes, alarm applications, monitoring operation mode). Filtering conditions are defined with multiple identifiers and AND/OR conditions. Different types of filters are provided according to operators’ roles on an alarm message monitoring display as predefined or on demands.

Sorting

Messages are sorted by predefined identifiers (e.g. timestamp, alarm priorities) as well as by newly defined identifiers (e.g. time to respond).

Eclipsing

The most prioritized alarms are displayed in the single line when same types of alarms are generated repeatedly by the same source (e.g. tag names, instrument names), or different types of alarms from the same source. By reducing the number of alarms visually, it enables operators to reach more important alarms quickly and easily. This function is effective for the alarms as shown below:

- High alarms among high-high alarms
- High alarms issued and recovered repeatedly
Shelving

Less important alarms are moved temporarily to the predefined areas (called “shelves”). By reducing the number of alarms visually, it enables operators to reach more important alarms quickly and easily. There are three types of shelving:

- **One-Shot Shelving**
  Operators move alarm messages to a shelf one-by-one by mouse operation. Notify operators after a predefined period of time passed (absolute or relative time)

- **Continuous Shelving**
  Operators move unnecessary alarm messages one by one by mouse operation. When the same alarm message occurs during the predefined period of time (absolute or relative time), those alarm messages are automatically moved to the shelf by the system. Notify operators after a predefined period of time passed.

- **Auto-Shelving**
  Alarm messages are moved to the shelves automatically in accordance with the predefined filtering conditions. Notify operators after a predefined period of time passed (absolute or relative time)

**Load Shedding (to Limit Monitoring Loads)**

If alarm messages appear frequently (e.g. 30 messages per minute), the system automatically applies the predefined filtering conditions to reduce the alarm messages to be displayed on the monitoring screen in order to reduce the operators’ work loads.
3. **CAMS for HIS**

The CAMS for HIS is the first product applying CAMS concept. The features of the CAMS for HIS are as described below.

- Providing the combination of a drastic EEMUA approach and a practical approach for sorting alarms for rationalization.
- The CAMS for HIS is optional software to run on CENTUM CS 3000 HIS (Human Interface Station). It enhances the current alarm functions of HIS remarkably.
- The main purpose of usage is the real-time alarm monitoring.
- The main users of the package are operators.

The basic design concept of CAMS for HIS is shown below:

![Diagram of CAMS for HIS](image)

**Figure: The basic Design Concept of CAMS for HIS**

The scope of implementing the CAMS concept in the CAMS for HIS is described in the following pages.
3.1 Alarm Processing and Configurator Functions

Acquisition of Alarms & Events
Dealing with real-time alarms & events generated from the following systems:
- Integrated Production Control System - CENTUM CS 3000
- Safety Instrumented System - ProSafe-RS
- Network-based Control System - STARDOM
- Plant Resource Manager - PRM

Alarm Prioritization
Determining alarm priorities quantitatively by alarm purposes and consequences, and defining only necessary alarms. This is an alarm design support function suggested by EEMUA. Rules can be modified by users.

Figure: Alarm Prioritization by EEMUA Approach
Adding Sorting Identifiers and Value-Added Information

The identifiers and value-added information can be defined from the EEMUA display, as shown in the above figure, “Alarm Prioritization by EEMUA Approach” such as follows;

- Alarm Priority (it is possible to set different priorities per alarm types)
- Alarm Purpose
- Consequence
- Time to Respond
- Guidance Message

Users can also determine the user-defined identifiers and value-added information in the table type. See Figure “Addition of Identifiers for Sorting (Table Type).”

Storing Alarms & Events

Alarms & events with identifiers and value-added information are sorted to hard disk of HIS. Monitoring is enabled by using a prototype A&E Historical Viewer.

Suppression

Unnecessary alarms to notify operators generated from out of service plant units are deleted from monitoring targets. Users are to define an alarm group list by the plant unit of suppression in advance. Alarm suppression will be switched ON/OFF manually by the group when it is necessary.
3.2 Real-time Alarm & Event Monitoring (Message Monitor) Functions

Filtering

Filtering alarm messages is done by the original identifiers (e.g. user name, plant hierarchy, alarm types, alarm priorities) and new identifiers (e.g. purpose of alarm monitoring, usage of alarms, operation mode to be monitored).

Filters are displayed in the filters pane in the lower left of the display screen as hierarchical folders. By selecting an arbitrary filter with the mouse, details displayed in the A&E message pane switches. It is possible to display two filters at the same time; one is a filter predefined by a supervisory user for each operator, and the other is a filter that operators themselves defined temporarily.

Sorting

Messages are sorted by the keys such as original identifiers (e.g. time stamps, alarm priorities) and new identifiers (e.g. time to respond) attributed to the alarm messages.

Sorting of the messages are done by clicking the name of the attribution by a mouse. It is possible to select two attributes continuously.
Eclipsing

Chattering alarms with the highest priority are shown in a single line when it is generated from the same source (e.g. tag name, instrument name) or same types of alarms. By reducing the number of alarm messages visually, it enables operators to access to the important alarms more quickly and easily.

Repeating (chattering) alarms can be integrated to one most important alarm as visual effect.

Figure: Eclipsing
Shelving

Alarm messages with low priority for monitoring are moved to another predefined message display area (called a shelf) temporarily. By reducing the number of alarm messages visually, it enables operators to access to the important alarms more quickly and easily. Three types of shelving functions are provided: One-Shot, Continuous, and Auto-Shelving.

One-Shot and Continuous Shelving, those are implemented by drag & drop of the relevant, unnecessary alarms to the shelves pane at the upper left of the window by the mouse operation. Continuous Shelving will also be done automatically from the second time for those alarms from the same tag numbers. Shelved alarm messages are displayed in the A&E Message Pane by clicking the arbitrary shelf by the mouse. The shelved alarms can be moved back to the original place by drag & drop of the mouse from shelves.

Figure: Shelving

Load shedding

If a number of alarm messages arise frequently (e.g. 30 messages per minute), predefined filtering conditions are automatically applied for the messages to be displayed in the main display area.
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3. CAMS for HIS
   “Figure: The basic Design Concept of CAMS for HIS” is revised
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   Description of “Normalization and Re-classification” is deleted
   Section of “Identical Alarm Grouping” is deleted