DESIGN OF USABLE ALARM SYSTEMS

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Alarm systems are essential aids for safe and efficient operation of many industrial settings. However, to design usable alarm systems, consideration needs to be taken to the human operator. This paper summarises important design guidelines to consider when developing alarm systems. The results show that the most important guidelines to adhere to are: (1) consistency within the alarm system, and between the alarm system and the overall control system, (2) the need to use an alarm definition and an alarm philosophy, and (3) is to start the human factors work early in the design process for success.

Alarm systems, Process control, Design Guidelines

1 Introduction

Alarm systems play an important role in the operation of process control settings. A reliable and user-friendly alarm system developed according to the operators' conditions contributes to maintaining safe and efficient operation. Further, it assists the operators to safely operate the plant and to avoid or manage disturbances. A well-designed alarm system can facilitate the work, whereas alarm system design deficiencies can contribute to incidents, e.g. Three Mile Island, Union Carbide in Bhopal, and Texaco Refinery in Milford Haven (Smith et al., 2003). Furthermore, poor performance of alarm systems can result in financial losses, environmental consequences and hazards to people.

Consideration to the human operator is necessary since the operator still is the last line of defence in many industries, and thereby, the process relies on efficient operation by the sharp end operators. Thus, it is important to consider the operator's whole working situation when alarm systems are developed. Otherwise, the safety and efficiency of a plant may be jeopardized (Bransby and Jenkinson, 1998a). Over the years, the knowledge about the importance of considering human factors aspects in design has increased. Today, it is widely acknowledged that an operator-centred approach is desirable from the beginning of a design project. However, Nachreiner et al. (2006) argue that human factors knowledge still does not play the important role it deserves. Improvements in alarm management work have commenced, but there is still much to improve (Smith et al., 2003).

Since the demands on the operators are increasing (e.g. due to process operation close to maximum efficiency, lower safety margins, higher costs for process interruptions, more complex processes, and fewer operators), the potential for problems are not decreasing but increasing. This emphasises the importance of considering the operator's role when designing alarm systems. The issue is how the operator's perspective should be taken into account during the design.

2 Objectives

The purpose of the study is to facilitate for future control room designers to utilise results from research to get further knowledge about how to prioritise among existing alarm design guidance and alarm system theory.

The aim is to present the general idea of alarm system design guidelines and alarm system theory needed to consider in control room design projects.

3 Method

This paper is based on results from several theoretical and empirical studies performed within a large research project about alarm system design in complex process control. The results presented are based on a comparison between existing theory and the results of the empirical research studies. The theoretical basis consists of journal papers, textbooks, handbooks, standards and guidelines for operator monitoring, alarm handling and alarm system design.

The empirical studies have been performed within different application areas (nuclear power, aviation, medical technology, process industry, petrochemical industry and pulp and paper industry). The aims of the studies have been to compile knowledge about how alarm systems are designed and function in the control rooms, and how the operators work and interact with their alarm systems.

The comparison between theory and practice has made it possible to prioritise among existing alarm guidance and to identify best practice and lessons learned.

4 Theoretical framework

Alarms and alarm systems are essential operating aids in the control room. The operators need help to detect, interpret and understand important operational information since they are not fully observant all the time, they are not omniscient and they can make mistakes. An alarm system should help the operators to diagnose faults and correct them.

4.1 Alarm and alarm systems

An alarm is defined as a signal indicating an abnormal or deviating condition, or a combination of conditions that requires the operator's attention (EEMUA, 1999). Further, the alarm should require a physical or cognitive response (O'Hara et al., 1994; Stanton, 1994; Sørenssen et al., 2002).

It is important to remember that the alarm system not only alerts the operator about different deviations. Instead, the whole aim of an alarm system needs to be considered when in the design. That is:

- Alert the operators about a deviation,
- Inform the operator about the nature of the deviation
- Guide the operator's initial response, and
- Confirm, in a timely manner, if the operator's response corrected the deviation.

4.2 Alarm design theory

Ergonomic design of control centres and alarm systems are presented in different standards and guidelines, e.g., ISO-11064 and NUREG-0711 (O'Hara et al., 2004). The standards emphasise a human-centred design approach which should be iterative and integrated with the engineering design process. Further, the design process should include different situations, tasks and risk analysis, and the users should be involved.

Four recurrent alarm system design principles are found in the literature:

- Alarm systems should be designed to meet the operators' needs and operate within their cognitive and physical capabilities.
- The purpose of the alarm system and its contribution to protection should be clearly identified.
- The performance of the alarm system should be assessed during design and commissioning.
- The design of alarm systems should follow a structured methodology.

An alarm system should be usable and effective under all operating modes and working situations. To be able to develop a usable alarm system, the alarms need to be justified. This implies that the role of the operator needs to be identified, including the changes of the role in different operating conditions. For a usable alarm system, the following characteristics of the output information need to be met:

- It is relevant to the operator's role at the time.
- It informs about the system state and the cause of the alarm.
- It indicates clearly what response is required.
- It is timely and is presented at a rate the operator can handle.
- It is easy to detect and understand.

(EEMUA, 1999; Koene and Vedam, 2000; Sørenssen et al., 2002)

Several studies have been performed to set guidelines for an ideal alarm system. For example, EEMUA (1999) has presented a number of important characteristics for an individual alarm.

- Timely – presented at the right time.
- Relevant – for the operators, not a false alarm.
- Unique – not a duplicate of another alarm.
- Prioritised – helps the operators to focus their attention.
- Understandable – speaks the operator's language.
- Diagnostic and advisory – indicates what has happened, what actions are needed.
- Manageable – not too many alarms.

5 Results and Analysis

The analysis of the literature shows that many problems with alarm systems have been identified and reported years ago, but still problems exist in real settings. The suggested design processes in ISO-11064 and NUREG-0711 (O'Hara et al., 2004) provide a more structured approach and emphasise that alarm system issues are dealt with early in the design process and in a systematic way. A general problem today is that the alarm system design work starts too late. Although ergonomic design processes can facilitate the work, it is important to coordinate the work with the alarm system with the regular engineering process of the control room. However, in some industries, alarm systems are still regarded as a separate system with its own design. This leads to problems with inconsistencies between the alarm system and the control system. Therefore it is important that the alarm system design process corresponds to the design process of the control system.

Further, it is difficult to evaluate the need for different alarms when the technical system is not decided. A proper task allocation and task analysis is needed to understand which tasks the operator needs to deal with and how the operator should manage these situations.

A general complaint from many industries is that the existing alarm system design recommendations are too general to apply. Though, some facilities had worked with these general guidelines and by considering them, they had developed their own plant alarm style guides or alarm philosophies. These documents were then regarded as very significant in further work. This shows that general guidance is very important, but the facilities need to adapt them to their own conditions.

Since many aspects of an alarm system need to be designed late in the design process, the flexibility of the alarm system in crucial. For example, it should be easy to change level of priority and set-points, to define different operating modes and to implement logical suppression even in late design stages. A problem today is that alarms to a great extent are used to present informative messages. This leads to problems with huge numbers of alarms and alarm flooding in disturbances. An alarm should always require some kind of action (mentally or physically) of the operator. For that reason, another recommendation is that the designer has an objective alarm definition, since the definition might vary depending on type of product, type of users and type of use context.

It is important to focus the alarm system design process on the work tasks performed by the operators. The alarm system itself should guide the operator, thus the main aim can not be to present the cause of an alarm. Sometimes, the operator's primary task is to mitigate the consequences rather than to understand and correct the underlying cause. If the aim of an alarm system is considered in the design, it will probably lead to better alarm messages. Today, problems exist with ambiguous or irrelevant information. Many alarm systems alert and inform the operators, but few systems guide the operators. This area is of special significance when improving the performance of the alarm system.

Many companies are working with different improvement and/or sanitation techniques to improve the performance of their alarm system. But, sanitation can not fix an alarm system with deficiencies.

Alarm design theory can be used to a greater extent when designing new alarm systems. Applicable theory exist, it is only a matter of identifying the relevant issues for the specific project. This depends on type of industry, type of project and design stage.

6 Conclusions

The main conclusion from the results of alarm system design presented in this paper is that the use of pro-active and general guidelines has not been used to a great extent in industries, although it is highly needed. Many companies are working with alarm system improvement techniques after the implementation of an initial alarm system. If an approach including human factors engineering knowledge is used already in early design stages, it facilitates and increases the possibilities of designing a safe and effective alarm system. No alarm sanitation method, irrespective of its efficiency, can fix a flawed alarm system design.

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