While checking the alarm systems of crude oil extraction and production facilities along the Norwegian continental shelf, the Norwegian Petroleum Directorate found substantial inadequacies in certain areas. As a consequence, the authority issued a corresponding body of rules for the design of alarm systems in the branch, which has decisively contributed towards establishing higher standards: The operators of oil and gas platforms in Norway are front runners with regard to plant safety. The Oseberg Field Center, an oil and gas extraction platform about 130 kilometers northwest of Bergen, also uses a highly effective alarm management system. At the suggestion of the specialists of the Norwegian Petroleum Directorate, the operator StatoilHydro implemented an exemplary alarm management system in order to improve the handling of alarms and thus minimize risks.

Reliable risk management is relevant not only in the oil and gas industry, but generally in process plants in all industries. An efficient alarm management system makes a decisive contribution in this respect and also presents economic advantages.
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Introduction

What is the purpose of alarm management?

Alarming states, in the truest sense of the word, often prevail in process plants with regard to alarm management. An after-effect of state-of-the-art instrumentation and control is the high alarm rates: Software-based alarms are much simpler and inexpensive to configure than hard-wired signals. The significantly lower effort required for alarm implementation and the high degree of communication of modern field devices, which themselves include a number of alarms, have resulted in a leap in the number of messages with which operators are confronted day-by-day. Due to the poor prioritization and conceptual design, the operators drown in downright "floods of alarms": Process status displays are listed as alarms, alarms are signaled that do not actually require any intervention by the operator, false alarms occur regularly, the displays in the control room are confusing and non-uniform, concepts and terms inconsistent. This situation overtaxes the operators and all too often result in unplanned and unnecessary plant shutdowns. The economic damage resulting for plant owners is estimated to amount to US$ 20 billion, according to a study.\(^1\)

However, the economic loss is only one aspect. The range of possible consequences of a poor alarm management system range from damage to plants and loss in product quality, through danger to humans and the environment, down to the resulting image loss for the respective company.

The excessive demands placed on the operating personnel and their desensitizing effect due to the high basic load of alarms can be avoided: Efficient alarm management systems create the required scope for monitoring and managing the system. They provide the operators only with the information required as a basis for actions and decisions, and ensure that the operators can do their actual work: Carrying out qualified interventions in the process when necessary.


Standards and recommendations

The dreadful conditions in the control rooms caused diverse organizations and committees to issue instructions and bodies of rules for the conception, application and maintenance of alarm management systems years ago. There are thus a number of standards of various origins existing parallel to each other that, depending on the background of the publishers, focus on different aspects.

These publications do not necessarily have a binding character for plant operators, but in many cases the publications are connected with corresponding specifications for the system manufacturers. They form the basis for technical developments in the field of alarm management. Current control system and technical possibilities allow the operators of process engineering systems to improve the quality of the alarm systems notably – and thus not only observe statutory requirements, but also profit with regard to safety and cost effectiveness from their implementation.

EEMUA 191
The guideline published in 1999 in the United Kingdom by the Engineering Equipment and Materials Users Association (EEMUA) provides practice-oriented recommendations for alarm management based on the experience of numerous end users and human factor studies. The basic idea is to keep the alarm occurrence at a level that is reasonable for the operator.

NPD YA 711
Principles for alarm system design
The body of rules of the Norwegian Petroleum Directorate on the principles for designing alarm systems from 2001 laid the foundation for alarm systems in particular for the oil and gas industry.

VDI/VDE Guideline 3699
Process control using monitors
The VDI/VDE Guideline 3699 of the VDI"VDE-Gesellschaft Mess- und Automatisierungstechnik" of 1998 deals with the configuration of graphical representations for process control, in particular for applications in the chemical and petrochemical process engineering. In addition to clear definition of concepts and terms, it represents a basis for process control using monitors. In addition to the principles of the configuration and organization of operator stations, the representation technique as well as aspects of the operability are addressed.

NAMUR NA 102 worksheet
Alarm Management
The worksheet with focus of the chemical industry in Central Europe was published in 2003 and supplemented in 2005 by the chapter "Alarm Management Engineering". NA 102 approaches the topic from two angles: On the one hand as instructions for the conceptual design, application and maintenance of alarm management systems that are intended for the planners and operators of process engineering plants. However, NA 102 also functions as a specification. Manufacturers and suppliers of process control systems are called on to make the required functions available.

Being prepared: ISA S18.02
Management of Alarm Systems for the Process Industries
This standard that is currently being developed will describe the alarm management system for control systems in detail. It is based on the existing recommendations and takes the current technical possibilities into consideration.
Systematic alarm management

Improved handling of alarms

An essential first step in the systematic management of alarms is their complete documentation and statistical evaluation by means of corresponding databases and analysis tools. The analysis of alarm messages allows the development of strategies for reducing the alarm frequency and operator interventions and for exposing weak points and potential improvements in the plant. However, progressive alarm management goes far beyond a statistical evaluation: It helps the operator to differentiate between what is important and what is not important, provides clearly comprehensible alarm messages including information about the required measures as well as the option to comment the message and to store it. In addition it should be possible to suppress alarms from field devices or from specific process sections that are not important. Superfluous alarms or scenarios that require additional training measures can be determined by analyzing the performance key data of the alarm system.

<table>
<thead>
<tr>
<th></th>
<th>Alarms / Day</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>effective processable</td>
<td>150</td>
<td>1 alarm / 10 minutes</td>
</tr>
<tr>
<td>barely manageable</td>
<td>300</td>
<td>1 alarm / 5 minutes</td>
</tr>
<tr>
<td>reality</td>
<td>&gt;1400</td>
<td>~1 alarm / minute</td>
</tr>
</tbody>
</table>

Figure 2: Number of alarms determined on average

Focusing on the essentials

When dealing with the management of alarms, one first has to define what an alarm actually is: "A message about a deviation of the process from the desired state that requires an immediate response from the operator".

This definition already suggests the converse argument that messages that do not require a response by the operator should not be displayed as an alarm for the operator.

In view of the high alarm rate with which the operator is confronted day-by-day – up to 2,000 messages a day are not unheard of in the control room – it is paramount that the number of messages be reduced to a maintainable level. Users should observe the established recommendations with regard to the number of alarms and priorities: In accordance with the directives EEMUA 191 and NA 102 one alarm within ten minutes per operator would be the ideal state. An efficient alarm management system is indispensable in order to approach this ideal.

Figure 3: How many alarms can an operator theoretically respond to?

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3 EEMUA

Alarm Management Lifecycle

The optimal alarm management system already begins in the planning phase and accompanies the plant operation as a continuous improvement process: Since the plants constantly change, the alarm management system has to be checked regularly and modified if necessary.

In reality the alarm management system also has a life cycle for the conception, application and maintenance of the corresponding systems that essentially consists of four phases.

1. Planning and conception: The right alarm philosophy

Careful planning is also indispensable in alarm management: Ideally, the process operator should already develop an alarm philosophy in the planning phase of the plant for the entire plant or even the whole company. This philosophy should be a concept taking into consideration his (branch-) specific requirements that is then implemented and observed consistently.

2. Alarm-Engineering

Economical alarm engineering is primarily control system engineering: The current control system provides a number of required tools and technical possibilities for configuring the alarms that help the plant operators to implement the philosophy. Since alarm philosophies are conceivably different, depending on the branch, location or country, a high degree of flexibility is required at this point from the DCS manufacturer.

3. Plant operation

During ongoing operation, the corresponding alarms have to be displayed to the operator in a structured form and prioritized. A clear separation of control-system and process alarms is of decisive importance since they address users responsible for different functions. Messages that come from field devices belong to the control system messages. They are typically directed to the maintenance personnel and it should be possible to visualize them on a maintenance station separated from the process. The operating personnel, on the other hand, only receive the events coming from the process, classified into message classes, on the operator station.

Every alarm should include instructions for the operator. This is realized ideally by the assignment of corresponding help texts in the control system.

4. Analysis

While the plant is operating, superordinate analysis tools or integrated tools have to be used to regularly check what form the alarm occurrence takes: Are there peaks or alarms that occur more often or are active for a particularly long amount of time? Are the recommendations and standards observed? The analysis makes it clear where there are problems in the system in spite of the alarm philosophy. It provides the basis for eliminating these problems either through the engineering or by replacing hardware, for example by replacing certain modules that are not able to avoid flicker alarms through filtering.

Two examples are used below to show how concrete problem areas from the industrial sector can be mastered or avoided completely by means of good alarm management.

Figure 4: Principle of the alarm management life cycle as envisioned by the ISA
Typical application examples

1. The alarm avalanche

Starting up and shutting down system components for maintenance or the activation of an emergency-off switch with which a complete unit is switched off often results in an alarm avalanche, i.e. a flood of subsequent alarms that can run into the thousands. However, particularly in these types of situations that are often critical, it is often not possible or necessary to react to every alarm, but only to the most urgent and important ones.

Being able to control the plant takes absolute precedence. This means that the system may not be overburdened during the alarm avalanche and it must remain possible for the operator to operate it. The reported alarms must furthermore always remain traceable, including chronological history and time stamp for every single alarm (so-called "sequence of events"). This can be realized, for example, with a time synchronization for all the components.

The most efficient approach is naturally to always avoid alarm avalanches. It is sufficient when the causal alarm is displayed, direct subsequent alarms are not as important for the operator. The course of action can be set in the engineering process: After an emergency-off, all the subsequent alarms are prevented by the corresponding programming in the automation system. This programmed solution involves disadvantages and risks, since the specified alarms are really no longer issued and are therefore no longer available for evaluation later.
A remedy for the operator is to use so-called alarm hiding, meaning that the alarms are hidden. The alarm avalanche is mitigated by intelligent mechanisms in the system. The Siemens Simatic PCS 7 process control system, for example, provides the possibility, in the form of the Smart Alarm Hiding tool, of hiding those alarms that are caused as a subsequent alarm of another alarm in the operator view. However, all the alarms are included chronologically in the archive, meaning that they remain traceable and that a substantiated analysis can be carried out later. The hidden alarms are listed in the so-called Hidden List that the operator can call up and view at any time. The hidden alarms are designated as such here. The Alarm Hiding is implemented in accordance with the plant philosophy. As a first step the causal relationships have to be configured. Engineering of the Alarm Hiding is in principle extensive. The task of the control system is to reduce this work as far as possible.

With Simatic PCS 7, the filter for hiding alarms can be defined in the process object view. To this purpose operating states are defined for the plant or system components (for example the operating state "Emergency-off", but also "Startup", "Normal operation", "Maintenance", etc.). In order to avoid having to program every single logic function to the full scope in the engineering process, the plant is reduced to typical operating states and then a matrix is used (for example as an MS Excel® spreadsheet) to specify which alarms are to be hidden at which operating states. If, for example, maintenance is carried out on a subsystem later, all the non-relevant messages arising during maintenance from this subsystem are not visible for the operator and also do not emit an acoustical signal. The matrix can then simply be reimported back into the control system. The work, costs and also error sources are thus reduced considerably and Alarm Hiding can also be configured without any knowledge of DCS engineering.

Figure 6: Definition of the hiding rules in a matrix
2. The flicker alarm

The cause of constantly recurring alarms, so-called flicker alarms, often lies in faulty sensors, in addition to poorly set measuring circuits. For example, a defective transmitter in a module triggers a flicker alarm at the level monitoring of a vessel. This flicker alarm is normally addressed not to the operator, but rather to the service personnel of the plant. The operator only needs the information that the level indication of the vessel is incorrect.

If the flicker alarm is nevertheless reported in the control room, it can cause important process-specific alarms to be obscured. In the worst case the operator may miss critical process signals so that the risk of an unforeseen incident increases. Several procedures for alarm suppression are available here. In the case of binary values this can be implemented process-controlled by means of a delay directly in the module. Although the alarm is still monitored in the module, it is only emitted once. In the case of analog measured values, hysteresis functions in the module or in the corresponding technological function block in the library can be used.

In addition, countermeasures can be initiated by using the operator control and monitoring system in the control room. The control system must give the operator the possibility to select a recognized flicker alarm in the alarm list and to hide it manually. With the Siemens Simatic PCS 7 process control system, the operator can use the Manual Hiding feature to ensure that the alarm is no longer displayed, but nevertheless archived. In the case of manually hidden alarms it should furthermore be possible to display the alarms again automatically after a selectable interval in order to ensure that hidden alarms are not forgotten.
Always ensure traceability

In the case of alarm avalanches, flicker alarms or, at worst, accidents, all the alarms have to be logged chronologically in the archive and must be traceable. None of the operator operations/ actions may be missing in the log. Only on the basis of this complete data basis is it possible to regularly draw up corresponding statistics and to check whether the alarm philosophy still holds true. All the data are also available for future analysis after an unforeseen incident.

It must be possible to filter the data to this purpose, for example by period, operator interventions, etc. Here, an analysis tool should be able to point out abnormal situations by itself. The findings from the analysis then ideally flow back into the engineering process. To this purpose the tools have to meet the following minimum requirements:

- Recognize the frequency of alarms
- Offer the possibility of filtering the alarms by the plant sections
- Record the alarm duration and priority

Figure 7: It must be possible to have sorted and displayed all the alarms on the basis of different aspects
Summary

In view of the increasing number of statutory requirements and with regard to the insurance aspects, plant operators nowadays can no longer avoid having to deal with the topic of alarm management systems. They should however also do it in their own interest: A carefully planned and optimally set alarm system provides a clear advantage for the cost effectiveness and safe and stable operation in production plants in all branches. A professional alarm management system contributes decisively towards increasing the process safety and the availability of a plant, ensuring the product quality and simultaneously reducing costs.

The ideal way to ensuring improved handling of alarms is the relief of the operator and his systematic guidance during ongoing operation. Strict avoidance of useless and unimportant alarms and already focusing on the important points while drawing up the alarm philosophy helps in avoiding excessive demands on and unsettling of the operators, and instead provides them with specific information about relevant deviations in the process or plant. The reduction in the alarm occurrence provides the operating personnel with more time and the necessary freedom to ensure reliable and safe process control. The support provided by a professional alarm management system to the instrumentation and control and its integration in the control system represent the optimal solution since this ensures that the load on the operator is not increased by an additional system.