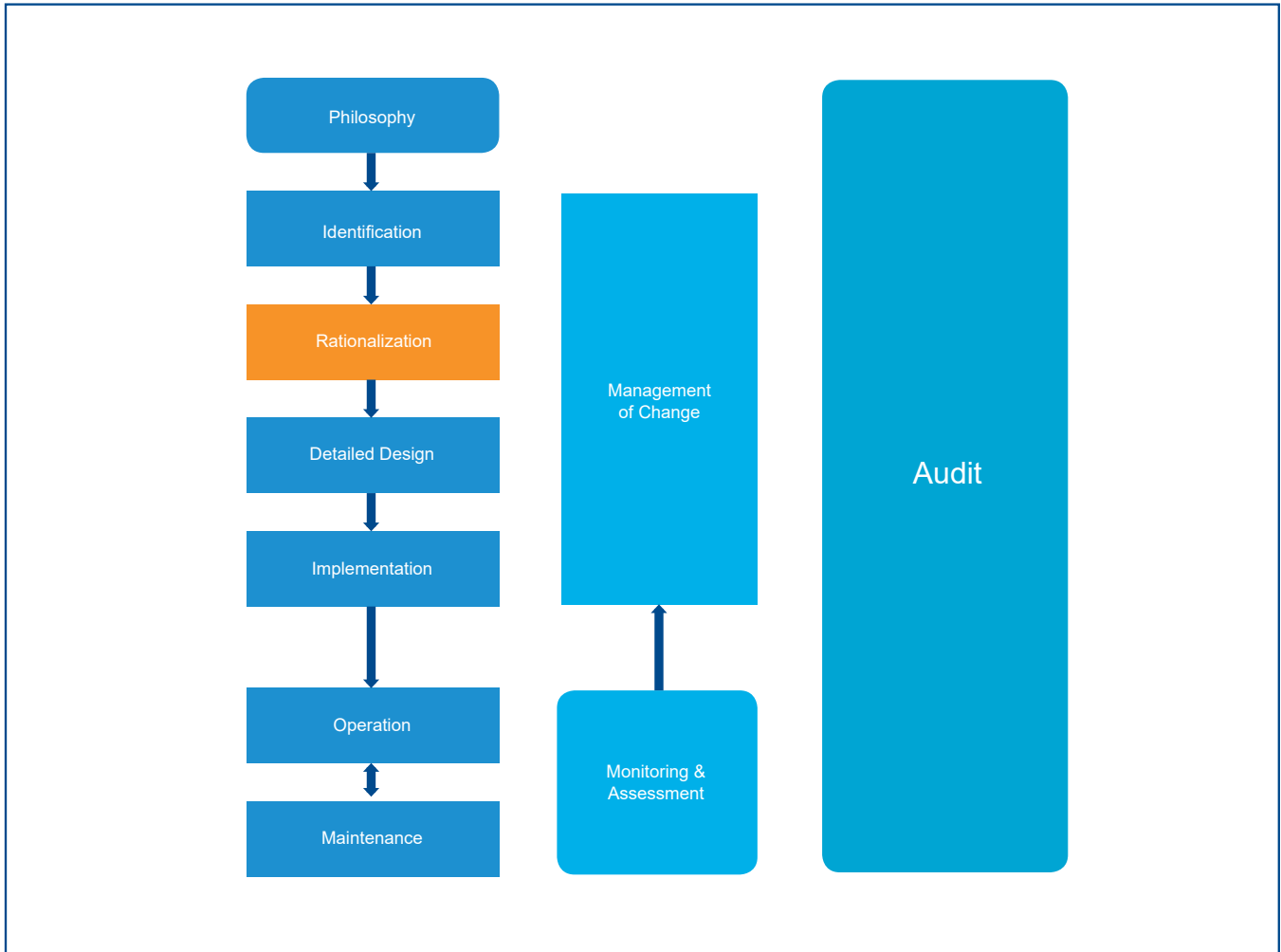


Alarm Rationalization

This document examines the ISA-18.2 alarm rationalization process, including dynamic alarm management and optional pre-rationalization methods employed by Emerson.



Rationalization is one step in the alarm management lifecycle defined in ANSI/ISA-18.2-2016 Management of Alarm Systems for the Process Industries. In this step, identified candidate alarms are judged against principles established in an alarm philosophy document to qualify which are legitimate alarms, to specify their design, and to capture rationale and other information to guide operator response.

Table of Contents

Introduction.....	3
Executive Overview.....	3
What is an Alarm?.....	4
What is Alarm Rationalization?.....	4
Benefits of Rationalization.....	5
What is Dynamic Alarm Rationalization?.....	5
Alarm Rationalization is a Team Effort.....	8
Organizing for Success.....	8
The Traditional Rationalization Method.....	9
The Dynamic Pre-Rationalization Method.....	10
Rationalization Scope.....	11
Management of Change.....	11
Estimating the Required Time.....	11
Emerson's Alarm Rationalization Offering - AgileOps™ Alarm Management Software.....	11
Tips for Effective Rationalization.....	12
References.....	13



Introduction

Modern control systems require very little effort to add an alarm. Consequently, operators are increasingly dealt more alarms than they can handle effectively and are often inundated with nuisance alarms. This multitude of configured alarms escalates the likelihood of an operator missing an important alarm and increases the difficulty for them to respond to a plant upset, raising the chance of an unplanned shutdown or an accident.

In 2009, a team of industry experts published the ISA-18.2 standard, which provides a framework and methodology for the successful design, implementation, operation, and management of alarm systems. The standard, which was revised in 2016, also presents techniques to help end-users address the most common alarm management issues. This document was adopted, with minor revisions, in 2014 as IEC 62682. Today, proper alarm management strategies are accepted as RAGAGEP (recognized and generally accepted good engineering practice) by insurance companies and regulators alike.

One of the key practices described in ISA-18.2 is alarm rationalization, which is a process for reviewing and documenting the alarms systematically to ensure that they are truly needed and are designed to help the operator diagnose and respond to abnormal situations. This document will outline the rationalization process and stress key principles of proper alarm management practices.

Executive Overview

Alarm rationalization is a systematic work process to evaluate all potential or existing alarms against principles established in an alarm philosophy document, to qualify which are legitimate alarms, to specify their design, and to capture rationale such as cause, consequence and corrective action which can be used to guide operator response.

The primary goal of alarm rationalization is to ensure that every alarm announced to the operator is a quality alarm. A quality alarm is one that is a unique announcement of an abnormal event that has available and necessary operator action to avoid a negative consequence. The principal benefits of alarm rationalization include reduced alarm load on the operator, elimination of nuisance alarms, and prioritization to help the operator respond to the most important alarms first, all of which lead to improved operator effectiveness.

The alarm rationalization team is led by a skilled independent facilitator, but otherwise formed from in-house staff representing operations, control engineering, maintenance, and other disciplines as required. To achieve consistent results and work efficiently, the team will require training and management commitment to allow adequate time and resources, and software designed specifically for alarm rationalization.

The process typically begins with the team completing the Philosophy phase of the alarm management lifecycle to ensure that there is common understanding of all terms, standard configurations, and common rationale used to define alarming methods within the facility. A work schedule is also established to make each contributor aware of his or her priorities and expectations for the project.

Emerson ensures that a complete Alarm Management Lifecycle solution is available to aid clients with implementing a sustainable lifecycle approach that complies with the ISA-18.2 standard. The solution incorporates tools and capabilities for alarm rationalization (e.g., AgileOps Master Control System Database, Dynamic Management), operator alarm response procedures (AgileOps Operator Helper, DeltaV Alarm Help), analysis and benchmarking of alarm system performance (AgileOps EventKPI, DeltaV Analyze, Plantwide Event Historian), and internal company expertise.

What is an Alarm?

As defined in ISA-18.2, an alarm is...

- **An audible and/or visible means of indicating...**

There must be an indication of the alarm. A limit can be configured to generate control actions or log data without it being an alarm.

- **to the operator...**

The indication must be targeted to the operator to be an alarm, not to provide information to an engineer, maintenance technician, or manager.

- **an equipment malfunction, process deviation, or abnormal condition...**

The alarm must indicate an abnormal condition or event with significant consequences of inaction; no alarm should annunciate for a normal process condition or control action.

- **requiring a timely response. [1]**

There must be a defined, necessary and available operator response to prevent or mitigate the consequence. If there is no operator response necessary, then there should not be an alarm.

What is Alarm Rationalization?

When it comes to alarms, more is not better. The ideal is to create a system containing the optimum set of alarms needed to keep the process safe and within normal operating limits. Alarm rationalization is a process where a cross-functional team of plant stakeholders review, justify, and document that each alarm meets the criteria for being an alarm as set forth in a company's alarm philosophy document.

A complete rationalization should review all tags in the control system, whether they have alarms configured or not. Tags that have no alarms are reviewed in rationalization; the team should verify that no alarms are needed or recommend that alarms be added. If tags with no alarms are left out of a rationalization review, the team may miss an opportunity to optimize alarm configuration. For instance, the team may choose to replace an alarm with an alarm on a different tag that provides better indication of an upset condition.

Justification is perhaps the most important aspect of rationalization. Justification ensures that each alarm is relevant and unique, meets the above criteria, and is the best indicator of an abnormal situation. To aid in the rationalization discussion, Emerson uses a five-keyword approach to justify the presence of each alarm configured:

- **Abnormal** – something unexpected or unplanned has occurred
- **Consequences** – an undesirable result (safety hazard, environmental release or revenue loss) is possible if no action is taken
- **Action** – there is necessary and available operator response, and enough time for response before the consequence might occur
- **Relevant** – the alarm is understandable to the operator and is needed in the current operating state of the plant
- **Unique** – no other alarm will sound to alert the operator of the same condition or event

Any proposed alarm that does not qualify under all five keywords is to be considered for deletion.

Rationalization also involves determining the attributes of each alarm as well as documenting the likely cause(s) of the alarm, potential consequence, response time, and operator action. Key attributes to document are:

- **Limit (aka setpoint or trip point)** – this is the process value threshold at which the alarm will annunciate
- **Priority** – relative importance assigned to an alarm to indicate the expected urgency of response

- **Classification** – a logical grouping of alarms based on common properties (such as safety, environmental, operational efficiency, etc.)
- **Type** – attribute that describes the alarm condition (e.g., low, high, deviation, discrepancy, digital state). This is typically one of several options available in the control system.
- **Deadband (hysteresis)** – change in process value from the limit required before the alarm returns to normal (prevents chattering)
- **On delay** – delay time after the process value passes the limit before the alarm annunciates
- **Off delay** – delay time after the process value clears the deadband before the alarm returns to normal

The output of rationalization is a Master Alarm Database (also known as an alarm catalog) containing the alarm configuration requirements.

Benefits of Rationalization

Rationalization is a key stage in the alarm management lifecycle defined in ANSI/ISA-18.2-2016 Management of Alarm Systems for the Process Industries, or ISA-18.2 for short. It forms the basis for implementing an alarm configuration and optimizing the performance of the alarm system. [1]

After completing a thorough rationalization:

- The alarm system can be expected to provide significantly fewer alarm activations and fewer nuisance alarms (chattering, fleeting or stale alarms or alarms without consequences/actions).
- Operator response to alarms will be swifter and more effective because alarms are more trusted, accompanied by good guidance, prioritized for correct action sequence, and free from clutter of secondary and often redundant alarms.

What is Dynamic Alarm Rationalization?

Dynamic alarm rationalization is the preferred methodology for controlling or eliminating alarm floods. One of the most compelling reasons for avoiding alarm floods is that they are the equivalent of a near miss. A flood of alarms can hide an important process alarm allowing a potential incident to follow.

The steps an operator typically executes to respond to a single alarm is as follows:

1. Operator hears / sees alarm
2. Operator silences alarm
3. Operator goes to appropriate display for alarm
4. Operator diagnoses issues
5. Operator makes necessary changes
6. Operator acknowledges alarm
7. Operator monitors variables to determine if changes are working
8. Repeat Steps 5 through 8 as needed

Alarm flood is defined by ISA-18.2 as more than 10 alarms annunciating in a 10-minute period. With this and the response steps given above, it is easy to see that an alarm flood might be burdensome and difficult to manage for some operators. When the flood contains hundreds or even thousands of alarms in a few minutes, an operator can be set up to fail by being overwhelmed by alarms and completely missing alarms entirely or by being distracted by the noise and activity. The end result is that an important alarm may not be addressed in the prescribed way and the boundary that it was protecting gets violated. In fact, during these flood events, the alarm summary screen can be so overloaded that alarms scroll off the display never to be seen again.

The approach used in Rationalization will be a prime determinant in the success or failure of the overall effort. A number of practices have emerged with the intent to reduce alarm floods. Most only affect average alarm rates and have little effect on floods. In fact, the ASM Consortium reported that peak alarm rate is not closely correlated with the degree of rationalization. [6] Only one process, dynamic alarm management, has proven to control alarm floods.

Dynamic (aka state-based or mode-based) rationalization is alarm rationalization for more than one process state. It is applied so that no alarm will annunciate when it does not satisfy the “Relevant” keyword. Static rationalizations can become dynamic when the question “When?” is added to the discussion for each point. As a result, the increased cost for performing a dynamic rationalization versus a static one is not as significant as one might think. Additionally, using the answers generated from the “when” questions allows engineers to properly configure alarm management software to enable and deactivate alarms appropriately for whatever the current state is for the process.

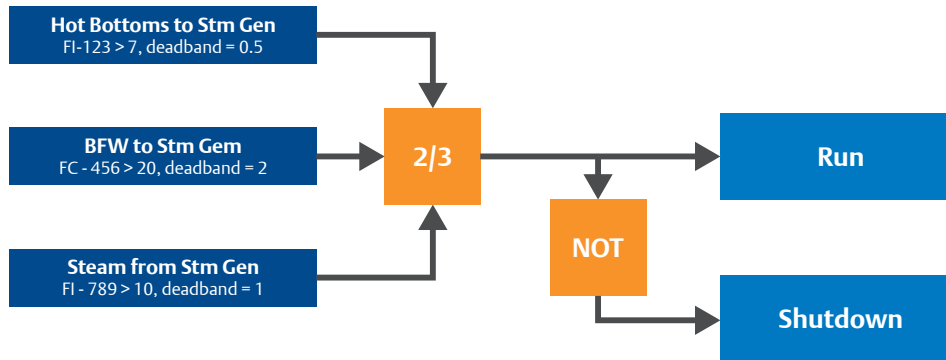
Answering the “when” question involves using operating experience and process knowledge to determine the detectable operating states of each section of the plant. The team determines key operating data and a logic structure which will be utilized to identify the current state. Once the states and logic are determined, it is a straightforward exercise to determine when (during which operating states) each alarm is to be annunciated and when it can be suppressed or disabled. Suppressed and disabled can mean different things in different control systems, but here, they basically mean that the alarm will not annunciate if the process value enters the abnormal condition. Additionally, dynamic rationalization can be used to change other alarm attributes, such as alarm limit or priority as a function of operating state.

Application of dynamic alarming consists of a few basic steps:

- Separate the process into systems. A system is a section of the process (set of process alarms) whose process state can be determined by a set of common logic. This can be a single piece of equipment such as a compressor, or can contain multiple pieces, such as a complete distillation unit.
- Determine the potential operating states (cases) for the system in question.
- Develop a logic structure using key process parameters and status indications to determine a logic structure that detects the current case.
- Determine the dynamic settings for each alarm:
 - Priority
 - Alarm limit
 - Enable/Disable state
 - Suppressed/Unsuppressed state

A simple system that demonstrates case logic and its use is a steam generator, which uses a hot process stream as its heat source. The steam generator can be bypassed while the rest of the process around it continues to operate. For that reason, it is separated as its own dynamic management system. Determination for the Run case is simply whether the hot stream, boiler feedwater, and steam are flowing. Emerson generally prefers to use at least 2-out-of-3 voting in case logic inputs, to provide for robust logic that can survive one bad or inaccurate measurement. Also included are deadbands to prevent chattering between cases. Case logic is drawn thusly:

Steam Generator Case Logic



Run case means that the generator is in use. Shutdown indicates that it is bypassed, or the process around it may be idle – either way, the generator is not in service. For this system, there are a few alarms that benefit from dynamic alarming. For example, if the generator is in Shutdown case, low flow, low pressure and low-level alarms are meaningless. This table indicates how the alarms might be managed:

	Run Case	Shutdown Case
Low steam pressure	Low Priority	Suppressed
Low level	High Priority	Suppressed
Low flow to exchanger	Medium Priority	Suppressed

Note that the high pressure and high-level alarms are not included in this table. This is because the high alarms are generally not suppressed. These conditions are not expected to occur when the system is idle; if high level or pressure does happen, it would be worthy of an alarm. Dynamic alarming can manage individual alarms, rather than treating all alarms on a tag the same way.

Most real process systems will be more complex than this simple steam generator, but the concepts of dynamic alarming are applied in similar fashion.

For more details on dynamic alarming, contact Emerson. Also, references 3 and 7 contain useful information.

Alarm Rationalization is a Team Effort

Alarm rationalization is an activity that is performed in a team setting amongst key stakeholders representing the various functions within a plant. It should be performed by representatives with the knowledge and skills listed below. In some cases, one person may have the knowledge to represent several different areas. Specific roles may need to attend only on an as-needed basis.

- Production and/or Process Engineers familiar with the process workings, economics, and with the control system
- Operators - Preferably two operators from different shift teams with experience in use of the control system
- Process Control Engineering - particularly when advanced control strategies or ESD logic are discussed
- Safety and Environmental Engineers (part time as needed, usually environmental permits are discussed)
- Maintenance / Equipment Reliability (part time as needed, usually when specific equipment is discussed)
- Management (at kick-off to emphasize value of the effort)
- Instrumentation/Analyzer Specialists (part time as needed)
- Alarm Management Facilitator

Rationalization can be a resource-intensive process. The alarm management facilitator, as described in ISA TR18.2.2 [2], plays a key role in orchestrating the process and making sure that it remains focused. The characteristics of a good facilitator are:

- Ensures that everyone stays involved
- Makes sure that everyone has a defined role and sticks to it
- Is independent and neutral (has no responsibility for the process area that is being rationalized)
- Understands the chemical process under consideration and is capable of discernment of proper alarming methodologies
- Keeps the process moving – creates a list of actions to be taken offline
- Can manage the tension and emotion of the activity
- Ensures the debate is framed properly/consistently
- Reinforces the rules of alarm management as defined in the alarm philosophy

Organizing for Success

The key ingredients to start a rationalization program are:

- An alarm philosophy document to establish the rules and key performance benchmarks. To a large extent, rationalization is the application of these rules to each potential alarm. In the absence of a good alarm philosophy, the rationalization effort will falter.
- Alarm rationalization software / layout to provide an organizational structure for review of individual alarms, productivity tools to relate/clone groups of alarms with similar aspects, management of change controls, and ability to document the results in a usable format (Master Alarm Database).
- A rationalization team with core members representing the operations, process, instrumentation, and system engineering disciplines.
- A well-qualified, impartial facilitator to lead the rationalization team.
- For existing (brown field) systems, a complete accurate list of all the current tags and alarms in the control system, and their configuration settings (priority, limit, hysteresis & delay, etc.)

Other important information to have on hand includes:

- Current P&ID and PFD documents
- Current Process / ESD / SIS / F&G Cause and Effect Charts
- Hazard & Risk Analyses (PHA reports, LOPA Results, Safe Operating Limits)
- Critical Operating Procedures
- Environmental permits
- System documentation tools for mapping tags across the automation assets
- A list of alarms that are duplicated in External Annunciation Panels

The Traditional Rationalization Method

Before beginning, the master alarm database (alarm catalog) should be populated with potential and/or existing alarms. The database should include all control system tags and alarms.

The basic methodology used by the rationalization team is relatively simple.

1. Organize the rationalization list for efficient review. This usually means organizing by process system, as defined for dynamic rationalization (see above section). For each system, the team will check each tag and its configured and potential alarms.
2. Determine if the alarms are justified. What is the consequence(s) if the alarm was not addressed? Is there an available operator action to mitigate the event and sufficient time to do so? Note that acknowledging an alarm, watching the control system work, or writing an entry in a logbook is not considered a valid operator action as these responses do not impact the event.
3. Check to see if any alarm is duplicated by another alarm. If so, pick only one to keep that is the best indicator of the anomaly.
4. Determine the correct priority based on the alarm philosophy rules.
5. Document key information that may be of use to the operator, such as possible cause, method to confirm/validate the alarmed condition, and recommended corrective action(s).
6. Document agreed-upon modifications to alarm attributes or specifications if the alarm is new. These would include the limit, hysteresis (deadband), off/on delays, conditional alarming, etc.
7. For processes with differing operating states, specify alarm settings that track the operational state of the plant.
8. Decide if the alarm is similar to other alarms that have already been rationalized. For example, if all compressors are to be treated in similar fashion, then much of the information can be copied from the first set of compressor alarms in order to minimize the level of discussion needed.

Alarm priority is typically determined from a matrix that considers two important inputs:

1. The severity of the potential direct consequence (typically a severity value from a table which covers safety, environmental and financial impacts)
2. The time available for operator response before the consequence can no longer be prevented. Response time is estimated, not calculated, and the matrix typically uses time ranges, such as <5 min, 5-15 min, etc.

The result of this approach is that highest priorities are assigned to alarms with the most severe consequences and shortest available response time.

An example priority setting matrix is included in ISA TR18.2.2 [2], subclause 7.1.

Documenting the cause of the alarm, the consequence of inaction, the operator's corrective action, methods of confirming the alarm, and purpose (design intent) is an important step in the rationalization process. An example of corrective action is starting a back-up pump or manually opening a valve. Acknowledging the alarm or making a shift note entry is not considered a valid operator response to an alarm as these actions do not help correct the problem. This information is valuable for use in operator training and can be provided to the operator as a means of helping them to respond more quickly and accurately during an upset condition.

Classification is a method for organizing alarms by common characteristics and requirements. It is typically used to group alarms together which have similar requirements for training, testing, alarm record retention, audit frequency, and management of change. Alarms can be part of more than one class. Classification often considers the source (identification) of the alarm, such as a Hazard and Operability Study (HAZOP) or an environmental permit. For more details on Classification, see Emerson's Whitepaper on that subject or References 1 and 2.

The Dynamic Pre-Rationalization Method

Essentially following the same steps as the Traditional Rationalization Method, the Dynamic Pre-Rationalization Method has the Process Owner delegate the bulk of the work to Emerson. The Emerson pre-rationalization team consists of a Lead alarm management facilitator who is considered a subject matter expert (SME) assisted by other Emerson alarm management engineers.

This method starts with the Emerson team reviewing the Owner's alarm philosophy and establishing the process to assign preliminary system designation for dynamic alarming. Next, is a joint Owner-Emerson kickoff meeting that usually lasts one to two days. The kickoff meeting typical agenda includes:

- Discuss Emerson's comments on the alarm philosophy and establish the alarm philosophy for the site or project.
- Discuss and establish conventions for handling common alarm types (this is documented in the philosophy).
- Establish process systems and discuss dynamic alarming, including states and logic.
- Establish project schedule.

From there, the Emerson pre-rationalization team develops and documents the alarm rationalization, including alarm properties, boundary information, causes, consequences and action information (CCA) and dynamic alarm settings per the alarm philosophy and agreed-upon conventions for all alarms identified in the scope of work. This saves the customer about 60% of the time that they would normally sit in a conference room and design the alarm system by committee. A typical unit can take up to 8 weeks' time for 2 board operators, a supervisor, a controls engineer, and a process engineer. Other engineers, such as rotating equipment, mechanical and environmental engineers will typically be required to spend about one-half of their time in the meeting during this 8-week period also.

Once this is complete, a pre-rationalization report is sent to the Owner for review. This review is much faster than the design phase, requiring a week or so of review time. A report with comments is returned to the Emerson team. The facilitator then reconvenes with the rest of the Owner's team to discuss the recommended changes that result from the rationalization process and documents the changes.

As dynamic alarm management is considered during pre-rationalization, there is a significant reduction in effort required to implement this compared to the traditional two-step process of static rationalization with dynamic rationalization added at a later time. Dynamic rationalization only accounts for 10-15% of the time estimate when done in one step, whereas adding dynamics later on can take up to 70% of the original rationalization time.

Rationalization Scope

Because alarm rationalization can be a resource-intensive activity, facility personnel may attempt to limit its scope. However, only a full rationalization provides the benefit of optimum alarm configuration with dynamic alarming. In a full rationalization, which can be done for new (greenfield) or existing (brownfield) facilities, all available standard alarms on all tags in the control system are rationalized. Typically, special care and time is spent on an alarm that:

- Is deemed critical to operations
- Has been clearly identified as a nuisance alarm
- Has been highlighted from operator feedback and can provide immediate benefit to operations

Management of Change

An essential part of the alarm rationalization process is the Implementation phase where the recommended changes are implemented in the control system. Integral to this is the Management of Change Process that ensures that changes are authorized, and stakeholders are informed of the changes and trained on any new software functionality.

Estimating the Required Time

A thorough alarm rationalization can use significant personnel resources. For larger systems with thousands of I/O points, the cost can be high. This must be balanced against the potential cost of an incident, which typically far exceeds the cost of rationalization.

The time to rationalize the alarm system can be minimized via effective facilitation and by use of tools and techniques which streamline the process. “Brute force” approaches will take longer than those which divide up the database to capitalize on commonality of alarms or equipment.

Pre-populating the master alarm database with all relevant information before the team meets has been shown to double the rationalized pace.

Using Emerson’s Dynamic Pre-Rationalization method, while no performance assurances can be given, a reasonable conservative figure to use for budgetary estimation is 80-100 alarms tags (single-variable DeltaV control modules) per day for pre-rationalization. During owner rationalization meetings when suggested changes are approved, rejected, or modified, about 300 modules are expected to be reviewed each day. Effectively, the Owner’s commitment is about one third of that for a traditional alarm rationalization project.

Emerson’s Alarm Rationalization Offering - AgileOps™ Alarm Management Software

Emerson’s AgileOps software is a suite of powerful tools that facilitates alarm rationalization as described above.

The primary module used for rationalization is Master Control System Database (MCSD). It is designed as a repository of approved alarm attribute values, as a tool for rationalization, and as a dynamic (state-based) alarming design and documentation tool. MCSD includes screens for:

- Showing all tags in the control system as read via OPC
- Reviewing and editing alarm attributes
- Creating systems and dynamic cases and assigning tags to systems
- Developing and documenting dynamic (state-based) alarming settings

- Developing and documenting alarm data, including boundaries, causes, consequences, actions, available response time, and other pertinent information
- Providing on-line data to the operator directly in DeltaV for each alarm (causes, potential consequences, expected actions, other information as needed) via Operator Help functionality

The second module that is important for alarm rationalization is Dynamic Management (DM). DM includes:

- On-screen development and review of case logic for each process system and operating case to be used for dynamic alarming
- Execution of alarm attribute changes per operating case as specified in MCSD
- A quick view of all alarm attribute changes to be performed when an operating case is selected by the logic, and the current status of each
- Read only / read-write and auto / manual modes for testing and troubleshooting

A third AgileOps module that is useful for rationalization is List Management (LM). This is Emerson's advanced alarm shelving tool. Alarm shelving is useful for temporarily suppressing alarms on misbehaving or out of service instruments. Because LM includes automatic shelving capability, it can also be employed by the rationalization team to handle alarms that can become stale but may not fit nicely into dynamic alarming.

For more details concerning AgileOps, readers are directed toward Emerson's product data sheets or the AgileOps Whitepaper.

Tips for Effective Rationalization

1. Preparation of the initial master alarm database prior to rationalization is critical to success. Without a complete and accurate database, or in the case of a new system a sufficient list of potential alarms, progress will be hindered.
2. All participants must understand and embrace the alarm definition and rules set out in the alarm philosophy.
3. Participation by all required disciplines, at every meeting of the rationalization team, is a must.
4. Allot ample time for rationalization. Time can be managed by reviewing one-time processes that are significantly alike, such as reactors, compressors, etc. doing the identical process.
5. Plan ahead such that subject matter experts from outside the core team can be brought in when required. Safety, Environmental and Maintenance and other specialty disciplines will need time to prepare. Consider providing a pre-meeting document to explain the key tenants of alarm definition, philosophy and rationalization.
6. Be rigorous in the consistent application of alarm philosophy rules. Exceptions must be well-documented and should be infrequent. Failure to do so will lead to countless wasted hours in discussion of "philosophy" and produce a final outcome where individual operator judgments and interpretation will fill the gap created by variable alarm system behavior.
7. Expectations can run high when the decision is made to undertake an alarm rationalization program to "address" the "alarm problem" at an existing site. Thus, it is typically worthwhile to devote some of the early effort tackling points with nuisance alarms while keeping the holistic view of the alarm system design in mind. Operators will appreciate the elimination of fleeting/chattering alarms and management can see that the rationalization program is producing useful results. Note this approach can result in inefficient rationalization committee effectiveness so try to move past this phase expeditiously.
8. Don't forget about diagnostic alarms and Foundation Fieldbus and HART device alerts. These are often responsible for a large percentage of alarm traffic and are typically considered nuisance alarms by an operator. Rationalization should strive for a consistent prioritization, determination of whether the operator needs to see the alarm, and creation of a message that is understandable and actionable.

9. It is generally not useful to assume multiple cascading failures when considering an alarm consequence scenario. Only the direct (proximate) consequences should be considered. While it may be the case that a protective system could fail further compounded by a subsequent incorrect human response, such what-if considerations are likely to lead to a vast skewing of alarm priorities toward critical. Rationalization works best when it is assumed that the design and reliability of systems and work processes not impacted by the alarm condition are functioning as expected.
10. It is generally a waste of time to ponder the probability of an alarm. Simply accept that it has happened or can happen and proceed to qualify and optimize the alarm following the rationalization process rules. The exception to this caveat is situations where the probability of an alarm annunciating is indeed zero (an impossible scenario). In this case, it's better for the team to simply recommend deleting the alarm and move on.
11. Other factors, such as staffing, operator fatigue, control room design, and high-performance HMI can overlap with alarm design considerations and can significantly affect operator performance. While outside the scope of this paper, these factors should be addressed in a facility's overall improvement plan.

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