PROCESS ALARM MANAGMENT- AN INVESTMENT TOWARDS SAFE AND RELIABLE OPERATIONS

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Abstract

Most of the commercial buildings and private homes are configured with a certain number of alarms to deal with emergency situations, such as fire alarms, HVAC fail alarms, theft alarms, water leakage alarms etc. However, for an industrial process plant, all alarms and their configuration parameters collectively feed into a big database. For a typical offshore installation, the alarm database for the integrated control and safety system may consist of 40000 to 150000 alarms which must be monitored.

Considering the vastness of an alarm database for a process installation, and the risk of missing critical alarms, there is a need for a regulated and a guided system to handle and integrate all aspects of alarm engineering to create a functional alarm system.
Such an alarm system must:

- Be built on “principles of alarm design” for process industries
- Be complaint with applicable regulations
- Be usable by process operators in management of abnormal situations
- Perform in line with organisational performance measures

As process industries are getting increasingly complex, with new technologies and expansion projects, process operators are becoming overloaded with new systems and new alarms dominate the unnecessary disturbance. Alarm systems need to be well specified and maintained to ensure safe operations.

During the period between August 2000 and September 2002, NPD (Norwegian Petroleum Directorate) has carried out the supervision of alarm systems on seven production facilities within the Norwegian Continental Shelf. Authorised mapping of alarm systems revealed essentially the same weaknesses and same problem areas, independent of system vendor, operating company, type of facility and age of device. Despite the limited mapping that has been made, NPD find it reasonable to assume that, the results from these activities are somewhat representative of the challenges of other facilities on the Norwegian continental shelf.

This thesis will choose to provide a proactive approach to draft various procedures for a functional alarm system with all the specifics mentioned above for an alarm system within the frame work of regulations limited to Norwegian continental shelf.

A well-functioned alarm system combines with coordinated operations management can drive not only safety and ensure regulatory compliance but promote better plant availability and throughput, delivering real business value. (Honeywell, 2017)

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Dedication

Dedicated to

My Father Prathipati Samuel Williams

My Mother Prathipati Padma

Who taught me being humble and responsible, and the importance of hard work

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Abbreviations

ALL	Action LowLow
ANSI	American National Standards Institute
ASM	Abnormal Situation Management
CAP	Critical Action Panel
CCR	Central Control Room
CCTV	Closed-Circuit Television
CSB	Chemical Safety Board (U.S)
DREAM	Detecting, Responding, Enforcing, Assessing and Modifying
EEMUA	The Engineering Equipment & Materials Users Association
EMS	Eldor Management System
ESD	Emergency Shutdown
FAT	Factory Acceptance Test
ESH	Environmental, Health & Safety
HMI	Human Machine Interface
HSE	Health, Safety and Environment
HSE	Health and Safety Executive (UK)
HVAC	Heating, Ventilation and Air Conditioning
IAT	Internal Acceptance Test
IEC	International Electrotechnical Commission
ISA	International Society of Automation
LSD	Large Screen Display
MCB	Miniature Circuit Breaker
NA	Not Applicable
NCS	Norwegian Continental Shelf
NDLA	Norwegian Digital Learning Arena
NOK	Norwegian Kroner
NPD	Norwegian Petroleum Directorate
OEE	Overall Equipment Effectiveness
O&G	Oil and Gas
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
P&ID	Pipe and Instrument Diagram
PA	Public Announcement

PSA	Petroleum Safety Authority
PSD	Process Shutdown
PT	Pressure Transmitter
SAS	Safety and Automation Systems
SDFI	State´s Direct Financial Interest
VDU	Visual Display Unit
WH	Warning High
WL	Warning Low
YA-711	Principles for alarm system design – Norwegian Petroleum Directorate
YF	Feedback Failure

Glossary

Alarm services: Referred to alarm engineering service provider company.

Chattering Alarm: An alarm that repeatedly transitions between the alarm state and the normal state in a short period of time. (International Society of Automation, 2009)

Customer: Referred to the company who owns the process installation.

Depressurised shutdown: A complete shutdown with blowdown. Total pressure within system will be released. Start-up time required to come back to normal operations is longer and normally referred as cold start-up.

Engineering company: Referred to an engineering company.

Event: Any status change in equipment, process parameter changes and operator performed actions logged as events. Operators will not be notified.

ESD: Emergency Shutdown System (designed to minimise the consequences of emergency situations).

Pressurised Shutdown: A partial shutdown without blowdown. Pressure within the system will be retained and start-up time required to come back to normal operations is less compared to depressurised shutdown. Normally referred as warm start-up.

PSD: Process Shutdown System (designed to minimise the consequences of unwanted process control thereby avoiding further escalation into ESD).

Suppression: Any mechanism to prevent the indication of the alarm to the operator when the base alarm condition is present. (International Society of Automation, 2009)

Operator: Process Control Room Operator or Central Control Room Operator.

Organisation: referred to the company who owns the process installation.

Standing alarm: An alarm in an active alarm state. (International Society of Automation, 2009)

Top-N: A certain number of first few alarms in descending order in terms of number of occurrences for a particular period.

Vendor: Referred to control system vendor company.

1. Introduction

An audit conducted by Petroleum Safety Authority (PSA) for North Atlantic Drilling alarm system, PSA identified non-conformity relating to deficient routines for establishing and following up the alarm system's performance as an active barrier against potential incidents (Petroleum Safety Authority, Norway, 2014). This is one of the problems among many identified at such installations.

An alarm system´s improved performance leads to safe and secure plant operations. A well designed alarm system with established routines to maintain, leads to better performance. The evolution in technical excellence of process automation, helps us in many ways to optimize the alarm design and change management.

This study will highlight the importance of planning alarm management activities right through early stages of an installation. Moreover, an alarm is meant to save equipment from getting damaged or alert an operator to counteract for an unwanted situation. In either case, it saves the cost involved with a shutdown or equipment damage, and create a safe working environment for employees by reducing escalating events.

1.1. Research Area

The inspiration for this research began while evaluating the Eldor Management System (EMS) with respect to alarm engineering processes. Eldor AS is a leading company in Alarm Management for the Oil and Gas industry in Norway. Eldor AS believes:

- "An optimized alarm system gives optimized decisions" and "Alarm systems need to be specified and maintained to ensure safe operations".

As the process industries are becoming more complicated by upgrading to new technologies, increased integration, more information from each sensor, increased digitalisation and reduced number of operators, becoming a challenge considering alarm load on operators with new systems and new alarms. Alarm systems need to be specified and maintained to ensure safe operations (Eldor AS).

Most process industries have their own alarm philosophy defined as per the plant operating conditions. But with expansion projects, it is quite mandatory to define the alarm strategy also to address alarms from different process sections efficiently.

Alarm philosophy is a document which specifies *how and when* the alarm should be generated, presented and archived on a general basis. Philosophy can vary from process section to process section keeping organization values intact.

Alarm strategy is a document which identifies different process sections and their inter-relation. It also describes *where* these alarms should be presented and *who* will be the responsible to take action on alarms from different process sections.

This research has identified 4 dimensions of an alarm system to justify the requirement for any alarm management activity:

1. Cost of Poor Performance of Alarm System (Risk to people, Environmental, Financial)
2. Alarm system is large and complex (A database consists of several thousand alarms)
3. Not a one-time fix (Continuous Improvement and Change Management)
4. Valid KPIs (An indication of safe and reliable operations rather than a statutory requirement)

Process operator's day to day experience with process controls and their insight into alarm systems is the key to establish principles of alarm design for effective operations. Along with process operators' insights, this thesis will try to gather inputs from discipline leads, regulatory authorities and control system engineers to establish the frame work to deliver a well-functional alarm system for safe and reliable operations.

Recognizing assorted regulations related to alarm system requirements in process industries, the obligation towards their compliance, and procedures and processes to aid will be the part of this research.

This paper will try to maintain that decorum while representing various sections, meanwhile not losing track of main research area and goal of this research which is producing a functional alarm system for safe, reliable and complaint operations.

1.2. Research focus

(Lindøe, 2017) has developed two contrasting modes of risk regulation, coined as command-and-control and enforced self-regulation. Here in these contrasting modes command-and-control regulation developed by state in its capacity to dictate legally binding norms. As a main characteristic, the US regime has relied on the command-and-control approach, in which the state forces the industry to comply with the relevant laws and the prescriptive rules (Referring to (Baram & Lindøe, 2014) work on US regime cited by (Lindøe, 2017) in his text).

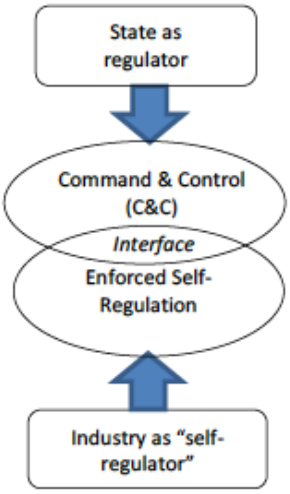


Figure 1 Modes of risk regulations (Lindøe, 2017)

In contrast, Industry as "self-regulator" with internal control principle allows the companies to check its own operations in systematic manner by establishing internal management systems to meet the targets set by the regulator. The Norwegian regime has been developed step by step in the direction of increased user of functional requirements expressed in legislation. The supervisory regime on Norwegian Continental Shelf (NCS) builds on the view that a regulator cannot "inspect" quality into the Norwegian petroleum sector, the responsibility for operating in compliance with regulations rests with the industry itself.

As (Lindøe, 2017) raised concerns about this approach – Industry as "self-regulator": The uncertainty about what is required for compliance, given that each industrial activity has a unique mix of characteristics, and ambiguity about governmental intervention and enforcement. This research has noted concerns related to industry as "self-regulator" approach and established relevant effort to find:

"What are the key regulations for an Alarm management activity within the frame work of Health, Safety, and Environmental (HSE) regulations for process industries?"

Examining these regulations and evaluating process operators´ requirements through interviews based on their valuable experience from various installations, so that results may be imparted into "Alarm Engineering" procedures proven to be cost effective solutions. This research believes in keeping this impeccable relation between regulator and regulated to ensure safe and reliable operations.

After all this reasoning, this research has narrowed down its focus to address:

1. **How to develop a supportive system for process alarm management describing procedures based on key regulations related to HSE framework?**
2. **Justification for an alarm management activity to evaluate and support a business case having key investment drivers in terms of losses due to poor performance of alarm system.**

1.3. Value of research

Thanks to the technology of digitalisation and telecommunications, it is now easier than ever before to conduct remote operations and utilise completely unmanned remote platforms. Remote operations can mitigate multiple challenges, including talent shortage, HSE exposure, employee security concerns, cost of service delivery (Schlumberger, 2017). But this also brings uncertainty in safe operations until and unless a functional alarm system is defined and maintained throughout all stages of life cycle.

Using one year's data from three hydrocarbon processing plants, it has been estimated that small disturbances from optimal production account for 3-8% of plant throughput. For a typical oil refinery, this equates to an annual cost of NOK 30-100 million. Not all this loss will be recoverable just from installing better alarm systems, but some part of it should be. It should be recognised that good alarms systems can play a significant part in reducing the likelihood of these kind of disturbances. (EEMUA, 2007)

Interviewing operators, team leads and various stakeholders and getting their insight into both financial losses and accidents due to alarm system failure, brings in required decision-supportive processes and improvement in procedures for alarm handling projects.

This research can be developed further, beyond the scope of this dissertation, and will elaborate and result in enhanced framework for alarm engineering processes in future. The specified research objects mentioned above shall be the basis for this research and serve as guidance in the examination of existing literature.

2. The Technical Backdrop

2.1. Background

Whether it's a process plant, a manufacturing industry, or simply our home, things can go wrong in many ways. Process parameter deviations, plant dynamics, electrical disturbances, or human errors, whatever the event, these deviations must be *"detected and alerted"*.

Alarms generated by detecting deviations on single process measurement or single pieces of equipment (Norwegian Petroleum Directorage, 2001)

Every year there are about 1,500 accidents in private homes due to fire. The reasons might be dry cooking, smoking, unauthorized repair of electrical installations etc. (NDLA, 2017).

Figure 2 Smoke detector (NDLA, 2017)

In a process industry, any deviation in a process parameter (pressure, temperature, flow, or any other variable) from its normal operating range may lead to numerous consequences. Consequences may affect personnel safety, the environment, or financial considerations, up to and including the safety integrity of the plant itself.

The explosion and fires at the Texaco Refinery in Milford Haven, is one of many examples to be considered when it comes to failure of control systems and underperformance of an alarm system.

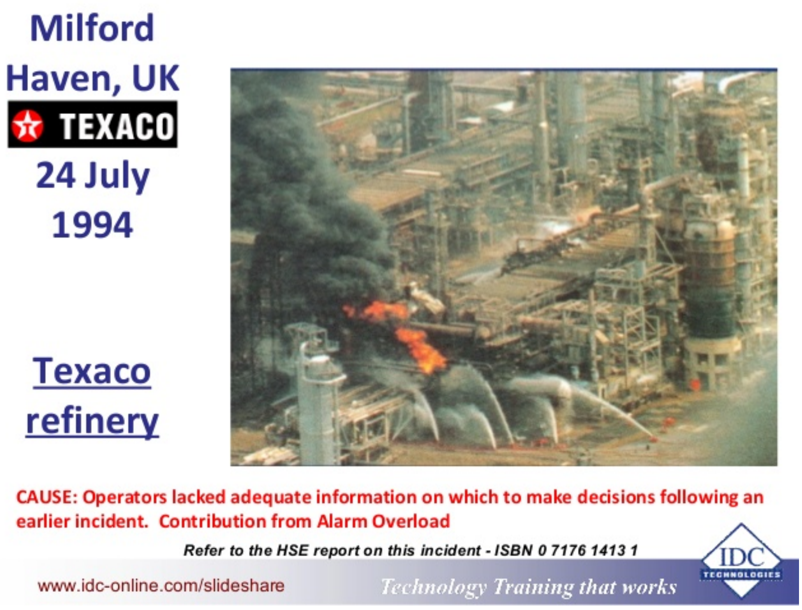


Figure 3 Texaco Refinery explosion (idc-online.com, 2014)

In a manufacturing industry, any deviation in a process parameter directly effects the quality of the final product and in some cases, it may lead to an HSE incident. Production facilities work within very narrow band of deviation envelope, which means a strict vigilant alert system should be in place to limit the consequences. e.g. cement, metal, textiles, car assembly lines, etc.

Events outside of these parameters could not only affect quality issues, but could jeopardise the company profile itself by producing defective products. Alarm systems play a vital role, irrespective of industry, to keep things under control.

2.2. Alarm and Alarm System

Brasnby Automation and Tekton Engineering jointly produced a report for the Health and Safety Executive on the management of alarm systems (Bransby & Jenkinson, 1998). Though there are number of ways to explain what is an alarm and what is an alarm system, this research has adopted definitions from (Bransby & Jenkinson, 1998) report.

Alarm: In mechanistic nuts-and-bolts terms, an alarm is some signal designed to “alert, inform, guide or confirm”

Alarm System: A system for “generating and processing alarms and presenting them to users”.

The primary function for an “Alarm” is to notify operator about an abnormal situation so that operator can regulate and avoid escalation

Figure 4 Process Alarm - Primary Function

Usually, alarms are presented to the control room operator in different ways depending upon the system they are supporting.

i. Alarms displaying on an individual alarm window on a unit control panel. The example shown below gives an overview of rotating equipment alarms, and the lamps indicate their severity.

Figure 5 Alarm window panel - Rotating Equipment

ii. Alarms presented in the form of lists on visual display unit (VDU) screens as shown in *Figure 5*. The list is dynamic and keeps the status of alarms like New, Acknowledged, cleared etc. The colour of the alarm text line indicates its severity.

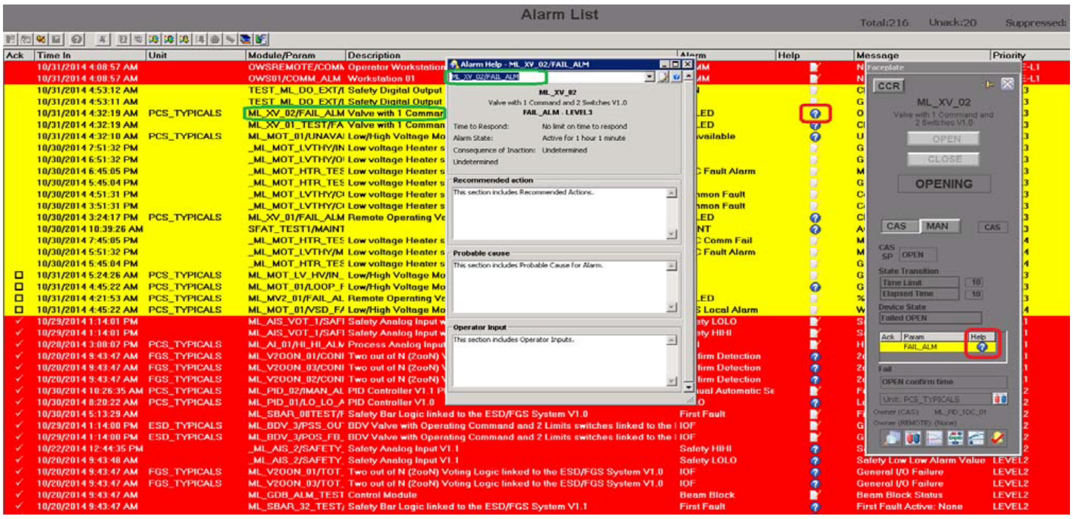


Figure 6 Alarm list presentation in a control system

The focus of this research is mainly the type described in alternative ii above, a computer based control system and its alarm list. Alarm lists are increasingly becoming overloaded with unnecessary information and status messages, overriding the principle purpose of an alarm system, which is to alert control room operators in case of an unwanted situation. Accidents such as the one which occurred at the Dupont plant in Belle, West Virginia in 2010 and the Texaco Milford Haven refinery accident in 1994, keep reminding us of the significance of a good alarm system and its management.

The CSB (U.S. Chemical Safety Board) investigation found common deficiencies in DuPont Belle plant management systems springing from all three accidents: Maintenance and inspections, alarm recognition and management, accident investigation, emergency response and communications, and hazard recognition. (U.S. CSB, 2011).

2.3. Alarm Management

Alarm management is all about the understanding, design, implementation, and operation of an effective *alerting capability* for plant operators. (Rothenberg, 2009). This research has outlined some of the symptoms based upon observations from various installations with respect to alarm system performance. The need for an alarm management activity review will be triggered by some or all of the symptoms, but not limited to the ones shown below.

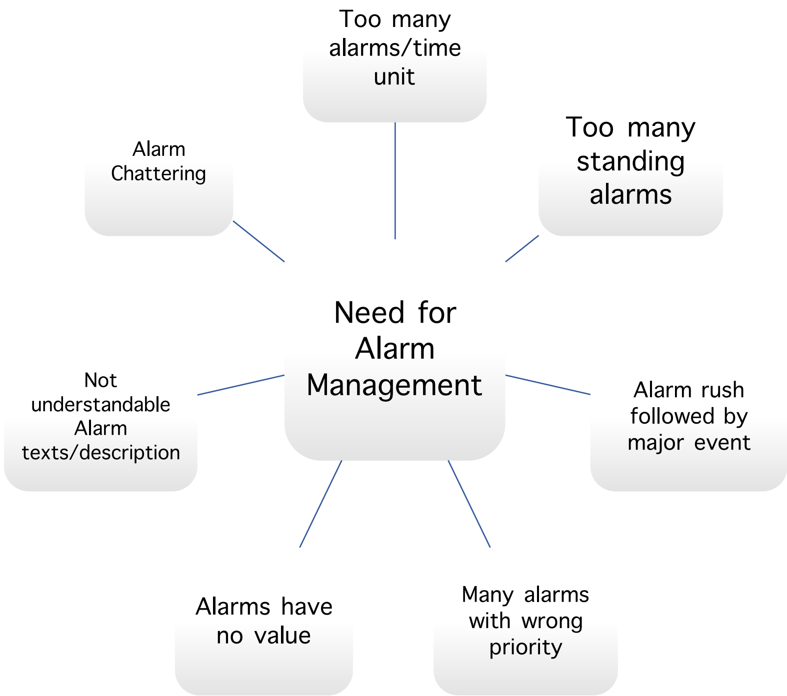


Figure 7 Alarm System Under Performance Symptoms

2.4. Performance Attributes

Alarm Value: Every alarm shall require an operator response, to ensure that no unnecessary alarms are defined in the system (Alarms with no action or no value are just noise)

Tag Name: The alphanumerical string of project specific equipment /area codes and tag name of filed device and alarm initiate by tag name. All tag names shall be unique.
e.g. 65-PT-1104, in this example 65 is area/system code, PT represents pressure transmitter, and 1104 is loop number.

Tag
65-PT-1104

Alarm Description: The text consists of equipment/process area details and service of equipment, it also consists of information about the placement of the filed device.

Tag	Description
65-PT-1104	1st Stage Separator Gas Pressure

Alarm Text: Constitutes type of alarm (High, HighHigh, Low, LowLow, Fault etc.)

Tag	Description	Alarm Text
65-PT-1104	1st Stage Separator Gas Pressure	High

Priority: The relative importance assigned to an alarm within the alarm system to indicate the urgency of response. Priority shall be mapped in combination with severity of consequence and urgency of the alarm. Each organisation has their own definition of priority distributions according to their risk tolerance. Basically, It's a mapping matrix of consequence severity vs. urgency.

Urgency vs. Severity	Minor	Major	Severe
Soon (> 15mnt)	Level - 3	Level - 3	Level - 2
Prompt (5 to 15mnt)	Level - 3	Level - 2	Level - 1
Immediate (<5mnt)	Level - 3	Level - 2	Level - 1

Table 1 An illustration of severity vs urgency matrix

Here the severity of consequence: Minor, Major, and Severe, is according to respective organisation policies and alarm philosophy document which must discuss these prioritisation methods. The following philosophy shall be covered:

- The basis for alarm prioritisation (time to respond, severity of consequence etc.)
- The metrics for alarm configuration (distribution of alarms among priorities)
- Impact of classification on prioritisation (Personnel, Environmental & Financial)

(International Society of Automation, 2009)

Alarm Load: This is represented in terms of the number of alarms received per operator per single time unit (1 minute, 10 minutes or 1 hour). Companies have the flexibility to choose reasonable alarm load criteria in line with company safety policies or adapt given recommendations from applicable standards.

Predictive	Robust	Stable	Reactive	Overload
<1	<10	<10	<100	>100

Table 2 EEMUA Recommendation (Metric: Average alarm rate, Time unit:10 minutes)

Standing Alarm: An alarm is called standing if the alarm condition persists for an extended period of time (varies between 1shift-12 hours to 1day-24 hours). EEMUA suggests target for this is under 10.

Alarm Rush: This is also referred as alarm flood, typically a situation in which more alarms are received than can be processed by a single console operator. EEMUA defines this as Maximum Alarm Rate (expressed as number of alarms in a 10-minute period)

Predictive	Robust	Stable	Reactive	Overload
<10	<100	<1000	>1000	>1000

Table 3 EEMUA Recommendation (Metric: Maximum alarm rate)

Alarm Chattering: This is a situation where a particular alarm keeps coming and going quite often, as often as 30 to 40 times per a minute. A typical scenario as “Ballast tank level” on a floating vessel offshore, due to high tide as the liquid level in the tank keeps touching level measuring probes due to wobbling.

2.5. Evolution of Practices and Life cycle stages

Accidents like the explosion at the Texaco Milford Haven Refinery in 1994, where two operators received more than 200 alarms within the final 10 minutes elevates the situation of alarm overload. The usability of the alarm system when it was needed the most, became overloaded and jeopardised the integrity of total plant. This kind of alarm system is neither acceptable nor useful, and resulted in the development of guidelines to design, manage, and procure alarm systems by EEMUA first published in 1999. EEMUA publication No. 191 is a guideline document which describes various engineering aspects of the performance attributes described above.

Ten years later, the International Society of Automation prepared a standard towards a goal of uniformity in the field of instrumentation called ISA 18.2 - Management of Alarm Systems for the Process Industries. This standard introduced the life cycle approach in alarm management and suggested various stages with in the life cycle as show in *Figure 8*.

In 2014, IEC (International Electrotechnical Commission) developed a standard, IEC 62682 – Management of Alarms Systems for the Process Industries, which is an extension to existing ISA 18.2 standard. As it is noticed, both ISA 18.2 and IEC 62682 are standards, whereas EEMUA Publication 191 is a guidelines document.

The various stages identified both in ISA 18.2 and IEC 62682 were identical, and required systems to follow a life-cycle which covers alarm system specification, design, implementation, operation, performance monitoring, maintenance and change management from initial conception through decommissioning.

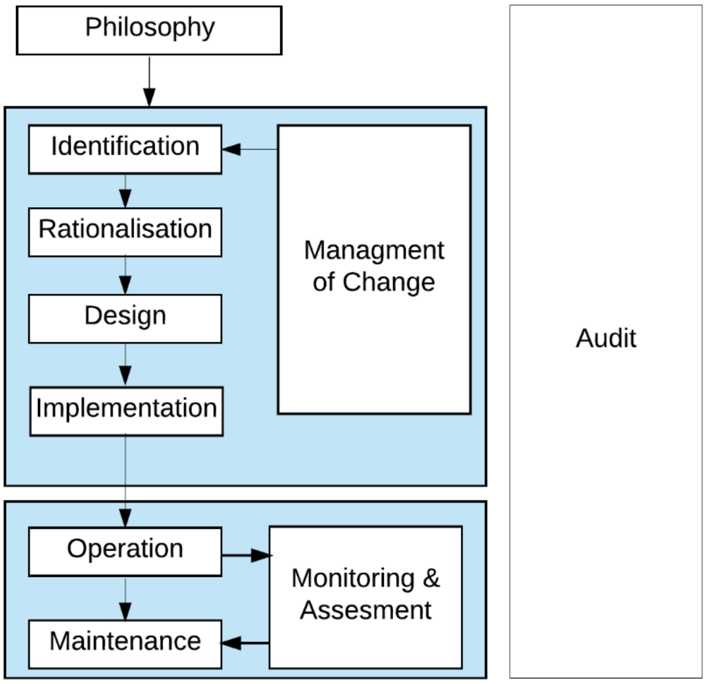


Figure 8 Alarm Management Life-Cycle ISA 18.2

Philosophy: This document specifies the various processes used in each stage of the life cycle, such as: alarm generation, design principles, roles and responsibilities, management of change, performance metrics, etc.

Identification: A predefined process to identify alarms through various process such as hazard analysis, P&ID development, review of operating procedures and good manufacturing practices.

Optimisation: Is an activity which is initiated by the need for an improvement in an alarm system, and it mainly includes defining understandable alarm text, prioritisation of alarms, identifying cause, consequence, and operator action for an alarm.

Design: Apart from basic alarm attributes specified in Optimisation, detailed design stage includes definition of HMI representation, annunciation of alarms along with advanced alarm techniques. Alarm applicability based on context of operations, grouping of alarms based on similarity in operator action and tuning of alarms by adjusting dead bands and filter times are some of the advanced alarm techniques.

Implementation: This stage specifies the activities necessary to install alarms and functional verification of system.

Operation: Alarm system is active and it performs as intended. Purpose of each alarm is supposed to be validated during this stage.

Maintenance: This is the testing phase of an alarm system, and periodic maintenance activity should ensure that the alarm system is performing as designed.

Monitoring & Assessment: This is in parallel with operations and maintenance. Routines should be established to monitor and asses the alarm system performance. The usability of the alarm system, alarm load and other performance metrics are specified in the alarm philosophy document.

Management of Change: Modifications to alarm systems are proposed and approved as per the roles defined in the alarm philosophy document. This change management process should be followed from identification to implementation stages to avoid any uncontrolled changes, considering the complexity and vastness of the alarm system.

Audit: Periodic reviews are conducted to maintain the integrity of alarm system and coordination among various stages in alarm management. This stage will ensure that necessary routines are established and maintained according to alarm philosophy.

2.6. Performance is the Key

Process system owners, suppliers, and vendors are starting to notice the importance of effective alarm system performance. All stakeholders including process owners, control system suppliers, and vendors are making sure that alarm management solutions are integrated into main control system delivery. If not implemented at the beginning, systems are capable of adopting alarm management solutions even after installation and long periods of service. To quote ABB, one of leading process automation system suppliers, “21st Century automation system technology frequently delivers centralised control and operations, improved equipment reliability and significant maintenance savings. However, all too frequently these benefits fail to be translated into increased uptime and improvement in OEE (Overall Equipment Effectiveness) due to ineffective alarm system performance.” (ABB Consulting, 2015)

Missing a systemic approach to control alarm system performance while adding new systems or enhancing existing systems for better throughput, may lead to catastrophic events. Martin Hollender and his team have done a review entitled, “Alarming Discoveries” for ABB and identified that alarm "floods" remain one of the biggest challenges for industrial facilities using distributed control systems (Hollender, et al., 2017). A classic example of an overloaded alarm system is the explosion at the Texaco Milford Haven refinery, where the two operators received 275 alarms in the last 11 minutes before the explosion. This is now seen as a characteristic of an overloaded alarm system, which makes it impossible for an operator to be properly aware of a situation and to diagnose and correct it.

Having control over safety incidents, which companies proudly present in their indexes, may not be the case of reality. There were several near misses which could have been potential incidents which should have been registered and actions identified. The Abnormal Situation Management (ASM) consortium emphasized gaps in reporting systems, for example in alarms which protect the process from potential problems other than safety – such as (non-safety) environmental release, product quality, equipment life, and economic objectives. However, the mechanisms of control, loss of control, and recovery are essentially the same for all these potential problems. Hence it can be argued that any loss of control so detected "under slightly different circumstances" could result in a safety incident, and thus should be categorized as a near miss. (Bullemer & Metzger, 2008)

Any incident, safety or non-safety, detected by alarm system needs to be registered as an observation. Creating an alarm management activity always requires analytical data in terms of these observations to support the decision of investing into an alarm project.

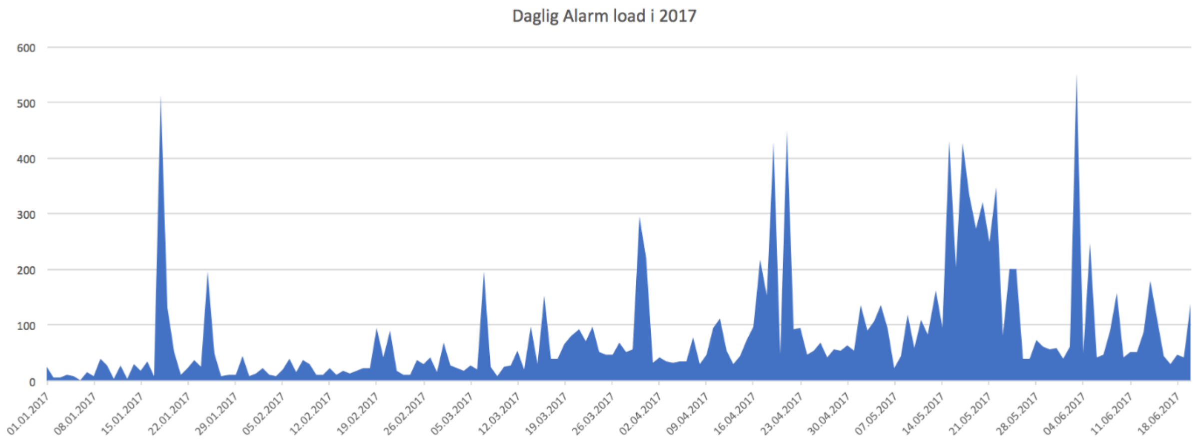


Figure 9: Alarm load histogram

The above picture represents an alarm load histogram for a typical land based industry. Alarm load variations and the intensity of the alarm load for the span of six-month period are represented. During a disturbance in a plant, the load may reach up to 500 to 600 alarms, whereas in normal operations there are about 20 alarms per day. The variation of alarm load during normal and disturbed plant conditions explains the control room scenario of “Alarm-To-Alarm”. A situation may exist where an operator is attending and responding to alarm after alarm, with relevant actions, without having enough space for regular mandatory checks and observations.

For instance, from the above histogram it is evident that the alarm load has been increased in late months, particularly during warmer months of the year where the alarm load is relatively high. Process measurements are so sensitive in such a way that there may be many factors contributing the disturbances in an industry including weather like ambient temperature. During this period, operators are more or less occupied with responding to alarms only. This kind of operations introduce uncertainty in safe operations.

2.7. Process Disturbance Model

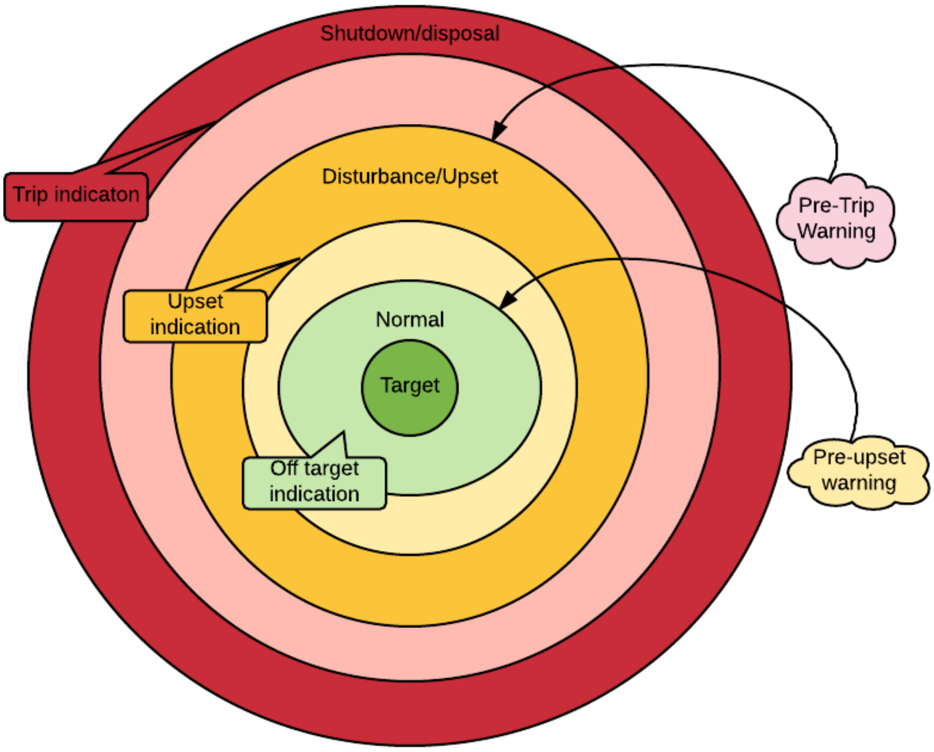


Figure 10 Process Disturbance model

The above illustration of process model is taken from (International Society of Automation, 2009), and the primary focus for this illustration lies in the transitions between different process conditions. In a typical process plant, there are several process areas, and each area has its own target zone. It is the responsibility of a process operator to keep all these areas within their target zones for safe and reliable operations. e.g Kårstø gas processing plant has several process sections or process areas: (GASSCO, 2003)

- Inbound logistics: Åsgard transport line operated by Gassco AS to the treatment plant at Kårstø
- Hydrocarbon products: This processing plant separates the rich gas arriving in the Statpipe and Åsgard Transport pipelines into its various components.
- Ethane separation plant: This production is sold under long-term contracts and shipped from the plant by sea.
- Outbound logistics: Natural gas is exported from Kårstø through the Europipe II pipeline to Dornum in Germany and through the Statpipe/Norpipe system to Emden

Any deviation from the operational target with in these mentioned process areas will have the possibility of uncertainty in quality of production and safe operations.

Off target indication: Process is not optimal anymore as targeted and getting into off-spec production but still in normal operating range. This is the time when an operator needs to interfere and streamline the process to get back into target zone. This is only possible if the operator is not engaged with Alarm-To-Alarm scenario.

Pre-Upset Warning: A transition where the process envelop is slipping beyond normal operating zone and getting into disturbance.

Upset Indication: An indication saying that the process has become disturbed and continuing with that disturbance could result in off-spec production, poor quality and escalation into a safety incident. Every transition may not be an alarm to an operator, but the consequence of an upset indication will be the guidance to determine the necessity for an alarm.

Pre-Trip Warning: The transition at this phase is normally configured with an alarm to alert the operator, if he/she is busy enough to capture the disturbance/upset situation earlier in affected area. This is the last opportunity for the operator to avoid going into shutdown mode.

Trip indication: An indication that a shutdown has occurred, and it is the point of no return past which that product is unusable. The operator has to act upon this alarm to do the post-trip analysis and secure the rest of the process areas to maintain the integrity of the plant as well as for quick start-up.

As it has been discussed earlier, alarms can be configured on different transitions based on the severity of consequence and time to respond for an operator, to avoid disposition limit violation. So, alarm system performance is the key when defining plant integrity in terms of safe and reliable operations.

3. The Norwegian Offshore Context

3.1. General Background

In late 1950s the discovery of gas at Groningen in Netherlands caused people to look for more opportunities in North Sea. In October 1962 after an attempt by Philips Petroleum to get exclusive rights over whole shelf and turned down by authorities, 22 production licenses for total of 78 blocks were awarded to groups of oil companies. The first discovery by Ekofisk in 1969 actually ignited the Norwegian oil adventure and production started in 1971 followed by many major discoveries.

(Karlsen & Lindøe, 2006) identified four distinct modes that have been applied in the development of OSH regulation in the Nordic countries during past 100 years. As depicted in Table 4, OSH regimes can build on a mixture of different regulatory principles: Protection by specific rules, participative action, knowledge-based development, and a market-based mechanism.

		Organisational Approach	
		Direct	Indirect
Legislative Basis	Statutory	1 Protection by specific rules	2 Participative action
	Voluntary	3 Knowledge-based development	4 Market-based mechanism

Table 4 A framework model for OSH regulation (Karlsen & Lindøe, 2006)

During 1980s, while increases in production and wealth were followed by the systematic production of technologically deduced hazards, medical and social risks became obvious. Both regulator and regulated were in need of better understanding, knowledge and methods to mitigate these risks, which demanded a large-scale reform in public administration and regulatory bodies.

(Feldman & Khademian, 2001) derives the trade-off between accountability and flexible management within government organisations. Public administration is held responsible for utilising public resources in a flexible manner. Flexible management can cut across structures or procedures that have traditionally provided a form of legitimacy for the expenditure of funds or exercise of government authority. Reformers within the "New Public Management" emphasize the bottom line, or the performance, of an agency as a form of accountability that can also accommodate flexibility. (Feldman & Khademian, 2001)

Public administration and regulatory bodies took on a more modern look due to reformation in public management system. Countries like Norway aimed at becoming more decentralised mechanisms of steering and control regarding risk-based regulation and risk-based safety management.

The Nordic model progresses through different phases due to various inflection points caused by Sevesco 1976, Bravo 1977, Alexander Kjelland 1980, Chernobyl 1986 and Pipher Alpha 1988. Now the Nordic model has taken its shape, and is mainly influenced by market forces and stake holders such as authorities, customers, suppliers, vendors and workers.

During this evolution process after two major accidents, Bravo and Alexander Kjelland, within the Norwegian continental shelf, the role of the Norwegian Petroleum Directorate (NPD) has strengthened. The era of New Public Management gives a decentralised mechanism of steering to the NPD, and has helped to create the possibly of the world´s most stringent labour legislation.

Norway established worker health and safety legislation known as the "Working Environment Act" on February 4th, 1977. The Act contains provisions about employers and employees' obligations with respect to ensuring an acceptable working environment. Enterprises are required to have safety delegates and working environment committees, and some enterprises are required to have a corporate health service where necessary.

The Norwegian Petroleum Directorate (NPD) has through supervisory activities revealed unsatisfactory conditions related to alarm systems on petroleum production installations on the Norwegian Continental Shelf.

Statoil was created in 1972 with 50 percent state participation. Later on, it was split into 2 parts, one linked to the company and the other becoming part of the State´s Direct Financial Interest (SDFI) in petroleum operations. But in spring 2001, the SDFI was resolved by Norwegian Parliament (Storting) and made the way for the privatisation of Statoil.

In the last 40 years, production of only 42 percent of expected resources on Norwegian continental shelf (NCS) has been produced. A total of 8,000 km of offshore gas pipelines with landing ports in four countries and 53 companies are currently licensees of NCS. (Ministry of Petroleum and Energy, 2013)

3.2. The Stakeholders

The regime developed for the Norwegian continental shelf (NCS) has balanced interests between the different groups of stakeholders, being largely successful and flexible in response to challenges within and outside the system. A major challenge in risk management and risk regulation is coordination and adjusting feedback from respectively; a self-regulation process with industrial stakeholders and professionals, and the enforcement process by laws and regulations enacted by inspectorates (Lindøe, 2017). This research has identified below stakeholders for alarm management activities with in NCS.

3.2.1. State Organisation

Framework for petroleum activities in Norway is set by The Storting (Norwegian Parliament) through its legislative powers. The Ministry of Petroleum and Energy regulates the petroleum sector and state ownership interests of various state-owned companies like Statoil ASA, Petoro AS and Gassco AS.

The Norwegian Petroleum Directorate (NPD) is an important advisory body for the Ministry of Petroleum. The Directorate have administrative authority over petroleum exploration and production on NCS and it has the power to adopt regulations and make decisions through petroleum legislation.

Whereas the Ministry of Labour and Social Affairs has the responsibility for safety and emergency preparedness in the petroleum sector, and the Petroleum Safety Authority is a subordinate agency which looks over the responsibilities for safe operations, emergency preparedness and working environment.

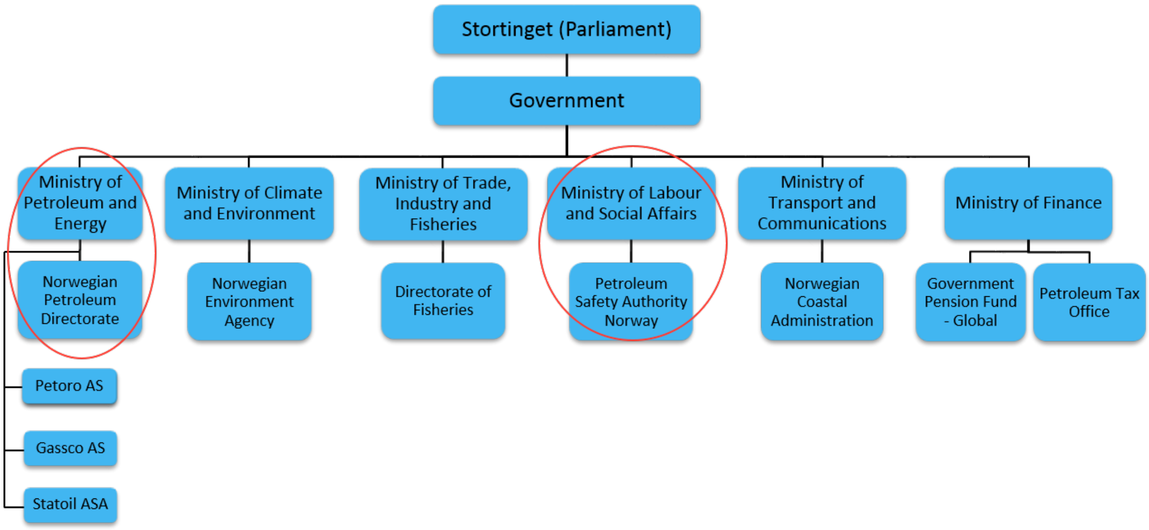


Figure 11 State Organisation of Petroleum Activities (Source: The Ministry of Petroleum and Energy -Norway)

Regulation is often thought of as an activity that restricts behaviour and prevents the occurrence of certain undesirable activities (Baldwin, et al., 2012). A whitepaper issued by Siemens regarding alarm management elevates the requirement of statutory guidelines (Siemens, 2008). 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 many standards of various origins existing parallel to each other that, depending of the background of the publishers, focus on different aspects.

When designing new systems, a certain degree of care is required and more attention is deserved during procurement of new systems. The statutory requirements also emphasis improving existing alarm systems as a mandatory measure.

(Macdonald, 2004) illustrates the legal requirements for hazard studies in his work about practical hazops, but the same can be applicable here for alarm management activities in terms of legal requirements.

3.2.2. The tripartite system

(Lindøe, 2015) has defined "Stakeholders in tripartite" in one of his works, mentioning employer, employee and union as tripartite and a regulation body as a supervising birds-eye to ensure safe operations within an organisation.

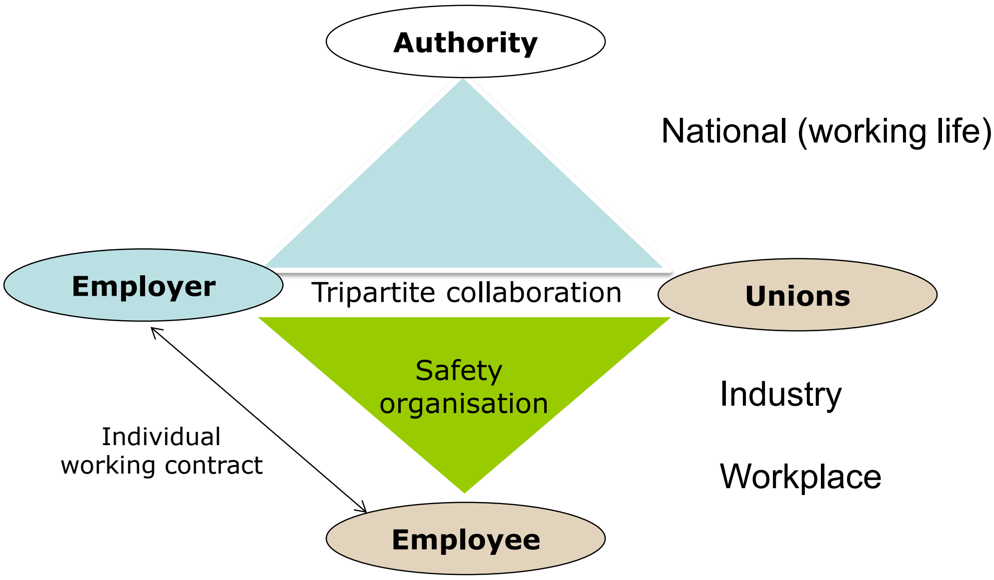


Figure 12 Stakeholders in the tripartite system – A foot note taken from "Risk Governance & Communication" classwork by (Lindøe, 2015)

3.2.3. The role of Labour Inspection Authority

The Isosceles Group Norway ESH audit protocol highlights the role of the Labour Inspection Authority. The authority ensures that enterprises comply with the requirements of the Working Environment Act and associated regulations. Supervision will mainly be aimed at enterprises with the poorest working conditions, where there is little willingness to correct problems, and where the agency's efforts will have the greatest effect (The Isosceles Group, 2014). This is done by:

1. Internal Control Audits

   Reviews of enterprises' internal control systems to reveal whether regulations and procedures are being followed. An audit can take place over several days.

2. Verifications/Inspections

Intermittent tests are used to check whether internal control systems function well and whether companies meet legal requirements.

3. Investigating Accidents

All serious and life-threatening accidents are investigated by the Labour Inspection Authority.

Within this research our discussion is limited to employer and employee compliance and regulatory supervision requirements for risk management incurred by poor performance of alarm systems. The element of unions not particularly related to subject of Alarm management scope for this thesis work and other elements of workplace is compliant enough to reduce the complexity of our study.

Experience has shown that alarm systems could have been given more attention during design and procurement of new systems as well as during modification and operation of existing systems. Since alarm systems are essential in safe and reliable operations in petroleum installations, the essential role played by an alarm system is recognised by NPD, and recommended to be designed based on principles for HMI design and human factor knowledge. This is applicable for both procurement of new systems and updates to existing alarm systems. (Norwegian Petroleum Directorage, 2001)

3.2.4. Petroleum Safety Authority

The Petroleum Safety Authority in Norway is an agency under the Ministry of Labour and Social welfare having core responsibility towards Safe operations, emergency preparedness including accidents and wilful acts along with the Working Environment Act. (Ministry of Petroleum and Energy, 2013). The key regulations relating to HSE on both offshore and onshore facilities and working environment are two sets of regulations subjected to PSAs supervisory authority.

3.2.4.1. Supervision

Supervision includes, but means more than, an audit of both offshore and land based plants, this refers to all possible contact between authority (PSA) and regulated (Company), says PSA. (PSA, 2017)

(Baldwin, et al., 2012) defines a framework called DREAM to organize a discussion of the main challenges that regulators encounter in seeking to apply enforcement on the ground.

1	DETECTING	The gaining of information on undesirable and non-complaint behaviour.
2	RESPONDING	The developing of policies, rules, and tools to deal with the problems discovered.
3	ENFORCING	The application of policies, rules, and tools on the ground.
4	ASSESSING	The measuring of success or failure in enforcement activities.
5	MODIFYING	Adjusting tools and strategies in order to improve compliance and address problematic behaviour

Table 5 Regulatory tasks: the DREAM framework

Looking at the challenges posed by regulators, the NCS supervisory regime builds on the view that a regulator cannot "inspect" quality into the Norwegian petroleum sector. The responsibility for operating in compliance with regulations rests with the industry itself. PSAs perspective towards regulating safety, moved in the direction of performance management over past 2 decades just like in any other part of the world.

3.3. Offshore HSE Regulations

3.3.1. Prescriptive Vs Performance-Based

The prescriptive approach sets detailed requirements through statutory regulations for structures, technical equipment, and operations to prevent any Health, Safety and Environmental hazard. Regulators determine the necessary requirements and checks that the companies comply.

This kind of approach often encourages a passive attitude among companies and a lack of commitment. Companies wait for the safety regulator to audit, identity faults and explain corrective measures to be taken. This allows companies to push the responsibility for safe operations towards the authorities, which is not a suitable way to ensure safe and reliable operations.

In contrast, the performance-based approach regulations are formulated to describe performance goals which need to be achieved. Here the task of regulators is limited to only "Responding" and "Enforcing" as defined in DREAM framework by (Baldwin, et al., 2012). Describing safety targets a company must meet, and checking that company has established a management system will ensure these goals are met. Of course, companies will have high degree of freedom in this approach to choose their own choice of solutions for satisfying regulatory requirements.

Prescriptive	Performance Management
Regulator sets detailed requirements	Regulator set the safety target a company must meet
Regulator determines the checks that company must comply	Company establishes the management system to meet targets set by the Regulator
The Government ends up as the guarantor that safety in the industry is adequate	Company has an independent duty to comply operating acceptably
Encourage passive attitude and lack of commitment among the companies – Wait for the safety regulator to identify faults	Adoption of "Internal Control Principle" by companies, which allow the company to check its own operations in a systematic manner.

Table 6 Performance based Supervision – The supervisory regime by PSA

3.3.2. The HSE regulations in general

Integrated and specific regulations for HSE in both offshore and onshore facilities are prepared and enforced jointly by the regulators for their respective areas of authority. A total of 5 sets of regulations have been adopted for HSE regulations in both offshore and onshore facilities, and consists largely of Risk and Performance based requirements.

1	The Framework Regulations	• Apply for both offshore and onshore • Provides frame work for risk reduction principles • Principles for HSE, including requirement for a good HSE culture
2	The Management Regulations	• Apply for both offshore and onshore • Brings overall management requirements relating to HSE • Barriers, processes and handling of non-conformities and improvements
3	The Activities Regulations	• Apply only offshore • Governing regulatory requirements for planning, operational preconditions, emergency preparedness and maintenance
4	The Facilities Regulations	• Apply only offshore • Governing regulatory requirements for safety functions and loads, materials, physical barriers, drilling and well systems and robust solutions
5	The Technical and Operational Regulations	• Apply to land based facilities – Similar to Activity Regulations offshore • Governing regulatory requirements for planning, operational preconditions, emergency preparedness and maintenance

Table 7 HSE Regulations -Petroleum Safety Authority-Norway

3.3.3. Working environment regulations

These regulations are issued by the Ministry of Labour and enforced by the Norwegian Inspection Authority and PSA within their respective areas of authority. Regulations are pursuant to Norwegian Working Environment Act.

As of January 1st, 2013, there were 6 six regulations were brought into force and replaced a total of 47 regulations issued under the Norway Working Environment Act:

1. Regulations relating to organisation, management, and participation
2. Regulations relating to design and layout of workplaces and work premises
3. Regulations relating to administrative arrangements
4. Regulations relating to abatement and threshold values
5. Regulations relating to conduct of work
6. Regulations relating to construction, design and production of work equipment

3.3.4. Guidelines and Principles

Neither of the HSE nor Working Environment regulations are legally binding. For all the given regulations in HSE, corresponding guidelines have been given to demonstrate how provisions in the regulations can be met. Similarly, the Norwegian Labour inspection authority has prepared guidelines on application of working environment regulations.

The prominence of PSA regarding regulations and the guidelines is that, they should be viewed jointly in order to obtain the best possible understanding of what the government wishes to achieve by their means.

(Hood, et al., 2001) referred to (Baldwin and Hawkins) work of toothpaste-tube-like characteristics of regulatory systems in one of their works regarding risk regulation regimes. The tendency of a toothpaste-tube which is squeezed in one place, is to bulge out in another. If a standard-setting component of regulation experiences a ´squeeze´ in terms of great rigour or transparency, there may be corresponding ´bulges´ somewhere. These may be in terms of increasing discretion or opacity of the implementation process, resulting in companies inclining towards a passive attitude of letting authorities come, inspect, identify the faults, and propose required solutions.

PSA has begun to accentuate the involvement of regulations for safe and reliable operations and has generated a mandate in relation to regulatory principles. What are risk-based regulations and performance based requirements? The discussion of this topic left us with the following set of regulation principles on Norwegian continental shelf.

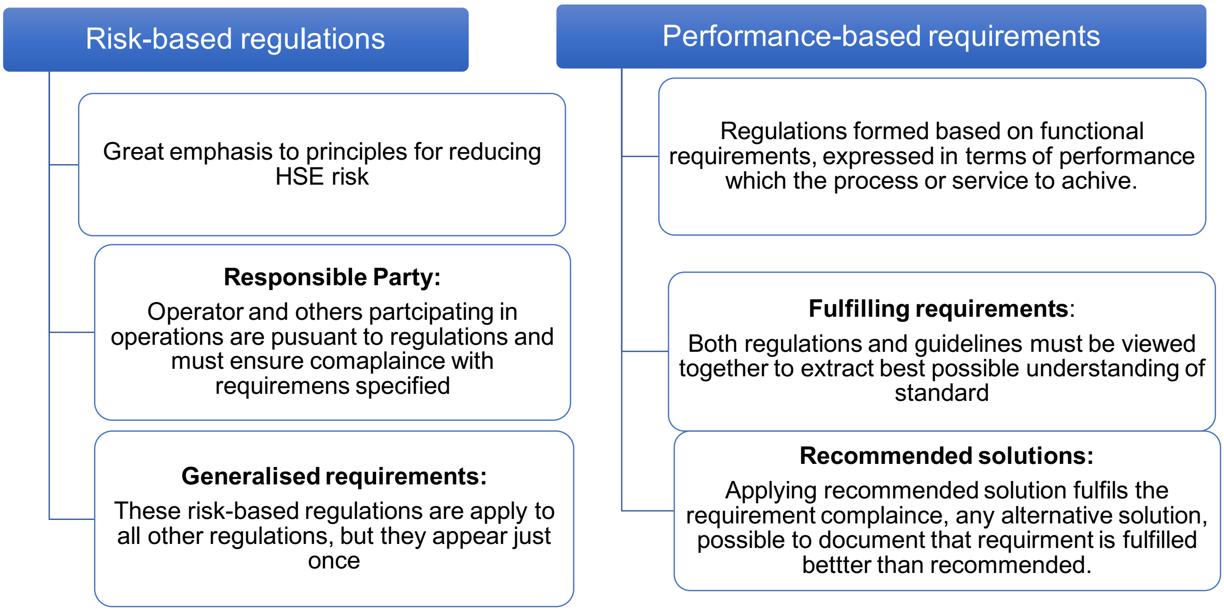


Figure 13 Regulation Principles - An illustration drawn based on PSA presentation

3.3.5. Regulation of Control and Monitoring System

In the early stages of any project involving potential hazards the question of regulations is bound to arise: Where do we stand with regard to legal requirements for safety? What does the law require us to do? The simple answer is the most industrialized countries have legal frameworks in place that similar in nature and have been substantially improved in the past 10 years. (Macdonald, 2004)

The concern noticed by this research earlier in the section 1.2 related to industry as "self-regulator" approach and relevant effort to find:

"What are the key regulations for an Alarm management activity within the frame work of Health, Safety and Environmental (HSE) regulations for process industries?"

does include examining these regulations to understand the role of the regulator, and the responsibilities of the regulated for an approved alarm system definition and design.

3.3.5.1. Regulations – Different Regimes

The new international standard for management of alarms systems for the process industries IEC 62682, provides a comprehensive method of applying alarm engineering processes. Apart from these international standard different industrial regions have different standards. The list is only the sample within the range of practices available.

Region	Regulatory Body	Framework	Standards/Guidelines
Norway	Petroleumstilsynet - http://www.ptil.no/ (Petroleum Safety Authority)	NPD Regulation	Principles of alarm design –YA 711 (PTIL, 2001)
Germany	Interessengemeinschaft Automatisierungstechnik der Prozessindustrie - **http://www.namur.net/** (Automation Systems Interest Group of the Process Industry)	NAMUR Worksheets	Alarm Management – NAMUR NA 102 (NAMUR, 2008) *These papers are neither normative standards nor guidelines.
UK	Health and Safety Executive - **http://www.hse.gov.uk/**	HSE Guidance	The Management of alarm systems – Contract Research Report 166/1998 (HSE, 2017)
USA	United States Department of Labour - https://www.osha.gov/	Occupational Safety and Health Standards	29 CFR 1910.119- Process safety management of highly hazardous chemicals. (OSHA, 2017)
International	ISA- International Society of Automation - https://www.isa.org/	ISA Standards	ANSI/ISA-18.2-2016, Management of Alarm Systems for the Process Industries (ISA, 2016)
International	EEMUA - The Engineering Equipment & Materials Users Association - https://www.eemua.org/home.aspx	International Standard	EEMUA Publication 191 Alarm systems - a guide to design, management and procurement (EEMUA, 2017)
International	IEC - International Electrotechnical Commission - http://www.iec.ch/	International Standard	IEC 62682:2015 Management of alarm systems for the process industries (IEC, 2014)

Table 8 Alarm Management Regulatory Framework –Different Regimes

Appendix (III) Regulations- Different Regimes and Agencies refers to full details of various regulatory regimes across the globe and their emphasis subjected to alarm management activities.

3.3.5.2. Regulations – PSA

Though there is a possibility of scrutinising vast number of regulations and standards, this research chooses to limit the scope of examining the regulatory requirements with in Petroleum Safety Authority (PSA) relevant to petroleum activities with in NCS.

Refer to the section The HSE regulations, except technical and operational regulations all other four regulations are applicable to offshore installations. The following table provides an overview of HSE regulations addressing control and monitoring systems, both offshore and onshore. PSA has extended their help in understanding these regulations by providing relevant guidelines for almost all regulations. After a close examination of the regulations, management and activity regulations are exempted from further analysis, considering the fact that process control and monitoring systems are not covered by these.

<table>
<tr><th>Key Regulations and Provisions w.r.t Alarm Management</th><th>Guidelines</th></tr>
<tr><td>Section 11 Risk reduction principles

In reducing the risk, the responsible party shall choose the technical, operational or organisational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved.

Section 17 Duty to establish, follow up and further develop a management system

The responsible party shall establish, follow up and further develop a management system designed to ensure compliance with requirements in the health, safety and environment legislation.

(The Framework Regulations, 2016)</td><td>Re Section 11 Risk reduction principles

• Risk means the consequences of the activities, with associated uncertainty. The term “consequences” is here used as a collective term for all potential consequences of the activities.
• Associated uncertainty here means uncertainty related to the potential consequences of the activities.
• The risk associated with the activities will depend on the context, including the information base and that which must be evaluated, planned and implemented

Re Section 17 The content of management systems
• Management systems shall cover the organisation, processes, procedures and resources necessary to ensure compliance with requirements stipulated in the health, safety and environment legislation. More detailed provisions regarding management systems, including the content, are stated in the supplementary Management Regulations.

(Guidelilnes-Frame Regulations., 2015)</td></tr>
<tr><td>Section 21 Human-machine interface and information presentation

Monitor-based equipment and other technical equipment for monitoring, controlling and operating machines, installations, or production processes, shall be designed to reduce the risk of mistakes that can have an impact on safety.

The presented information shall be correct and easily understandable. Information systems shall be designed for both normal and critical situations.

Section 34a Control and monitoring system

Facilities shall have control and monitoring systems which, using associated alarms, warn of incidents, nonconformities or faults that are significant for safety. The alarms shall be issued such that they can be perceived and responded to within the time required for safe use of equipment, plants, and processes.

(The Facilities Regulations, 2015) – Apply only offshore</td><td>Re Section 34a Control and monitoring system

Alarms should be defined and designed such that
• The alarms that are presented, are relevant, easy to register and understand, and clearly show where possible nonconformities and hazardous situations have arisen
• The alarms are coded, categorised and assigned priority based on the safety significance of the alarms and how quickly measures must be taken to avoid undesirable consequences
• The alarm systems allow for suppressing and reducing alarms, so as to avoid mental stress for control room personnel during interruptions in operations and accident incidents.

With regard to the design of the alarm systems, the principles of the Norwegian Petroleum Directorate's (now the Petroleum Safety Authority Norway’s) publication YA-710 (English edition YA-711) should be used.

(Guidelines-Facilities Regulations., 2016)</td></tr>
<tr><td>Section 21 Human-machine interface and information presentation

Monitor-based equipment and other technical equipment for monitoring, controlling and running machines,</td><td>Re Section 33a Control and monitoring system

Alarms should be defined and designed such that
• The alarms that are presented are relevant, easy to register and understand, and clearly show where any</td></tr>
</table>

Key Regulations and Provisions w.r.t Alarm Management	Guidelines
installations or production processes, shall be designed so as to reduce the risk of mistakes that can be significant to safety. The presented information shall be correct and easily understandable. **Section 33a Control and monitoring system** Onshore facilities shall have control and monitoring systems which, using associated alarms, warn the operator of incidents, nonconformities or faults that are significant for safety. The alarms shall be issued such that they can be perceived and responded to within the time required for safe use of equipment, plants and processes. **Section 51 Training in safety and working environment** The individual employee and manager shall be provided with training in working environment factors of significance for conducting their work. The training shall be adapted to changed or new risk in the enterprise, and repeated when necessary. **(Technical and Operational Regulations, 2016)** – Apply to land based facilities	nonconformities and hazardous situations have arisen, • The alarms are coded, categorised and assigned priority based on the safety significance of the alarms and how quickly measures must be taken to avoid undesirable consequences, • The alarm systems allow for suppressing and reducing alarms, so as to avoid mental stress for control room personnel during interruptions in operations and accident incidents. With regard to the design of the alarm systems, the principles of the Norwegian Petroleum Directorate's (now the Petroleum Safety Authority Norway's) publication YA-710 (English edition YA-711) should be applied. **Re Section 51 Training in safety and working environment** There exist minimum requirements are set for training for self-protection measures and trainings mentioned in various subsections. But this does not exempt the business from its obligation to carry out additional training measures if risk and emergency preparedness analyses show a need beyond the minimum requirements. (Guidelines-T&O Regulations., 2016)

Table 9 Regulations pertaining to control and monitoring system - Framework HSE (PSA)

Identification of relevant regulations left us with greater responsibility to comply within their areas of application. The control and monitoring system plays a vital role managing safe and reliable operations. The regulated (Company) has to communicate these requirements to operations management, thereby creating work instructions for the successful implementation of these regulations with given guidelines.

4. Theoretical Perspectives

Having understood the technical backdrop and relevant regulations within the Norwegian offshore context, a model is required to continue this study for successful results. The model should be enable us to address the hierarchical flow of instructions from “Regulations – to – Realise Operations”. Effective communication must be at the core of any successful activity to asses and manage risks (Renn, 2008). This research study tries to establish this communication among various stakeholders mentioned in previous sections, and translates the needs and requirements into procedures and processes.

(Lindøe, 2017) discussed about *handling flexibility* saying that, effective and safe production is enhanced by introducing rules, procedures, and routines to guide organisational activities. By implementing procedures and technical processes, human activities and practices become more predictable and safer. Developing and establishing procedures keeping a blind eye on requirements from operations is proven to be a useless effort in several occasions. The interaction between system development and system operations is mandatory for learning, and thereby contributes those experiences back into system development.

A theoretical perspective of safety critical hierarchy cited by (Hollnagel, et al., 2006), has been used for this study, considering the guidance this model imparted to this study while determining the interaction between system development and system operations. Though this study is more focused on system development wing of the model, the interaction that Hollnagel established is the core element for this study.

This study also recognised the importance of learning phases in an organisation at various levels. This “experienced learning” is a vital element in generating, integrating, and interpreting ideas to act in order to propagate those experiences back into system for greater good. This thesis has adopted the “Experienced Learning Cycle” model referenced by (Dixon, 1999), looking at the possibility of preferred framework given by this model.

4.1. Safety Critical Hierarchy

(Hollnagel, et al., 2006), elaborated resilience engineering into safety critical systems. By definition, when a system continues to operate or recovers to operate in stable state after a mishap, this is called resilience. This thesis would like to adapt a model from (Hollnagel, et al., 2006) work, which depicts a general form of socio-technical control shown below.

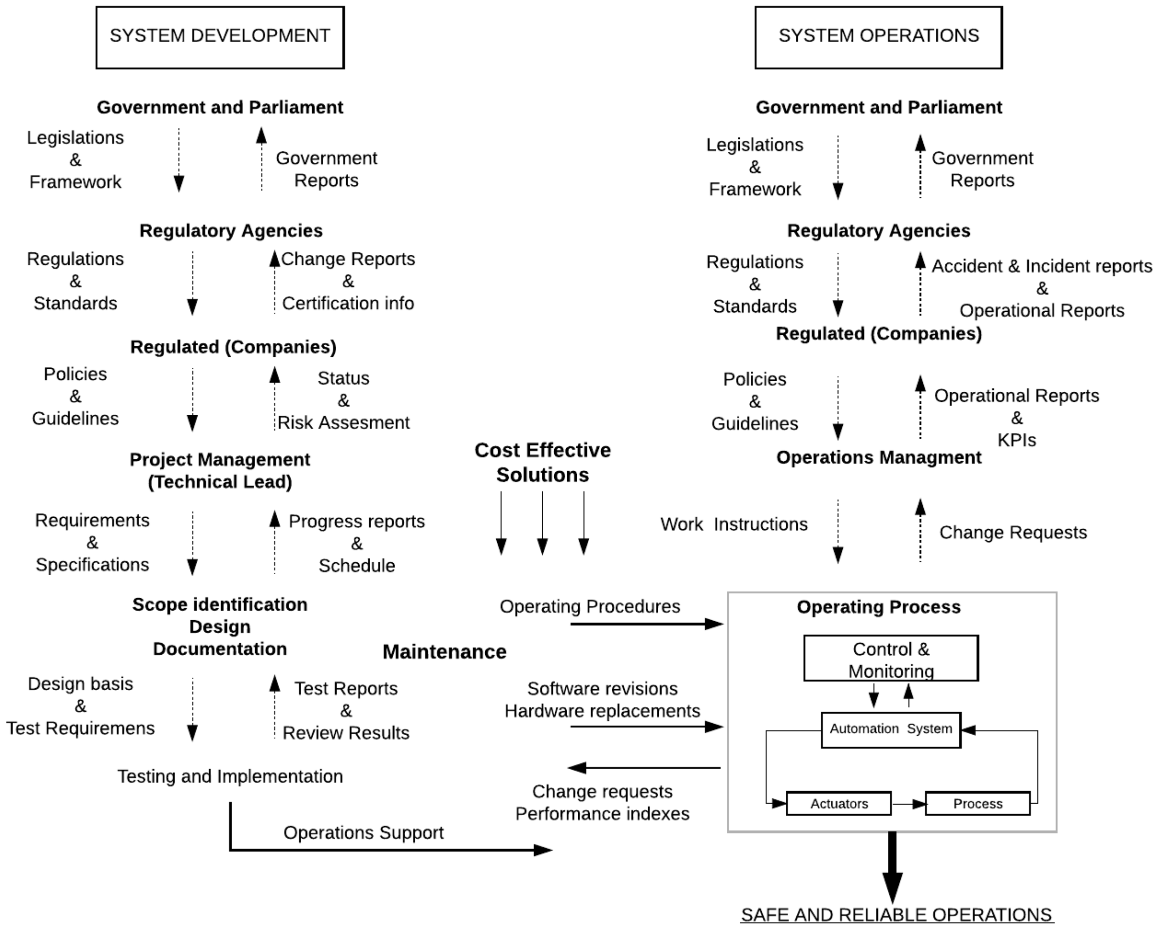


Figure 14 Hierarchical model for safe and reliable operations - Derived from (Hollnagel, et al., 2006)

Though the original model integrates all aspects of risk including organizational and social, this study chooses to limit its discussion related to organisational aspects and models which have been rebuilt based on our constraints and scope of research. This model emphasizes the interaction between system development and system operations. Without such interaction, the inherent safe design within the development will not benefit during system operations.

Applying this model to an alarm management system enhances the opportunity for clear and effective communication channels between the various stakeholders mentioned earlier in this chapter. Effective communication channels need to be established within this hierarchy, whereas the downward reference channel provides *instruction* and the upward reference channel provides *measurements*. Instructions are discussed in terms of regulations, standards, specifications, work instructions, etc., while measurements are considered to be reports, schedules, and performance indexes.

Development of an alarm system following this hierarchy, along with cost effectiveness, demands a management system. A system which can accommodate the interaction between system development and system operations, transforming regulations into standard practices with a built-in “safety aspect.”

Incorporating this safety embedded design into operations provides effective results so that the motive of inherent safe design is accomplished successfully. Refer to section 6.7 “Research Case Study,” for the achieved results and accomplished goals rendering the focus defined by this research.

4.2. The Experiential Learning

Whether it is an alarm system or any other support system, it takes a collective effort by all stake holders involved to understand the system and to lay out continuous improvement plans by learning the core purpose of the system. Organisational learning is a cyclic process defined by (Dixon, 1999) consisting of four major steps including generation of information, integration of new information, collective interpretation and taking responsible action based on interpretation.

As it is shown Figure 15, Dixon has laid out the individual experiential circle (known as Kolb´s circle) within a greater learning circle, a complete fit for an organisation learning. An individual learning progress is represented by this inner circle and represents the seed for greater learning.

- The ´concrete experience´ does not mean the vicarious experience we receive through books, but a real experience.
- The ´reflective observation´ is a conscious reflection of what has occurred through experience and it is prominently influenced by our expectations.

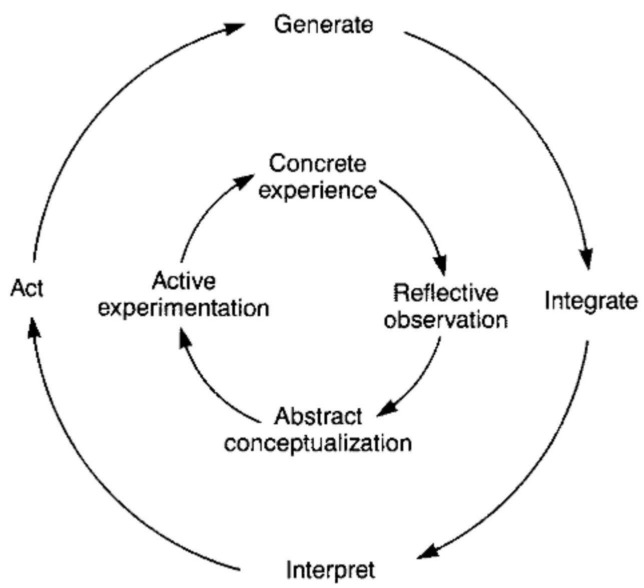


Figure 15 The Experiential learning cycle with in an Organisational Learning Cycle (Dixon, 1999)

- The ´Abstract Conceptualization´ involves relating the new information we have experienced to existing meaning structures and create a new meaning.
- The ´Active experimentation´ is the final step in Kolb´s model and at this step we test out the meaning that we have constructed by taking action in the world.

The term meaning refers to “making sense out of what we have experienced or learned”, Dixon has referred (McClellan, 1983) to work regarding categorisation of this meaning as private, accessible, and collective.

Private meaning can be referred to that meaning which the individual constructs from his/her learning or experiences, but does not make accessible to others in the organisation. A second category of meaning is that which individuals do make available to others within the organisation, and it is known as accessible meaning. Whereas the collective meaning is that which organisational members hold in common such as norms, strategies, policies, etc.

In her work, Dixon mainly underscores accessible meaning, and she believes in organisations learning in the “hallways”, a concept of sharing acquired knowledge freely among co-workers, team leads and stake holders.

The greater circle including the steps of generating, integrating, interpreting, and acting which represents an organisational learning circle, is typically carried out by different departments within the organisation, and may severely limit the capability of organisation learning. This part of the model highlights the fact that the organisational members who generate new ideas will need to be involved in the interpretation, and need to have complete understanding of the context. The organisational members who make their interpretation, need to act on it to learn the extent to which their interpretation made sense. (Dixon, 1999)

However, this research limited its focus to the internal circle of experiential learning having stages of concrete experience in alarm systems from various control rooms and reflective observations by operators through their learning during all their years of experience. The methodology of this research referred to in further sections allows us to abstract and conceptualise the findings through interviews conducted.

There are many opportunities for research in the area of alarm management activities related to life cycle activities as shown in Figure 8. The stage of active experimentation consists of testing the meaning we have constructed through interview findings and identifying required procedures to fit into the “Eldor Management System” (EMS) for successful implementation in future projects. (See Appendix (I) Eldor Management System).

5. Methodology

Many past accidents such as the Texaco oil refineries of (1994) reported some unpremeditated influences but not limited to, failure in alarm response, high alarm rates, wrong prioritisation of alarms, inconsistency in presentation of alarms, and lack of systematic training of the control room operators in dealing with critical situations.

As a consequence of these events, many standards and guidelines have been established as we discussed earlier in 2.5. However, it is not certain to what extent these design principles and recommendations have been applied to operational systems.

This research has identified four dimensions of an alarm system as shown in Figure 16, and established a questionnaire to address these challenges. By adopting the concept of experiential learning stage 1 ´concrete experience´, interviews have been conducted with various process control room operators covering both offshore and onshore, to reflect their observations during their experience with alarm systems.

A separate set of questionnaires has been developed for the regulatory authorities to abstract a conceptualisation from the experience of various supervision audits conducted by petroleum safety authority in Norwegian continental shelf.

(Bockelmann, et al., 2017) highlight having a comprehensive checklist to analyse the current design quality of alarm systems and alarm management routines to use in various control rooms across different branches of industry.

With the identified regulations for alarm system management and performance requirements, the questionnaires have been carefully laid out to address the rest of the research focus area:

How to develop a supportive system for process alarm management describing procedures based on key regulations related to HSE framework?

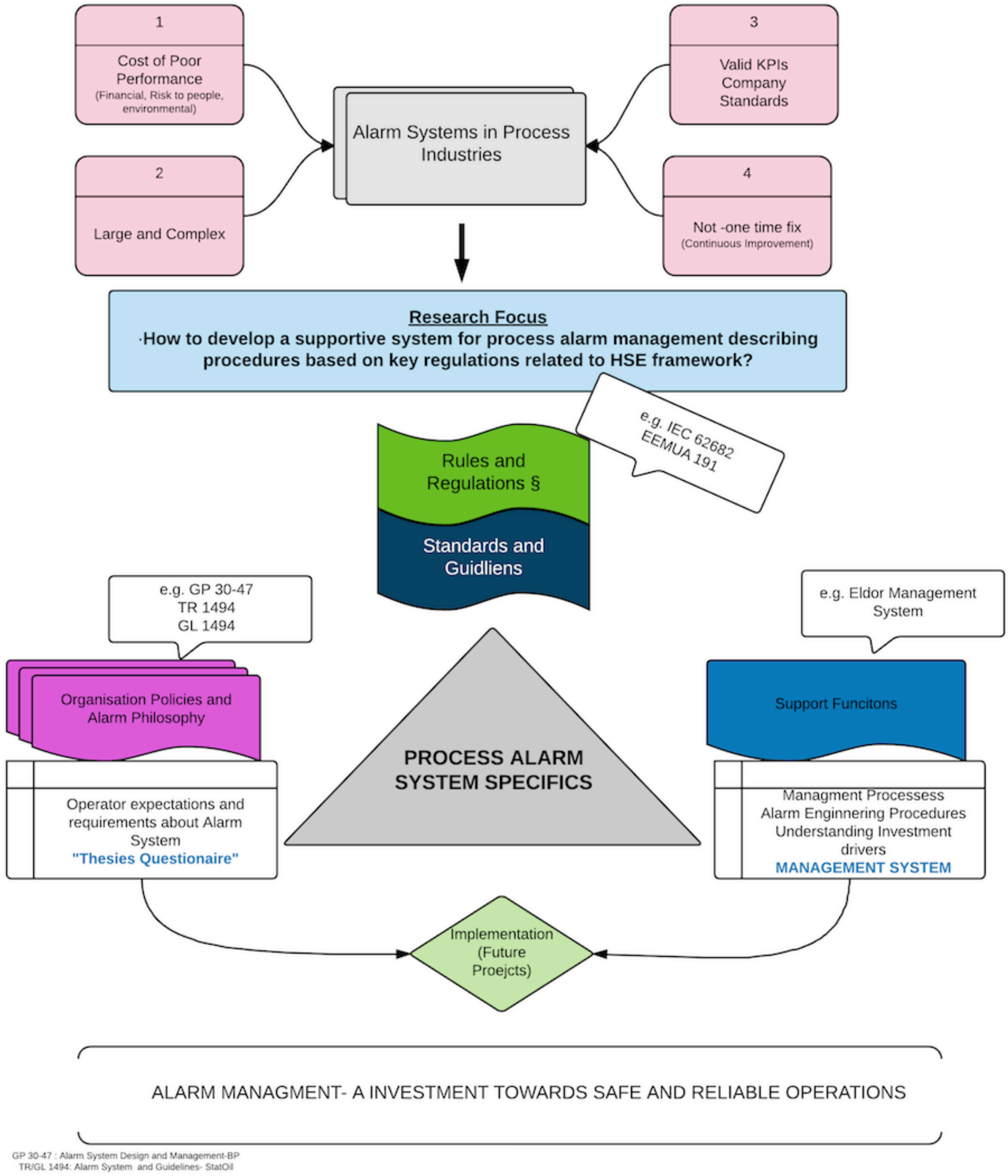


Figure 16 Research Methodology - Process Alarm System Dimensions

5.1. Strategy

Significant research into existing regulations and understanding of organisation policies does partially identify the specifics of an alarm system. As shown in the above methodology triangle, for a reasonable completion of defining all specifics of an alarm system, a research strategy should be in place.

Mixed methods research is a methodology for conducting research that involves collecting, analysing, and integrating both quantitative and qualitative research. This strategy has been used for this research as it provides a better understanding of the research problem than either a pure quantitative or pure qualitative approach.

Quantitative data includes close-ended information in order to help us measure various dimensions of an issue through observations and behaviours. The analysis of this type of data consists of statistically analysing scores collected on tools used, in this case “questionnaires” to answer research questions.

Qualitative data consists of open-ended information that the researcher usually gathers through interviews, focus groups and observations. The analysis of the qualitative data typically follows the path of aggregating it into categories of information and presenting the diversity of ideas gathered during data collection. (ResourceCentre, 2016)

(McKim, 2017) mentioned the value of mixed methods research and specifically cited passages of purely quantitative and purely qualitative approaches. The increase in perceived value of research using mixed methods is comparable with a purely quantitative or purely qualitative study. Mixed methods research requires additional time due to the need to collect and analyse data in two different ways.

5.1.1. Time Horizon

Researchers compare many different variables at the same time, characterised by cross-sectional study, in contrast to longitudinal study researches which make several observations on the same subject over a period of time, sometimes lasting up to many years (AT WORK, 2015). Both types of research studies are observational, and researchers record information about their subjects without manipulating the study environment.

This research is a combination of both longitudinal and cross-sectional study. The competent experience of operators on alarm systems for so many years brings the longitudinal characteristics along with acquired expertise from various participants imparts cross-sectional features to this research.
As it is clearly evident that, the longitudinal feature of this research is intangible phenomenon, keeping a set period of 8 months’ time horizon been chosen, especially with the necessity of data collection and analysis from various interviews, chosen time horizon proved to be optimal.

5.1.2. Levels of Research

As opposed to a traditional purely quantitative approach or purely qualitative approach, this thesis administrated participants a questionnaire and conducted interviews. The results were presented in a typically quantitative format with included statistics median and mode values, along with derived specifics of alarm management requirements through interviews. The detailed levels in this research are explained below.

The research has been divided into various levels as shown in table below, and each level has its own significance in carrying relative meaning towards the final stage of research outcomes.

Level 1	Questionnaire development
Level 2	Identify relevant Offshore/Onshore fields and organisations
Level 3	Informal introduction and preliminary screening
Level 4	Fine tuning of Questionnaire
Level 5	Interviews and Data gathering
Level 6	Abstract Conceptualisation (Median/Mode)
Level 7	Final interpretation (Active experimentation)

Table 10 Levels of Research

5.2. Questionnaires

With the given problem defined and corresponding research focus identified in section 1.2, a research questionnaire was developed during the first level of this research. Various sets of questions were prepared conferring to the target group, covering the following to achieve the specifics required for the research focus specified above.

i. **Operators Questionnaire:** A questionnaire to realise CCR operators experience and reflect their observations

ii. **Alarm System Audit Questionnaire:** A questionnaire to gather alarm system audit essentials and regulatory authority's perspective for an acceptable alarm system in both Offshore/Onshore industries.

5.2.1. Operator Questionnaire

This questionnaire was mainly divided into 4 sections. Section 1 and section 2 focused on the personnel profiles of interviewees, and the working environment of control rooms in process industry cover the following:

1. Position in the organisation, length of service, and roles and responsibilities
2. Working environment conditions and alarm system role as a support function

Section 3 and 4 were specifically designed to assess the quality of present alarm systems and post alarm project improvements, covering the following:

3. What is the quality of the alarm system in process control room?
4. What are the consequences due to poor performance of the alarm system in terms of personnel, environmental and financial losses?
5. What are the operator's expectations and their team leader's confidence with regards to support they are getting during normal and disturbed operational conditions?
6. What was their previous experience in alarm projects?
7. What would be the requirements for a change management aspect considering maintaining alarm system in line with specified performance standards?

5.2.2. Audit Questionnaire

This questionnaire has been designed particularly to conceptualise the alarm system audit supervision essentials, such as:

1. Regulations and their compliance requirements
2. The role of various government agencies while drafting regulations
3. Understanding auditing processes and tools which support the auditing process
4. How to assess the quality of alarm system design
5. Companies' obligatory requirement towards compliance

5.3. Preparation and Preliminary Screening

During the initial phases of this research, the emphasis was to select organisations and their operational profile, focusing on learning and reflecting their observations from various types of assets, offshore and onshore, mainly in oil and gas sector.

A team of 3 participants (One Operator, Engineering Manager and Department Manager) having expertise in alarm management activities at various stages were presented the concept with the draft version of questionnaire. Interviewees were asked to depict characteristics that they felt were relevant and suggestions to improve the questionnaire. The "words and expressions" used by these interviewees were taken into consideration carefully, to see if they could be modified in cases where the existing words were too complex to understand (or) failed to convey the point of interest.

Through this preliminary screening, roughly around 17 alarm performance characteristics, changes in various sections and meaningful wording in questions were suggested. Both questionnaires, Operators Questionnaire and Audit Questionnaire were adjusted according to these findings and it will be the basis for final interviews.

See Appendix (IV) Operators Questionnaire and Appendix (V) Audit Questionnaire.

5.3.1. Interviews

As the questionnaire was restructured based on preliminary interview suggestions, the process of face-to-face interviews was initiated. Interview schedules were based on offshore rotations and simulator training sessions in such a way that participants were able to give the interviews their full attention. Broadly, the respondents were divided into 4 categories: Process Coordinator (n=2), Control Room Technician (n=4), CCR Operators (n=3) and Automation Engineer (n=1)

The organisations were grouped considering the fact that responsibilities shared by particular positions in any organisation are more or less similar in nature. The experience carried by each category varies from 36 months to 228 months, with statistical median of 84 months. See *Appendix (VI) Interviews- Quantitative phase descriptive statistics* for statistical results of quantitative data included in this research.

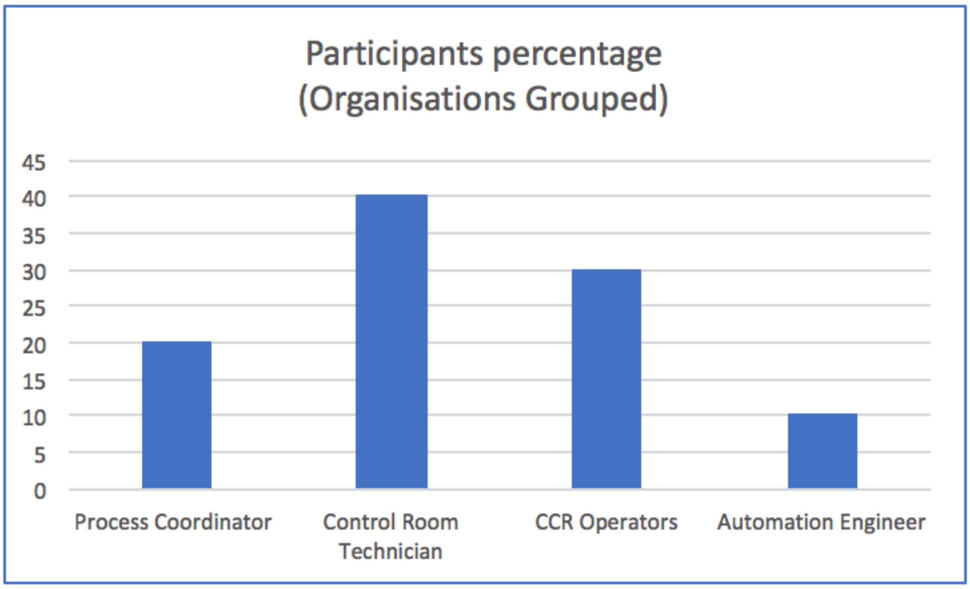


Figure 17 Respondents portfolio & Participation percentage

This level of the research is a result of concrete experience and reflective observations mentioned in Kolb´s circle shown in Figure 15 and the work cited by (Dixon, 1999) as discussed in our earlier sections. To abstract and conceptualise the reflections observed through interviews, this research used quantitative data analysis.

5.3.2. Data Analysis and Final Interpretation

The system development hierarchical model suggested by (Hollnagel, et al., 2006), which we defined in section 4.1, underlines the steps that may lead to design documentation based on the requirements as a result of experience based reflections. It also identified regulations and individual organisational policies overlaying set criteria for design basis, but the result of quantitative data analysis added additional elements of alarm system specifics for better operational support.

The observations both quantitative and qualitative, will be discussed in a short while and these findings will clarify the elements required for alarm system specifics.

5.4. Validity and Reliability

The team of interviewees and organisations chosen for this research contributed to successful dialogue and predominantly set the right course of action throughout the process. The questionnaire administered and the respondent´s belief in it, has been the key reliable factor to continue with the methodology this thesis believed to practice. As each individual has been interviewed face-to-face and completed the interview within a limited period (say 60 minutes), and has provided the necessary information required, there was no misunderstanding or failure in perception of the existing meaning.

It is made to maintain the confidentiality of the respondent to ensure that the participants response is valid. The assurance was given to participants through thesis consent that their participation in this research would not be revealed either implicitly or explicitly. As the research was conducted within various organisations and the length of experience of participants differs greatly, the results should be representative of experience from present systems or experience from the installations in the past.

6. Findings Analysis and Discussions

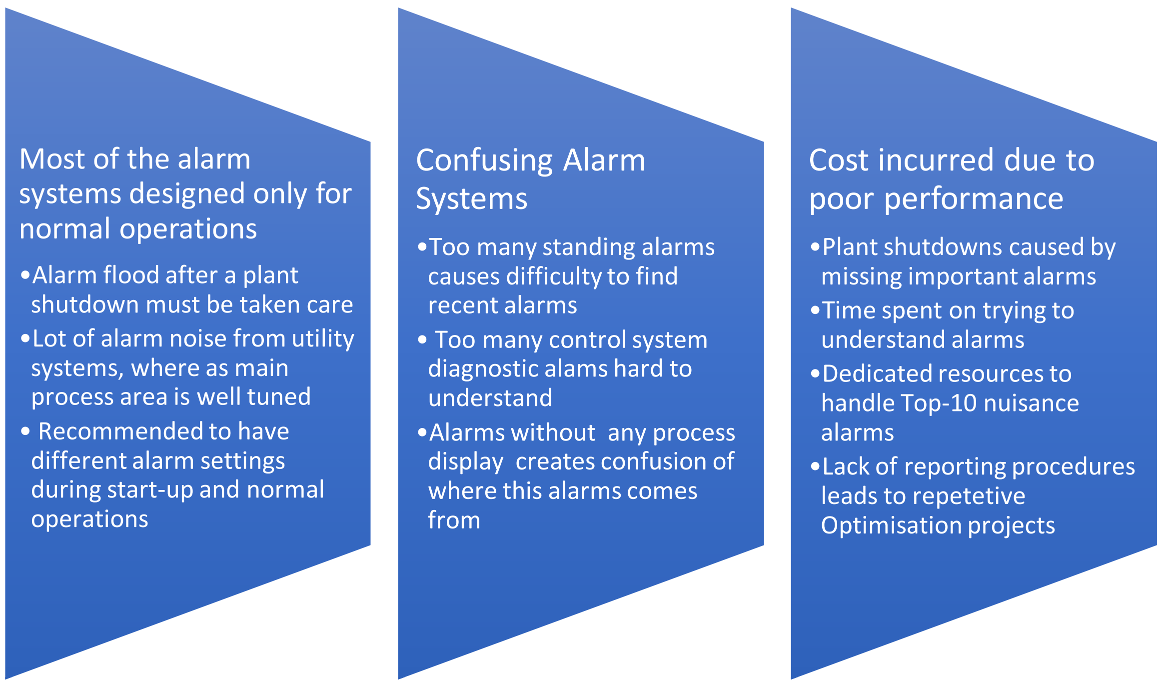
The research area and research focus identified in section 1.2 continues to be in focus while transferring the empirical findings into relevant processes for alarm system specifics.

How to develop a supportive system for process alarm management describing procedures based on key regulations related to HSE framework?

Therefore, to answer one of this research question, the supportive functionalities which may need to be included must be examined for overall alarm system performance. The underlined findings, and their analysis, synthesis against existing literature, and lastly literature, will be produced.

6.1. Interview Results

Following is a quick summary of interview findings and their meaning related to a functional alarm system before getting into quantitative and qualitative data analysis:



As cited in Kolb's circle, shown in Figure 15, data has been collected based on operators' experience with alarm systems and their reflective observations, it's a phase of conceptualising the given data and abstracting the interview results.

6.1.1. Design Constrains

Based on the results, it is quite evident that most of the alarm systems are designed only for normal operations. When there is a plant shutdown or a disturbance, there are a large number of consequential alarms (e.g. Equipment not running, pump discharge pressure low etc.) which come from the equipment which is out of operation. These alarms are not relevant in that context, and they fill up the alarm list creating a situation called alarm flood or alarm rush. Most of these alarms in the alarm flood belong to supportive systems (utility systems) rather than the main process area.

Similarly, it is challenging to use or rely on alarm systems during plant start-up, where the majority of the plant dynamics operate at different working levels compared to regular operations (e.g. The buy-back gas flow value is relatively high during start-up, whereas it's almost zero during normal operations). The alarm settings on individual process parameters are different during the start-up operating envelope, resulting in a lot of alarm noise during plant start-up. This kind of noise in alarm system will result in abandoned alarm system core functionality such as "Alerting an operator about deviation in process parameter."

6.1.2. Complexity creates Confusion

Enhanced technology in control systems and its feasibility to accept multiple communication interfaces makes it easier for control system engineers and vendors to interface a large number of 3rd party packages with the main control system. This simplicity in engineering level brings a lot of complexity at the operations level. Process engineers or control room operators who were typically competent with process knowledge are not quite comfortable with technology related diagnostic alarms. As highlighted in his own words by one of the senior operators:

"System diagnostic alarms are the most annoying thing in alarm system"

System diagnostic alarms do not carry any useful information either to operators or team supervisors. This challenge is further intensified by a lack of proper display or control system panel/cabinet details within the alarm text or alarm help. It has been observed that most of the fire and gas alarms detector alarms are also missing proper process displays, without which it is quite hard to evaluate the consequence of an alarm and action which needs to be taken due to lack of alarm whereabouts.

The second most annoying thing about alarm systems is "Standing Alarm", an alarm which has been active for quite long period, typically more than 24 Hrs. A high number of standing alarms will result in the whole alarm screen being filled up and difficulty in finding the most recent alarms.

6.1.3. Cost Incurred

Though its unsure to impart poor performance of an alarm system towards an unwanted incident such as safety incident, environmental spillage, or plant shutdown, it certainly plays a vital role whenever there is an unwanted incident. As revealed during the interviews, an unwanted incident may not necessarily be an incident which has happened, but an uncertainty in plant operations due to non-understandable alarms, too many alarms, alarms without any value etc.

A functional and supportive alarm system was stressed in both regulations and organisational policies during normal and plant disturbed conditions. Interviewees also agreed about the same regarding lack of proper procedures to assess the performance of an alarm system periodically. The management routines to assess the performance of an alarm system were specified as an important stage in alarm management life cycle during operations and maintenance (See Figure 8 Alarm Management Life-Cycle ISA 18.2). Any incident which we think of as alarm system failure should be reported and documented, missing these routines makes it harder to make any investment decisions to further improve alarm systems.

Most of the installations usually have a dedicated team to deal with the top 10 nuisance alarms, chattering alarms and standing alarms. Usually, failed instrument diagnostic alarms and chattering alarms cause a lot of noise and fill up nearly 70 to 80 percentage of total alarm load. Proper management routines and reporting processes help the engineering team deal with these alarms well before they become actual noise, thereby reducing the cost incurred.

6.2. Quantitative Phase Results

Descriptive statistics were calculated for each alarm system specification based on interviews, where the specifications were projected as questions. The results, calculated using statistical analysis, are presented below (see Table 11 Quantitative descriptive statistical analysis - Alarm System Specifications). The descriptive statistics revealed several interesting facts about control and safety alarm system improvement specifications as a result of abstractive conceptualisations based on experienced operator's reflections.

The descriptive statistic results shown below are purely based on the interviews conducted with participants with portfolio discussed in section 5.3.1 with respondent's portfolio and participation percentage as shown in Figure 17.

Working Environment/Alarm System Specification	**Median**	**Mode**	**Minimum**	**Maximum**	**Result**
	Statistic	***Statistic***	***Statistic***	***Statistic***	
No: of days per rotation in CCR?	**14**		10	240	14 days Rotation
Do you serve in Field as well?	**50**		40	100	50 % field position
Length of experience in site /installation –Yrs./Mon?	**84**		36	228	84 months
Does this process plant have more than one control room?	**1**		1	2	1 Central Control Room
No: of operators per shift in CCR?	**2**		1	3	2 Operators
No: of Operator stations?	**4**		1	5	4 Operator Stations
Alarm Response Allocation, when new alarm comes?	**0**		0	6	Based on operator availability
Supporting systems for process monitoring / emergency?	**6**		6	6	Alarm Systems, HMI, Radio, Lamps, PA, CAP, CCTV, LSD
Other means of alerting apart from control and safety alarm system?	**-2**		-2	6	No Others
Does Alarm system support you as it should for different plant conditions?	**8**		0	10	OK (Designed to support during normal operations only not very supportive during plant shutdown)
How often alarm comes in normal operations?	**10**		2	10	Very Often
What is the most annoying thing about the alarm system – 1st		**12**	2	26	Too Many Standing Alarms (700 standing alarms)
What is the most annoying thing about the alarm system – 2nd		**2**	2	26	Non-Understandable Alarm text
What is the most annoying thing about the alarm system – 3rd		**8**	6	26	Alarms without any value
Do you believe in better control of operations if alarm system improved?	**10**		6	10	Yes
Do you think of any incident connected to poor performance of alarm system?	**10**		10	10	Yes
How many incidents?	**2**		-2	12	1-5
Any Health, Safety and Environmental incident among these?	**6**		2	6	Environmental Damage

Working Environment/Alarm System Specification	Median	Mode	Minimum	Maximum	Result
	Statistic	*Statistic*	*Statistic*	*Statistic*	
Major consequence for a process shutdown	**4**		2	6	Economic Losses
Time to get back to normal production after Pressurised shutdown?	**12**		6	12	12 Hours
Time to get back to normal production after De-Pressurised shutdown?	**24**		8	48	24 Hours
Typical financial loss in case of a process shutdown?	**6**		2.5	200	6 Million Dollars Per day
Investment drivers for an alarm engineering project	**4**		4	6	Reducing Downtime and Regulatory Compliance
Does your team leads/Supervisor takes alarm system in confidence?	**10**		-1	10	Yes
Previous experience with in alarm projects?	**0**		-2	16	Optimisation Projects
Alarms per Workshop (Time spent on Optimisation)	**500**		500	500	500 Alarms per 5 days' workshop
Difference in alarm system performance before and after (If there is an alarm project) – 1st		**16**	2	32	Less number of standing alarms
Difference in alarm system performance before and after (If there is an alarm project) – 2nd		**2**	2	32	Understandable Alarms
Alarm load after alarm project (If there is an alarm project)	**2**		0	6	Stable: 1 to 10 Alarms/ 10 minutes
Did alarm project had all aspects of alarm engineering (If there is an alarm project)	**8**		6	10	To some extent
Continuous improvement aspect among alarm system specifications? – 1st		**12**	6	24	Maintain Alarm philosophy
Continuous improvement aspect among alarm system specifications? – 2nd		**8**	6	24	Alarms on Removed Equipment
Usability of improved alarm system (If there is an alarm project)	**8**		-1	10	OK (Still there is possibility to improve thereby enhance the plant operations)

Table 11 Quantitative descriptive statistical analysis - Alarm System Specifications

The results have been derived based on descriptive statistics evaluated among working environment in CCR, operators experience on alarm systems, and alarm projects' role in improving operations. To accommodate all possible results both (Median: A number in statistics that tells where the middle of a data set is) and (Mode: The value that occurs the most often in a data set) have been used. Wherever the operator must select multiple choices among given alternatives, “Mode” formula has been used, otherwise “Median” formula used in all other instances.

A further analysis of these results enable us to understand the core problems related to alarm systems, control room operating conditions and operator’s response allocation. As differentiated by various shades in above table the results are grouped into three categories

1. Control room operator experience profile and working environment
2. Control room operator experience on control and safety alarm system
3. Commencement of alarm projects role in improved operations

For instance, operators were asked to rank design constrains in an alarm system on which they are working, among four different ratings given below.

- Very Good: Alarm system is supportive during both normal operations and plant disturbed conditions
- OK: Alarm system is supportive during normal operations only
- Poor: Alarm system is supportive partially
- Very Poor: Alarm system is not supportive

The below graph represents the participants’ ranking of the alarm systems they are working on among four given ratings.

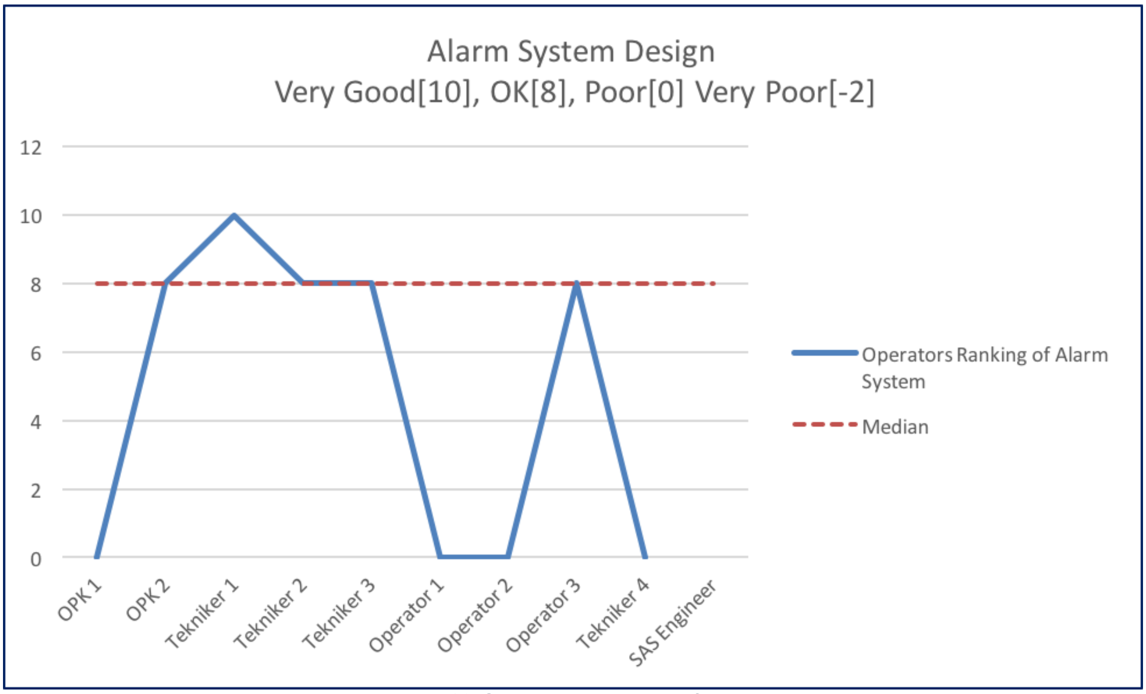


Figure 18 Operators ranking of alarm system

Similar kind of ratings and participants' ranking for various specifications of alarm system have been collected and analysed to abstract the operators experience and their reflections. For a complete analysis, see Appendix (VI) Interviews- Quantitative phase descriptive statistics.

6.3. Qualitative Phase Results

The qualitative component of this study pursued to answer those questions which were not possible to be addressed in the quantitative phase of study such as documentation requirements, management routines etc. This component of the study allows this research to further understand qualitative features of the alarm systems by taking inputs from both questionnaires (see Appendix (IV) Operators Questionnaire and Appendix (V) Audit Questionnaire).

Participants were asked about alarm system specifics on which they work, performance, past experience with alarm projects, working environment in CCR, and other supportive systems, the findings were interesting, and the value of this qualitative study was twofold. First, it helps to understand the operator's view about alarm systems not just as a supportive system, rather as an important functional element in safe operations. Second, this study reveals the basic building blocks required to design and establish a functional alarm system.

Alarm System Attribute	Findings	Remarks
Documentation	• Alarm system functionality has not been formed based on documentation available • More or less alarm systems are designed and presented based on SAS system vendor standard solutions	In a typical process plant, offshore or onshore the control systems are delivered by multiple vendors. Without a common integrated system philosophy, operators will be presented with alarms differently on different systems, which may lead to confusion about understanding alarms and possibility of missing required operator action.

Alarm System Attribute	Findings	Remarks
Management Routines	• Most of the organisations have not established routines and systematic procedures to maintain alarm system, though this is one of the defined safety barrier • Minimum focus on alarm system problems in formal reporting, based on regulations for registering and following up of unwanted incidents	such as Routines for measuring alarm system performance are missing Definition of Roles and Responsibilities corresponding to alarm system improvements are not clearly established
Alarm Load (Alarms per time period, e.g. 10minutes)	• Operators are presented with so many alarms in both normal operations and disturbed conditions • Emergency shutdown causes several consequence alarms leads to alarm rush	5000 events per second in case of ESD 1.0 (Highest level of shutdown). The stress levels of operators tend to increase due to high alarm rush.
Alarm Value (The purpose of alarm)	• A greater part of the alarms presented to the operator have less or no value to the operator • Sometimes signals are not configured as alarms where they supposed to be. It misleads operators and spends lot of time to investigate shutdowns	Most of the alarms just carry the status information rather than the situation which needs some action from operator Investigation to find root cause of a shutdown nearly takes 50 minutes
Alarm Description/ Text	• Difficult to understand text/ Abbreviations in alarm description •	Too many abbreviations in alarm description leads to difficult to understand the context of alarm
System Related Alarms (Control system Diagnostic Alarms)	• Too many control system diagnostic alarms rather than process alarms	Control system generates too many diagnostic alarms and they are hard to understand. The uncertainty about operator action for system diagnostic alarms leads to mistrust alarm system.

Alarm System Attribute	Findings	Remarks
Prioritisation (Criticality assigned to alarm based on severity of consequence and urgency for operator action)	• Alarms not been prioritised in a way, it helps the operator to identify and take necessary action in various operational conditions	The risk tolerance defined by urgency vs severity is not properly defined or not followed
Presentation	• Inconsistency in alarm presentation for different systems due to lack integrated philosophy and control system vendor dependability for designing alarm systems • Navigation between alarm screen is not consistent	Operators fatigue due to too many colours and audible sound frequencies. Stress on operators to memorise various layouts of alarm screen for different systems
Unnecessary Alarms (Alarms comes from the removed equipment or out of operation)	• A large quantity of alarms have been observed coming from equipment which has been stopped (Standby equipment), or equipment under maintenance • 4 extra alarms on each real alarm	A large number of nuisance alarms come from marine and utility systems such as cooling water, ballast and storage tanks, sewage and cargo systems etc. 2 or 3 alarms are only useful out of 10 random alarms
Safety Related Alarms	• Safety related alarms are not explicitly identified. It is important to present in a different way to make sure that operators cannot oversee or misunderstand information	It is a requirement to distinguish between normal process alarms and safety related alarms presentation
Training	• Training on new systems and their alarm behaviour is missing	Implementing in simulator and training for the operators could have been given more awareness of newly adapted design

Table 12 Qualitative analysis - Alarm System Specifications

6.3.1. Analysis- Alarm Optimisation Process

The Optimisation activity predominantly consists of:

- Removing unnecessary alarms (Alarm clean-up)
- Configuring alarms with meaningful and understandable text
- Correct prioritisation
- Alarm help preparation including: cause, consequence, and operator action

Though there are some additional methods of alarm management activities such as alarm suppression, alarm grouping and alarm tuning are part of alarm Optimisation, these activities will be called upon during either Top- 10 (sometimes its referred as Top- N) analysis, standing alarm analysis or to reduce alarm chattering.

Here are some findings and observations which dramatically change the perception of “Activity of Optimisation” during this study. Optimisation is not a one-time event, it is a continuous clean-up activity, and revision of work and reporting of bad actors shall be in place. An Optimisation level of 100% is only achieved right at the start, and over the course of some years, the performance will be degraded. Continuous focus, reporting and revising on the alarm engineering works is necessary, and a change management process should be in place.

This study also reveals that, most of the alarm projects did not assign a dedicated team for Optimisation. An alarm team which is chosen during the early stages of the project should continue to improve the efficiency by keeping the same focus and philosophy. Failure to maintain the same team throughout the Optimisation process leads to loss of consistency in work and clear understanding. It is very important to have experts from different systems on the team during Optimisation, it gives operators confidence in prioritisation, good text, and on top of that it saves a lot of time in workshops.

This thesis chose to use the term optimisation instead of rationalisation. The process of optimisation and the improvement effect on operations is not linear, achieving 30% optimisation does not mean you will get 30% better performance. An illustration of the progress of an alarm project- Optimisation progress and its effect on improved operations is shown below.

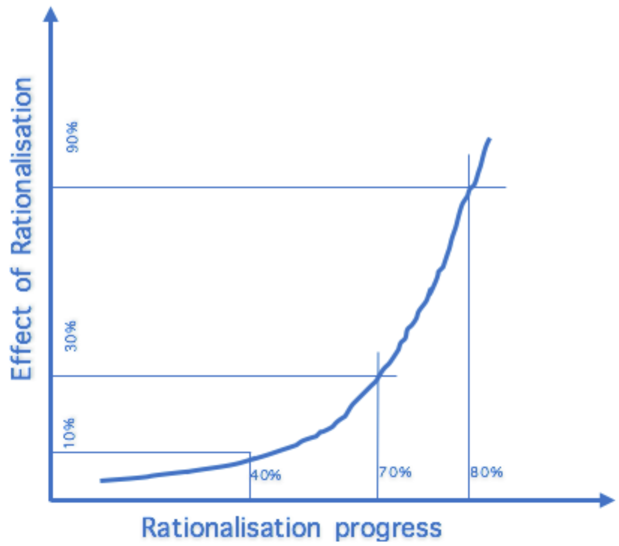


Figure 19 Alarm Project - Optimisation activity effect on improved operations

As shown in the above diagram, the result of Optimisation project activity will not be visible until it reaches the tail end of the project stage. Both operators and control system engineers agree upon the fact that alarm projects like Optimisation activities shall be performed for the whole plant to realise improved operations. Largely, the focus for alarm projects is on random systems, based on high alarm load at that moment rather than a systematic Optimisation methodology. A detailed pre-study is required to ensure the subprojects (different activities) come in the correct order to optimise workflow.

During alarm clean up activity, which is a part of Optimisation, participants observed that while the project is undergoing commissioning, one should follow a more stringent alarm philosophy and be more restrictive when implementing alarms from 3rd party systems. “Implement-all-available-alarms-during commissioning” as it will be hard to clean up alarms afterwards when all the “Vendors are gone”, as they figuratively drown in “black boxes”.

6.4. Connecting the Quantitative and Qualitative Findings

Overall, the quantitative results show the consequences of poor performance of alarm systems in terms of number of plant shutdowns, time to get back to normal production, economic consequences, and time spent on alarm projects. A qualitative study shows operators’ concerns about the quality of alarm systems when it comes to validity of alarms during disturbed plant conditions, management routines for reporting, and training.

The findings from the qualitative phase also reveal that, organisation expenses are mainly based on the value it produces at the moment, so any production shutdown creates a deficit and equates to spending money with no return. Economic loss may not be directly related to the deficit created by plant shutdown but also consists of:

1. Time spent on trying to understand alarms
2. Time spent without fixing the issue is a type of economic loss.
3. Moving focus from regular operations to fixing the alarm issues

This part of the research represents the “Active experimentation” stage of experiential learning cycle, referred to by (Dixon, 1999) in his work on organisational learning. Though there are several aspects of alarm systems, which were abstracted through both quantitative and qualitative findings, this part of the research is only interested in addressing the core issues identified by the participants as given below for active experimentation.

Research and relevant regulations serve as a benchmark to measure and estimate the gap between the findings identified through quantitative and qualitative study. The estimated gap and associated findings lead us to the development of required processes. The system development of the (Hollnagel, et al., 2006) model described in section 4.1 suggests this hierarchy for further design and interface into operations:

Aspect of Research	Regulation	Quantitative finding	Qualitative finding
Alarm system support	(The Facilities Regulations, 2015) § 21 The presented information shall be correct and easily understandable. Information systems shall be designed for both normal and critical situations.	Alarm system design constrains limited its performance to 80%, a further possibility of 20 % improvement is identified	Alarm systems are designed only for normal operations and limited functionality during plant shutdown
Alarm Rush	(The Facilities Regulations, 2015) § 34a (Technical and Operational Regulations, 2016) §33a The alarm systems allow for suppressing and reducing alarms, so as to avoid mental stress for control room personnel during interruptions in operations and accident incidents.	5000 events per second in case of emergency shutdown	The stress levels of operators tend to increase due to high alarm rush

Standing Alarms and Chattering Alarms	(The Facilities Regulations, 2015) § 21 Monitor-based equipment and other technical equipment for monitoring, controlling and operating machines, installations or production processes, shall be designed to reduce the risk of mistakes that can have an impact on safety.	Nearly 700 Standing alarms 2 or 3 alarms are only useful out of 10 random alarms	Hard to manoeuvre between alarm screen to find recent alarm Unwanted consequential alarms from equipment out of operation Faulty equipment No dead band sets No 'delay-off' set Instrument out of range errors
Management routines and Optimisation templates	(The Framework Regulations, 2016) §17 The responsible party shall establish, follow up and further develop a management system designed to ensure compliance with requirements in the health, safety and environment legislation. (The Management Regulations, 2016) § 8 The responsible party shall set internal requirements that put regulatory requirements in concrete terms, and that contribute to achieving the objectives for health, safety and the environment, cf. Section 7 regarding objectives and strategies. If the internal requirements are expressed as functional requirements, achievement criteria shall be set.	NA	Most of the organisations have not established routines and systematic procedures to maintain alarm system, though this is one of the defined safety barrier Implement-all-available-alarms-philosophy during commissioning is hard to clean afterwards when all the "Vendor's are gone", as they sort of drown in "black boxes".
Economic loss	NA	12 to 24 hours to revive from a major shutdown 1 to 5 shutdowns per year accredited to poor performance of alarm system nearly 6 million dollars per day	Loss of time spent on understanding alarms Moving focus from regular operations to fixing alarm issues

Table 13 Research findings chosen for active experimentation

6.5. Discussions

Recalling our research focus, identifying regulations and adapting these findings will help us to define procedures to build a functional alarm system.

How to develop a supportive system for process alarm management describing procedures based on key regulations related to HSE framework?

and

"Justification for an alarm management activity to evaluate and support a business case having key investment drivers in terms of losses due to poor performance of alarm system"

Referring to the model chosen for this research derived from (Hollnagel, et al., 2006), the system development is one step closer to redefining and adapting this research methodology. (See Figure 14 Hierarchical model for safe and reliable operations - Derived from Hollnagel, et al., 2006). The interaction between system development and system operations suggested by this model has been studied partially during this research through answering the questionnaire "Section 4: Alarm Management Activity Experience" (See Appendix (IV) Operators Questionnaire).

As shown further below in the hierarchical model (See Figure 20), each and every organisation has their own philosophy document which they use to design alarm systems. By definition, "The alarm philosophy serves as the framework to establish the criteria, definitions, and principles for the alarm lifecycle stages by specifying items including; the methods for alarm identification, rationalization, classification, prioritization, monitoring, management of change, and audit to be followed". (International Society of Automation, 2009)

Regulations and guidelines will establish the rule set of "Shalls" and "Shoulds" on various aspects of alarm systems. The same set of rules will be inherited by companies and adapted to their organisation policies to recreate a modified rule set called "Alarm Philosophy". None of these documents clearly mentions "How to achieve" this rule set of "Shalls" and "Shoulds", and that will be the core focus area for this research as depicted in below illustration.

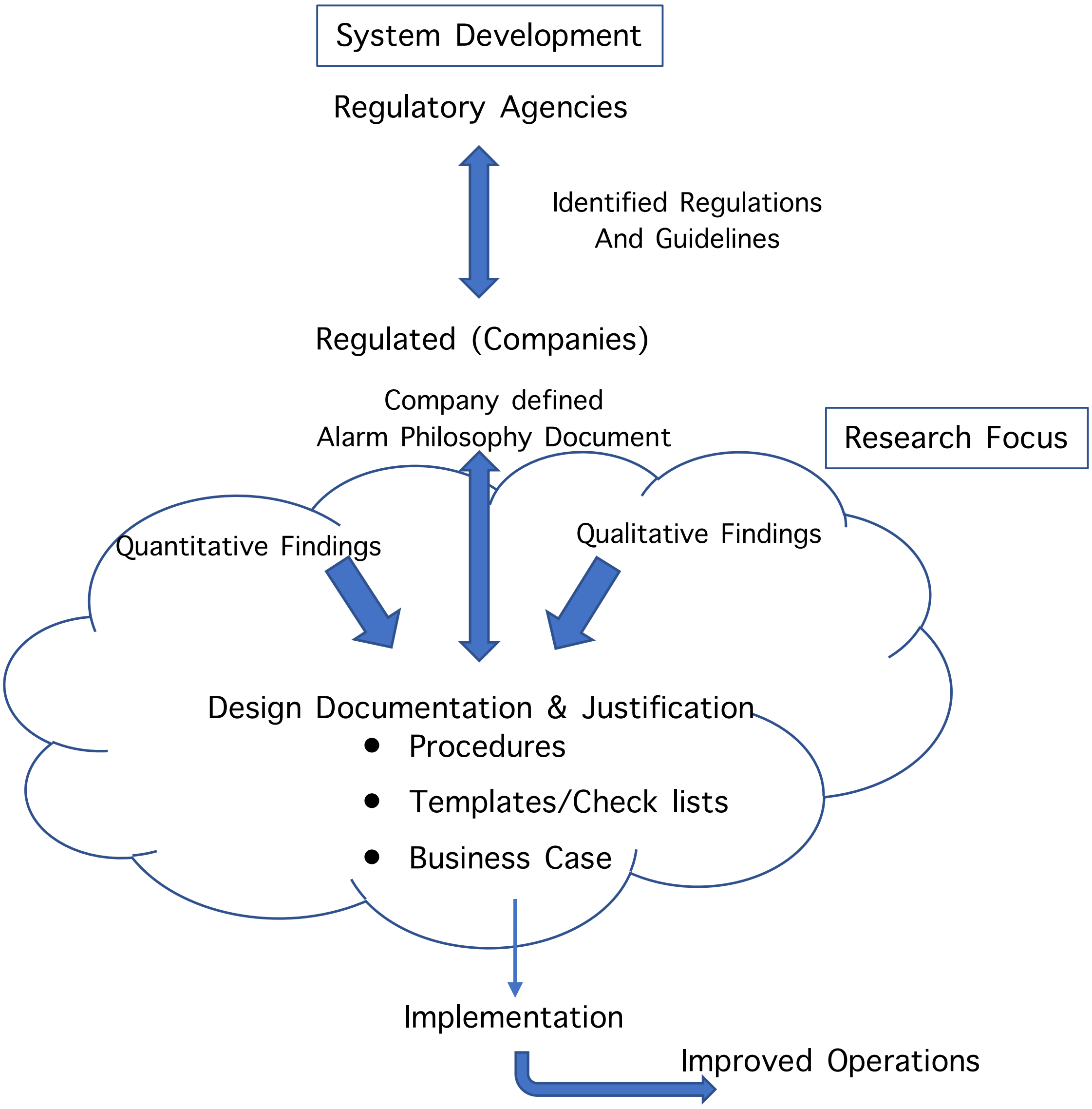


Figure 20 Hierarchical model - System development (Research Focus identified)

6.5.1. Active Experimentation - Procedures

As this research has already delineated in previous sections, "Eldor Management System" (EMS) has been used as an intermediate accompanying system to compare and there by producing necessary processes to answer those research findings chosen for active experimentation stated in Table 13.

A further examination of the existing process map within EMS (see Appendix (II) EMS Process Map – Process Alarm Management), the following actions are recommended to address the findings chosen for this stage.

Aspect of Research	Potential Consequence	Typical Cause(s)	Recommended Action(s)	Method(s) for Addressing Issue
1. Alarm Rush	Alarm floods overwhelm an operator's ability to properly respond to alarms	ESD / PSD (ESD 1.0/ ESD 2.1/ ESD 2.2 /PSD 4.0) Depressurised shutdown Main Power Loss	Using the status of the plant, recommended to hide all the alarms.	Automatically hide alarms according to the operating mode of the plant
2. Number of standing alarms at any instance in time	Standing alarms can become "stale" and after some period, become meaningless. One needs to consider if the alarm does not clear, is a hazard still present.	Equipment not running Equipment out of order	Recommended auto suppression based on equipment status (e.g. Running status, Out of Service or Decommissioned)	Automatically suppress alarms based on equipment status.
3. Unnecessary and chattering alarms	Alarms that annunciate and clear before the operator can respond, will create a situation where the operator becomes insensitive to the alarms that could one day be genuine	Faulty equipment No dead band sets No 'delay-off' set Instrument out of range errors	Check alarm configuration i.e. dead band, delay-off, filter Check instrument installation, configuration, etc. Carryout data analysis to determine conditions that causes the fleeting alarms	Tune alarm settings on nuisance alarms Adjust dead bands on alarms which often repeat

Table 14 Active experimentation measures

6.5.1.1. Major Event Detector – Alarm Rush

Many installations have the following Emergency Shutdown (ESD) levels which will trigger power outage called "Main Power Loss". This will lead to an alarm rush with in first 10 minuets with almost 400 Alarms and nearly 5,000 status messages.

ESD1.0 – Main Power Isolation – Safeguarding of Non-Hazardous Area

ESD 2.0 – Depressurization –Blow down –Safeguarding of Hazardous Area

ESD 3.0 –Safeguarding of Process

This study has noticed that a large number of alarms come from the electrical equipment on/off status due to main power loss therefore contributing to the major portion of alarm rush. All these alarms are an expected consequence of main power loss. This research has taken this as a primary measure to control alarm rush in the event of emergency shutdown. (Rothenberg, 2009) referred to it as a "Major Event" detector and the detector must be capable of identifying events such as breaker open, feeder tripped, and feedback error as mentioned above. The following actions have been identified as a guidance for this activity:

Process	**Activities**
Design phase	• Identify correct ESD level and respective power outage blocks with in the plant due to this shutdown • Identify all relevant electrical equipment and alarms configured on these equipment (Group of Alarms) • Prepare a design basis for workshop for further justification.
Workshop	• The workshop team might consist of process operators, system/electrical engineer and workshop facilitator • Tools to be used: Emergency shutdown reports, Single line diagrams, Emergency shutdown level diagrams and Motor control centre details • Justify for each group, its non-validity during emergency shutdown and safe to hide these alarms from operator visibility • Prepare a design basis for Implementation
Review and Work Package	• Vendor to review and update implementation typical per each group of alarms • Based on review comments and implementation typicals prepare a work package for software updates
Implementation	• Implement the required changes in software in test system and prepare the software for testing
Internal Approval test (IAT) and Factory Approval test (FAT)	IAT: Full function test internally FAT: spot checks (Along with approval authority and system owners)
Installation offshore	• Install approved changes offshore (Remote implementation)
As build Documentation	• Update documentation as built

Table 15 Procedural stages to handle Alarm Rush

6.5.1.1.1. Cost Effectiveness

Looking at the number of alarms (nearly 400 to 5,000), the volume of work involved in making any software changes on individual alarms is huge. Software configuration for each alarm is time consuming and cost involved in terms of resources, offshore travel, and safety approvals. The suggested procedural stages mentioned in Table 15, have following cost benefits.

With Procedural Stages	Without Procedural stages
A group of alarms hided based on major event (ESD 1.0 or ESD 2.0)	Individual alarm hiding in place
Grouping of alarms do not need logical changes with in controllers	Individual alarm hiding needs logical changes in controllers
No logical changes mean, no work permits or safe job analysis	Needs work permits and safe job analysis
Grouping can be implemented from onshore, no offshore travel	Offshore travel is mandatory for logical changes (considering changes in safety nodes)
Easy maintenance and less changes in existing documentation	As builds need to be developed

Table 16 Cost benefit analysis - Alarm Rush Procedure

6.5.1.2. Alarms on Equipment OutofOperation – Standing Alarms

Alarm suppression is a mechanism to prevent the indication of the alarm to an operator (International Society of Automation, 2009). Process parameters such as pressure, flow, temperature, and level on various process equipment need to be monitored to indicate if there is any deviation. Alarms such as “High Pressure/Low Pressure”, “Low Level /High Level”, “No Flow” or “High temperature/ Low Temperature” are mostly relevant and useful during normal operations.

During process shutdowns, when equipment is under maintenance, or completely removed from operations, some of these alarms are not relevant and operators were not necessarily being informed about these alarms. In such cases, alarm suppression will be used based on equipment status or shutdown status. Usually low pressure and low flow alarms will be supressed when the equipment is not in operation using an Equipment Non-Running signal.

The below scatter chart gives an overview of the total number of low alarms configured and relevant suppression mechanism implemented by Equipment Non-Running signal for a typical offshore installation. From this scatter chart, it is clearly evident that out of the total configured alarms (indicated by Orange colour), only a minor percentage of alarms are taken under suppression mechanism (indicated by Blue colour). This may be due to the unavailability of running signal for most of the alarms.

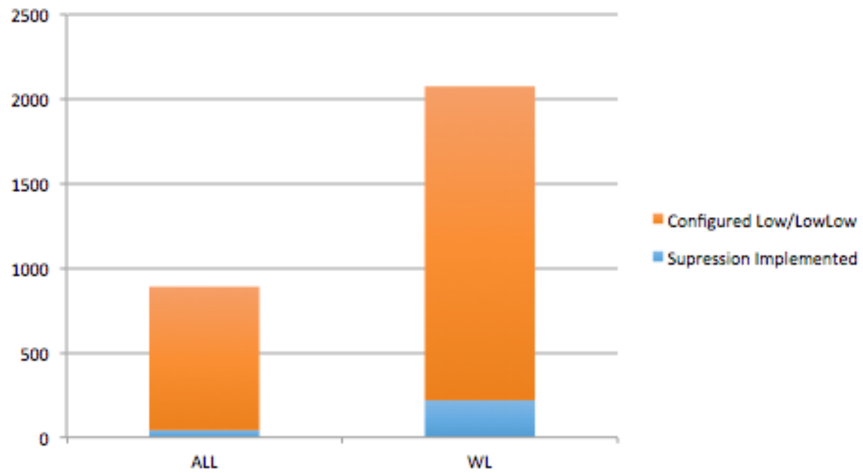


Figure 21 Alarm Suppression configuration – A typical offshore installation

Note: WL indicates "Warning Low" Alarm, ALL indicates "Action LowLow" alarm

Nearly 40 to 50% of configured alarms can be supressed using process shutdown status instead of equipment non-running status. Without proper suppression, most of these alarms remain in the alarm list during equipment idle period and they become standing alarms. This thesis tries to capture this potential and recommended procedural guidance to supress these alarms based on process shutdown status.

Process	**Activities**
Design phase	• Identify all configured low pressure and low flow alarms on various process equipment • Ignore those alarms which already been taken into suppression using equipment non-running status • Prepare a design basis for workshop for further justification
Workshop	• The workshop team might consist of process operators, process engineer and workshop facilitator • Tools to be used: Process Shutdown Level Diagrams, Pipe and Instrumentation Diagrams, Process Graphics • Justify each alarm for its non-validity during process shutdown and safe to hide this alarm from operator visibility • Prepare a design basis for Implementation "Special measures shall be considered to allow independence between safety systems"

Process	Activities
Review and Work Package	• Vendor to review and update implementation typical per each alarm • Based on review comments and implementation typicals prepare a work package for software updates
Implementation	• Implement the required changes in software in test system and prepare the software for testing
Internal Approval test (IAT) and Factory Approval test (FAT)	IAT: Full function test internally FAT: spot checks (Along with approval authority and system owners)
Installation offshore	• Install approved changes offshore
As build Documentation	• Update documentation as built

Table 17 Procedural stages to handle Standing Alarms

6.5.1.2.1. Cost Effectiveness

As a safety measure, standing alarms due to equipment out of operation can only be suppressed using Equipment Non-Running signal (Hardwired Signal), in case of no hardwired running signal availability it is not allowed to supress an alarm. Having understood the concept of independence between safety systems (i.e. a failure in one system shall not adversely affect the intended safety function of another system), no communication shall occur between a non-safety system and any safety system. If special measures are implemented, a limited degree of interconnection can be allowed. (The Norwegian Oil Industry Association, 2004). The procedural stages suggested above have inherited those necessary special measures and having the following cost benefits:

With Procedural Stages	Without Procedural stages
Standing alarms hide using process shutdown levels (Provided valid interconnection is possible)	New hardwired signal need to laid out for implementation of suppression
Easy to implement only logic level changes	Hard to implement, requires space in panel, spare capacity, competent resources
No shutdown required	Shutdown required
Less updates on documentation	As builds need to be developed

Table 18 Cost benefit analysis - Standing Alarm Procedures

6.5.1.3. Chattering Alarms – Faulty Equipment

Chattering Alarm is an alarm that repeatedly transitions between the alarm state and the normal state in a short period of time. (International Society of Automation, 2009)

A detailed analysis of alarm loads reveals that only a small number of repetitive alarms contribute to nearly 70% of the alarm load. In any typical offshore installation, alarm load is largely contributed by only the top 10 repetitive (Or Chattering) alarms. The below illustration is drawn based on top 2,000 alarms for a particular period. It clearly shows that the first four alarms (YF, Y, WL and WH) cumulatively contribute 63% of the total number of alarms. (1250 out of 2000 alarms).

By looking at the distribution shown in Figure 22, the importance of Top- 10 alarm supervision is quite apparent for improved operations, without which the operator soon abandons the alarm system due to fatigue created by the large number of chattering alarms.

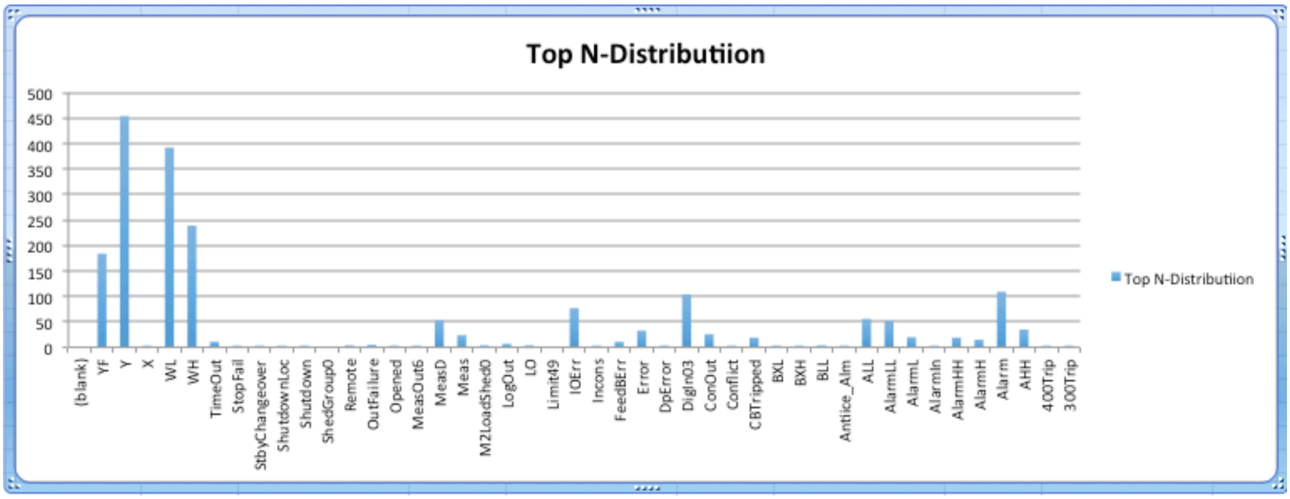


Figure 22 Top 2000 Alarm distribution - A typical offshore installation

This thesis chooses to adopt this challenge and recommended a procedural guidance to reduce the chattering to the least possible level. The complete avoidance of chattering is hard to achieve as the plant dynamics are too large to control only using recommended procedures.

Process	**Activities**
Design phase	• Select the time period to limit the scope of analysis (Recommended to select 1 year) • Select a criterion to filter out less noisy alarms (e.g. alarm comes more than 100 times with in a selected period) • List out all the alarms including both analog and digital signals along with frequency of occurring within a selected period • Prepare a design basis for workshop for further justification

Process	**Activities**
Workshop	• The workshop team might consist of process operators, process engineer and workshop facilitator • Scrutinise each alarm for its repeated occurrence • Tools to be used: Past trends, pending work orders (If equipment is in maintenance or repair), Plant dynamics based on age of the installation. • Justification to increase dead band or delay time for each alarm • Prepare a design basis for Implementation
Review and Work Package	• Vendor to review and update implementation typical per each alarm • Based on review comments and implementation typicals prepare a work package for software updates
Implementation	• Implement the required changes in software in test system and prepare the software for testing
Internal Approval test (IAT) and Factory Approval test (FAT)	IAT: Full function test internally FAT: spot checks (Along with approval authority and system owners)
Installation offshore	• Install approved changes offshore
As build Documentation	• Update documentation as built

Table 19 Procedural stages to handle Chattering Alarms

6.5.1.3.1. Cost Effectiveness

Most organisations have an internal team to handle top-N alarms, the suggested process and its implementation may not completely eliminate the challenges involved with repeated alarms, but still have the following cost benefits:

With Procedural Stages	**Without Procedural stages**
One time analysis for repetitive alarms and suggested measures	Loss of time and resources for repetitive analysis on same kind of problem
Moving focus from repetitive analysis to operational improvements	Repetitive analysis on same issue sets in loss of confidence
Improvement in performance indicators	Few repetitive alarms create large deviation in performance indexes

Table 20 Cost benefit analysis - Chattering Alarm procedures

6.5.2. Active Experimentation – Templates

6.5.2.1. Alarm Optimisation

It is very common to leave the detailed configuration of alarms to a later stage in major development projects. The Process and Safety systems will be engineered and installed leaving behind the alarm configuration. Most of the Alarm projects or Alarm Management activities will be realized only on demand in terms of unwanted incidents or audit findings from Authorities (Such as PSA).

During this study, it has been repeatedly stressed by various stakeholders that commencement of alarm project activities should begin right from the start. “Implement-all-available-alarms-during commissioning”, it will be hard to clean afterwards when all the “Vendor’s are gone”, as they sort of drown in “black boxes”.

During the phase of qualitative study as mentioned in 6.3.1, the alarm optimisation process and its importance should be highlighted right from the beginning during green field development projects. This thesis has developed a standard temple which can be deployed and maintained throughout the life cycle of alarms projects. (See Appendix (VII) Alarm Optimisation Template)

Alarm Specific	Configurable Parameter	Remarks
Alarm Text	Alarm Description	Understandable text to describe, such as “Equipment>service> destination area” This syntax is only for guidance
	Alarm Type	High alarm, Low Alarm etc.
	Alarm Message	Any additional information related to alarms (e.g. Alarm on driving end bearing etc.)
Alarm Help	Purpose of Alarm	Describe purpose of alarm (e.g. to warn about high level in tank)
	Possible Cause	Describe cause of alarm (e.g. Downstream valve closed)
	Consequence	Describe consequence of alarm (e.g. May lead to oil spill on platform)
	Operator Action	Describe relevant actions necessary (e.g. Visual check and open downstream valve)

Alarm Specific	Configurable Parameter	Remarks
Priority Evaluation	Time to Respond	Complex parameter to asses, but based on operator's experience define some time scales such as (5 Min, 15 Min, 1 Hours and > 12Hrs etc.)
	Urgency	Define urgency in terms of time available to respond (Refer company guidelines and operational procedures)
	Severity	Asses the severity of consequence (Refer company guidelines and safety policies)
	Priority	Based on above three asses the priority (Ref company specific Alarm Philosophy document)
Context Sensitivity	Start-up	Check if alarm is relevant during start-up
	Process Shutdown	Check if alarm is relevant during process shutdown
	Emergency Shutdown	Check if alarm is relevant during emergency shutdown
	Alarm Hiding	Based on context sensitivity hide the alarm from operator visibility
Signal Conditioning	Alarm Delay	default settings are available in (EEMUA, 2017), but its recommended to asses each alarm during optimisation process and suggest relevant setting
	Dead band	default settings are available in (EEMUA, 2017), but its recommended to asses each alarm during optimisation process and suggest relevant setting
Grouping	Validity	Check if the alarm can be grouped with any other alarm. (Alarms having same operator actions can be grouped, individual alarms in group will be hided from operator visibility) *
	Details	List of all alarms that need to be grouped
	Group Name	Mention relevant group name
Classification	Personnel Safety	Classify according to identified consequence
	Financial Consequence	Classify according to identified consequence
	Environmental Protection	Classify according to identified consequence
Key Alarm	Validity	All Fire and Gas alarms are key alarms, but apart from Fire and Gas alarms if there is any alarm which need special focus to avoid escalation into safety incident, then classify that alarm as key alarm
	Likely	Check if recommended operator action most likely removes the alarm situation

Alarm Specific	Configurable Parameter	Remarks
Operator Response Effectiveness	Challenging	Check if recommended operator action is good enough to control the situation but challenging to remove the alarm condition
	Unlikely	Check if recommended operator action is not good enough and needs further support to remove alarm situation #

Table 21 Alarm Optimisation Template Specifics

*During this research, the result of an audit questionnaire observed that safety authorities are not so lenient towards alarm grouping as it creates uncertainty due to operator unawareness of individual alarm status.

Alarms with "Unlikely" response effectiveness can be considered as maintenance alarms so that the load on the operator is reduced

6.5.2.2. Change Management

The responsible party shall establish, follow up and further develop a management system designed to ensure compliance with requirements in health, safety, and environmental legislation. (The Framework Regulations, 2016)

So far, this research has identified the required processes and procedures considered to be cost effective for successful deployment in alarm projects. To achieve control over the project activities among various stakeholders, there must be a plan. It is the management process, which enables us to lay out a sequence of activities for successful transition between various processes.

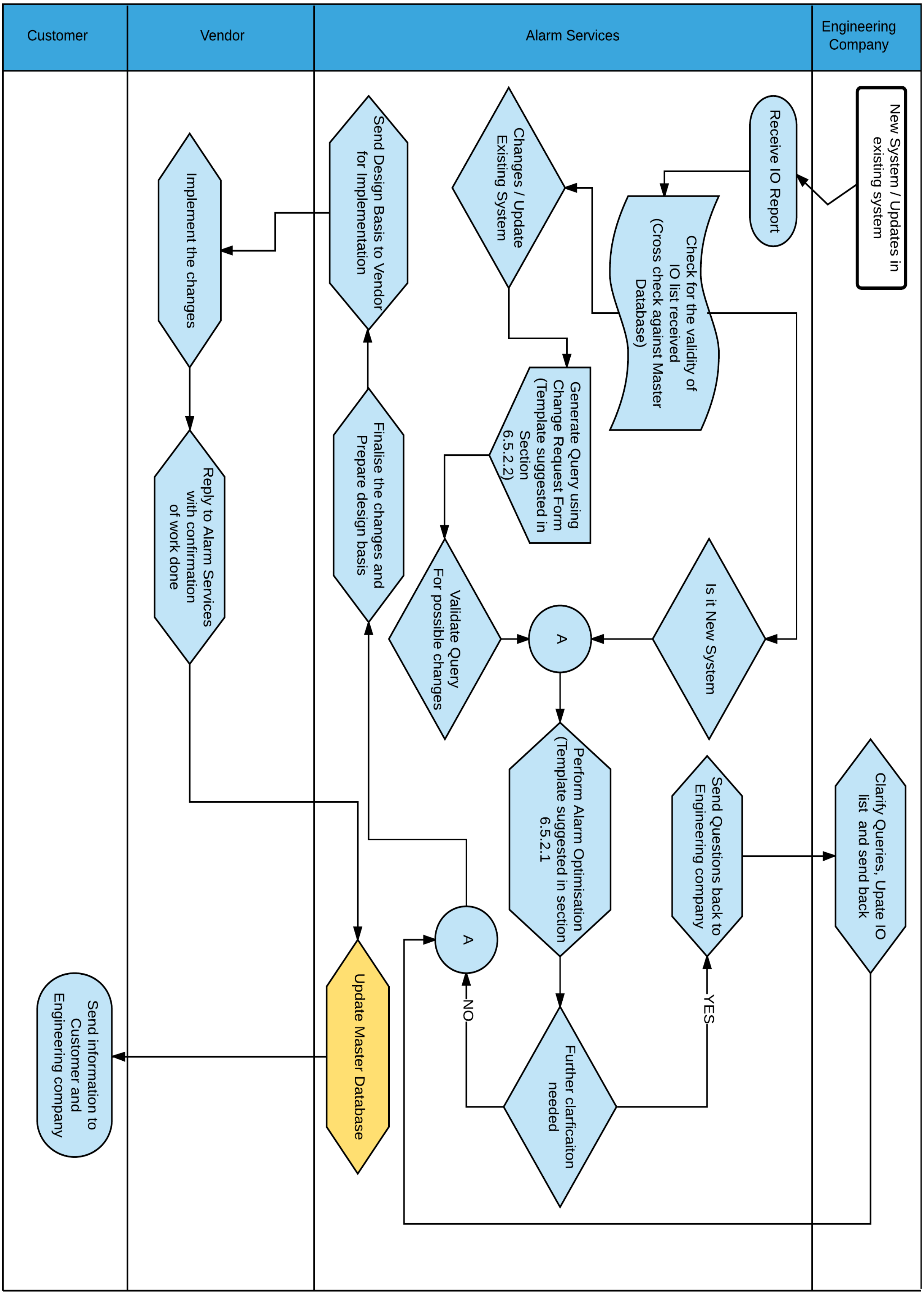


Figure 23 Management of Change - Alarm Projects

The management process described in Figure 23 is highly applicable for various activities within alarm projects. The stakeholders involved in this process must have their boundary mapping defined. It ensures that stakeholders (including vendors, customers, and engineering companies) are properly represented in planning and decision making. The transition among various activities in the management process is carefully designed to meet the needs of the different levels in the management system.

The defined structure within this management model is suitable for both “New Installations” and “Updates in existing installations”. The alarm optimisation process discussed in 6.5.2.1 is valid in both cases except for the updates in existing installations, changes need to be validated before they have been subjected to optimisation process. To fulfil the purpose of this study, the template for a change request form has been developed and suggested to make appropriate changes where necessary.

Alarm Configuration Change Request Form	
Description	**Answer**
Please explain the reason to make changes to this Alarm.	e.g. Due to aging of well, the pressure reduced, so need to change alarm low limit
What is the purpose of the Alarm?	e.g. Same as before no change
What is the consequence of no response to the Alarm?	e.g. Same as before no change
What is the required operator response to the Alarm?	e.g. Same as before no change
Do we still consider this as an Alarm or a status message?	e.g. Yes - alarm - priority changed from Prio 2 to Prio 1
Is there an existing Alarm in the system equal to this? (If so, is this Alarm necessary?)	e.g NO
How much time is it expected that the operator response would require?	e.g. Same as before no change
Is this a trip Alarm?	e.g. No
Is this a warning Alarm?	e.g. Yes
If warning alarm, has the operator time to intervene before an associated trip occur?	e.g Yes
Can this alarm be grouped with other existing alarms?	e.g. Not relevant
Select the correct alarm priority according to the alarm philosophy	Alarm priority 1

Table 22 Alarm Change Request Form Template

6.6. Business Case Development

Considering that, the suggested cost-effective solutions and management routines will provide organisations a motivation to invest in alarm projects for better performance, but organisations still need a justification and reason for capital investment in alarm projects. This is in line with this research focus final question:

"Justification for an alarm management activity to evaluate and support a business case having key investment drivers in terms of losses due to poor performance of alarm system"

The purpose of the business case theme is to establish a mechanism to judge whether the project is desirable, viable, and achievable as a means to support decision making in its (Continued) investment (Axelos, 2014).

Financial losses and accidents occur for a multitude of different reasons in process plants. Often, because designers have tried hard to prevent such incidents, the ones that do happen are due to combinations of several unexpected events occurring simultaneously. In addition, it is difficult to collect data about all incidents involving financial loss or risk to people or the environment, especially smaller incidents and near misses (EEMUA, 2007). Because of these difficulties, it is hard to make an exact assessment of cost incurred due to poor performance of alarm system.

However, this thesis will try to adapt a potential method for estimating the cost of poor alarm system performance by use of a risk-based approach suggested by (Bransby & Jenkinson, 1998) along with the data abstracted through these research quantitative and qualitative findings.

It would be desirable to be able to estimate figures for what poor performance of an alarm system "costs" in terms of financial losses and increased hazards. If this were done, it would provide a sound basis for making decisions about investments in alarm system improvements. This section suggests how this might be done. The contract report by (Bransby & Jenkinson, 1998) suggested that the cost of poor alarm system performance may be expressed as:

Loss = Cost of missing x Frequency of demand x Chance of missing

where

Loss = the cost of not having a good system for presenting a specific alarm.

Cost of missing = the cost of the event that the detailed alarm protects against. In a well organised design, this figure should be exposed in the trip/alarm justification process - either in financial terms or in risk to life terms.

Frequency of demand = frequency of the event protected by the alarm. Again, this figure should be exposed in the trip/alarm justification process.

Chance of missing = the chance of the operator missing the alarm. This figure is hard to quantify accurately. However, it will depend on the overall adequacy of the alarm system. It will be correlated with things like average rate of alarms, % usefulness of alarms, effectiveness of alarm display on operator interface, etc.

This research does not claim that the following illustration is a result of rigorous analysis, and it may need to be further refined, considering the fact not all the parameters assumed for this calculation were statistically proven. However, it does provide a pointer to an approach than might usefully be taken for a plant where there has already been in-depth risk analysis.

Offshore Installation: (Size of 40,000 Alarms)

Refer to the section 6.2, the quantitative phase results as shown below provides an estimation of financial losses due to an unwanted process shutdown.

Research Question	Finding
No of unwanted shutdowns per year due to poor performance of alarm system	1 to 5
Length of shutdown period for partial shutdown	12 Hours
Length of shutdown period for full shutdown	24 Hours
Typical financial loss per shutdown	$ 6M per day

Table 23 Financial Losses Illustration - Process Shutdown

Based on these findings, it is assumed that on an average 3 shutdowns in a year, 1 partial and 2 full shutdowns imparted to poor performance of alarm systems. (Missing a high-level alarm)

1x 12 hours + 2 x 24 hours = 60 hours of process shutdown. This results in cost of missing an alarm approximately

$$C = 60/24 * \$ 6M = \$ 15M$$

If it is *assumed* that the probability of the high-level alarm occurring without operator action will be: Once in 2000 years.

F = 500 x 10-6 per year

If it is assumed that the probability of the operator missing the high-level alarms is: 1/100

P = 10-2 per year

Cost of Fault due to an alarm missing	Frequency of that alarm without operator action	Probability of Operator missing this alarm
C = $ 15M	**F = 500 x 10-6 per year**	**P = 10-2 per year**
Calculated loss attributed to missing alarm $ 15M x 500 x 10-6 x 10-2 per year = **$ 75 per year**		

Table 24 Calculation of loss due to missing alarm

This is a small figure - as indeed the offshore systems are well-designed. It represents the annual saving that might be made by eliminating the chance of the operator missing a single high-level alarm. However, these would not be the only alarms on the plant or the only faults that could occur, and the losses must be integrated across all the alarms.

With an offshore installation having 40,000 alarms configured, there might be few trip alarms (Say 2,000 trip alarms). ignoring these 2,000 alarms results in 38,000 high-level alarms and each alarm with loss of $ 75 associated with it.

Cost of Fault due to an alarm missing	Frequency of that alarm without operator action	Probability of Operator missing this alarm
C = $ 15M	**F = 500 x 10-6 per year**	**P = 10-2 per year**
Calculated loss attributed to missing alarm $ 15M x 500 x 10-6 x 10-2 per year = **$ 75 per year**		
The total benefit from improving the alarm system would be: **38000 *$ 75 = $ 2.85M per year ≈ NOK 23.6M per year**		

Table 25 Cost benefit calculation from improving alarm system

<u>Justification</u>

This might be used to justify a capital expenditure of NOK 30 to 40M for argument's sake having payback period of 1 to 2 years. Remember that improvements in an alarm system are not only for financial benefits, but could be seen to look at the benefits in terms of reduction of hazards, improvements in operations and various other intangible benefits from improving the alarm system.

6.7. Research Case Study

This research study is a combination of both the cross-sectional and the longitudinal study. Referring to section 5.1.1, the time horizon for this study is certainly more than the time set for this thesis. The suggested processes, procedures, and templates would be the result of a prolonged study rather than the time available for this study.

The validity of this research is taken into consideration and the suggested processes are applied to realise the benefits and cost effectiveness in a pilot project. The results observed were promising and approved for full life cycle projects on various installations of the organisation. Since confidentiality and data protection have been agreed upon in all circumstances, this research has decided to address the case study results as anonymous.

The result of executing procedural stages suggested in section 6.5.1.1, to control alarm rush in the event of major shutdown, in terms of performance gain and cost effectiveness shown below.

Process	**Alarm Rush (Case study shutdown ESD 4.4)**	
Procedural stages to control Alarm Rush as shown in Table 15	Before implementation of procedure described in Table 15	After implementation of procedure described in Table 15
No: of Alarms observed during study	577 alarms per Minute	208 alarms per Minute
Performance gain	Nearly 300 alarms per Minute rush has been reduced	
Safe and Improved Operations	Since the numbers of alarms has been reduced, operator have the possibility to check the root cause of the event quickly and revive the plant operations safely in short time.	
Cost Effectiveness	Saving cost and resources required to implement logical changes for nearly 300 alarms, as this method uses grouping instead of logical changes. (For instance, a single logical change needs nearly 4 to 5 offshore hours from engineering to implementation)	

Table 26 Evidence Report Analysis - Major Event Detector

The result of executing procedural stages suggested in section 6.5.1.2, by reducing standing alarms during equipment out of operation due to process shutdown, in terms of performance gain and cost effectiveness shown below.

Process	Equipment OutofOperation
Procedural stages to handle standing alarms as shown in Table 17	Implementation of procedure described in Table 17 on selected list of unwanted consequential alarms due to equipment out of operation.
Performance gain	63 Standing alarms will be taken away from operator screens. (assume one full screen can accommodate 30 alarms, meaning that 2 full screens of scrolling is avoided)
Safe and Improved Operations	It's easy to get overview of recent alarms. Helps the operator to gain confidence on plant situation.
Cost Effectiveness	Saving cost, resources and competency required to mount hardwired running signals from field panels. (For instance, for each hardwired signal it may take anywhere between 2 to 3 days of offshore days)

Table 27 Evidence Report Analysis – Equipment OutofOrder

The result of executing procedural stages suggested in section 6.5.1.3, by reducing alarm chattering due to bad tuning of alarm dead bands and alarm delays, in terms of performance gain and cost effectiveness shown below

Process	Chattering Alarms
Procedural stages to handle standing alarms as shown in Table 19	Implementation of procedure described in Table 19 on selected list of top 101 alarms
Performance gain	A result of tuning these 101 alarms with correct dead band and delay time settings causes, 27708 repeated occurrences has been eliminated.
Safe and Improved Operations	The noise and fatigue created by 100 alarms repeated occurrences (27000 + times) is highly stressful and distractive. Implementing these measures relieves the operator from this noise and helps to concentrate more on safe operations.
Cost Effectiveness	Saving cost on having a dedicated team to analyse the alarm noise repeatedly.

Table 28 Evidence Report Analysis – Chattering Alarms

7. Conclusions

This research sought to determine, if it is possible to find any cost-effective solutions within process industry alarm management activities, considering the challenges in the industry due to cost cutting measures. There have been times when alarm management was not given enough emphasis while considering safe operations. But accidents like the explosion in Texaco Milford Haven Refinery in 1994, where two operators receive more than 200 alarms with in last 10 minutes elevates the situation of alarm overload and the necessity of its management.

7.1. Research Focus: Summary of Findings and Conclusion

In 2004, when safety responsibility was separated from the Norwegian Petroleum Directorate and a separate entity was formed called PSA (Petroleum Safety Authority), a clear definition of regulations was made possible. Further, the Norwegian Oil and Gas association developed guidelines for application of IEC 61508 and IEC 61511 in the petroleum activities on the continental shelf (previously known OLF guidelines). This way both government and regulation authorities ensure that the necessary regulations and necessary guidelines have been established for safe operations for use in the Norwegian petroleum industry.

7.1.1. Regulations

This research started with its primary focus on finding out key regulations for alarm management activities within the framework of HSE compliance. Though this research is predominantly confined to Norwegian continental shelf, encouraged to explore regulations and standards defined in various regions across the globe. The acknowledged awareness gained through regulations, worksheets, standards and guidelines led this research in right direction to establish relevant procedures as a result of this study. This study also reveals that Norwegian continental shelf (NCS) have more balanced regime among various stakeholders within and outside system than any other regions.

The supervisory regime on the Norwegian continental shelf builds on the fact that, the regulator cannot “supervise and inspect” quality and the responsibility lies within the operating company in the Norwegian petroleum sector. The responsibility for operating in compliance with regulations rests with the industry itself. (Lindøe, 2017) has explained the step by step development of the Norwegian regime in more detail in his work.

The importance of a performance-based approach as opposed to a prescriptive approach is noticed during this study. The performance-based approach being adopted as an "Internal Control Principle" allows the companies to check their own operations in a systematic manner. This approach gives companies enough freedom to establish internal management systems to meet the targets set by the regulator. Providing necessary framework to help organisations to establish required management routines for successful deployment of alarm management activities is an underlying objective of this research.

As a unique feature of this research, all key regulations concerning alarm systems within the framework of petroleum safety authority HSE regulations are identified. Key regulations and corresponding guidelines were basic building blocks to what this thesis believed to build on, and took the responsibility to convey what they mean in safe operations.

7.1.2. Procedures

A total of 10 participants were interviewed having different roles and responsibilities but a unique similarity, to strive for better alarm systems. Operators, Engineers, Leaders, and Authorities, everyone takes it as a challenge to address the issues, contribute their own experience based observations, suggestions, lessons, and specifics about the alarm system they are working on. Some results were quantified, some were qualitative, but the abstract conceptualisation is carrying more than what individual process results are speaking about. Due to time limitations and resources available for this study only three aspects of alarm engineering were taken into detailed experimentation in coordination with Eldor Management System.

The package of three selected aspects such as alarm rush, standing alarms and chattering alarms are unique in nature and have a high focus being observed by organisations and authorities. The procedural stages for the package which I would like to call "Dynamic Alarm Handling" activities have been drafted and been validated to implement on one offshore installation.

To answer the very basic unspoken objective of this research "find cost-effective solutions", the proposed solutions were tested hypothetically for their cost-effectiveness and results were satisfactory. Though this research wanted to limit its scope by defining procedures only for selected aspects, the relevance gained by the "alarm optimisation" process from qualitative study, left me with no choice except to produce a suitable template for alarm optimisation process both in green filed and brown field projects.

Referring to clause (The Management Regulations, 2016) § 8, “responsible party shall set internal requirements that put regulatory requirements in concrete terms, and that contribute to achieving the objectives for health, safety and the environment”. This research has started to understand the significance of this clause more in details concerning to alarm management as a result of dialogue with authorities. “Audit Questionnaire” was the tool used to conceptualise the interview findings and this research suggested a relevant management model for alarm management activities.

The procedures, templates and management model suggested by this research as an “active experimental” measure, provides a guidance and is flexible in nature. These methods can be adjusted and adopted according to organisational policies, performance measures and internal management routines.

7.1.3. Justification

It has been a demanding question, since beginning of this research, “Why should organisations focus on alarm management activities?” Understanding the improvement of performance in operations and the operator’s availability for safety operations instead of fixing alarm issues, does not give enough justification for a capital investment. This thesis tries to quantify the benefits and thereby provides a justification to have focus on alarm management activities in both offshore and onshore industries.

Based on the facts derived from interviews and a contract report produced by Bransby Automation Limited (Bransby & Jenkinson, 1998) for “The Health and Safety Executive –UK”, the justification for the alarm management is derived. The loss due to poor performance of alarm systems is derived in terms of the cost of the shutdown that the detailed alarm protects against, frequency of shutdown protected by the alarm and the chance of the operator missing the alarm.

Determining cost and associated financial loss due to poor performance of an alarm system might be used to justify an investment plan which will focus on alarm management activities. This research does not claim that the above represents a rigorous analysis, and it may need to be further refined. However, it does provide a pointer to an approach than might usefully be taken for plant where there has already been in-depth risk analysis.

7.2. Contribution to Knowledge

This research identifies the power of "Research focus defined," which empowers and enables organisations to identify key regulations concerning alarm management activities. It was not long before that all of the concerned regulations were identified and had sufficient knowledge to apply these regulations in various alarm management activities. By creating a question about developing required procedures, much of the details of the alarm engineering methods were solved and created safety integrated solutions.

The justification to keep focus on alarm management activities and estimation of incurring losses due to poor performance of alarm system does generates an awareness of this intangible aspect of alarm systems and helps the organisation to keep continue this focus throughout the life cycle.

7.2.1. Recommendations

Based upon the experience gained by this research and the knowledge acquired through various levels of this research, the best advice about working with alarm systems summarised below:

- Organisations, support functions and leaders who is involved in safety operations, need to maintain a continuous focus on new and updated versions of management of alarm systems within the process industry. (Includes regulations and industry standards)
- Every organisation's internal management routines must ensure that, alarm system performance metrics must be defined and tracked on regular basis. Any deviation found needs to be addressed and take necessary measures to keep the performance metrics with in the specified limits.
- Though deployment of processes defined in this thesis reduce the intervention of repeated analysis of alarm systems, it is recommended to have a team to deal with top 10 nuisance alarms on continuous basis to be able to maintain the alarm system within the specified limits.
- Once the need for an alarm project is identified, the integration of various aspects of alarm projects (Discussed elsewhere, not in the scope of this thesis) need to be maintained for better results.
- While executing alarm projects, care should be taken to maintain the same team and ensure respective system experts are available based on the desire for successful project completion as scheduled.

- After the alarm project is finished, often alarm systems are allowed to degrade over a period of time due to lack of discipline in following change management procedures. This must be avoided so that expensive and time-consuming alarm project upgrades can be avoided in later stages.

With these recommendations, I'm concluding my research on process alarm management – an investment towards safe and reliable operations.

7.3. Self-Reflection

This research study has been an educational and inspirational process. As I'm approaching the end of the journey and looking forward to the thesis being submitted, accepted, I can see graduation as a reality. I would highly recommend others to obtain a research based Master's Degree. During this study, I often found myself not being able to help but to bring up the concepts I have learned during discussions on regular basis. I quote those findings, comments, send links and emails for further clarification of my understanding based on conversations of related matters.

The concept of building the context was difficult to truly grasp at first. There are so many others who have researched much more than I have, spent years of studying, and even working in the areas of alarm management. How to define the focus for this research considering the numerous problems to solve and make this study unique? But later I realised that, these are not the questions I have raised to solve, but the chosen methodology and unspoken objective of this thesis "cost-effective solutions" brings the uniqueness to this study.

The knowledge gained through existing literature review, understanding offshore context and HSE regulations will certainly affect my project management skills going forward. The concept of identifying the relevant regulations will help to understand the Norwegian offshore context in a greater way not limited to alarm management activities only.

In response, the number of characteristics to be evaluated in the questionnaire have been increased and became diversified among various disciplines. This diversification helps to develop individual questionnaires, so that there could have been more focused questions on specific characteristics, yet with fewer questions in each questionnaire.

The multitude of the work required due to the utilisation of cross-sectional and longitudinal study methodologies created an extra workload that was nearly unmanageable for a 35-week dissertation process. A fair amount of research work resulted in analysing various offshore installations for their nature in production, supportive systems they are using for process control, and working culture was digested, as this was needed to establish a viable research instrument to gather the data needed for interviews. But the process itself did not factor into thesis work due to the irrelevance it created for the topic chosen. However as in the end, the data took me to analyse interview results in more simple way.

In addition, I have learned to work more disciplined and structured than I have in the past. The financial obligation, even though on the part of my employer, is a good motivation to reach the goal. The process of data collection and storing the information in a systematic way has been a great challenge, but believing in receiving my Master's encouraged me enough to find methods and manners in which I could accomplish this.

I have also learned about research and analysis, and this too will be helpful in my current position. I was so surprised to see that I enjoyed the part of analysis thoroughly. I never been a statistical mathematician, so I enjoyed doing the data analysis and was surprised to see the results coming in and fitting the purpose.

I'm pretty sure that I am not the first person who has said that eight months is not a lot of time for process such as this. The amount of work and consideration needed in research study took me off guard and delayed my progress significantly at some point of time. I am pleased with the result and I'm glad that I made the investment of time.

As an end note, I wonder if the goal chosen for this research is vast and I am not certain if I identified all relevant aspects of alarm management, but certainly that the processes identified has proven to facilitate successful implementation resulting in performance improvement in alarm systems, and the end result would be safer and more reliable operations in process industries.

I'm glad that I chose to get a Master of Technology and Operations Management and look forward to the possibility of a doctorate to further investigate this.

7.4. Limitations and Future Scope

As repeatedly mentioned, this research is more or less confined to process alarm systems within the petroleum industry on the Norwegian continental shelf. The idea this thesis generates from the concept of covering vast range of process industries and regulation regimes with respect to alarm systems. Though the regulation regime is more or less the same in various regions (Limited to Alarm Management regulations), the variations in process industry might pose an altogether different set of alarm system specifics to deal with.

There seems to be a reasonable suggestion of generalisation in this research addressing various types of process industries, but an increased sample size would be required to further confirm this.

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Appendixes

Appendix (I) Eldor Management System

Eldor AS has been providing alarm services for past 10 years leaving its foot print in various offshore plants and now expanding its horizons towards digitalisation into operational support by notifying upcoming alarm situation based on plant model.

Moving from core specialization towards more varied services may improve the quality of work life and this flexibility thus benefits the employee and the organization. (Heizer & Render, 2014). By looking at the Eldor Management system and its implementation for various alarm projects over the last few years, through a pre-dialogue with process owners, regulator and control system vendors its observed that challenges have arisen due to variation in requirements for the job from different clients and different control systems.

(Heizer & Render, 2014) mentioned, variation in job improves the quality of work life, but only if it is clearly defined. It is hoped this research will bring some standardized routines and procedures for the alarm engineering process in EMS and same can be inherited to other processes as well.

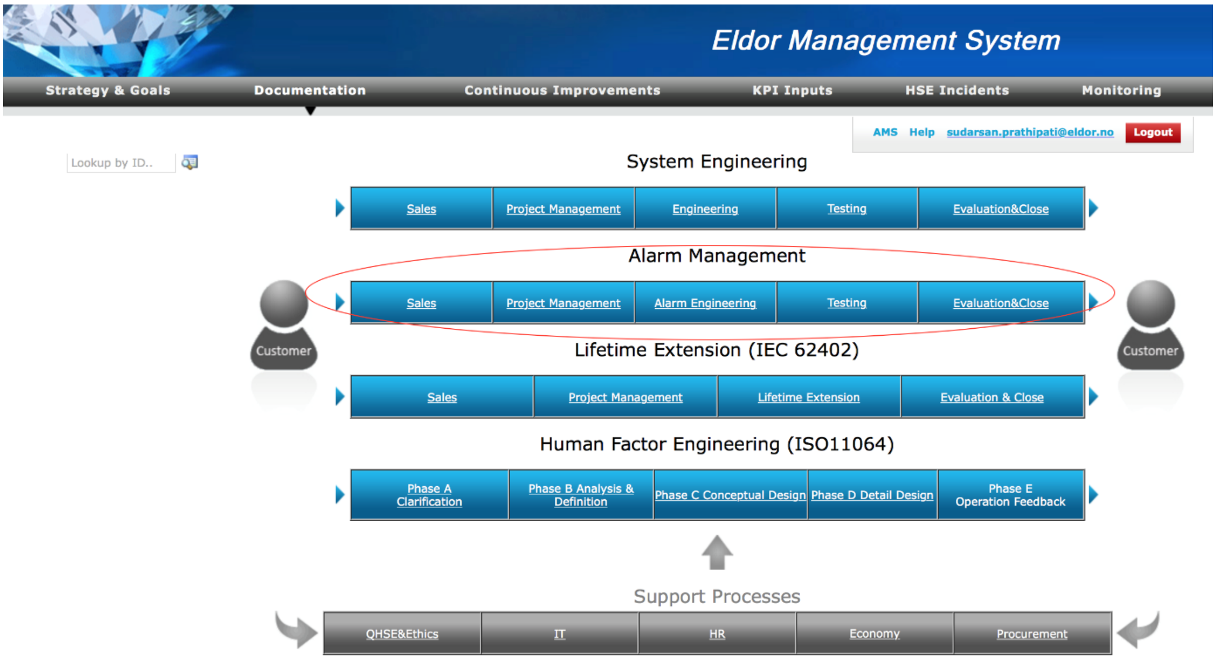

Figure 24 Eldor Management System

The above figure shows various services provided by Eldor and their processes with in the EMS system, such as system engineering, alarm management, life time extension and human factor engineering. This research will choose to constrain its study related to procedures involved in alarm management process.

The service of alarm management consists of following processes

- Sales
  - Procedures related but not limited to marketing, sales and business case development are covered within this process
- Project Management
  - Procedures related but not limited to project initiation, scheduling, management and deliverables are covered with in this process
- Alarm Engineering
  - Engineering aspects of alarm engineering including checklists, templates, standards, guidelines and quality assurance procedures are covered with in this process.
- Testing
  - Testing requirements for an alarm system is specified
- Evaluation & Close
  - Performance measures after implementations, customer feedbacks, lessons learned and change management procedures are involved with in this process.

Appendix (II) EMS Process Map – Process Alarm Management

ELDOR

Process Alarm Management

Department	Alarm Management	Document Type	Processmap
Process	Alarm Management	Process Owner	Arvid Halrynjo (arvid.halrynjo@eldor.no)
Document Level 2		Standard Ref.	
Revision Description Updated link to Process Evaluation			

Alarm Management Process

(Responsible icon)	Responsible	(HSEQ risk icon)	HSEQ risk	DM:	Department Manager	DC:	Document Control
(Accountable icon)	Accountable	(Financial risk icon)	Financial risk	PM:	Project Manager	HM:	HSEQ Manager
(Consulted icon)	Consulted	(Checker icon)	Checker	PE:	Project Engineer	AM:	Administration Manager
(Informed icon)	Informed			EM:	Engineering Manager	R:	Risk
						AA:	Add Item

No	Activity							R	Comment
	Process Project Management	START							
0.0	**Alarm Guidelines and Standards**								
	EEMUA 191	Informed	Informed	Informed	Informed				
	YA711	Informed	Informed	Informed	Informed				-
	ISA 18.2	Informed	Informed	Informed	Informed				
	IEC 62682	Informed	Informed	Informed	Informed				
1.0	**Philosophy**								
1.1	Write alarm philosophy	Accountable	Responsible	Checker					Philosophy example / FDS
1.2	Write a site technical specification	Accountable	Responsible	Checker					Template Alarm System FDS
2.0	**Identification**								
2.1	Interviev of operators		Responsible	Checker					Template Interview of Operators Template Report after interview of Operators

Document ID: 390093
Rev. date: 29 Sep 2017

2.2	Evaluate work process and training of users to use the workprocess	
2.3	Master alarm database with candidate alarms, or current alarms in the case of an existing system	
2.4	Identification and removal of "Bad Actors" in existing system by use of top 10 lists	
3.0	**Alarm Rationalization**	
3.1	Define rules and regulations valid for the project Write a Alarm Project Study report Update of MDR/MDL as required. Change request to be sent to project DCC.	Template Alarm System FDS Alarm Study Report Template Template MDR Change Request Template Request for doc issue
3.2	Get offer from control system vendor for participating in the project	
3.3	Make information and training plan for stakeholders	Alarm Management training
3.4	Get SAS vendor to make test and installtion philosophy	
3.5	Define members in workshops and get customer approval	
3.6	Define output format from workshops and get it approved from control system vendor and customer. Ensure that all Output formats are delivered with identical setup of coulumnes and cells within the same project	Template Design Input 800xA Template Design input ABB MP_Advant Template Design input Kongsberg
3.7	Make workshop plan and invite all members	
3.8	Get lists with process alarms	
3.9	Make list with system alarms for prioritizing	Alarm priority query list
3.10	Make list with fire and gas alarms	
3.11	Make list of alarms on communication links and communication usses to be prioritized	
3.12	Make document of alarm parameters for different objects	
3.13	Make list of alarms suitable for using in workshops	
3.14	Make set of valid P&ID for use in workshops	
3.15	Make a set of valid ESD&PSD C&E, block	

	diagrams and F&G C&E for workshops	
3.16	Checklist output from Workshops	Check list Alarm Rationalization Project
4.0	**Detailed Design**	
4.1	After workshops send design basis to control system vendor.	
4.2	Make control system vendor to write work packages	
4.3	Get work shop outcome approved by process technical autohrity	
4.5	Get wellhead priorities approved by well engineer	
4.6	Get F&G priorities approved by safety technical authority	
4.7	Present continues reports of distribution of priorities during the Alarm project. (According to goal figuers)	Template Progress report_results
5.0	**Implementation**	
5.1	Update installtion timeestimate and schedule	Template Alarm Rationalization WS and installation plan Template Project progress tracking master
5.2	Make a report of alarm priorites before and after workshop	
6.0	**Operation**	
5.3	Arrange MOC	Alarm modification MOC form
5.4	Arrange information meetings	
5.5	Implement installtion activities in customer maintenace system	
7.0	**Maintanance**	
7.1	Periodic review of key performance indicators against the defined alarm philosophy	Alarm Integration Report_KPI
7.2	Auditable documentation showing alarm system changes are done in accordance with the site alarm philosophy, MOC	Alarm modification MOC form
7.3	Training Alarm Management	Alarm Management training
8.0	**Audit**	
8.1	A audit report documenting that the alarm management system is performing as described in the site alarm philosophy and fulfilling the necessary guidelines and standards	
	END	Process Evaluation

Appendix (III) Regulations- Different Regimes and Agencies

The purpose of this section is only for informative and should not be considered to be a legal advice, safe operation or any other advice. This thesis will not discuss any other regulation with in Norway or any other part of the world with the exception of those explicitly mentioned by the name.

Regulatory Regimes and Their Emphasis

Each regulation is emphasizing on various dimensions of the alarm management activity. In jurisdictions where the governing authorities (e.g., national, federal, state, county) have established process safety design, process safety management, or alarm management requirements, these should be taken into consideration along with available international standards.

OLJEDIREKTORATET	Principles of Alarm Design – YA 711
Version History	February 2010
Regional Version	Prinsipper for utforming av Alarmsystemer –YA 710
Emphasis	• Alarm generation, structuring, prioritisation, presentation and alarm handling • Intended to help both in improving existing systems as well as during development of new systems and modifications

Table 29 Alarm Management Guidelines – Norway

NAMUR	NAMUR Worksheet Alarm Management NA 102
Version History	Current Edition :02.10.2008 First Edition : 31.10.2003
Regional Version/Comments	NAMUR-Arbeitsblatt – NA 102 *These papers are neither normative standards nor guidelines.
Emphasis	• Sets out a procedure for designing alarm management within a process control system starting from a global view of the process as a whole. It includes message signals but focuses on alarms • During the engineering and erection phase, the worksheet is intended as a general guide from which a part of an individual PCS specification can be derived by tailoring it to fit a particular unit of Equipment

Table 30 Alarm Management Guidelines - Germany

	HSE: The Management of alarm systems – Contract Research Report 166/1998
Version History	First Published 1997
Regional Version/Comments	It has been produced as a part of a research project funded by the UK Health & Safety Executive. The project objectives were to survey alarm systems in the power and chemical industries and hence identify and report current industry best practice
Emphasis	• Gives recommendations on current best practice in the procurement, design and management of alarm systems • Describes alarm improvement exercises and provide a rapid way of obtaining an insight into the potential for alarm reduction

Table 31 Alarm Management Guidelines – UK

	29 CFR 1910.119- Process safety management of highly hazardous chemicals.
Version History	Last updated October 10, 2017
Regional Version	Part of Federal Regulations
Emphasis	• This section contains requirements for preventing or minimizing the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals • Describes about process hazard analysis, emergency preparedness, operator training requirements, operational efficiency procedures including proper alarm management

Table 32 Alarm Management Guidelines – USA

	ANSI/ISA-18.2-2016, Management of Alarm Systems for the Process Industries
Version History	ANSI/ISA-18.2-2016 supersedes the original edition (2009)
Regional Version/Comments	To achieve uniformity in the field of instrumentation, this standard was prepared by ISA (International Society of Automation). In 1955 ISA formed a survey committee titled Instrument Alarms and Interlocks. The committee evolved to Standard & Practices committee 18. In 1965 the committee completed ISA–RP18.1, Specifications and Guides for the Use of General Purpose Annunciators. In 1979 ISA released, as a product of the ISA18 and ISA67 committees, ISA–18.1–1979 (R2004), Annunciator Sequences and Specifications

Emphasis	• This standard specifies general principles and processes for the lifecycle management of alarm systems based on programmable electronic controller and computer-based human-machine interface (HMI) technology for facilities in the process industries • The practices in this standard are applicable to continuous, batch, and discrete processes

Table 33 Alarm Management Guidelines – ISA

EEMUA	EEMUA Publication 191 Alarm systems - a guide to design, management and procurement
Version History	First published in 1999 December 2013, EEMUA has launched the Third Edition of Publication 191
Regional Version/Comments	The publication, developed by users of alarm systems with input from the UK Health and Safety Executive
Emphasis	• The aim of this Guide, EEMUA 191, is to assist in the design, development, procurement, operation, maintenance and management of industrial alarm systems • This guide provides clear – and now tried-and-tested – guidance on alarm system design, maintenance and continuous improvement.

Table 34 Alarm Management Guidelines –EEMUA

IEC	IEC 62682:2015 Management of alarm systems for the process industries
Version History	First Edition Publication: 2014-10-15
Regional Version/Comments	International Standard IEC 62682 has been prepared by subcommittee 65A: System aspects, of IEC technical committee 65: Industrial-process measurement, control and automation
Emphasis	IEC 62682:2014 specifies general principles and processes for the lifecycle management of alarm systems based on programmable electronic controller and computer-based human-machine interface (HMI) technology for facilities in the process industries. It covers all alarms presented to the operator, which includes alarms from basic process control systems, annunciator panels, safety instrumented systems, fire and gas systems, and emergency response systems

Table 35 Alarm Management Guidelines - IEC

Appendix (IV) Operators Questionnaire

Thesis Questionnaire
Process Alarm Management
In Coordination with University of Stavanger and Eldor AS

University of Stavanger

ELDOR
SYSTEM ENGINEERING
deeper into details

This questionnaire is a part of a master thesis *"Process Alarm Management – An Investment towards Safe and Reliable Operations"*.

This questionnaire will focus on understanding a control room operator insight into an alarm system and requirements for well-functioning alarm system for safe and reliable operations. This research has identified 4 dimensions of an alarm system to justify the requirement for any alarm management activity

1. Cost of Poor Performance (Financial, Risk to people, environmental)
2. Large and Complex (A database consists of several thousand alarms)
3. Not -one time fix (Continuous Improvement and Change Management)
4. Valid KPIs (An indication of safe and reliable operations rather than a statutory requirement)

Process operator's day to day experience with process controls and their insight into alarm systems is the key to establish principles of alarm design for smoother operations. Along with process operator's insight, this thesis will try to gather inputs from discipline leads, regulatory authorities and control system engineers to establish the frame work to deliver a well-functional alarm system for safe and reliable operations.

Eldor AS is a leading company in Alarm Management for the Oil and Gas industry in Norway for past 10 years. Eldor AS believes in

- Optimized alarm system gives optimized decisions
- Alarm systems needs to be specified and maintained to ensure safe operations

Eldor Management system (EMS) is the framework of strategy, goals, processes and procedures used by Eldor AS to ensure that the tasks delivered by the organisation is in line with their vision and mission. "*Alarm Engineering*" is one of the core process in EMS where it describes several procedures for various alarm management activities.

This results from this research will primarily evaluate and recommend improvements in existing EMS-Alarm engineering process according to principle of alarm design (Norwegian Petroleum Directorate, 2011). Keeping the principles of design intact, this study will also try to identify the key invest drivers behind the desire to improve alarm management such as

1. Regulatory compliance and safety concerns
2. Improving operations and reducing trips/downtime
3. Retention of operator knowledge

A well-functioned alarm system combines with coordinated operations management can drive not only safet and ensure regulatory compliance but promote better plant availability and throughput, delivering real business value. (Honeywell, 2017)

Thesis Consent

Name of the Researcher: Sudarsan Prathipati
University of Stavanger
Master in Technology and Operations Management

This interview will take about 50mnts to answer these questions. Considering their complexity of questions with regards to technical details involved, this questionnaire is designed for face to face interview instead of online survey.

Each question will carry a weighted score and median of all these weighted scores from all participants will be taken for further analysis.

Thank you for taking time to participate and before we begin, could you please read the following statements and then confirm your participation?

- I understand that this questionnaire is designed to gather information about academic work for faculty of science and technology – University of Stavanger.
- I understand that I will be one of the 10 people being interviewed for this research
- I understand that this research involves, answering questions related to day to day activities related to alarm systems in my organisation
- I understand that interviewer will make the notes during interview and no audio tapes will be used for this interview
- I understand that information about me will be treated in strict confidence and researcher will not identify me by name but my position. My confidentiality as a participant in this study will remain secure.
- I understand that no one will have access to raw notes or transcripts other than researcher from my interview.
- I have read and understand the explanation provided to me regarding this research and agreed to participate in this study.
- I have been given a copy of this thesis consent form

Participant Signature	Researcher Signature
Offshore Prod´n Coordinator	*Sudarsan Prathipati*

Section – 1: Alarm System Performance

1 ABOUT YOU

1.1 Position in Organisation?	Offshore Production Coordinator (OPK)
1.2 How many days per rotation working in process control room?	7 out of 14 days.
1.3 Do you serve as an area operator in the field? (always/sometimes/never)	Sometimes, but mostly coordination work when it comes to field activities.
1.4 How long you have been working in this site/installation –Yrs./Mon?	Started March 2010

2 WORKING ENVIRONMENT

2.1 Does this process plant have more than one control room?	
- Unit based control rooms / Central control room (CCR)	No, only CCR. (We have some alternative OS's, but they are not manned)
2.2 How many operators for per shift in CCR?	
- CCR or Area or Unit control room	3
2.3 How many Operator stations in CCR and Operators per station?	
- Process control, F&G, Subsea, Marine etc..	3 manned OS's in CCR, that means one OS each operator. Operator dedicated for marine operations, but work task overlap. There is two additional OS's available in CCR for use in special work or special occasions.
2.4 How the alarm response actions are allocated among the available operators?	
- Operator availability - Process system - Operator station etc.	Both system and operator availability. Same alarm filter (predefined) is default on all OS's.
2.5 What are the supporting systems for process monitoring and control for daily operations?	
- HMI, Radio, Well controls, Alarm systems, Lamps, LSD etc.	Kongsberg AIM control system, four screens on each OS. Kongsberg LSD (4 overview displays). 1 display CCTV-camera. Tetra radio communication (UHF), but also VHF-boat-communication and Helicopter communication.

	CAP-panel (hardwired).PA-speaker. Metering flow control screen for export oil/gas. Additional marine systems as NAPA (Loading/Offloading computer), MIROS weather station, Radar system, POSMOR.
2.6 What are the supporting systems for process safety and emergency preparedness?	
- PA, CAP, Pre-defined routines, Alarm system etc..	PA, CAP, ESD/PSD, IOPPS, OPPS, KM Alarm system including 3rd part equipment alarms communicating to KM. POSMOR (positioning system with heading control). Automatic alarm to muster personnel in F&G-situations.
2.7 Is there any other means of alerting apart from control and safety alarm system? (For process control)	
- Blinking lights, Horn, Stand-alone panels etc..	DARPS, Lightning, Fogg horn, reflectors, radar.
2.8 Does Alarm system supports you as it should for different plant conditions?	
- Normal operations - Start-Up - Shutdown Very good/ Ok / Poor/ Very Poor	Yes, mostly very good, at least in normal operations, but also quite good during start-up. In shutdowns we get alarm rush, so we risk drowning/missing valuable process information. But the, we keep track on level-1-alarms (F&G), so we do not risk missing on these.
Any other comments	

3 CONTROL AND SAFETY ALARM SYSTEM – (BEFORE ALARM MANAGEMENT ACTIVITY)

<table>
<tr><td colspan="2">3.1 How often alarm comes in normal operations? Very often, Often, Normal, Few</td></tr>
<tr><td>- Working situation (Feel of alarm load)
- KPI basis</td><td>In steady state, it varies, but most common maybe 3-6 alarm per hour. During operational set-up-situations (or bad weather), maybe 20-30 per hour.</td></tr>
<tr><td colspan="2">3.2 What is the most annoying thing about the alarm system you are working on</td></tr>
<tr><td>- Wrong prioritisation
- Alarm text of description
- So many system related alarms
- Alarms without any value/nytteverdi
- Inconsistency in presentation of alarms in different systems
- Too many standing alarms
- Too many alarms from equipment out of operation
- Safety related alarms are not explicitly identified
- No alarm-help available</td><td>System alarm is probably most annoying, as we get them on daily basis, and often we do not know what to do, or exactly what I mean.
We also have some common alarms in KM from third part systems, and often we cannot “find a way out of alarm state” on these.

We also have too many standing alarms and alarms from equipment out of operation, but hopefully an alarm project will handle many of these.</td></tr>
<tr><td colspan="2">3.3 Do you think the plant integrity in terms of “safe operations” could have been better, if alarm system is improved? Yes/No</td></tr>
<tr><td>- F&G system navigation corresponds to alarms
- Calibration of detectors/ correct level of alarm settings, to avoid false alarms
- Alarm rush handling
- Alarm response procedures</td><td>Yes. Alarm-system-rationalization project has already removed a lot of noise, and I expect it would be quite OK when project is finished. We well have less alarm-system-bugs.
Alarm response procedure for system alarm would be valuated grants.</td></tr>
<tr><td colspan="2">3.4 Do you think of any incident (Plant shutdown / Safety incident) connected to poor performance of alarm system? Uncertainty/Vulnerable to mistakes/ Incidents</td></tr>
<tr><td>- Alarm text (Description/message) not understandable or text misguided to wrong equipment/plant area</td><td>Yes, we have had an incident with loss of F&G detections on a huge area, but the system alarm was so poor that the operator did not understand what had happened. This lasted a</td></tr>
</table>

- Root cause alarm missed due to too many alarms in the system - Wrong prioritisation misguided the action to be taken - Not enough time between warning alarm and trip action - Wrong alarm limits lead to untimely warning - Too many standing alarms creates fatigue on alarm screen - Kind of new/first time alarm, so unaware of operator action (what to do, whom to contact, what is the consequence etc.)	hole nightshift until KM support discovered the situation next day. We assume we have had some process alarms earlier of poor quality, leading to process shutdown or process challenges, but I cannot remember any specific episodes.
3.5 How many incidents can you impart to poor performance of alarm systems in a year?	
- 1-5 - 5-10 - >10	1-5
3.6 Is there any Health, Safety and Environmental incident among these?	
- Near Miss - Minor to Severe injury - Environmental damage	Near miss, and minor incidents leading to flaring of gas.
3.7 What is the major consequence for a process shutdown (Provided no HSE incident)?	
- Start-up issue - Delayed production - Well integration - Quality - Off-loading schedule - Economic loss	Economic loss.
3.8 How long it will take to get back to normal production after a major shutdown? Hours	
- Pressurised shutdown - De-pressurised shutdown	Pressurised shutdown→8-12 hour to full production. De-pressurised: 16→48 hours

<table>
<tr><td colspan="2">3.9 What is the typical financial loss in case of a process shutdown? Barrels/MSM3/Dollars/Hours</td></tr>
<tr><td>- Loss of man hours
- Start-up expenses
- Production downtime
- Quality and off-loading issues</td><td>Production downtime is the major cost. Could be from 1-12 Million $.
The other costs are there, but they are small.</td></tr>
<tr><td colspan="2">3.10 Do you see the necessity of an alarm engineering project for improved performance, and what is the main driver for that?</td></tr>
<tr><td>- Regulatory compliance and safety concerns
- Improving operations and reducing trips/downtime
- Operator knowledge and Alarm help</td><td>Both regulatory and safety concern is equally relevant. (Reducing trips and safer operations)</td></tr>
<tr><td colspan="2">3.11 Does your team leads/Supervisor takes alarm system in confidence with regards to its support and KPIs? Yes/No</td></tr>
<tr><td>- Trust and believe in alarm system for safe and reliable operations
- Track the performance of alarm system
- Review action list from alarm performance reviews
- Launch efforts to deal with alarms occurring at an excessive frequency</td><td>Yes, partly. They are not implemented in main overall KPI's, but they run alarm reports on a daily/weekly basis. Keeping track on frequency, repetitious and fault solving.</td></tr>
<tr><td colspan="2">Any other comments</td></tr>
<tr><td colspan="2"></td></tr>
</table>

4 ALARM MANAGEMENT ACTIVITY EXPERIENCE

4.1 Have you been involved with any of the alarm project activities?	
- Rationalisation - Top-N alarms - Alarm Suppression - Signal conditioning (Hysteresis, Filter time.) - Alarm Rush handling	Yes, all mentioned activities.
4.2 How long it took for one alarm including workshops, work packs and implementation?	
- Design input - Workshops - Approvals - Control system work packs - Installation	Around 3.5Hrs
4.3 What kind of activities have under taken in the last project?	
- Rationalisation - Top-N alarms - Alarm Suppression - Signal conditioning (Hysteresis, Filter time.) - Alarm Rush handling	All mentioned except from Top-N alarms.
4.4 How do you see the difference before and after alarm project?	
- Differentiation between alarm and information - Understandable alarms - Right prioritisation - Sufficient Response time - Alarm rush - Less number of standing alarms - No chattering - No duplicate alarms	More understandable alarms, less standing alarms, no duplications, and the "fake" alarms without any expected operator response, is removed.
4.5 How is the alarm load after alarm project (Ref: EEMUA 191)?	

- Predictive 1 alarm per 10 minutes - Stable 1to 10 alarms per 10 minutes - Over load >10 alarm per 10 minutes	If we remove the top-10-alarms which is caused by various faults/bugs, it is less than 1 alarm per 10 minutes.
4.6 Does alarm project achieve the integrity among all aspects of alarm engineering? (Ignore disturbances due to plant operations)	
- Text, Prioritisation, Response time, hiding, grouping, standing alarms, alarm rush and Top-N	Hopefully yes, especially when it comes to text. But there should be a noticeable overall improvement in the end.
4.7 Do you see any missing aspect of alarm engineering? Yes/No	
- Useful alarms missing - No enhanced filtering or dead bands - Operations are vulnerable due to wrong suppression - Lack of operators training on newly adopted methods - Alarm configuration not according to philosophy	Some alarms from third part systems, should have be avoided/removed, but these often comes to KM from "black boxes" as common alarms, and they are often hard to dig into.
4.8 If we should adapt same kind of alarm engineering aspects into other projects, what would be your advice for even better results	
- Methodology / Alarm engineering Process - Co-relation among different activities	Detailed pre-study to make sure the subprojects (different activities) comes in correct order to optimise workflow.
4.9 If the plant has multiple tie-ups, is there any strategy defined to handle alarms from different tie-ups?	
- All alarms to CCR - Individual tie-ups have their own manned consoles - Only remote observation etc.	As I see it we do not have any pre-defined strategies for different set-ups if that's the question. It is all based on actions based on alarms to CCR.
4.10 How do you describe the handling of alarms from remote tie-ups?	
- Too many alarms from tie-ups with limited access to control - Could have been used more grouping rather than individual alarms	Same answer as above

- Well defined procedures	
4.11 What is the one thing that you see and needs to be maintained even after alarm project is finished	
- Alarm priorities - Alarm limits - New alarm additions - Alarms on removed equipment - Alarm philosophy and strategy	Focus on alarm Top-list need to be a continuous work. When it comes to new projects we need to make sure that all the agreed roles are followed according to philosophy.
4.12 How do you rate the usability of improved alarm system	
- Have been very good support tool since then - Just right and needs some fine tuning - Could have been done in bit other way	Very good, but maybe we need some fine tuning on the way forward.
4.13 Does your team leads/Supervisor takes alarm system in confidence with regards to its support and KPIs after alarm project? Yes/No	
- Trust and believe in alarm system for safe and reliable operations - Track the performance of alarm system - Review action list from alarm performance reviews - Launch efforts to deal with alarms occurring at an excessive frequency	No, not officially. But I assume they have better confidence to the system. I guess it will come as an argument later in discussions about minimum operators needed to properly "run" CCR.

5 GENERAL QUESTIONS

5.1 Can you add any other comments which might help us improve alarm systems?
During commissioning, one should be more strict to alarm philosophy and restrictive when implementing alarms from 3rd part systems. Implement-all-available-alarms-philosophy during commissioning is hard to clean afterwards when all the "Vendor's are gone", as they sort of drown in "black boxes".

Appendix (V) Audit Questionnaire

Thesis Questionnaire

Process Alarm Management in Coordination with University of Stavanger and Eldor AS

University of Stavanger

ELDOR SYSTEM ENGINEERING deeper into details

This questionnaire is a part of a master thesis *"Process Alarm Management – An Investment towards Safe and Reliable Operations"*.

This questionnaire will focus on understanding a control room operator insight into an alarm system and requirements for well-functioning alarm system for safe and reliable operations. This research has identified 4 dimensions of an alarm system to justify the requirement for any alarm management activity

1. Cost of Poor Performance of Alarm System (Risk to people, Environmental, Financial)
2. Alarm system is large and complex (A database consists of several thousand alarms)
3. Not -one time fix (Continuous Improvement and Change Management)
4. Valid KPIs (An indication of safe and reliable operations rather than a statutory requirement)

Process operator's day to day experience with process controls and their insight into alarm systems is the key to establish principles of alarm design for smoother operations. Along with process operator's insight, this thesis will try to gather inputs from discipline leads, regulatory authorities and control system engineers to establish the frame work to deliver a well-functional alarm system for safe and reliable operations.

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- Optimized alarm system gives optimized decisions and Alarm systems needs to be specified and maintained to ensure safe operations

Eldor Management system (EMS) is the framework of strategy, goals, processes and procedures used by Eldor AS to ensure that the tasks delivered by the organisation is in line with their vision and mission. "*Alarm Engineering*" is one of the core process in EMS where it describes several procedures for various alarm management activities.

This research chooses to analyse existing regulations and evaluate process operator's requirement based on their valuable experience from different installations, so that results may be imparted into "Alarm Engineering" procedures available in EMS system. This research believes in keeping this impeccable relation between regulator, regulated and system support to achieve

1. Safe and Reliable operations
2. Retention of operator knowledge
3. Regulatory compliance and reducing trips/downtime.

A well-functioned alarm system combines with coordinated operations management can drive not only safety and ensure regulatory compliance but promote better plant availability and throughput, delivering real business value. (Honeywell, 2017)

Thesis Consent

Name of the Researcher : Sudarsan Prathipati
University of Stavanger
Master in Technology and Operations Management

This interview will take about 30mnts to answer these questions. Considering their complexity of questions with regards to technical details involved, this questionnaire is designed for face to face interview instead of online survey.

Each question will carry a weighted score and median of all these weighted scores from all participants will be taken for further analysis.

Thank you for taking time to participate and before we begin, could you please read the following statements and then confirm your participation?

- I understand that this questionnaire is designed to gather information about academic work for faculty of science and technology – University of Stavanger.
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- I have been given a copy of this thesis consent form

Participant Signature　　　　　　　　　　　　　　Researcher Signature

- I have been given a copy of this thesis consent form

Participant Signature   Researcher Signature

Section – 1: Alarm System Performance

1 ABOUT YOU

1.1 Position in Organisation?	
1.2 Main responsibilities?	

2 UNDESTANDING REGULATIONS

2.1 Major difference between Standards, Regulations and guidelines	
- Standards - Regulations - Guidelines	
2.2 What is the common source of regulations w.r.t to Alarm Management	
- PSA (Ptil)- Frame Work Regulations - ~~Lovdata - Arbeids- og sosialdepartementet~~ - ~~Any other~~	
2.3 Apart from Facilities regulations does there any other regulations w.r.t to Alarm systems	
- Innretningsforskriften Section 34a (Control and Monitoring Systems)	
2.4 Does these regulations are legally bound?	
- Regulations (Guidelines)	
2.5 Which authority is responsible for drafting regulations and their compliance requirements	
- PSA (Ptil) - ~~NPD~~	
2.6 (As in Facilities Regulation Guidelines) - With regard to the design of the alarm systems, the principles of the Norwegian Petroleum Directorate's (now the Petroleum Safety Authority Norway's) publication YA-710 (English edition YA-711) should be used.	
- Does this changeover (NPD to PSA) only limited to Alarm design principles?	
2.7 Will there be any new revision on YA-710/711	
- Last version on February 2001	IEC EEMUA
2.8 Any valuable comments on other Standards/guidelines about Alarm System	
- NAMUR Alarm Management NA 102 - HSE Management of Alarm System (166/1998) - ISA 18.2 - EEMUA 191 - IEC 62682 - Any other	
Any other comments	

3 AUDITING

3.1 Is there any difference in auditing process while auditing offshore and onshore facilities w.r.t to alarm system	
- Offshore IF - Onshore TOF	
3.2 What is the initiating criteria for an audit for any installation w.r.t to alarm system	
- Statutory requirement - Post incident survey - Scheduled activity for all installations	Intern planlegging Risiko-basert, skjønn
3.3 Which authority have the principal responsibility towards Alarm Management Audits	
- ~~Norwegian Directorate~~ - Petroleum Safety Authority	
3.4 What is the difference between observation and deviation in an alarm management audit	
- Observasjoner /Forbedringspunkt - Avvik	
3.5 Which document will be the basis for defining Observasjon or Avvik?	
- Company defined Alarm philosophy - Principles of Alarm system design (YA-710/ YA-711) - International standards like ISA	SF 5 - 8 IF 21 / 340
3.6 What is the obligation for the company towards these two findings	
- Observasjoner - Avvik Korrigeres	
3.7 What takes the priority when it comes to "shall" and "should" requirements	
- Company defined Alarm philosophy - Principles of Alarm system design (YA-710/ YA-711) - International standards like ISA and EEMUA	Should som, likeverdig løsning ok.
3.8 How does the "Regulator" (PSA) identify weakness of an alarm system	
- Operator questionnaire - Observation in CCR - KPI analysis - Technical/Operations Team lead interviews - Any other } Alle	
3.9 It's been quite evident from various audit reports, that Regulator is keen on procedures to assess performance and quality of alarm systems by companies, how does this assessment will be done	
- Requirements set by the Company - Regulations	Selskapene må sette de spesifikke kravene.
3.10 What is the timeline for fulfilling compliance after an audit	
- Months Selskapets ansvar	å fastsette
3.11 Will there be any follow-up audit after implementation	
- Yes/No	Kan være, ikke vanligvis.
Any other comments	

Prosess-tilpasning, grense-verdier, last-alarmer.

4 GENERAL

4.1 Can you add any other comments which might help us improve alarm systems?

Appendix (VI) Interviews- Quantitative phase descriptive statistics

See below attached excel sheet for results

Expereinced Learning :: Concrete Experience and Reflective Observation ::Thesis Questionnaire Alanylsis - Process Alarm Management - Control Room Operators

In Coordination with University of Stavanger and Eldor AS

1 ABOUT YOU	2 WORKING ENVIRONMENT	3 CONTROL AND SAFETY ALARM SYSTEM (BEFORE ALARM PROJECT)	4 CONTROL AND SAFETY ALARM SYSTEM (AFTER ALARM PROJECT)
1.1 Position in Organisation?	2.1 Does this process plant have more than one control room?	3.1 How often alarm comes in normal operations?	4.1/4.3 Have you been involved with any of the alarm project activities?
*	- [1,2,3, etc.,]	- Very Often [10], Often [2], Normal [-2], Few [-6]	Rationalisation [0] ,Top-N alarms [2], Alarm Suppression [6], Signal conditioning (Hysteresis, Filter time.) [8], Alarm Rush handling [12], All Above [16], None of the Above [-2]
1.2 How many days per rotation working in process control room?	2.2 How many operators for per shift in CCR?	3.2 What is the most annoying thing about the alarm system you are working on	4.2 How long it took for one alarm including workshops, work packs and implementation? (Alarms per Workshop)
- [Days]	- [1,2,3, etc.,]	Wrong prioritisation [0], Alarm text of description [2], So many system related alarms [6], Alarms without any value/nytteverdi [8], Inconsistency in presentation of alarms in different systems [10], Too many standing alarms [12], Too many alarms from equipment out of operation [14], Safety related alarms are not explicitly identified [16], No alarm-help available [18], ESD Rush [22], No Display to Alarm [26]	[> 1] Assume One Week Workshop
1.3 Do you serve as an area operator in the field?	2.3 How many Operator stations in CCR and Operators per station?	3.3 Do you think the plant integrity in terms of "safe operations" could have been better, if alarm system is improved? Yes/No	4.4 How do you see the difference before and after alarm project?
- [CCR = 100/ Field =0 / CCR+FIELD= 50 / % of time in CCR]	- [1,2,3, etc.,]	- [YES = 10/ NO =0/SOME EXTENT = 6/ DONT KNOW = -1]	Differentiation between alarm and information [0], Understandable alarms [2], Right prioritisation [6], Sufficient Response time [8], Alarm rush [12], Less number of standing alarms [16], No chattering [20], No duplicate alarms [24], MUCH MORE TO IMPROVE [28], OVERALL IMPROVEMENT [32]
1.4 How long you have been working in this site/installation –Yrs./Mon?	2.4 How the alarm response actions are allocated among the available operators?	3.4 Do you think of any incident (Plant shutdown / Safety incident) connected to poor performance of alarm system? Uncertainity/Vulnerable to mistakes/ Incidents	4.5 How is the alarm load after alarm project (Ref: EEMUA 191)?
- [Expressed in terms of Months]	- Operator Availability[0], Proces Area[2], Both[6]	- [YES = 10/ NO =0/DONT KNOW = -1]	- Predictive 1 alarm per 10 minutes [0] - Stable 1to 10 alarms per 10 minutes [2] - Over load >10 alarm per 10 minutes [6]
	2.5/2.6 What are the supporting systems for process monitoring and control for daily operations and safety/emergency preparedness?	3.5 How many incidents can you impart to poor performance of alarm systems in a year?	4.6/4.7 Does alarm project achieve the integrity among all aspects of alarm engineering? (Ignore disturbances due to plant operations)
	- Alarm Systems, HMI, Radio, Lamps, PA, CAP [0]+ CCTV [2]+ LSD [6] + Well Control [12]	1-5 [2], 5-10 [6], >10 [12], HARD TO TELL [-2]	- [YES = 10/ Some Extent = 6 /NO =0/DONT KNOW = -1]
	2.7 Is there any other means of alerting apart from control and safety alarm system?	3.6 Is there any Health, Safety and Environmental incident among these?	4.11 What is the one thing that you see and needs to be maintained even after alarm project is finished
	No Others [-2], Marine [0], Marine, Radar [2], Marine, Radar, Others(DARPS,Lightining,Fogg etc.,) [6]	NEAR MISS [2], MINOR TO SEVERE INJURY [4], ENVIRONMENTAL DAMAGE [6]	Alarm priorities [0], Alarm limits [2], New alarm additions [6], Alarms on removed equipment [8], Alarm philosophy and strategy [12], Top- N Alarms [16], Standing Alarms [20], All of the Above [24],
	2.8 Does Alarm system supports you as it should for different plant	3.7 What is the major consequence for a process shutdown (Provided no HSE incident)?	4.12 How do you rate the usability of improved alarm system
	Very Good[10], OK[8], Poor[0] Very Poor[-2]	START-UP ISSUE [2], ECONOMIC LOSSES [4], OTHERS (QUALITY,WELL INTEGRATION etc., [6]	- Very Good[10], OK[8], Poor[0] Very Poor[-2], DONT KNOW = [-1]
		3.8a How long it will take to get back to normal production after a major Pressurised shutdown? Hours	
		- [2-24]	
		3.8b How long it will take to get back to normal production after a major De-pressurised shutdown? Hours	
		- [8-48]	
		3.9 What is the typical financial loss in case of a process shutdown? Per Day	
		[> 1] (Actuals)	
		3.10 Do you see the necessity of an alarm engineering project for improved performance, and what is the main driver for that?	
		REGULATORY COMPLAINCE [2] +REDUCING TRIPS/DOWNTIME [4] + OPERATOR KNOWLEDGE AND ALARM HELP [6]	
		3.11 Does your team leads/Supervisor takes alarm system in confidence with regards to its support and KPIs? Yes/No	
		- [YES = 10/ NO =0/TAKEN AS GRANTED = -1]	

ID	Q1.1	Q1.2	Q1.3	Q1.4	Q2.1	Q2.2	Q2.3	Q2.4	Q2.5/2.6	Q2.7	Q2.8	Q3.1	Q3.2	Q3.2	Q3.2	Q3.3	Q3.4	Q3.5	Q3.6	Q3.7	Q3.8a	Q3.8b	Q3.9	Q3.10	Q3.11	Q4.1/4.3	Q4.2	Q4.4		Q4.5	Q4.6/4.7	Q4.11	Q4.11	Q4.12
1	OPK –Offshore Process Coordinator/ Senior Process- SKARV/BP	14	100	72	1	3	5	6	6	-2	0	10	8	8	8	10	10	6	6	6	12	20	2,5	4	NA	0	NA	NA	NA	NA	NA	NA	NA	NA
													22	22	22																			
													26	26	26																			
2	Offshore Production Coordinator (OPK)- SKARV/BP	14	50	84	1	3	5	6	6	6	8	2	6	6	6	10	10	2	6	4	12	48	12	4	10	16	NA	2	2	0	10	12		10
													12															16				16	16	
													14	14	14													24	24					
3	Process Tekniker / Control Rooms Tekniker -Total	240	50	54	2	2	2	0	6	6	10	10	2	2		10	10	12	6	4	12	24	6	6	10	16	NA	2	2	6	6	24	24	-1
													6	6	6													16						
													12																					

Expereinced Learning :: Concrete Experience and Reflective Observation ::Thesis Questionnaire Alanylsis - Process Alarm Management - Control Room Operators

In Coordination with University of Stavanger and Eldor AS

	1 ABOUT YOU				2 WORKING ENVIRONMENT							3 CONTROL AND SAFETY ALARM SYSTEM (BEFORE ALARM PROJECT)														4 CONTROL AND SAFETY ALARM SYSTEM (AFTER ALARM PROJECT)								
4	Senor control room technician – ULA AkerBP	14	50	156	1	2	4	0	6	-2	8	10	8	8	8	10	10	6	2	2	6	12	6	6	10	-2	NA	6	6	2	6	NA	NA	8
													2	2						4														
													12							6														
5	Senior Control Room Technician – Valhall AkerBP	14	50	228	1	3	3	6	6	-2	8	2	2	2		6	10	-2	NA	4	12	48	11	4	-1	-2	NA	16		NA	NA	NA	NA	NA
													12																					
6	CCR Operator 1 – Snore A	14	50	144	2	2	4	0	6	-2	0	2	2	2		10	10	-2	NA	NA	12	24	2,5	6	10	0	NA	28	28	NA	NA	8	8	NA
													8	8	8																	20	20	
													12																					
													14	14	14																			
7	CCR Operator 2 – Snore A	14	50	36	2	2	4	0	6	-2	0	10	8	8	8	10	10	-2	NA	NA	12	24	12	6	10	8	NA	20	20	NA	NA	8	8	NA
																																12		
8	Operator 1 - Åsgard - Kårsta	10	40	60	1	1	1	0	6	-2	8	10	6	6	6	10	10	-2	NA	4	8	NA	6	4	10	-2	NA	28	28	NA	NA	NA	NA	NA
9	Process Tekniker / Train 300 - Kårsta	30	50	120	1	3	3	0	6	-2	0	2	2	2		6	10	2	6	4	6	8	200	4	10	NA	NA	NA	NA	NA	NA	NA	NA	NA
													6	6	6																			
													26	26	26																			
10	Automation Engineer- SAS Kåsta	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	16	500	32	32	2	10	6	6	8
R1	**Summery Median/Mode**	**14**	**50**	**84**	**1**	**2**	**4**	**0**	**6**	**-2**	**8**	**10**	**12**	**2**	**8**	**10**	**10**	**2**	**6**	**4**	**12**	**24**	**6**	**4**	**10**	**0**	**500**	**16**	**2**	**2**	**8**	**12**	**8**	**8**

Alarm Text			Alarm Help				Priority Evaluation			
Alarm Description	Alarm Type	Alarm Message	Purpose of the Alarm	Possible Cause	Consequence No action	Operator Action	Time to Respond	Urgency	Severity of Consequence	Priority
Prepare a text in following	High	Mention any					5 Min	Immediate	None	Prio 1
syntax	High High	additional					15 Min	Prompt	Minor	Prio 2
Equipment>service>	Low	information					60 Min	Soon	Major	Prio 3
destination area	Low Low	which is			Mention the	Describe relevant	6 Hrs	No Action	Severe	Prio 4
This syntax is only for	Fault	relevant	Mention the purpose	Mention the cause of alarm	consequence	actions	> 12Hrs			Event

Context Sensitivity			Alarm Rationalisation Static Suppression	Signal Conditioning		Grouping		
Start-Up	Process Shutdown	Emergency Shutdown	Alarm Hiding	Alarm Delay	Deadband	Validity	Details	Group Name
		Check if alarm		Flow - 2 sec	Flow - 5%			
		is relevant		Lvl - 2 sec	Lvl - 5%		List of all	
		during		Pres - 1 sec	Pres - 2%		alarms that	Mention
Check if alarm is relevant	Check if alarm is relevant	emergency		Temp -0 sec	Temp -1%		need to be	relevant
during start-up	during process shutdown	shutdown	Yes/No			Yes/No	grouped	group name

Extended Information			
Classification	Key Alarm	Operator Res Effective	Alarm Status
Personnel Safety		Likely	Maintenance/Info Alarm
Financial Consequence		Challenging	Duplicate Alarm
Environmental Protection	Classify if its key alarm so that	Unlikely	No Alarm Configured
	operator have more attention		SOFT signal
	towards it		

Workshop Comments and Revision Handling				
Comments	Additional Comments	Checked	Signature	Rev
		X: Completed		
		Y: Query		