University of Southern Queensland

Faculty of Health, Engineering and Sciences

Best practice management of industrial process control alarm floods

A dissertation submitted by

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Abstract

This report aims to determine recommendations for best practices in managing alarm floods in real time under all operating conditions, by identifying the underlying attributes and purpose of an alarm, including human factors impacting the alarm management system. Alarm floods are introduced in the context of process control systems. Three standards and two companies were investigated to assess control systems technology, alarm philosophy, alarm flood management techniques and alarm flood control.

Analysis methods have been developed using standard software to compare company alarm performance against industry standards EEMUA Publication 191, ISA 18.2 and IEC-62682. The investigations and alarm data analysed identified improvement areas in the alarm standards lifecycle stage 'monitoring and assessment'. Analysis proved high frequency alarms corrupt data and performance measurements therefore require timely identification, repair, replacement and or removal. Alarm priority distribution analysis identified a tendency for alarms to be assigned high priority, averaging 5 to 6 times the standard percentage limit. Causing stress on operator's to respond faster than a low priority alarm require. Analysing unspecified performance areas for time periods between alarm annunciation, acknowledgment and returning to normal, identified a potential 30% reduction in alarm rates through targeted suppression, certain alarms for tuning, repair or review and contributes to the assessment of alarm manageability and operator work rate.

Continuously assessing all alarm performance areas specified in the standards will identify areas necessary to improve alarm performance, inversely increase profits and reduce exposing companies and public to undue hazards and risk.

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Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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1.0 Introduction

This dissertation explores alarm management for process control systems in the oil and gas hydrocarbon processing sector. The investigation sought to understand and determine the causes of industrial process control alarm floods and recommend approaches to help prevent or manage high alarm rate events in consideration with other industry standards and practices with the hope new improvements opportunities and practices may be identified.

Alarm management has two aspects one being hardware (process control design engineered alarm management) solution and the other a human optimisation solution through integration with technologies hardware.

Studying alarm management is often due to personal experience with poorly performing alarm systems. Alarms are audible and/or visible means of indicating to the operator an equipment malfunction, process deviation, or abnormal condition requiring a response. Unfortunately, responses are often hindered during high alarm rates because operators become stressed during the abnormality however prolonged the alarm period and whatever aged technology is employed.

Technology continues to evolve at its rapid rate, cheaper new, complex microprocessor-based self-diagnosing products enter the market daily, often making it more economical to implement newer fast and intelligent sensors and control systems as opposed to maintaining the old. The new technology introduces countless programmable alarms via selectable options which help operators, engineers, vendors and maintenance personnel understand equipment health and behaviour through monitoring and reporting. The desire to design and build most intuitive control systems with a titanic alarm system that monitors an infinite number of variables can and has inadvertently designed into the control system a potentially hazardous condition of alarm overloads. The consequences of alarm overloads often exacerbate the abnormal situation by overwhelming the operator into abandoning the alarm system or downplaying the alarms which can be part of a safety instrumented function (SIF) further eroding another layer of protection.

Unfortunately, poor alarms systems and their effects are well documented. Governing authorities across the world that investigate industrial incidents report poor performing alarm systems contribute as a cause or the escalation of major industrial accidents in most cases. In response, governing authorities and organisations have collaborated to develop standards and guidance practices to best implement and manage alarm system performance against these benchmark standards.

This dissertation studies the relevant standards, company procedures, policies, technical papers and alarm data in the pursuit of gauging, improving or finding a benchmark for alarm management in the oil and gas or industry at large.

2.0 Alarm Overview

2.1 Brief overview from the beginning

Over the past 60 years the number, type and frequency of alarms in control systems has increased rapidly with electronic microprocessor based technology.

Historically, process control was manual or semi-automatic (Figure 1) and the demand for labour was high due to the manual operation of localised plant spread across a large geographical area comprising of the processing plants installation. Personnel (operators) attended to the processes by reading analogue gauges and adjusting the pneumatic controls to maintain steady production at desired values via this semi-automated instrumentation process control system. Discrete alarm signals were routed to the various control room(s) via micro-switches and relays, alerting the operator to abnormal conditions via an audible and visual means typically a (lamp based) annunciator matrix panel and siren. As technology evolved, alarm printers were introduced in the form of dot matrix ribbon printer, used to record alarms and events as they occurred in sequence. Unfortunately, the printer was considered distracting in operation, bulky, consumed large amounts of paper and required expensive replaceable ink ribbons. It is said the printed alarm records were not very useful and operators would save disposal time by feeding the printed alarm record directly into a shredder (Liptak, 2006). However, in spite of these technological challenges, the additional operators shared the workload and stress by assigning functional duties to areas of plant.

During the early days, installing new process alarms often amounted to significant costs partly due to the size of the device, apparatus or equipment, the labour to install, operate and maintain as well as carrying an inventory of spare parts to help support the maintenance of the installation or system over its lifecycle.

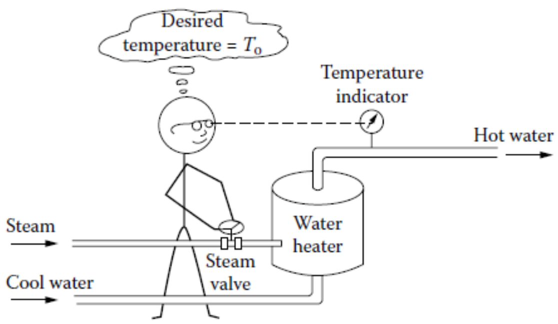


Figure 1: Manual operator control system. (Bela G. Liptak, 2006, Vol.2, p.107, fig.2.1y)

Although hard-wire systems initially installed to monitor alarm states, computer-based control systems developed and wire systems soon became the accepted and preferred method for control replacing pneumatic signal tubing which was limited by function, speed and distance. Physically smaller and able to span greater distances, hard-wire signals condensed an installations footprint transmitting a greater number of signals in real time as opposed pneumatic signals. Soon a centralised control room emerged in preference to various process area control rooms scattered across the processing plant.

Given the emergence of the centralised control room, technology improvement and integration into the process control loop reduced the demand for labour. Electronic control hardware (electronics are static have limited movement hence no wear and tear) improved reliability reducing maintenance and the centralised control room condensed multiple areas and operators to a few, as illustrated in Figure 2.

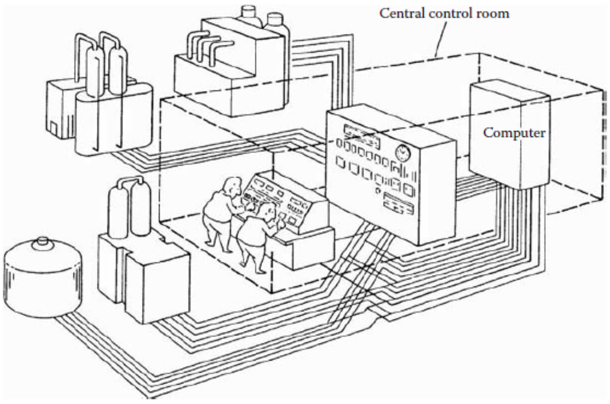


Figure 2 : Pneumatic / Electric central control room. (Bela G. Liptak, 2006, Vol.2, p.196, fig.2.11h)

The introduction of the basic, less expensive and compact personal computer (PC) in the 1990's, replaced the noisy alarm dot matrix printers in the control room. PC's also provided a means of storing and analysing alarm data in a user friendly environment as opposed to the paper based system, at this point alarm analysis and performance measuring was born.

As industry strived to develop new technology, new features and applications, the modern digitalised plant arrived and business overheads continued to be reduced. Compared to the pneumatic plants of yesterday, fewer personnel were out in the field resulting in less injuries and labour costs, plant complexity and performance increased through automation, continuous monitoring and adjustment which led to greater output of product. In addition, apparatus costs continue to decrease with the increase in products available adding to greater profits and returns for shareholders.

For different reasons manufacturers tried to limit third party system connections in preference for their own proprietary control systems however, in the early 2000's more mainstream products became available. Distributed Control Systems (DCS) soon adapted to employ third party platforms with products like Microsoft based operating systems now commonplace. These third party products utilised a system of object linking and embedding (OLE) for process control (www.opcfoundation.org) that led to an industry consortium specifying open connectivity PC solutions for industrial control. With the advent of OLE consortium, open platform communication (OPC) was soon linking third party systems with the controllers, transferring alarm, events and other data in a standard format from the controller to external PC's and third party products. With OPC read / write functions, alarms and configuration files are accessed readily between control system and third party hardware/software.

Figure 2 and 3 illustrate the reduction in interconnecting hardware between equipment by way of data highway cables replacing multiple analogue wire signals, also included was a reduction in personnel for the same process infrastructure on account of automation. Not captured in the illustration is the new wireless technology, which replaces interconnecting cables between field device and the controller.

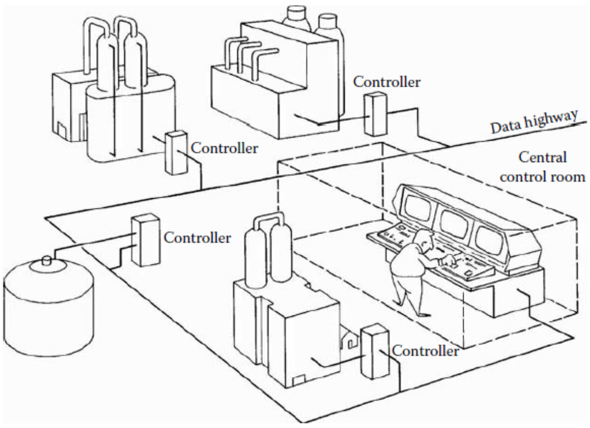


Figure 3: Modern process plant with control system (Bela G. Liptak, 2006, Vol.2, p.196, fig.2.11g)

The control and alarm system evolution would not be where it is today had it not been for dedicated people within industry forming steering committees or technical bodies who consistently engaged, facilitated and guided industry as a whole on matters involving alarm management. This ensured those responsible designing, commissioning, maintaining and using alarm management systems were provided relevant publications and standards to align.

To provide an overview of the timeline –

1955 – International Society of Automation (ISA) formed a committee for titled instrument alarms and interlocks that later evolved into Standards and Practices committee 18.

1965 – The ISA committee 18 published the ISA-RP 18.1, ‘Specifications and Guides for the use of general purpose annunciators. Lamp based annunciators are a panel mounted matrix of lights with transparent coloured text labels printed to outline the alarm condition or state.

Figure 4: Example of a panel mounted annunciator (Engineered Solutions, 2012)

1979 – (R2004) Annunciators Sequencers and Specifications

1994 – A consortium of private enterprise industry representatives and U.S. National Institute of Standards and Technology (NIST) formed the ‘abnormal situation management (ASM) consortium focused on better response to industry incidents.

1999 – Engineering Equipment and Materials Users’ Association (EEMUA) issued its first publication 191 Alarm Systems: A guide to design management and procurement was released

2003 – User Association of process control technology in chemical and pharmaceuticals industries (NAMUR) issued recommendation NA102 – Alarm management.

2007 – EEMUA publication 191

2009 - ISA-RP 18.2, – Management of alarm systems for the process industries

2014 – IEC 62682 - Management of alarms systems for the process industries was accepted by vote as the international standard. Derived from American National Standards Institute (ANSI)/ International Society of Automation (ISA) Standard 18.2 - Management of Alarm Systems in the Process Industries

2015 – ISA-RP 18.2 – Management of alarm systems for the process industries

Today these standards committees still convene to share knowledge and produce publications for industry and also underpin this report.

Today’s modern control system resembles more of a computer than controller. Illustrated in figure 5 is Honeywell’s Experion process control system architecture. The lower line supervisory control network allows controllers to interacting with the field devices and each other, rising up to the advanced control network and business network of computers, all talking and supporting the controllers below. This illustration summarises an integrated control safety system (ICSS) from process sensors, old legacy technology integration via a local control network, supervisory control, advanced networks servicing remote stations, CCTV or operator simulation and up to a business network catering for web browsing and maintenance package integration.

Likening the modern control system to a computer portrays how alarms can be created or changed within a programming environment which has resulted in alarms being configured at low cost and a greater numbers introducing the ability to monitor anything and everything, resulting in an increase in safety and operability through programmable diagnosis.

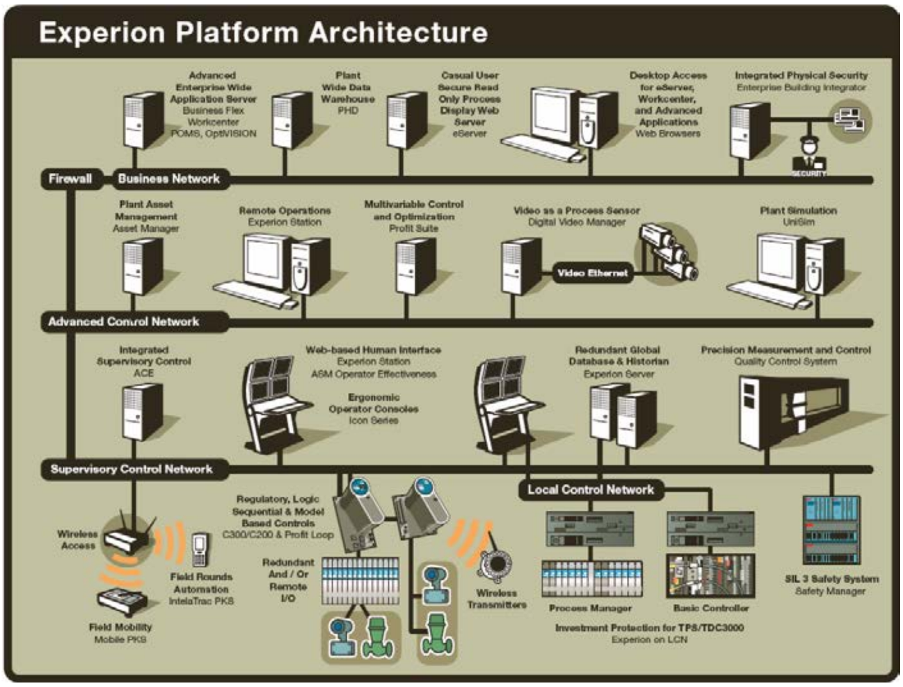


Figure 5: Honeywell Experion process control system network (Sheehan, 2008)

Furthermore, microprocessor technology is also embedded in the transmitters and sensors. Single modular auto-ranging remote transducers (SMART) facilitate functional online changes via their microprocessor base, allowing communication over networks such as data highways, Modbus, HART, Foundation fieldbus and more. Integrating the transducer into the control system allows the transducer / transmitters to provide self-diagnostic abilities, alarms (sensor failure), performance data or degradation, calibration, history, loss of signal, maintenance and other data on request. Another type is the highway addressable remote transducer (HART) standard helps instruments to digitally communicate with one another over the same two wires used to convey a 4-20 milli-ampere analogue instrument signal (Liptak, 2006).

In conclusion, automation has enabled industry to remove people from harm and ensures optimum performance by continually monitoring and adjusting. The introduction of computer based technology provides personnel with the ability to obtain every bit of information no matter how trivial to use or present this information in ways to remain in control of the process and the equipment controlling the process. Where human intervention is required the information exchange occurs via the human machine interface (HMI) or operator console (see figure 5), alarms are configured to alert the operator of an abnormal condition requiring a response to correct the condition. It is the exchange and human interaction or involvement in the control function that requires closer scrutiny.

2.2 Alarming Hazard

Poor alarm management systems expose companies, governments and the public to unnecessary hazards, environmental damage, loss of reputation, financial cost, injury and potentially loss of life. The US Chemical Safety Board (CSB) a leading authority in incident investigations cite alarm floods as a significant contributing cause to industrial incidents (Beebr et al, 2012). Supporting CSB's claim, the British-based organisation Engineering Equipment & Materials Users' Association (EEMUA) reported similar root causes contributed to major incidents around the world, including Three Mile Island, Bhopal and Texaco Milford Haven as documented in their alarms systems publication 191 first released in 1999 (EEMUA, 2013).

The Milford Haven refinery explosion resulting in a major fire on the 24th July 1994 injured twenty-six people (HSE Books, 1997). The plant was struck by lightning, which caused the process control instruments to fail or become unreliable for over five hours. It is estimated the rate of alarms was in excess of 1 alarm every 2-3 seconds Consequently, the operators were overwhelmed by alarms and failed to identify a build-up of liquid in a knock-out vessel that eventually overflowed, leading to the explosion and fire (EEMUA, 2013). This abnormal situation demonstrates the hazards alarms floods present to process operations by effectively rending the operator and alarm system helpless during high rates of alarms. The investigating authority Health Safety Executive (HSE) of the United Kingdom (UK) prosecuted company's Texaco Ltd and Gulf Oil (Great Britain) Ltd. Each company pleaded guilty to the charges under the Health and Safety at Work Act 1974, sections 2 and 3, at Swansea Crown Court on 22 November 1996, the costs included £200 000 in legal fees, £143,700 in fines and £48 million in plant damage (HSE Books, 1997).

The United States of America, West Virginia 28th August 2008, the Bayer Cropscience pesticide process plant experienced a chemical reaction runaway causing a pressure vessel to explode killing two and injuring eight people (CSB, 2011).

Figure 6: Bayer vessel explosion (CSB, 2011, p.0)

The first indication of the incident was a high pressure alarm. Investigating the controller trends revealed the residue treater pressure was above the maximum operating pressure and climbing rapidly as illustrated in Figure 7. Suspecting a blockage, the control room operator contacted two outside operators to check the vent system. Without advice, the control room operator manually reversed the residue treater recirculation system to full cooling mode in an attempt to slow or stop the climbing pressure (CSB, 2011). A few minutes after sending the outside operators to investigate, a violent explosion erupted. Operators scrambled to shut down the system.

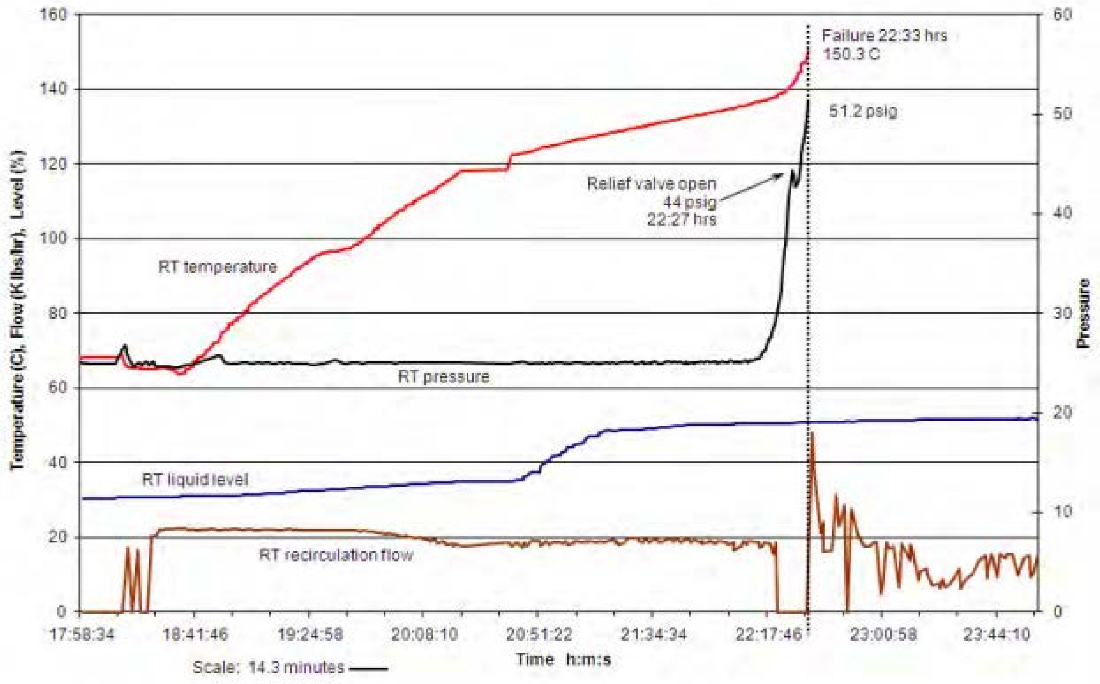


Figure 11. Residue treater process variables before the explosion. Failure occurred at 22:33, as shown at vertical dotted line

Figure 7: Trends leading into the Bayer vessel explosion (CSB, 2011, p.39)

The CSB investigators highlighted a number of contributing factors. The old control system problems were transferred to the newly upgraded control system. Due to the hazardous process and risk to people, public and environment, a separate safety instrumented system (SIS) to the basic control system was required. A SIS would have averted this disaster through a controlled shutdown (CSB, 2011). Another contributing causal factor was operators could make unauthorised program changes and or alter alarm settings outside if management of change processes which would have involved closer scrutiny by engineering staff.

Unfortunately, the West Virginian pesticide plant was no stranger to large scale incidents (CSB, 2011). Fifteen years earlier on the 18th August 1993, under different ownership, a similar incident occurred resulting in a fatality and two people injured. The explosion occurred in the chloracetaldoxime (CAO) reactor loop of the methomyl unit. Investigators believe a flow indicator malfunction led to over-chlorination of acetaldoxime, causing a violent decomposition in the chemicals which resulted in an explosion which ruptured pipes, releasing flammable liquid that fuelled and sustained a large fire. The investigation also reported the workers activities were not causally related to the incidents. However, the investigation team recommended the company identify and treat all emergency shutdown interlock alarms as critical. A Further recommendation were to apply the plant alarm management procedure with regard to nuisance alarms, review and revise procedures for disabling alarms and by-passing interlocks a practice used during a process unit start-up to bypass safeguards. Basically a carbon copy the recommended improvements required from both incidents, the difference being had the first recommendations been applied in 1993, the August 2008 incident could have been prevented.

Another incident in the US involved a company named DuPont. Regarded as an industry leader of workplace health and safety practices DuPont's sound reputation and widely used safe practice guidance system interested CSB when examining reasons that led to a decline in adherence to DuPont's higher standard of performance. Being a chemical company, where incident severity has greater consequence potential, the U.S. Chemical Safety and Hazard Investigation Board (CSB) examined three serious incidents that occurred at the Belle chemical manufacturing facility over a 33-hour period starting on January 22, 2010. The trio of incidents began with an alarm, leading operators to discover an estimated 2,000 pounds of methyl chloride, a flammable gas or refrigerant, had been leaking for 5 days unnoticed.

The CSB findings identified deficiencies in DuPont's operational management systems which included the lack of -

- Maintenance and inspections
- Alarm recognition and management
- Incident investigation
- Emergency response and communications
- Hazard recognition

In the United Kingdom (UK), the Health Safety Executive (HSE) (an equivalent authority to America's CSB), commissioned a research project conducted by Bransby Automation Ltd to determine best practice on the procurement, design and management of alarm systems. Of the sites visited, the research team quantified several million pounds in losses across 15 industrial sites, attributable to missed alarm incidents (Bransby et al, 1997). However the report suggests the untold stories and costs not mentioned during the research interviews would compound this value.

To quantify the benefits of an effective alarm system the following incidents provide an overview of alarms implicated in industrial incidents in the UK.

2.2.1 Plant damage

- A compressor tripped in a large petrochemical plant causing two days production loss before resuming production estimated cost around £1M. This event caused other components damage, requiring another unscheduled plant outage months later to repair the damage and undertake repairs to other equipment at a cost of £12M. The investigation revealed six weeks prior to the compressor trip a high axial displacement alarm occurred which the operators accepted but did not report or investigate. Three days prior to the trip there was a second axial alarm also not reported or investigated. This example demonstrates the need to ensure adequate prioritisation, attention and or reporting occurs to ensure the right people are made aware even if the alarm is considered trivial (Bransby et al, 1997).

- A newly trained power plant operator experiences repeated high thrust bearing temperature alarms on a feed pump over a period of minutes. Rather than reference the alarm instructions available in the Distributed Control System (DCS) he decided to send the field operator to investigate the pump. Twenty minutes later the field operator reports back and shuts down the pump. Unfortunately this delay caused £250,000 in pump damage, had the operator used the DCS instructions advising to stop the pump on alarm activation, the pump may only have sustained repairable damage at less cost (Bransby et al, 1997).

2.2.2 Lost production

- An operator concentrating on a disturbance on one part of a large petrochemical plant misses an alarm in another part of the plant resulting in a trip plant and consequently a plant shutdown. This is the only plant trip in the last two years that would have been preventable with a better alarm system. The typical cost of such a trip was estimated at £250,000 (Bransby et al, 1997).

2.2.3 Environmental incidents

- A vessel containing hazardous chemicals was overfilled 3 times in the past 10 years due to operators failing to respond to alarms and the high level protection did not operate. The incidents had resulted in a breach of environmental constraints and reported injury to people (Bransby et al, 1997).

- Another environmental incident involves exceeding environmental statutory limits from an uncontrolled chemical discharge into the sea. The cause was a chemical tank level controller left in manual, the tank level increased to overflow allowing product to enter the drain. A drain analyser with a sample rate of ten minutes intervals delayed the analyser's alarm before the operators were alerted to take corrective action. The investigation found that the operator first missed the tank high level alarm among other associated alarms due to experiencing an alarm flood (100 alarms per hour) (Bransby et al, 1997).

2.2.4 Commissioning

- A newly commissioned process plant was tripping frequently. Analysis of the high level spurious alarms proved the trips were due to poor operability of the plant. During low alarm floods the alarm rates were in excess of 30 alarms per hour however post plant-trip there would typically be 3 to 4000 alarms in the first 10 minutes. An estimated £500,000 project to improve the operability of the plant would save £1M per year in reduction of unplanned trips (Bransby et al, 1997).

- During commissioning a power station's 125V DC control supply failed. The operator did not notice the 125V DC alarm on account of experiencing a high rate of spurious alarms, 72 hours passed before the fault was discovered. During this period the electrical protection systems was inoperable, the danger being had an electrical fault occurred during this period would have caused major plant damage, injury to personnel, and significant delay to the commissioning programme (Bransby et al, 1997).

2.2.5 Australia

- Australia's oil and gas industry has also experienced catastrophic failures, one involving a high pressure gas compressor on board a Floating Production and Storage Offtake (FPSO) facility in 2010. Maersk Ngujima-yin FPSO was operating in the Vincent Field off the coast of North West Australia, Ningaloo National Park. Originally built as a large crude cargo vessel in 2000 until September 2007 when the vessel was transformed into an FPSO in Singapore. In June-July 2008, the Ngujima-yin was commissioned and commenced oil production. At approximately 12:50pm on the 13th of April 2009 an explosion and subsequent fire occurred. The incident resulted in a hydrocarbon release (natural gas flammable gas cloud) that subsequently ignited (ignition source most likely a hot surface in the compressor enclosure) producing a jet fire (concentrated fire caused by high pressurised gas escaping from a containment system i.e. vessel, piping or compressor) at the compressor area and secondary fire in the enclosure. Fortunately, no fatalities or injuries recorded.

The National Offshore Petroleum Safety Environment Management Authority (NOPSEMA) identified the control room operator was overwhelmed by ‘nuisance alarms’ causing the operator to overlook significant alarms (NOPSEMA, 2010). An excerpt from NOPSEMA’s prohibition notice number 0197 dated 20th April 2009:

“The ABB Central Control Room (CCR) Alarms Management System record of initiated alarms during the period 1st March 2009 to 16th April 2009 details daily alarm counts from 192 up to 3605 per day with the majority in excess of 300 per day. The Control Room display screen available to the Operator only provides three lines of alarm detail. The control room operator’s console is exposed to constant distraction with other activities ongoing at other work stations.” (DMA, 2009)

A key lesson communicated by NOPSEMA in an industry communication, incident report alert 39, states companies are to ensure control room operators are not overloaded by ‘nuisance alarms’ and advised this will be achieved through an effective alarm management strategy where repetitive alarms are minimised through what is known as an alarm rationalisation process. Also advising the removal or dependence on operators to safeguard facility compressors by an effective fail safe control system, fortunately no casualties resulted from this major incident (NOPSEMA, 2010).

In addition to NOPSEMA’s investigation, an independent investigation into the same event by the Division for Investigation of Maritime Accidents, through the Danish Maritime Authority, 16th November 2009 Case – 200905173. This report outlined similar findings in relation to alarm management. Surprisingly, the facility employed modern day technology and engineering practices which should have ensured this type of situation would not have occurred (*(DMA, 2009)*.

As these incidents demonstrate, there is much evidence to justify investing capital and resources to continuously improve the performance of an organisations alarm management and process control alarm system. This should help ensure plant process safety strategies are executed during abnormal situations, improve commercial asset security through prompt diagnosis and response by staff, reduce overhead costs caused by facility downtime and minimise potential liabilities through an effective alarm system. Lastly, the alarm system is an auditing tool used by authorities when investigating incidents hence, a poorly performing alarm system implicated in an incident will cloud perceptions of a company’s ability to operate safely.

2.3 Alarms

Modern industrial process control systems play an essential role in providing the operator an overview and also access to a multitude of process variables via cleverly designed human machine interfaces (HMI). These HMIs help attract the operators attention to abnormal situations by audio and visual signals or warnings in the form of an alarm.

The purpose of an alarm is to direct the operator’s attention towards a plant condition requiring timely assessment and action (EEMUA, 2013). The alarm system should alert, inform, confirm and guide the operator with relevant alarms and useful information. Alarm annunciation should allow enough time to for the operator to respond and prevent unnecessary shutdowns and limit process upsets (off specification product) which undermine profits. Alarms need to be purposeful and prioritised, highlighting critical conditions and provide detailed information for necessary response action to return the process variable back to the targeted set point value or operating envelope. It is important to note the operator is human; therefore consideration must include a rational expectation of one’s ability to manage numerous abnormal situations in a short period of time.

The term alarm systems relates to the system(s) as a whole including an alarm philosophy, alarm management, generation, logic, processing, alarm presentation and monitoring. A control system may be integrated (see figure 8) with many dedicated control systems integrated as one i.e. safety instrumented system (SIS) or emergency shutdown system (ESD), distributed control system (DCS) or basic process control system (BPCS) and Fire and Gas (F&G) system. Each controller communicates via dedicated networks to deliver alarms to the operator via HMI.

For this reason, different types of alarms and alarm systems may be implemented and titled by defining naming conventions according to their functional relationship. The overviews of the listed terms below are in reference to EEMUA 191.

- **Process alarms –** Primarily derive from the DCS or BPCS by sharing the same sensor. A process alarm’s functional relationship generally assists by optimising efficiency by monitoring targeted envelopes of a process.

- **System status and Equipment alarms -** Identify and alert problems with equipment i.e. communication network fault, remote controller failure, battery backup failure. These types of alarms target maintenance or engineering personnel however, they are often brought to the operator attention first given their severity should, for example, a controller communication network fail.

- **Safety related alarms -** High in priority, safety alarms advise potentially dangerous or damaging condition in the plant. These alarms protect the control system and are often independent of the process sensors and alarms. These alarms serve as a pre-alarm to pending executive action taken by the SIS if the condition continues to escalate. In many cases this type of alarm is generated by the SIS also known as the safety shutdown system. This approach is good in some ways providing independence from the main control system. However, the disadvantage can include double up of alarms (shutdown or safety related) or the risk of common cause failure between the SIS and the pre-alarm system and must be considered in the reliability analysis of the overall protection system.

- **Shutdown alarms -** Advises the operator of an automatic shutdown has been initiated by the SIS to return the plant or process back to a safe state. Shutdown alarms and events are important information as well as knowing the sequence of events and timelines. This often help operators diagnose shutdown cause and to target responses. In some cases, only the first shutdown alarm annunciates the subsequent shutdown alarms are a result of the process returning to a safe state and are suppressed to prevent an alarm flood.

Note Figure 8 shows a single sensor and final control element connected to various controllers including SIS and BPCS via the input/output (I/O) modules. Normally, these controllers well have separate sensors and final control elements to ensure system integrity based on control function and criticality i.e. the SIS will have a standalone sensor and final control element.

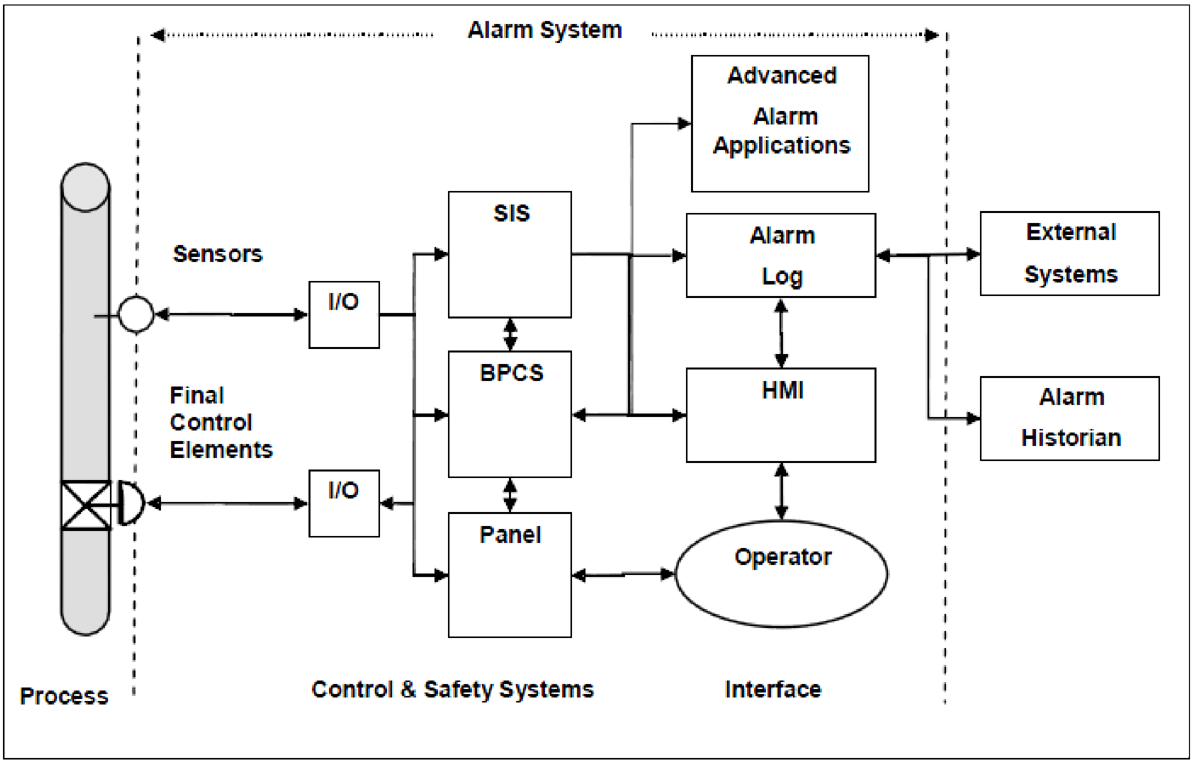


Figure 8: Alarm system data flow through hardware (ISA 18.2, 2009, p12)

Alarms are typically configured around an operational state i.e. when a pump is required to operate (run) any change in its run state i.e. pumped overloaded and tripped, should trigger an alarm for the operator to investigate and correct the reason causing the pump to trip.

Alarms and their messages may require a simple correction or acknowledgement of a change in condition. However; an alarm may also be generated from a serious safety hazard emerging. Therefore the allocation of the type of alarm associated with equipment or condition varies in design, it is critical an alarm is functional by type and prioritised, otherwise the performance of the alarm system, process, safety and operator reaction will be undermined.

Alarms and alarm floods typically result from a change. Change is the transition between considered states as shown in Figure 9. The events surrounding a change could include plant/equipment changing from run to shut-down, run to upset state or a change in state (on – off / tripped). Given there is a vast array of alarms that can be configured in a control system for a single piece of equipment and condition, potentially hundreds or thousands of alarms could occur simultaneously in a process upset. It is not uncommon for today's controllers to annunciate numerous alarms in a short period of time with a minor change in conditions. Often the first couple of alarms annunciate the initiating event, after which the following alarms can be unnecessary or redundant.

Unnecessary alarms distract the operator's focus, especially when generated from a similar cause and do not aid the operator to manage the situation. Distractions amount to the operator workload having to decipher the alarm (or many in an alarm flood), differentiate between alarms using any instructions or process information available before acknowledging and responding. This additional diagnostic time on account of unnecessary alarms can compromise an operator's response. If an alarm forms part safety instrumented function (SIF) a layer of protection by design will be compromised for a period. In any case, effective alarms ensure the process remains within its normal operating envelope.

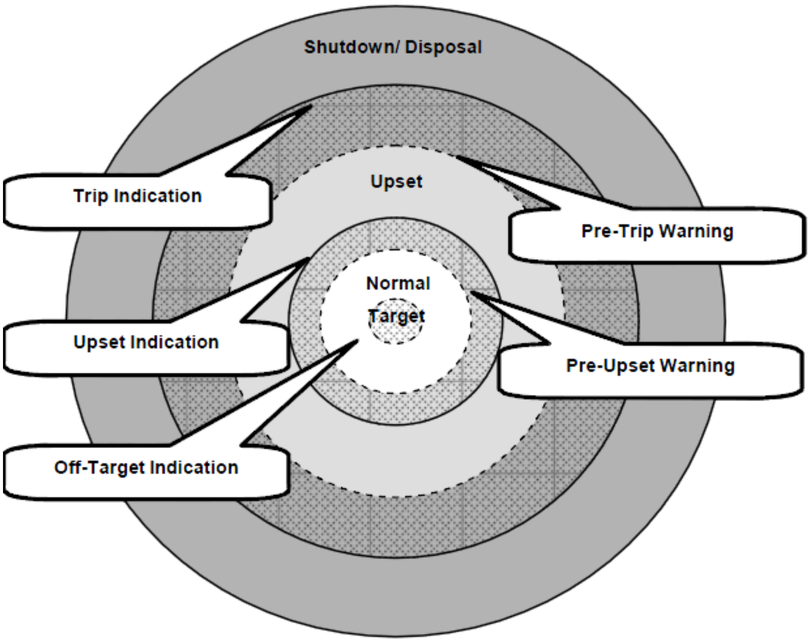


Figure 9: Targeted areas of operation (ISA18.2, 2009, p28)

Another side-effect of being able to readily generate software alarms has also blindsided engineering controls (management of change) when creating alarms. It would appear on account of the low costs to implement an alarm, the juggle between want, need and required can often become blurred often undermined by a perceived improvement in integrity of a singular monitored condition rather than considering collective alarm systems operation. Therefore it is prudent that any alarm change requires a complete review prior to implementation (ISA, 2009).

Naturally, some alarms are not necessary or are configured incorrectly, leading to nuisance alarms. Nuisance alarms do not assist the operator, they only crow the event log and load the controller's microprocessor.

Alarms are vital in assisting operators to determine abnormal conditions in a plant which require a response. Their intended purpose cannot be underestimated based on industry evidence, however the authority and control surrounding alarm implementation or removal appears relaxed or token.

2.4 Alarm Management Governing Bodies and Standards

Generally, the governing authorities for alarm management reside within each county, state and industry authority. In counties like Australia, industry has adopted global industry best practices and guidelines for alarm system management where process control systems are utilised.

The key standards and or guidelines for alarms management in Australia include but are not limited to –

- The Engineering Equipment and Materials Users' Association (EEMUA) Publication 191 - Alarm systems - A guide to design, management and procurement.
- International Society of Automation (ISA) Standard 18.2 - Management of Alarm Systems in the Process Industries
- Abnormal Situation Management (ASM) Consortium Guidelines - producing various publications on process control system and alarm management.
- IEC 62682 - Management of alarm systems for the process industries

A governing body for offshore oil and gas sector in Australian is the National Offshore Petroleum Safety Environment Management Authority (NOPSEMA). NOPSEMA regulates industry through company based safety cases that document how the company will safely manage their business and operations without damage to people and the environment.

Included in Australia are relevant acts of law that empower authorities i.e. Petroleum (Submerged Lands) Act 1967. Apart from the newly voted IEC 62682 – 2014 standard to which Australia aligns, there appears to be no Australian acts or regulations calling up (standard becomes enforceable by law) a specific standard for alarm management. Therefore, given industry's adoption of the mentioned standards, research will be focused on these standards, publications and guidelines.

3.0 Literature Review

3.1 Alarm Standards

The three standards reviewed are ANSI/ISA18.2, IEC-62682 and EEMUA 191. ANSI/ISA18.2 and IEC-62682 are very similar, mostly differing in language use. Hence IEC-62682 will be covered as part of ANSI/ISA18.2 in this review. In comparison, EEMUA 191 and ANSI/ISA18.2 are similar as cross-referenced below.

EEMUA 191	**ISA 18.2**
Chapters 1&2	Philosophy
Chapters 2&3	Identification
Chapters 2&3	Rationalization
Chapters 4&5	Detailed Design
Chapters 5&7	Implementation
Chapter 6	Operation
Chapter 6	Maintenance
Chapter 3	Management of Change
Chapter 6	Audit

However similar, both EEMUA 191 and ANSI/ISA18.2 (ISA 18.2 from this point forward) are different in their own right and shall be reviewed separately for the purpose of identifying opportunities to better manage alarm systems.

3.1.1 American National Standards Institute (ANSI)/ International Society of Automation (ISA) 18.2 - Management of alarms systems for the process industries

ISA 18.2 summarises alarm management effectively through its lifecycle diagram (Figure 10) with stages summarised and cross-referenced to ISA 18.2 clauses (Table 1).

The alarm lifecycle diagram identifies three rounded edge boxes A, H and J (Figure 10). These three stages are identified as initial entry points for managing an alarm system. The alarm philosophy stage (A) is covered in detail within the standard and only reviewed should stages (H) and (J) identify a need. Therefore monitoring and assessment stage (H) and auditing stage (J) are useful entry points to evaluate how effective an alarm management systems is designed, implemented and managed based on the philosophy and standard benchmarks.

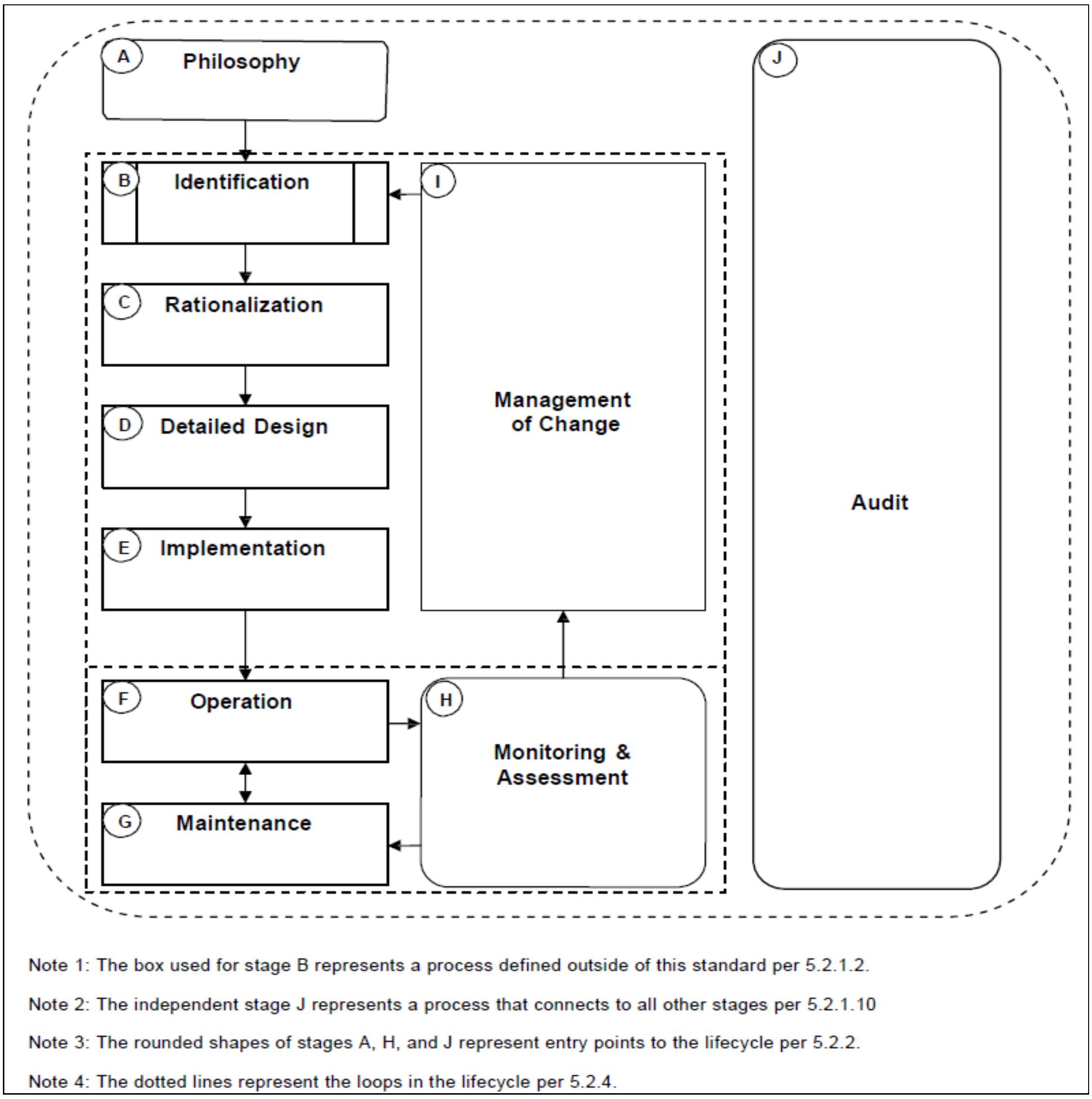


Figure 10: Alarm management life cycle (ANSI/ISA 18.2, 2009, p 22)

Monitoring performance is essential to control improvement, especially over time as sensors age and process conditions change. However, assessment of an alarm systems operational stages F, G and H in Figure 10 will also help gauge, predict or identify areas of improvement in maintenance / operator execution strategies.

As to the audit stage (J) where the alarm management system may be reviewed holistically against revised standards or areas considered or identified requiring attention.

Alarm Management Lifecycle Stage		Activities	Clause Number	Inputs	Outputs
Stage	Title				
A	Philosophy	Define processes for alarm management and ASRS.	6,7	Objectives and standards.	Alarm philosophy and ASRS.
B	Identification	Determine potential alarms.	8	PHA report, SRS, P&IDs, operating procedures, etc...	List of potential alarms.
C	Rationalization	Rationalization, classification, prioritization, and documentation.	9	Alarm philosophy, and list of potential alarms.	Master alarm database, alarm design requirements.
D	Detailed Design	Basic alarm design, HMI design, and advanced alarming design	10,11,12	Master alarm database, alarm design requirements.	Completed alarm design.
E	Implementation	Install alarms, initial testing, and initial training.	13	Completed alarm design and master alarm database.	Operational alarms, Alarm response procedures.
F	Operation	Operator responds to alarms, refresher training.	14	Operational alarms, alarm response procedures.	Alarm data.
G	Maintenance	Maintenance repair and replacement, periodic testing.	15	Alarm monitoring reports and alarm philosophy.	Alarm data.
H	Monitoring & Assessment	Monitoring alarm data and report performance.	16	Alarm data and alarm philosophy.	Alarm monitoring reports, proposed changes.
I	Management of Change	Process to authorize additions, modifications, and deletions of alarms.	17	Alarm philosophy, proposed changes.	Authorized alarm changes.
J	Audit	Periodic audit of alarm management processes.	18	Standards, alarm philosophy and audit protocol.	Recommendations for improvement.

Table 1: Alarm Management Lifecycle Stage Inputs and Outputs (ANSI/ISA 18.2, 2009, p27)

The various stages of an alarm's lifecycle from activation to normal state are illustrated in detail by the alarm state transition diagram Figure 11. This transition diagram shows various paths an alarm may take depending on its configuration, equipment, criticality or process being monitored. Generally, well-designed control systems monitor and record each transition state to help determine the alarm systems performance. The transition stages G, H and I, are separate stages used for supressing (high frequency alarms requiring maintenance), alarms that are not required at the time (equipment shutdown or undergoing a plant trip event), alarms undergoing a management of change process or out of service. Utilising transition stages G, H and I allow the operator the ability to manage abnormal situations while ensuring the integrity of the alarms system does not overloaded the operator with unnecessary or nuisance alarms as identified.

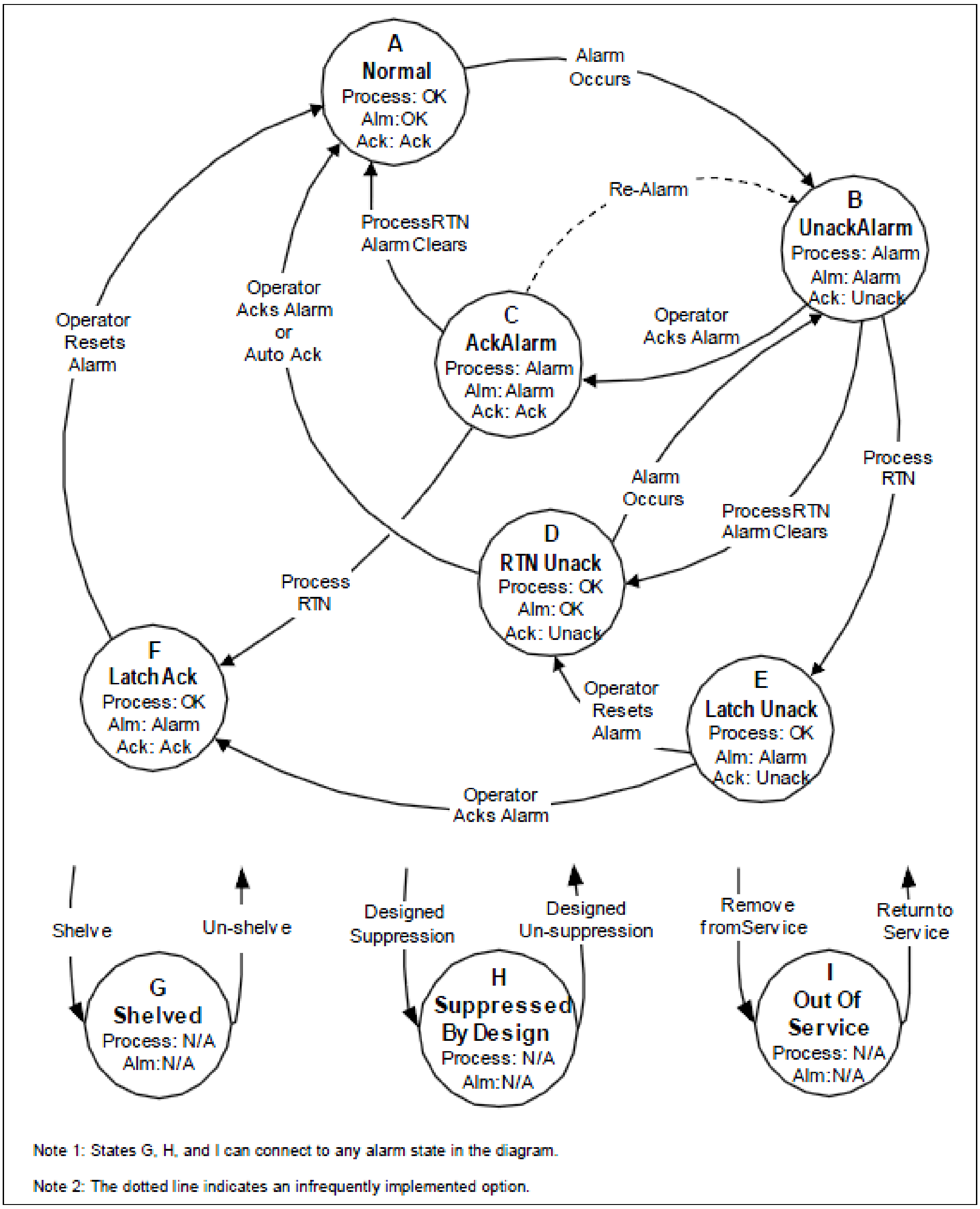


Figure 11: Alarm State Transition Diagram (ANSI/ISA 18.2, 2009 p30)

There are several factors that affect the transition states of an alarm (ISA 18.2, 2009):

1. Measurement accuracy
2. Control system processing speed
3. HMI design and clarity
4. Operator response delay (includes awareness, workload and training).
5. Complexity of determining the corrective action
6. Complexity of the corrective action.

7. Process dead time in response to the corrective action
8. Process response time to the corrective action
9. Dead band of the alarm set point

These factors contribute towards what is referred to as a consequence threshold. Surpassing the consequence threshold causes an undesired chain of events which, depending on criticality, can result in a loss of production, environmental pollution, reduced asset service life and or unsafe plant condition.

In terms of measurement accuracy, control system processing speed and process response dead time, these are considered maintenance / engineering areas of influence. However, the role of the operator in employing these systems to avert a consequence threshold requires consideration.

Operator training for highly managed alarms is considered in ISA 18.2, outlining areas of training however, ISA 18.2 does not specify timeframes i.e. 2 yearly for refresher training. Operator refresher training in a simulated environment allows operators an opportunity to react and gauge their performance against high alarm rate scenarios. Disasters mentioned earlier highlight the importance and provide a model for such scenario training.

Human performance shaping factors in section 5.6.4 of this report identify a variety of other variables that affects an operator’s ability to perform. These include workload, short term or working memory limitations, fatigue, training, and motivation. However means to measure human aspects is limited within the standard, hence given further consideration.

Depending on the alarm criticality, alarm enhancement techniques outlined in the ISA18.2 section 12.3 can be employed. The four alarm enhancements categories are -

1. Information linking – by making information available to the operator i.e. procedures from within the HMI
2. Logic based alarming – utilising logic to indicate or predict plant conditions
3. Model based alarming – provides the operator with predictions based on simulated scenario results of the current process variable conditions predicted into the future
4. Additional Alarm considerations – utilisation of auxiliary alarms systems.

These categories are just a few of the various alarming methods employed to ensure operators receive a manageable alarm rate particularly during process upsets where higher alarm rates are expected.

The possibility of alarm analysis or design providing the wrong algorithm, effectively supresses or removes an alarm from the operator attention. These omissions should be identified during assessment audits. Audits should critically analyse undesirable events or poor alarm performance to determine whether alarms were mistakenly supressed or journaled in the event that had the suppressed alarm alerted the operator, the abnormal situation may have been averted.

Some control systems have software capabilities to compare the rationalised master alarm database with the operating alarm system configuration in the controller. This auditing tool helps alert engineers to changes. The ISA 18.2 benchmark for unauthorised alarm changes is targeted for zero improperly changed alarms, meaning changes outside of the alarm philosophy and management of change procedure.

ISA18.2 proposes completing audits periodically however leaves discretion to the companies alarm management philosophy and policy. The philosophy also outlines reporting of alarm system analysis to those identified responsible or concerned with the alarm management system. Suggesting a tailored approach to the needs of the recipient, the frequency and content contained in the report.

The content of a report generally provides some performance criteria for comparison which is fundamental for improvement. It is expected the alarm systems performance will deteriorate over time as field equipment ages or process changes occur. Table 2 extracted from ISA 18.2 provides a summary of the alarm performance metric. This benchmark metric suggests comparing 30 days of data against the metric however advises caution using averages as they can be misleading. This statement introduces the question of whether an average is acceptable to accurately gauge the performance of an alarm system and to what degree do these metrics help identify improvement opportunities within the alarm system. Furthermore ISA 18.2 suggests alarm rates alone are not an indicator of acceptability.

Table 2 provides the alarm rate averages categorised in per day, hour and 10 minute periods. These areas are divided into two columns for alarm rates i.e. likely to be acceptable and maximum manageable by the operator.

Alarm Performance Metrics Based upon at least 30 days of data		
Metric	**Target Value**	
Annunciated Alarms per Time:	Target Value: Very Likely to be Acceptable	Target Value: Maximum Manageable
Annunciated Alarms Per Day per Operating Position	~150 alarms per day	~300 alarms per day
Annunciated Alarms Per Hour per Operating Position	~6 (average)	~12 (average)
Annunciated Alarms Per 10 Minutes per Operating Position	~1 (average)	~2 (average)
Metric	**Target Value**	
Percentage of hours containing more than 30 alarms	~<1%	
Percentage of 10-minute periods containing more than 10 alarms	~<1%	
Maximum number of alarms in a 10 minute period	≤10	
Percentage of time the alarm system is in a flood condition	~<1%	
Percentage contribution of the top 10 most frequent alarms to the overall alarm load	~<1% to 5% maximum, with action plans to address deficiencies.	
Quantity of chattering and fleeting alarms	Zero, action plans to correct any that occur.	
Stale Alarms	Less than 5 present on any day, with action plans to address	
Annunciated Priority Distribution	3 priorities: ~80% Low, ~15% Medium, ~5% High or 4 priorities: ~80% Low, ~15% Medium, ~5% High, ~<1% "highest" Other special-purpose priorities excluded from the calculation	
Unauthorized Alarm Suppression	Zero alarms suppressed outside of controlled or approved methodologies	
Unauthorized Alarm Attribute Changes	Zero alarm attribute changes outside of approved methodologies or MOC	

Table 2: Alarm performance metric summary (ISA 18.2, 2009, p76)

Lastly the specification for alarm data is divided into two categories alarms records (time stamped raw data of all alarms and events) and alarm attributes (priority, set points, action, class, response, dead bands and types). These categories help arrange, filter and determine if the performance of the alarm system meets the design.

3.1.2 EEMUA Publication 191

Alarm systems – A guide to design, management and procurement

EEMUA publication 191 covers a large scope detailing the various aspects of alarm systems design, management and procurement.

The amount of configurable alarms, their design and generation varies considerably. It is therefore vital any changes to an alarm must consider the complexity of the alarm for example.

- **Absolute alarms:** compares the measured variable against a set point
- **Bit-pattern alarms:** matches a predetermined pattern of digital signals.
- **Calculated alarms:** based on various signal and conditions i.e. efficiency.
- **Control and instrumentation system alarms:** self-diagnosed faults within the control and instrumentation system hardware or software.
- **Deviation alarms:** Compares signals for variation
- **Discrepancy alarms:** generated by comparing an expected plant state against an actual plant state.
- **Rate-of-change alarms:** Occurs when a rate of change exceeds a predetermined setting i.e. speed or temperature.
- **Adaptive alarms:** generated using the 'rate-of-change' or 'deviation principle in combination with absolute thresholds.
- **Adjustable alarms:** absolute alarms in which the alarm settings are adjusted to suit operating conditions.
- **Re-triggering alarms:** alarms which are automatically re-annunciate to the operator in certain conditions.
- **Recipe-driven alarms:** alarms that are turned on or off in different plant states.
- **Statistical alarms:** utilising statistical calculations /process to filter out significant changes amongst noise.
- **First-up alarms:** used for examining the order of occurrence of alarms.

What should not be an alarm?

- Alarms without a defined operator response.
- Process variable or plant status changes that do not require the operator's attention.
- Events too fast for the operator to prevent.
- Events that are recorded in an alarm/event log which the operator does not need to see.
- Alarms to confirm successful operator actions.
- Duplicate alarms (may need to be logically suppressed).

Effective management of an alarm system resides with designating roles and responsibilities to ensure organisational ownership and accountability. EEMUA 191 provides an alarm management organisational / flow diagram (see Figure 12) referencing clauses within EEMUA 191 should further information be required.

Alarm management and functional roles –

- The steering committee (clause 3.1.1) - ideally comprises managers with a vested interest in improving and maintaining the alarm systems and who can provide the necessary resources. This committee should only meet once or twice a year.

- Alarm Coordinator (clause 3.1.4) - Provides the day to day management of the alarm systems, taking ownership of assessment programs, databases, audit tools, analysis and identifies improvement opportunities within the alarm system.

- Alarm assessment (rationalisation) (clause 3.1.5) - Varies based on knowledge and experience. Often the alarms coordinator will select and lead the assessment team based on the topic of focus and advise the steering committee of actions.

Alarm management measuring alarm performance against metrics outlined in EEMUA 191 –

- Summary alarm metrics (clause 3.1.9): Normally used to produce key performance indicators showing the general health of the alarm systems over defined periods (daily/weekly/monthly). Audience management and general users.

- Detailed alarm metrics (clause 3.1.10): review the alarm performance in detail or greater resolution (10 minute time slices). These are particularly useful for identifying design issues, bad actors, standing alarms and alarm floods.

- Operations reporting and feedback action (clause 3.1.11): suggests any problems identified in the analysis should be discussed as part of a regular operations/engineering maintenance meeting. Where possible causes are discussed and solutions sought from the various disciplines or if further resourcing is required referred to the steering committee for action.

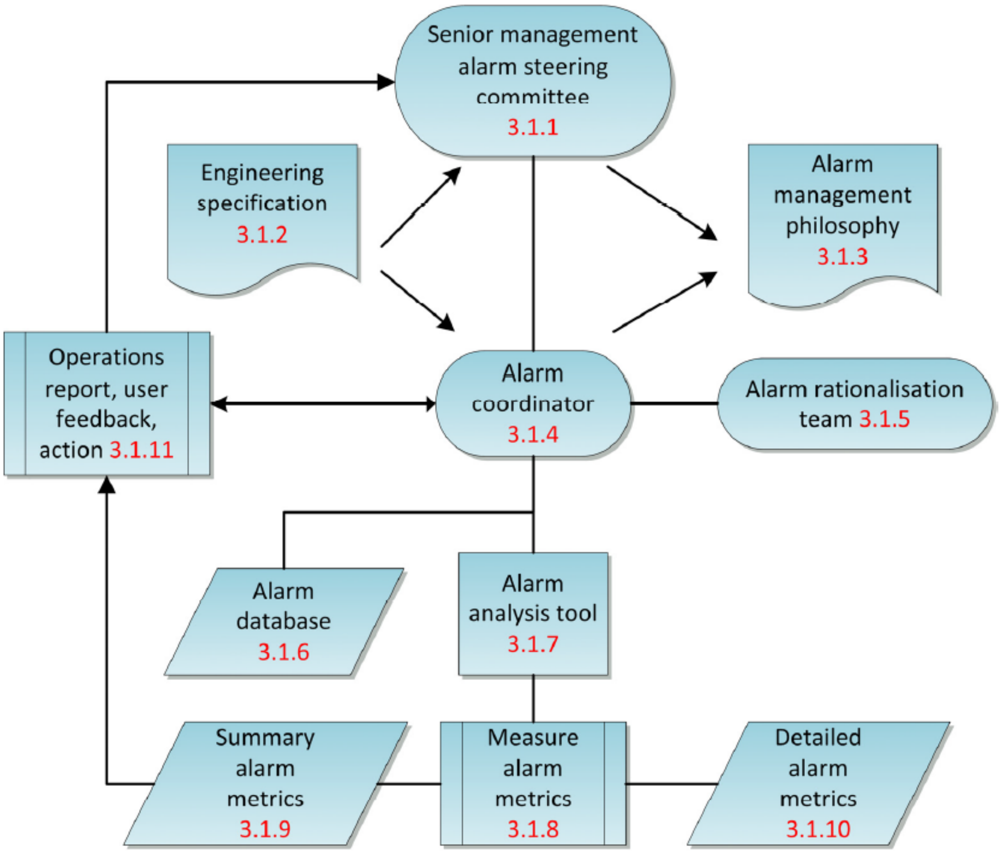


Figure 12: Alarm system management organisation (EEMUA 191, 2013, p43)

Fostering such a culture of accountability and continuous improvement sets this standard apart from other standards in the interest of industry best practice alarm management.

EEMUA 191 provides information and techniques to help improve the alarm systems deemed to be underperforming. Table 3 shows how EEMUA 191 categorises improvement techniques under high, medium benefit and other.

Techniques for improving alarm systems
High benefit
– Review alarm behaviour following all upset incidents to confirm usability
– Tune alarm settings on nuisance alarms
– Adjust deadbands on alarms which often repeat
– Eliminate alarms which have no defined operator response/no business purpose
– Ensure critical and high priority is allocated to appropriate alarms
– Review alarm messages which operators do not understand or know how to respond to
– Introduce an alarm shelving facility
– Introduce single line annunciation of repeating alarms on alarm list displays
Medium benefit
– Suppress alarms from out of service plant
– Replace nuisance absolute alarms on controlled variables with deviation alarms
– Apply filtering, transient suppression and de-bounce timers to repeating alarms
– Replace digital alarm sensors causing nuisance with analogue sensors
– Install automatic control/protection to reduce the operational importance of alarms
– Redesign actuator discrepancy alarms causing nuisance
– Re-engineer alarms from 'bad' signals so that they do not cause nuisance
– Introduce logic to combine and simplify redundant sets of alarms
– Introduce logic for eclipsing multi-level alarms (e.g. high and high-high)
– Introduce logic to dynamically re-prioritise alarms
Other
– Introduce automatically adjusted alarm settings
– Introduce operator set alarms
– Apply counters and auto-shelving to repeating alarms
– Group alarms which all need the same operator response
– Automatically suppress alarms according to the operating mode of the plant item
– Develop intelligent logic for identifying the most important alarms

Table 3: Effective techniques for improving alarm systems (EEMUA, 2013, p59)

Caution should be used before actioning or implementing these techniques for improving alarm systems. EEMUA 191 touches on the importance of completing an initial assessment against current best practice benchmarks. This ensures baseline performance data is obtained and any improvements shall be measurable once improvements are implemented.

Step so take during the initial improvement assessment are –

- ✓ plan what needs to be done to improve the system
- ✓ prioritising critical items against benchmarks
- ✓ provide timelines to gauge the improvement process and progress

In all cases, changes to an alarm system requires a management of change with appropriate approvals outlined in the alarm philosophy and management of change procedure for each respective company to ensure the alarms system integrity is not jeopardised.

Performance monitoring / improvements cover numerous metrics, benchmarks, key performance indicators and performance levels.

Collated in Table 4 are two type of performance metrics, objective (quantitative) and subjective (qualitative). Quantitative metrics are found using software filters and query tools based on the alarm system recorded data stored in the historic database. Qualitative metrics consider other factors such as operator workload, experience, environment and other areas which can be difficult to assess.

Operator training is briefly covered in EEMUA 191. Training should cover all realistic operational usages of the alarm system (EEMUA, 2013). Simulator training should expose the operator spurious alarms and alarm floods.

To measure an operator's workload qualitatively, EEMUA 191 formula for work rate (W) of an operator is calculated by the average alarm rate (R) multiplied by the average time (T) to respond.

What to measure	Type of measurement	How
Performance during a major upset	Quantitative	Measure major plant upset alarm rate per 10 min. period during upset
Performance in steady state operation	Quantitative	Measure average alarm rate. Per X time period/number of 10 min. periods
Alarms which are occurring most often (and hence causing most problems)	Quantitative	Measure individual alarm frequency per X time period
The distribution of alarm priorities	Quantitative	Measure percentage priority distribution of all alarms on the system
Alarms which have been active on the system for a long period	Quantitative	Measure the number of alarms which have been active for X period
Number of alarms configured	Quantitative	Measure total number of alarms on the system
Operators general satisfaction with the system	Qualitative	Operator questionnaire
Operators view of how useful the individual alarms are and the quality of the alarms	Qualitative	Alarm usefulness questionnaire
Operator response time	Quantitative/Qualitative	Measure time
General performance during a plant upset	Qualitative	Recording and analysing alarm data when a plant incident has occurred

Table 4: Summary of possible alarm metrics per operator station (EEMUA 191, 2013, p94)

The UK HSE report CRR 166 published in 1998, surveyed and analysed data from various process industries and concluded –

- Typical alarm rates in steady operation are around 1 every 2 minutes, which is hard to cope with on a sustained basis.

- It would appear that a rate of 10 alarms per hour is generally seen as acceptable and not a major cause for concern.

Table 5 specifies the benchmark performance metrics which are similar to ISA 18.2 performance metric. The alarm priority distribution metric indicates how well the plant control system is designed and how usable it will be during high alarm loads i.e. 80% of alarms should be a low priority alarm.

Usability metric	Benchmark value	Acceptability
Usefulness questionnaire	Nuisance score of 2.0 or less	
Average alarm rate in steady operation	Less than one per 10 minutes	Acceptable
	One per 5 minutes *	Manageable
	One per 2 minutes *	Over-demanding
	Greater than 1 per minute	Unacceptable
% of time outside average alarm rate	< 10%	
Alarms in 10 minutes after plant upset	Under 10	Acceptable
	10 – 20 *	Manageable
	20 – 100 *	Over-demanding
	Greater than 100	Unacceptable
% of time outside 'Acceptable' plant upset alarm rate.	<1%	
Average number of standing alarms	Under 10	
Average number of shelved alarms	Under 30	
Priority distribution	80% low, 15% medium, 5% high	

* It should be noted that the benchmarks given here apply to process industries, working with centralised control rooms. For different industries and different scenarios (e.g. distributed systems) the benchmarks will need recalibrating specifically to their industry (see later). However the basic KPIs remain valid.

Table 5: Summary of metrics and benchmark values (EEMUA 191, 2013, p99)

When a large number of standing alarms occur, one may draw conclusions of poor initial design or on-going maintenance issues. Regular occurrence of a high number of standing alarms should be referred to the steering committee with evidence to justify additional maintenance resources to reduce the backlog of standing alarms. Another concern being long standing alarms may lose visibility among other alarms listed in the alarm display log.

A primary key performance indicator (KPI) quantitative assessment tool comprises of four KPI's.

- **KPI-1 -** Average alarm rate - the total number of alarms annunciate to the operator / total number of time periods

- **KPI-2 -** Percentage of time steady state alarm rates are outside of acceptability target

- **KPI-3 -** Percentage of time upset alarm rates are outside of 'acceptable' alarm target. The average number of alarms for the 10 min. periods, which exceeded the 'acceptable' target figure of less than 10. (Accumulated number of alarms/ number of 10 min. slices). The % time for which the system exceeded the target number. ((10*number of time slices / total time period in minutes) * 100).

- **KPI-4 -** Maximum alarm rate (usually during plant upset) this is the worst case load during any ten minute slice.

Secondary KPI consider lower value metrics which include –

- **Shelved alarms** – target of less than < 30 shelved alarms and the duration of each shelved alarm

- **Standing / stale alarms –** targets less than < 10 alarms and the duration of each alarm. A standing alarm becomes a stale alarm when its standing duration is greater than > 24hrs.

- **Top 10 load percentage** – considers the percentage of alarm occurrences (frequency) over the set measurement period

Bad actors (high frequency repeating alarms) can be viewed as noise in an alarm system. Easily becoming a nuisance to an operator, nuisance alarms do not require analysis on activation once diagnosed. If a bad actor contributes a significant percentage of the overall alarm total (percent alarm load > =10%) then it is reasonable to remove it from the average calculation to better gauge the underlying alarm system trend. In some cases it may be necessary to shelve the bad actor while maintenance / engineering investigate.

Table 6 summarises performance metrics in two plant states, steady and upset. The four states termed robust (acceptable), stable (manageable), reactive (over-demanding) and overloaded (unacceptable) describe the individual alarm rates in a prescriptive manner.

		Steady State		Upset State	
		Ave alarm rate /10 min.	% Time outside target ave value.	Max. alarm rate /10 min.	% Time outside target
State 4	Overloaded (mitigation required)	>10	>25% & <50%	>100	>2.5% & <5%
State 3	Reactive	<10	>10% & <25%	<100	>1% & <2.5%
State 2	Stable	<2	>1% & <10%	<20	<1%
State 1	Robust	<1	<=1%	<10	<1%

Table 6: Alarm system performance metrics (EEMUA 191, 2013, p104)

To support communication of the alarm system state a colourful graph (see Table 7) is included. Utilising such to demonstrate an alarm state would be effective if plotted over time or after an improvement was implemented (Upset before change / Stable after change).

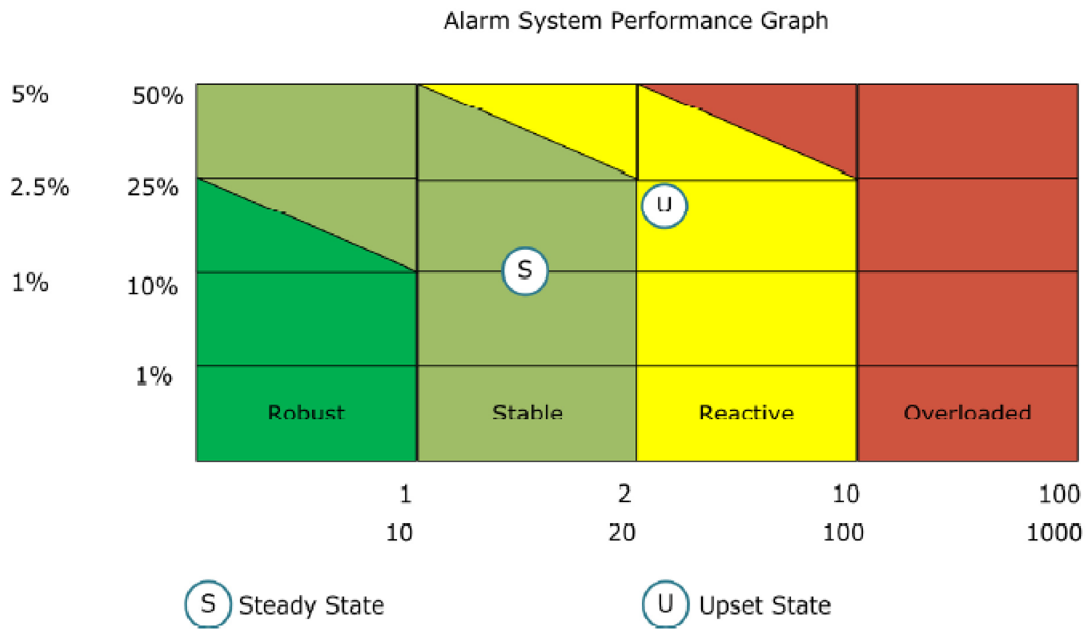


Table 7: Alarm system performance (EEMUA 191, 2013, p104)

The details for the four states defined can be found in EEMUA 191, should the alarm data analysis require reference to these tables, definitions shall be included when referred in the analysis.

Interestingly, EEMUA has included a validation report of the metrics completed by the Abnormal Situation Management Consortium (ASM). ASM studied the performance metric prescribed in EEMUA 191 against 37 unique operator HMI consoles. ASM study found one third of consoles were able to achieve EEMUA 191 the normal alarm rate. However, only 2 of 37 consoles came remotely close to the not more than 10 alarms in the first 10mins. This indicated more dynamic or model based alarm handling method was required. The ASM Consortium concluded there was no silver bullet to achieve EEMUA 191 alarm system performance recommendations (EEMUA 191, 2013)

In addition to the performance metrics provided, EEMUA also provides a questionnaire template which operators can complete. The aim of such is obtain the users impression of the alarm system Interestingly an alarm system may appear substandard yet the questionnaire may suggest otherwise. An example of an alarm systems operators questionnaire can be found in appendix F.

In summary, ISA-18.2, IEC-62682 and EEMUA 191 support one another. EEMUA 191 describes in detail the tools and techniques of various aspects of alarm management (e.g. rationalization, risk assessments, graphics design, management structure, key performance indicators (KPIs) and more). ISA 18.2 and IEC-62682 clearly define what is required of an alarm system and the overall lifecycle approach to alarm management. Based on such, there is enough information to determine an alarm systems performance by comparing alarm data to the listed benchmarks. In addition referencing corrective measures where poor performance areas are identified is very useful, as covered in EEMUA 191. Although the metrics are clear, the onus rests with those tasked with analysing the raw alarm data and presenting the results in such a way to gain and maintain interest and resources so the alarm systems performance does not degrade with time and neglect.

3.2 Human Factors

As part of understanding process control alarm, one must also consider or better understand human factors and human performance given humans (operators) are the targeted audience of the alarm. Human performance has been a major contributing factor to many industrial incidents and accidents throughout the world. Human error is documented in a number of thoroughly investigated, high-profile events in the nuclear power industry (Gertman et al. 2002).

In the 1990's, the U.S. Nuclear Regulatory Commission (NRC) commissioned a need to devise a traceable method to analyse human reliability. In 1994, in conjunction with the Idaho National Laboratory (INL), the Accident Sequence Precursor / Standardized Plant Analysis Risk Model (ASP/SPAR) human reliability analysis (HRA) method was developed and used in the development of nuclear power plant (NPP) models. Based on experience gained in field testing, this method was updated in 1999 and renamed SPAR-H, for Standardized Plant Analysis Risk-Human Reliability Analysis method. The SPAR-H method is an adequate HRA tool for use with the SPAR models in performing risk analyses of operational events/conditions.

SPAR's research identified eight performance shaping factors (PSF) capable of influencing human performance. PSF are included in the SPAR-H quantification process these include (Gertman, 2005) –

- Available time
- Stress and stressors
- Experience and training
- Complexity
- Ergonomics (including the human-machine interface)
- Procedures
- Fitness for duty
- Work processes

3.2.1 Available Time

Available time is the amount of time operators have to diagnose an alarm condition and execute corrective action. Reduced available time limits the operators ability to consider alternatives and ultimately their ability to perform. This problem often occurs when annunciator alarm set points are set too close to the abnormal condition and limit the operator(s) available time to react and perform the necessary alleviating actions (Gertman, 2005).

3.2.2 Stress/Stressors

Stress and arousal are broadly defined, describing negative and positive motivation factors of human performance. SPAR-H refers to stress as undesirable conditions and circumstances affecting one's ability to perform well and complete a task. Some contributing factors to stress include mental stress, excessive workload, physical stress (environmental factors i.e. poorly designed office, hot or cold environment, noise, lighting etc.), narrow attention field, muscular tension as well as apprehension or nervousness associated with an event. All these broadly define related causes of stress that can affect an operator's mental and physical performance (Gertman, 2005).

3.2.3 Complexity

Complexity naturally refers to the difficulty of a task performed along with the task environment. The greater the difficulty in performing the task increases the chance of human error. Mental effort such as performing mental calculations, memory requirements, understanding the underlying model of how the system works, and relying on knowledge instead of training or practice all contribute to task complexity. (Gertman, 2005)

Figure 13 neatly outlines factors contributing to a tasks complexity and for metric purposes a highly complex task(s) would include higher ambiguity in diagnosing, prioritising and executing many variables and concurrency. A nominal level task complexity has no ambiguity, one or a few variables and is not difficult to perform.

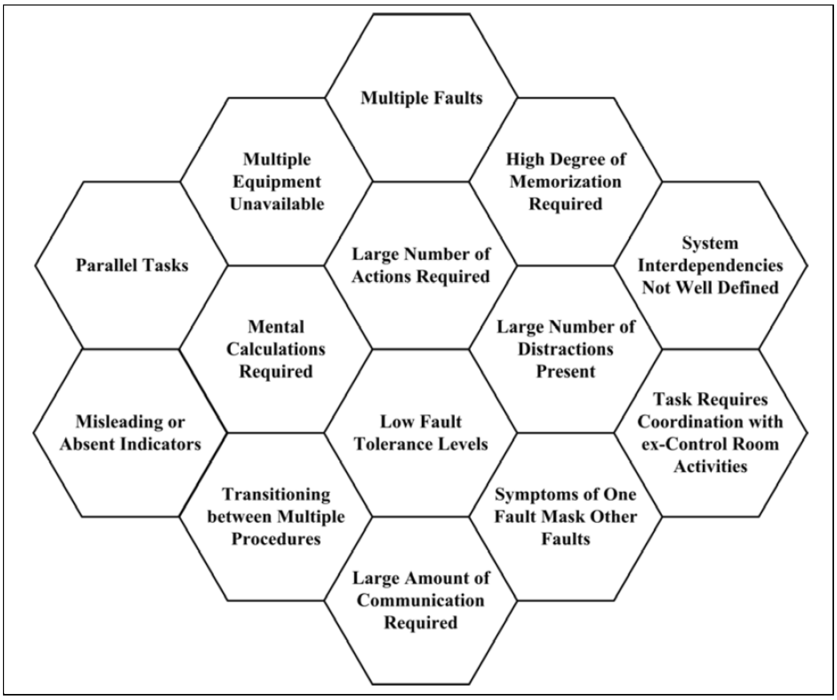


Figure 13: Task complexity (Gertman, 2005, p 22)

3.2.4 Experience and Training

Experience and training of operators involved in a task includes the years of experience an individual or crew has, training on conceived process scenarios or accidents, time since last scenario training and actual involvement in an operation scenario. To gauge a metric for experience and training a rating score of low considers less than 6 months experience and or training that ensure adequate knowledge or practice required to safely perform required tasks during various possible abnormal operating conditions. An operator with a high level of experience and training would have demonstrated extensive knowledge and practiced various potential scenarios, demonstrating high proficiency. It is well documented that good training makes operators well prepared for possible situations further demonstrated in air travel flight simulators and military applications. (Gertman, 2005)

3.2.5 Procedures

Formal operating procedures are vital in guiding operators on tasks and contribute towards PSF. Procedural problems are often identified during an incident investigation, where procedures are considered wrong or provide inadequate information. PSF levels differ depending on whether the activity is a diagnosing or action situation. SPAR-H advises when analysing the PSF consideration given to the task complexity, where multiple procedures and transitions between procedures and groups are required to support a task or grouped tasks. Where procedures are problematic or inadequate then the HRA analyst should assess the procedures and determine whether they should be assigned an inadequate or poor rating on the metric. (Gertman, 2005)

3.2.6 Ergonomics and human machine interface (HMI)

Ergonomics refers to the ease with which humans can interact with the equipment and includes a number of facets from room or plant layout, ease of access, lighting, chair type to limit fatigue and human machine interface (HMI). HMI ergonomics include the ease of interaction with the controller, type of displays, location to the operator console, and ease of navigating around the control system, screen layout, quality and quantity of information. Extensive studies have been conducted on the design of controller displays and will be considered in further as part of a graphic design alarm filter.

An example of poor alarm annunciator design have been found where only a single acknowledge button is used for all alarms present at the point in time, this increases the probability of overseeing alarms that may require action and hence a problem may escalate until diagnosed. (Gertman, 2005)

3.2.7 Fit for Duty

Fit for duty describes the physical and mental state of an individual to perform the assigned tasks at the required time. Sickness, fatigue, drug use (legal or illegal), personal problems and other distractions are known to hinder ones fitness for duty. Fit for duty includes factors associated with overconfidence or complacency but are not related to training, experience or stress. A measureable metric operator would be considering unfit for duty due to illness, intoxication, physical or mental incapacitation. Fit for duty means the person is healthy, fit, willing and able to complete the assigned task in a reasonable timeframe. (Gertman, 2005)

3.2.8 Work Processes

Work processes effect performance through organisational structure, management team, safety culture, planning, and communication and company policies. The work flow process from planning, communication and execution can affect individual and team performance. Lagging indicators of poor management processes, communication and execution can amount to increased rework, maintenance program backlog, enforcement actions, turnover and performance inefficiencies. It is important the supervisor maintains a position of leadership in the control room, rather than taking over an operator role in the case of an event they are familiar with (often having progressed from such rank) as this would indicate a breakdown in work processes. (Gertman, 2005)

A measure of work process success or failure could be gauged in parts from alarm systems analysis as well as the computerised maintenance management system. Both would reiterate any perceived notions by providing key performance indicators (KPI) that could be incorporated into the shift handover and management meeting possibly adding to individual and team success i.e. rework relating to effectiveness or double up of alarm system corrective work orders.

Where there are humans involved the automated machine is in part limited by the human factor. The number issues involved in an alarm response have many variables both from a control system and human intervention. To develop a metric of performance numbers seems difficult as there are also social issues where a company starts to pry and/or ask personal questions about one's mental or physical state at work. Hollifield and Habibi (2011) in the ISA comprehensive guide suggest a performance metric cannot be established. "Alarm response is not an automated process involving deterministic machines; it is a human cognitive process involving thought and analysis."

Several step have been identified which operator take to respond to an alarm (Hollifield & Habibi, 2011). (Refer to Figure 11 also for the Alarm State Transition Diagram)

1. Detecting the alarm.
2. Acknowledging the alarm via the HMI (often operator opt to silences the audible alarm and in designed cases the graphic highlighting the alarm state will change indicating acknowledged.)
3. Investigates the alarm by navigating to the appropriate graphical screens to determine contextual information of alarm state and origin. This process involves analysing the process sometimes using trends to determine the alarm's cause

4. Verifying the alarm ensures the alarm is not a result of hardware malfunction or software problem.
5. The Operator decides on the appropriate action(s) in response to the alarm. This may be a direction of text selectable from the display or involve consultation with other people.
6. Implementing the chosen action(s) is often through the HMI or control system however, may involve assistance from the others. In the case of a field operator the control room operator often makes contact via radio explains the task and wait for feedback. In cases, there may be a need to venture into the field to perform the necessary action or a combination.
7. Monitoring the system(s) ensures the corrective action(s) performed extinguishes the alarm and returns the system to its operating envelope.

In reference to Hollifield and Habibi (2011) suggest in relation to an operator's process "There is no such thing as a single number that represents a time quantity or duration. In general, how much time does it take for an operator to handle an alarm?" The answers depend upon the alarm, the interface, system response and the operator!" This statement in part seems to concede defeat, yet a measure seems possible.

Therefore, referring back to the ISA 18.2 standard, Figure 14 demonstrates a clear relationship between alarms, an operator assessment, and action in response to time.

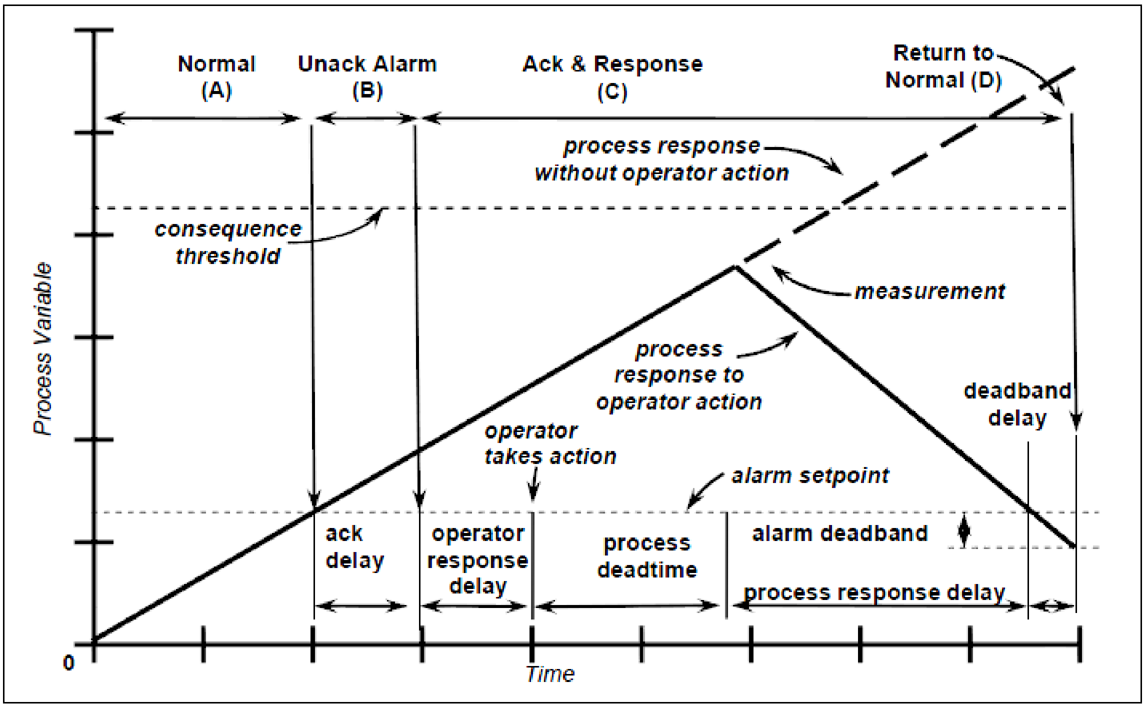


Figure 14: Alarm time line (ANSI/ISA 18.2, 2009, p33)

Figure 14 outlines the possibility of measuring time for the different alarm states that will aid quantifying alarm load. However, this appears singular however often operators have to juggle multiple alarms and or consider multiple variables. An example suggested by Hollifield and Habibi (2011) considers a simple tank with a high tank level alarm, unfortunately the tank has three inputs and three outputs either of which could be contributing to the tank high level alarm or even that the sensor itself has failed. This is where alarm management aids the operator performance through effective instrumentation and monitoring strategies. In this example, if a restriction at an outlet is the cause, the alarm logic if designed well, would calculate the required rates in and out of the tank and alert the operator to the problem prior to the tank high level alarm, which if exceeded may shut down or reducing fill rates based on the tank available capacity above high level. Also there may be preconfigured trends which will aid the operator identifying the cause. In this case the response time from alarm to return to normal is a collective measure of the human and controller's ability or effectiveness to manage an abnormal situation. Where less human interaction with the controller responding to alarms measured by time, would indicate an effective control system.

The aim is to reduce the alarm rates to a manageable level to reduce the likelihood of an alarm being missed or response delayed. Alarms indicate abnormal situation requiring attention, this indirectly is a measure the control system design and effectiveness to contain the process within operation envelope minimising manual intervention by an operator. The various design technique to reduce alarms are covered in further sections. Where human factors are concerned, as complex as it may seem, one must be set for success otherwise the system fails. The measure of success for operators will be evident through KPI's, scenario based training, management support, clear communication and openness for continuous improvement.

Monitoring performance in 10 minute, hourly, daily and monthly intervals greatly assists the visualisation of performance. How best to measure and visually present performance, depends on the available data and targeted audience. Performance calculations, averaged and used in isolation can be misleading, so too the mean, median, standard deviation, Roche limit and other analysis techniques. A problem may arise with measuring and calculation of an operator's workload Results may show one operator can handle another operator's workload. Hence, this misleading information may lead management to consider the opportunity to reduce overhead by removing an operator. However, doing so would expose the company to a hazardous situation during an abnormal event when the second operator's availability and skill set is required, quantified in the form of a risk assessment.

It is well documented that during alarm overload the operator’s handling capacity is exceeded resulting in the operator ignoring alarms. This dangerous condition leaves limited assurance the right alarms are being prioritised and managed, leaving cases where the wrong alarms are actioned resulting in incidents. Human factors play a significant role in an operator’s ability to respond having both inside and outside influences and complexities which constantly alter a human’s ability and performance. Although surveys are available (see appendix F) for management to implement, personal information aspects present challenges in the form of confidentiality and truth (example - few would suggest they are mentally unstable). In most cases, effective supervision and relationships, built on respect and trust will ensure transparent communication and minimise human factor errors.

3.3 Human Machine Interface (HMI)

Effective HMI in modern day processing plants has developed in leaps and bounds given the important role HMI’s play. The effective transfer of information between operator and human is vital therefore great amount of research, development and guidance though the Abnormal Situation Management (ASM) consortium part of Honeywell Incorporated has been completed. A publication released in 2007 by ASM titled Effective Operator Display Design complements a growing knowledgebase if effective techniques expedite an operator’s reaction to an alarm or abnormal condition. (Bullemer et al, 2007)

Some of the simple techniques recommended by the ASM consortium include the use of grey scale graphic screens that change colour to highlight an alarm, location and priority levels. Figure 15 illustrate a grey scale display noting minimalist colour is displayed.

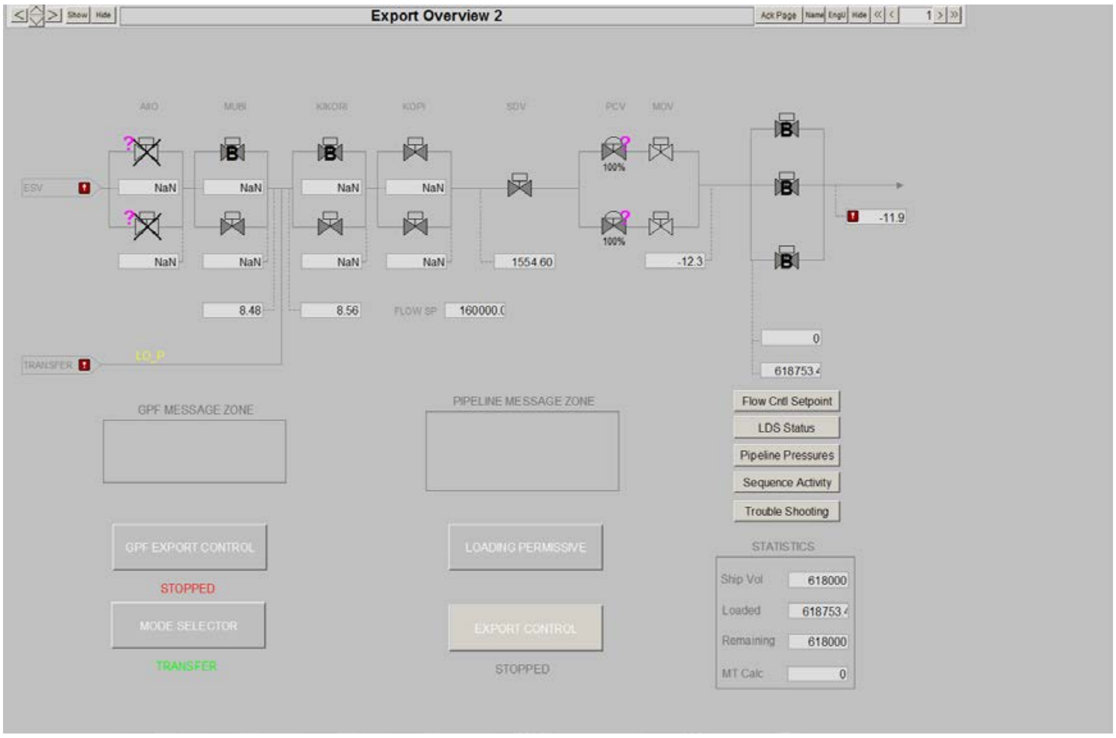


Figure 15: Grey HMI graphic example with colour alerts. (Company B graphics page)

Grey scale displays appear in contrast to older colour graphic technology, colour being used to represent different process lines and equipment. Unfortunately although colour graphics looked smart they often masked subtle detail, in some cases an alarm state, delaying an operator's assessment and response. Figure 16 demonstrates the older style colour HMI graphics.

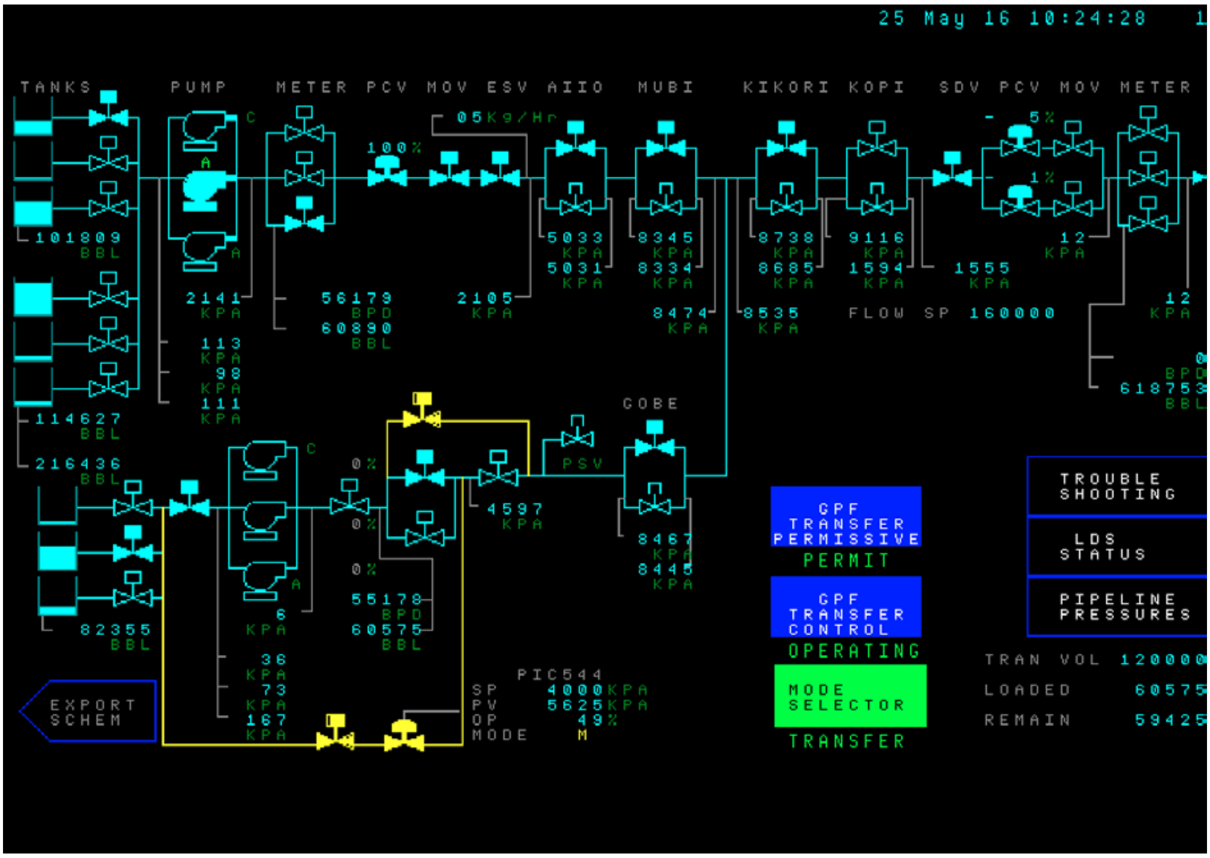


Figure 16: Example of an older DCS graphics HMI (Company B graphics page)

A study conducted in 2005 by Errington et al (2005) noted that operators using an ASM designed display demonstrated considerable time reductions in responding to alarms. Table 8 compares the traditional time to respond in comparison to ASM consortiums grey scale results.

Measure	Traditional	ASM consortium
Scenario time to complete (min)	18.1	10.6
Scenario completion (%)	70	95.5
Early Event Detection (%)	10	47.7

Table 8: Measured improvements using ASM graphic guidelines (Bullemer et al, 2007, p199)

Based on ASM consortiums research and guidelines into effective operator display designs, no further research was explored into HMI's this area appears well researched and effective in use.

3.4 Company approaches to alarm management

As part of this research, two companies have kindly allowed access to their alarm management systems. Both will remain anonymous on account of their privacy as the intended purpose is to explore alarms management not the companies. The Pseudonym shall be used from this point forward Company ‘A’ and Company ‘B’. Company ‘A’s’ alarm management system is in the implementation / design stage (commissioning pending), it is hoped involvement in the commissioning will occur while this report is being written. Company ‘B’ is a mature company with aging equipment and a well-established alarm management system.

3.4.1 Company “A” review

Researching company ‘A’ corporate alarm strategy refers the using the following industry accepted standards and guidelines.

- IEC-62682: Management of Alarm Systems for the Process Industries
- ISA 18.2-2009: Management of Alarm Systems for the Process Industries, published by the international society of automation (ISA)
- EEMUA 191: Alarm Systems – A guide to design, management and procurement, published by the Engineering Equipment and Material Users Association (EEMUA)

The company “A” alarm management procedure states purpose of the alarm management procedure is to ensure the lifecycle of alarm management systems cover key areas prescribed in ISA 18.2-2009 and EEMUA 191. The alarm management lifecycles include –

- Identification
- Rationalisation
- Design
- Role and Responsibilities
- Management of training and competency of personnel
- Implementation
- Operation
- Maintenance
- Monitoring and Assessment
- Assurance Review
- Management of change (MOC)

Another stated functional purpose of the alarm management corporate document is to clearly demonstrate to the authorities and other interested parties alignment and use of industry accepted standards and practices in alarm management and to define key roles responsible for its success.

Company ‘A’ has selected a software based alarm management system supplied by PAS Incorporated, referred to as PlantState Suite (PSS). The PSS shall be located at the head office and interface with the integrated control safety system (ICSS) (Yokogawa’s Exaquantum) via mirrored remote terminal databases (RTDB). All necessary information from the ICSS will be directed to the PSS including alarms, events, configuration, shelving and other relevant information to support, monitor and assess the alarm management system. Due to the remote physical locations of the interconnected facilities (4000km plus), it is vital the corporate alarms management system remains synchronised with each of the interconnected systems. To ensure the PSS system is synchronised, a periodic validation check will be completed. However, synchronisation issues and delays are considered to be a vulnerability of the corporate alarm management software reporting system. Given the PSS software is custom designed, no recognition of prior learning will be granted for those responsible for the PSS system. Therefore, only company identified personnel will be trained as super-users, and required to acquire specific training competency supplied by the vendor.

Although Yokogawa Exaquantum has an optional alarm management system, NTPS100 Exaplog Event Analysis Package, PSS is the preferred external alarm management suite given specific reporting and analysis functions.

The alarm design principles align with EEMUA 191, alarms shall inform the operator of an abnormal condition, guide and advise actions to take allowing adequate time for the operator response, correcting the alarm condition parameter back to its optimum operating envelope. Alarms will not duplicate an action nor will they risk being potential nuisance alarms if so that will be rationalised.

Alarm prioritisation is divided into 4 categories low, medium and high as per the risk matrix below. Each priority level is associated to the highest possible consequence scenarios and priorities based on maximum time for the operator to control the situation and hence overt the considered consequence.

The fourth priority level not listed on the matrix is critical. Critical alarms are reserved for confirmed fire or gas (immediate danger), alarms identified in companies performance standard or where the alarm is part of an instrumented protection layer (IPL). Such cases are part of a safety instrumented function (SIF) requiring the operator undivided attention when in alarm state, as the operator is part of the equipment's safety integrity level (SIL). The higher the level of safety integrity level (SIL) the lower the probability that the SIF should fail to carry out the required functions. It is possible during an alarm flood the operator action / monitoring may be distracted and SIL undermined. This is different to other instruments that have a SIF build into their design providing a higher SIL however, in a few cases some instruments do not or are specialised and therefore require additional operator monitoring and action (SIF) to achieve a higher SIL level required for the application. These requirements are set out in the international standard IEC 61508.

IEC61508 has been widely been accepted as the basis for specification, design and operation of Safety Instrumented Systems (SIS). The company has applied strict conditions for IPL alarms; ensuring training is conduced so personnel understand the importance and management of such alarms. Included is refresher training so the operator is familiar with these types of alarms. There is no specification of refresher training frequency or suggestion of higher alarms event scenarios to familiarise the operator with considered possible scenarios and importantly allow the company to gauge response of the alarm system as other industries, example pilot flight training and the nuclear industry.

The corporate standard sets out a risk-based approach for deciding the SIL for systems performing safety functions.

						Max Time to Respond			
	Production / Financial	Health & Safety	Environment	Legal		> 15 minutes	10 -15 minutes	3 -10 minutes	1 - 3 minutes
Consequence	$10M < X ≤ $100M	Major injury or illness, permanent partial disability, lost time injury	Local to medium scale event with short to medium term impact on environment. No threat to overall population viability of protected species	Serious breach of regulation. Investigation by regulatory authorities. Potential litigation and moderate fines	Severe	Low	Medium	Medium	High
	$1M < X ≤ $10M	Minor injury or illness, alternative duties injury, medical treatment injury	Local scale event with short term impact on the environment. Minor and temporary impact on a small portion of the population of protected species	Minor legal issues. Report provided to regulatory authorities. Potential for minor fines	Major	Low	Low	Medium	High
	< $1M	Slight injury or illness, first aid injury	Local scale event with temporary impact on environment. Behavioural responses inconsequential ecological significance to protected species	Breach of internal standards. Potential scrutiny by regulatory authorities	Minor	Low	Low	Low	Medium

Figure 17: Alarm prioritisation matrix (Company A, 2015, p67)

Company 'A' requires reassessment of the design if a consequence of an alarm is risk ranked greater the highest level of a SIF, this suggests greater than severe or the response time cannot achieve in the maximum time to respond.

The alarm priority distribution per workstation per operator aligns with EEMUA 191 section 6.3.4, general usability benchmarks and also appendix A3.3 - priority distribution of alarms table 27. By ensuring the priority distribution (Table 9) is adhered to, the operator should be able to effectively manage the alarms in a 12 hour shift.

Table 2: Target Priority Distribution

Priority Band	Alarms Configured
Critical	~20 / console
High	5 %
Medium	15 %
Low	80%
Logging	No limit[2]

Table 9: Target Priority (Company A, 2015, p29)

Alarm filtering and alarm suppression considers the following techniques in the alarm management procedure.

To minimise nuisance alarms a technique mentioned in ISA18.2 section 10.4.3.2 is used, introducing a delay on or off function where other means have failed. Consideration is required not to limit the response time by the operator when using the suppression technique.

To prevent nuisance alarms generated by fast transient analogue signals, a first order signal filter time constant may be applied as outlined in EEMUA table 32 – table of filter time constants. Caution is advised not to negatively impact the response of the controller where safety critical alarms are involved.

The use of a hysteresis or dead band applied around the set point as an operating envelope may prevent alarms when the signal moves slightly off normal (set point) but in between hysteresis limits during normal operation. This technique is covered in EEMUA 191 and ISA18.2 (clause 10.4.2.2) to prevent chattering and nuisance alarms. In the case of the measure variable a percentage hysteresis of the total devices range is limited to less than 5% for flow and level, less than 2% for pressure and 1% for temperature measurement and control. Hence, these measurements are found to be alarming within the percentage, applying the percentage hysteresis is allowed in the standard.

Company ‘A’ equipment notification alarms section 12.7 and 12.8, outlines notifiable alarms and priorities. Table 10 identifies actions required the operator and maintenance to investigate, yet there is no time specified to respond based on priority. This observation could be a suggested opportunity for improvement. Applying and reviewing alarm KPI’s assigned to maintenance could be measured under a standing alarm or shelved alarm. Consideration should also be given to work processes such as maintenance work order, approvals all amounting to the effort to return the alarm back to normal.

Detection Scenario	Standard Application Ref.	Reason for Priority	Priority
PCS cabinet fault (marshalling, network, server, system, workstation & PDP cabinets) *Earth leakage fault, termination board fault, power supply module or unit fault*	N/A	Notify maintenance	Low
PCS cabinet high temperature *Cabinet temperature above 30 degrees*	N/A	Notify maintenance	Low
PCS cabinet UPS fault *Surge protection alarm*	N/A	Notify maintenance	Low
SIS / FGS fault (server, system cabinets)	N/A	Notify maintenance	High
SIS / FGS cabinet high temperature (server, system cabinets)	N/A	Notify maintenance	Low

Table 10: System diagnostic priorities (Company “A”, 2015, p38)

Table 11 shows the various alarm types and the action required by the operator. In the cases below most require the operator to notify maintenance assigning a low priority to the condition.

Detection Scenario	Standard Application Ref.[12]	Reason for Priority	Priority
Motor Operated Valve *MOV internal Fault (-FLT.ALM)*	1480	Notify maintenance	Low
Motor Operated Valve *Output failure or disconnection (OOP)*	1480	Notify maintenance	Low
Motor Operated Valve *Input value above range (+IOP) or below range (-IOP)*	1480	Notify maintenance	Low
Motor Operated Valve *Conflicting / illegitimate feedback state (PERR)*	1480	Notify maintenance	Low
Motor Operated Valve *Command disagree (ANS+, ANS -)*	1480	Notify maintenance	Low
PID *Output failure or disconnection (OOP), or output bad connection (CNF)*	1700, 1710	Notify maintenance	Low
PID *Valve position above (IOP+) or below low (-IOP) limit*	1700, 1722	Notify maintenance	Low
PID *Valve has not reached the desired position (DV+, -DV)*	1700, 1722	Notify maintenance	Low
PCS Redundant valve control *Output failure or disconnection (OOP), or output bad connection (CNF)*	1712	Notify maintenance	Low
PCS Redundant valve control *Valve position above (IOP+) or below low (-IOP) limit*	1712	Notify maintenance	Low
PCS Redundant valve control *Valve has not reached the desired position (DV+, -DV)*	1712	Notify maintenance	Low
Modbus loop fault *Transmitter fault state (-TF.ALM)*	4000	Notify maintenance	Low
Safety SDV output connection *Output failure or disconnection (OOP)*	1401, 1404	Notify maintenance	Low
Safety SDV / BDV Digital feedback *Conflicting / illegitimate feedback state (PERR)*	1401, 1404, 1430	Notify maintenance	Low
Safety SDV / BDV Digital feedback *Command disagree (ANS+, ANS -)*	1401, 1404, 1430	Notify maintenance	Low

Table 11: Equipment notification priorities (Company "A", 2015, p 40)

From an alarm management perspective the opportunity to improve the alarm system, is by first allowing the operator to shelve the alarm, ideally under a maintenance assigned alarm shelf, this would allow better distribution and accountability between production and maintenance shelved alarms. Potential maintenance response KPI errors based on duration of the shelved alarm could occur if the operator does not follow advised alarm action procedure and notify maintenance promptly. This error will should be minimised through a hierarchy of control by requiring certificate, access to shelve alarms and approval outlined in the shelving alarm condition. Equally, maintenance should not be penalised based on alarm acceptance, hence the response time would be gauged through the maintenance management system from the time the work order was created to closure.

#	One-Off / Continuous	Name	Max. Duration (HOLD 25)	Use Case	Management	Approval	User Access on Console
1	One-off	One-shot Shelf	7 days	Removal of standing alarms. Once alarms normalise they are automatically removed from this shelf.	None	ATL / PTL	Supervisor
2	Continuous	Shift Shelf	12 hours	Removal of chattering alarms due to faults (except Critical alarms). To be used whilst permission to shelve under Shelf 4 is organised.	Alarm Shelving Certificate	ATL / PTL	Supervisor
3	Continuous	Critical Alarm Shelf	3 days	Shelving of Critical Alarms	Bypass Certificate	Site Controller & TA2	Supervisor
4	Continuous	Short Term Shelf	14 days	Removal of alarms due to faults that are extended duration (except Critical alarms)	Alarm Shelving Certificate	ATL / PTL	Supervisor
5	Continuous	Maintenance Shelf	2 years (Long-term)	Removal of alarms due to maintenance activities of extended duration. Excludes critical alarms.	Cold Work Permit	ATL / PTL	Supervisor
6	Continuous	MoC Shelf	2 years (Long-term)	Removal of problematic alarms (including critical alarms) that are to be addressed under the MoC process	MoC	I&C TA2	Engineer

Table 12: Alarm Shelving (Company “A”, 2015, p47)

Dynamic suppression when enabled is limited to the process control system (PCS) and not the Safety Instrumented System (SIS). Rigorous testing and control to any logic application to dynamically suppress an alarm must be peer reviewed. Through the PlantState Suite any dynamic suppression event must be review to ensure no suppressed alarms were generated or critical alarms required suppressed by the logic.

There is an opportunity to develop a graphic page for use during a dynamic suppression event giving the ability for the operator to gauge a section(s) of the plant for example depressurising a process system where shut off valves return to closed and depressurising valves open. In the event these conditions or status hasn’t been reached but may be dynamically suppressed to prevent alarm floods the operator can view the state of plant and request further investigation whilst attending to the depressurising event and potentially higher priority alarms.

The alarm management strategy in section 15.2, deals with operator response to elevated alarm levels. The work process supports human factors during elevated alarm states by suggesting less operationally significant tasks must be reduced to allow the operator to focus on the abnormal plant state.

A permitted operation KPI is calculated for each operator control console, to aid a response by operations while engineering or maintenance investigates the elevated alarm state. Table 13 shows three column tables, titled frequency, standing and flood. These alarm states help value each condition adding towards a collective average using the permitted operations formula above Table 13. It is considered as a guide when the permitted operations value increases scaled 1-10, the operators have can use the decision matrix Table 14 to help manage decisions during the abnormal situation.

$$\textit{Permitted Operations KPI} = \min(KPI_{frequency} + KPI_{standing} + KPI_{Flood}, 10)$$

Frequency *1 hourly rolling average* *(calculated hrly)*	**KPI**
>40	10
31-40	8
21-30	6
12-20	4
6-11	2
3-6	1
<3	0

Standing *12 hourly rolling average* *(calculated hrly)*	**KPI**
>100	10
31-100	8
16-30	6
10-15	4
6-10	2
2-4	1
<2	0

Flood *Max. alarms per 10 minute interval over last 2 hours* *(calculated hrly)*	**KPI**
>80	10
50-80	9
41-50	8
31-40	7
21-30	5
10-20	3
<10	0

Table 13: Contributors to permitted operations KPI (Company A, 2015, p 54)

KPI	Rating	Action
0	Target	
1	Normal	
2	Normal	Use shelving to remove nuisance alarms
3	Normal	
4	Elevated Stabilise	Limit communications to control room operator. Halt new permit that increase alarm workload
5	Elevated Stabilise	
6	Elevated Stabilise	
7	Elevated Slowdown	Suspend permits that contribute to alarm workload
8	Elevated Slowdown	
9	Elevated Slowdown	
10	Abnormal Shutdown	Add additional control room operators, shutdown parts of the process

Table 14: Operator response for permitted operation KPI (Company A, 2015, p 53)

It is recognised that a flood situation will be masked by an averaging filter hence there is an opportunity to consider other avenues to improve the analysis to better represent the KPI. An alarms flood is described in ISA 18.2 clause 3.3.10 as a condition where the operator cannot effectively handle more the 10 alarms in a 10 minute period. The start of an alarm flood occurs for the first regular 10 minute interval of such a rate and ends when the rate is less than 5 alarms per 10 minute for a regular 10minute interval.

Set targets have been specified for alarm rates and standing alarms as per Tables 15 and 16. This represents alignment with benchmark standards.

Acceptability	Hourly Alarm Rate
Unacceptable	>12
Target	3 to 6
Ideal	<3

Table 15: Acceptable alarm frequency rates KPI (Company A, 2015, p 50.)

Acceptability	Average Standing Alarms
Unacceptable	>10
Target	< 10
Ideal	<2

Table 16: Acceptable standing alarm count KPI (Company A, 2015, p 50.)

Monitoring and improvements benchmarks have been recognised with reference to ISA 18.2 clause 16.5.1, with the improved condition to reduce an average filter by reducing the sample time periods to monthly, weekly and hourly data samples. This will better reflect the true state of the control system and operator loading.

The following monitoring metrics reports are proposed –

Weekly –

- KPI Trends (instantaneous values)
- Alarms per hour
- Stale alarms per hour
- % time spent on flood
- Number of standing alarms
- Number of shelved alarms
- Average alarm frequency
- Average alarms per unit / hour
- Average standing alarms per count
- Average shelved alarm count
- Maximum alarm rate over 10 minutes for the last 7 days (flood)
- Chattering alarms

- Frequent alarms
- Standing alarms
- Shelved Alarms

Additionally a monthly report will include

- Number of shelved alarms in each shelve
- Shelved alarms per shelf for the month
- Priority distribution

It is noted that the alarms rates, or number of alarms are generally measured however in determining and alarm priority a response times was considered as per the alarm risk matrix which ultimately determined the alarms priority. Therefore, in addition to the monitored variables suggest each console include a KPI for -

- Number of shelved alarms
- Distribution of alarms shelve used
- Priority distribution per console
- Time to respond
- Average rate of time to respond
- Max duration to respond
- Minimum time to respond
- Maximum time in alarm
- Average time in alarm per alarm

3.4.2 Company 'B' review

Company 'B' is a mature oil and gas company with 4 producing fields APF, CPF, KMT and GPF all having various integrated control systems both new and old. Their alarm management system specifies alignment with the same standards as company 'A', therefore research into company B will focus on monitoring and assessment.

An extract report of company 'B' (Table 17) compiles all alarms and events covering four facilities for a period of one week. Where the recorded data exceeds the set target, the values change to red allowing easy recognition for the reader. For example during this period the CPF's total alarms count (annunciate and non-annunciate) was over 6.8 times the targeted alarm count of 1008 alarms. Furthermore, the CPF spent 6.65% percentage time in an alarm flood state during this period. Aligning to ISA18.2 clause 16.9 Table 14 alarm performance metric is <1% of the time spent in alarm flood state. Therefore, both company and standard metrics are exceeded.

13/05/2016 6:00:00AM – 20/05/2016 6:00:00AM						
METRICS NAME	**TARGET**	**APF - APF**	**CPF - CPF**	**GPF - GPF**	**KMT - KMT**	**UNITS**
Total Alarms (Annunicated + non-Annunicated):	1008	**2454**	**6861**	**4030**	**362**	Alarms
Total Annunciated Alarms:	1008	**1960**	**2062**	**2213**	**256**	Alarms
Average Alarms Per Day:	144	280.00	294.57	316.14	36.57	Alarms/Day
Average Alarms Per 10 Minutes:	1.00	1.94	2.05	2.20	0.25	Alarms/10 Mins
Maximum Number Of Alarms in 10 Minute Period:	50	55	81	190	16	Alarms
Percentage of Time in Flood:	1.00	3.67	6.65	5.16	0.40	%
Percentage Contribution of the Top 10 Most Frequent Alarms:	50.00	42.33	42.69	42.51	41.47	%
Number of Distinct Chattering Alarms:	5	12	7	14	1	Distinct Alarms
Number of Alarms Caused By Chattering Alarms:	500	841	1274	1040	12	Alarms
Total Number Of Standing Stale Alarms:	10	6	3	1	0	Alarms
Current Number of Alarms Disabled:	10	107	330	18	51	Alarms
Percentage of hours containing more then 7 Alarms:	1.00	50.00	39.29	33.93	4.76	%

Table 17: Seven day site wide analysis of alarm management system (Company "B", 2016, data)

The best performing site KMT has been used as a basis to analyse or understand the workload applied to the operator and system. An extract has been included as Table 18, selected from the alarm and events log to demonstrate alarms and events. Note the columns allocated to time, tag, action (ACK = Acknowledge, RTN = Return to normal and ALM = Alarm) and priority. When reviewing the alarm data what becomes evident is within a 5 minute window, there are lots of variable events, changes and alarms being logged. This would be distracting, not to mention potentially delaying the operator trying to start of a transfer of material between sites.

Events Log

1/02/2016 12:00:00 AM – 20/05/2016 12:00:00 AM

Time	Tag	Description	Unit	Action	Alarm Type or Parameter	Priority	Current Value or Old Value	New Value
1/02/2016 12:20:39 AM	9HS607B	DIESEL FUEL TRANSFER PMP	KMT_0		OP		STOP	START
1/02/2016 12:24:49 AM	9HS607B	DIESEL FUEL TRANSFER PMP	KMT_0		OP		START	STOP
1/02/2016 12:26:00 AM	14P544OM		KMT_1		PV		-	1.0000
1/02/2016 12:26:00 AM	14P544OM		KMT_1		PV		-	1.0000
1/02/2016 12:26:00 AM	14P544OM		KMT_1		PV		-	1.0000
1/02/2016 12:50:17 AM	14P544OM		KMT_1		PV		-	1.0000
1/02/2016 12:50:17 AM	14P544OM		KMT_1		PV		-	1.0000
1/02/2016 12:50:17 AM	14P544OM		KMT_1		PV		-	1.0000
1/02/2016 12:53:53 AM	14PC544C	PIC544 AUTO AND INIT SP	KMT_0		PV		ON	ON
1/02/2016 12:53:53 AM	14PC544C	PIC544 AUTO AND INIT SP	KMT_0		PV		ON	ON
1/02/2016 12:53:53 AM	14PC544C	PIC544 AUTO AND INIT SP	KMT_0		PV		ON	ON
1/02/2016 12:54:05 AM	3TCLCMD	START/STOP TRANSF SYSTEM	KMT_0		OP		START	STOP
1/02/2016 12:54:05 AM	3TCLCMD	START/STOP TRANSF SYSTEM	KMT_0		OP		START	STOP
1/02/2016 12:54:05 AM	3TCLCMD	START/STOP TRANSF SYSTEM	KMT_0		OP		START	STOP
1/02/2016 12:54:08 AM	3TCLTP18	CHECK GOBE MLV	KMT_0	ALM	OFFNORM	Low		OFFNORM
1/02/2016 12:54:08 AM	3TCLSTA3	TCL-STOPPED INITIATED	KMT_0	ALM	OFFNORM	Low		OFFNORM
1/02/2016 12:54:15 AM	3TCLTP18	CHECK GOBE MLV	KMT_0	ACK	OFFNORM	Low		
1/02/2016 12:54:17 AM	3TCLTP18	CHECK GOBE MLV	KMT_0	ACK	OFFNORM			
1/02/2016 12:54:18 AM	3TCLSTA3	TCL-STOPPED INITIATED	KMT_0	ACK	OFFNORM	Low		
1/02/2016 12:54:20 AM	3TCLSTA3	TCL-STOPPED INITIATED	KMT_0	ACK	OFFNORM			
1/02/2016 12:54:33 AM	3TCLTP16	GOB MLV MUST BE CLSD NOW	KMT_0	ALM	OFFNORM	High		OFFNORM
1/02/2016 12:54:45 AM	3TCLTP16	GOB MLV MUST BE CLSD NOW	KMT_0	ACK	OFFNORM	High		
1/02/2016 12:54:47 AM	3TCLTP16	GOB MLV MUST BE CLSD NOW	KMT_0	ACK	OFFNORM			
1/02/2016 12:54:56 AM	7PY1063	PS PRESSURE INTO LINE	KMT_0	RTN	PVHI	Journal	2150.0000	2152.36
1/02/2016 12:54:57 AM	14HS520	OPEN LOW GOBE TIE-IN VALV C	KMT_4	ALM	CHNGOFST	Low		BADPV
1/02/2016 12:54:57 AM	14HS520	OPEN LOW GOBE TIE-IN VALV C	KMT_4	RTN	CHNGOFST	Low		BADPV
1/02/2016 12:55:03 AM	14HS520	OPEN LOW GOBE TIE-IN VALV C	KMT_4	ACK	CHNGOFST	Low		
1/02/2016 12:55:03 AM	82PIG064	MUBI PIGSIG 64 SAMPLES	KMT_8	ALM	PVHI	High	10.000000	- 10.291
1/02/2016 12:55:03 AM	82PIG056	MUBI PIGSIG 56 SAMPLES	KMT_8	ALM	PVHI	High	10.000000	126.807
1/02/2016 12:55:03 AM	82PIG048	MUBI PIGSIG 48 SAMPLES	KMT_8	ALM	PVHI	Low	10.000000	41.795

Table 18: KMT alarm event log data extract (Company “B”, 2016,)

Delving further into KMT event data in Table 19, demonstrate a nuisance alarm. Alarm 9LI659 consumes the alarm and events log as well as loads the controllers microprocessor as each alarm event is process almost every second.

18/02/2016 3:51:43 AM	9QL118TF	TRANSFER FROM PCL TO PM	KMT_09	ACK	CLFALM	Low	
18/02/2016 3:51:43 AM	SWVAL	LDS Temp Switching Val	KMT_09	ACK	CLFALM	Low	
18/02/2016 3:51:46 AM	9QL118TF	TRANSFER FROM PCL TO PM	KMT_09	RTN	CLFALM	Low	
18/02/2016 4:01:10 AM	9LDI659	ODC OIL LVL	KMT_09	ALM	BADPV	High	
18/02/2016 4:01:10 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ALM	BADPV	Low	
18/02/2016 4:01:11 AM	9LDI659	ODC OIL LVL	KMT_09	ACK	BADPV	High	
18/02/2016 4:01:13 AM	9LDI659	ODC OIL LVL	KMT_09	ACK	BADPV	High	
18/02/2016 4:01:14 AM	9LDI659	ODC OIL LVL	KMT_09	RTN	BADPV	High	
18/02/2016 4:01:14 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	RTN	BADPV	Low	
18/02/2016 4:01:28 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ACK	BADPV	Low	
18/02/2016 4:01:29 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ACK	BADPV		
18/02/2016 4:01:29 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	SHELVE	BADPV		Nuisance Alarm
18/02/2016 4:02:59 AM	9LDI659	ODC OIL LVL	KMT_09	ALM	BADPV	High	
18/02/2016 4:02:59 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ALM	BADPV	Low	
18/02/2016 4:03:01 AM	9LDI659	ODC OIL LVL	KMT_09	ACK	BADPV	High	
18/02/2016 4:03:01 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ACK	BADPV	Low	
18/02/2016 4:03:03 AM	9LDI659	ODC OIL LVL	KMT_09	ACK	BADPV	High	
18/02/2016 4:03:03 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ACK	BADPV	Low	
18/02/2016 4:03:05 AM	9LDI659	ODC OIL LVL	KMT_09	RTN	BADPV	High	
18/02/2016 4:03:05 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	RTN	BADPV	Low	
18/02/2016 4:04:31 AM	9LDI659	ODC OIL LVL	KMT_09	UNSHLV_S	BADPV		
18/02/2016 4:04:58 AM	9LDI659	ODC OIL LVL	KMT_09	ALM	BADPV	High	
18/02/2016 4:04:58 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ALM	BADPV	Low	
18/02/2016 4:05:00 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ACK	BADPV	Low	
18/02/2016 4:05:00 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ACK	BADPV	Low	
18/02/2016 4:05:02 AM	9LDI659	ODC OIL LVL	KMT_09	RTN	BADPV	High	
18/02/2016 4:05:02 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	RTN	BADPV	Low	
18/02/2016 4:05:17 AM	9LDI659	ODC OIL LVL	KMT_09	ACK	BADPV	High	
18/02/2016 4:05:18 AM	9LDI659	ODC OIL LVL	KMT_09	ACK	BADPV		
18/02/2016 4:05:18 AM	9LDI659	ODC OIL LVL	KMT_09	SHELVE	BADPV		Nuisance Alarm
18/02/2016 4:05:47 AM	9LDI659	ODC OIL LVL	KMT_09	ALM	BADPV	High	
18/02/2016 4:05:47 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ALM	BADPV	Low	
18/02/2016 4:05:48 AM	9LDI659	ODC OIL LVL	KMT_09	ACK	BADPV	High	
18/02/2016 4:05:48 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ACK	BADPV	Low	
18/02/2016 4:05:49 AM	9LDI659	ODC OIL LVL	KMT_09	ACK	BADPV	High	
18/02/2016 4:05:49 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ACK	BADPV	Low	
18/02/2016 4:05:50 AM	9LDI659	ODC OIL LVL	KMT_09	RTN	BADPV	High	
18/02/2016 4:05:50 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	RTN	BADPV	Low	
18/02/2016 4:08:36 AM	9LDI659	ODC OIL LVL	KMT_09	ALM	BADPV	High	
18/02/2016 4:08:36 AM	9LI659	OC SEAWATER INTERF LVL	KMT_09	ALM	BADPV	Low	
18/02/2016 4:08:37 AM	9LDI659	ODC OIL LVL	KMT_09	ACK	BADPV	High	

Table 19: KMT nuisance alarm scenario extract (Company "B", 2016)

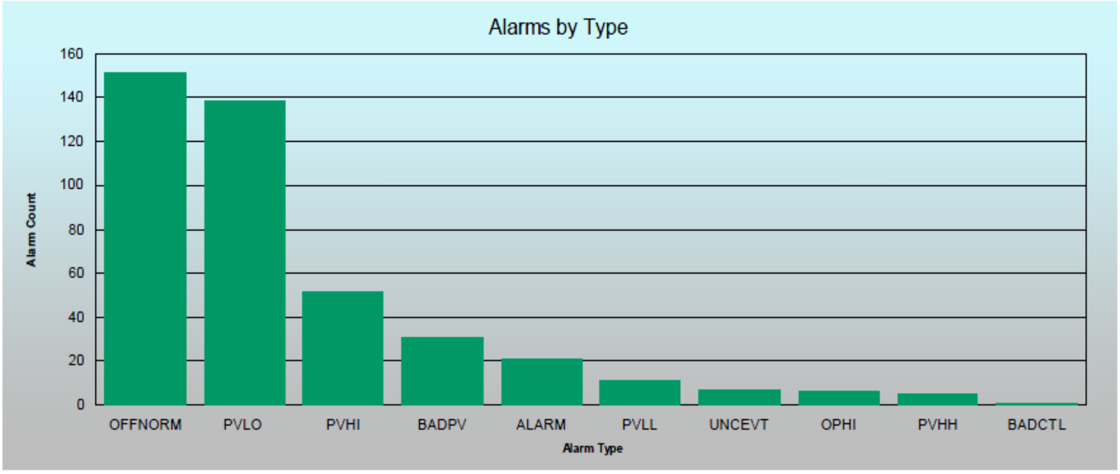
Surprisingly, company 'B' mature alarm systems data supports the theory that alarms will increase as a facility ages i.e. sensors deteriorate, controllers become sluggish. Knowing company 'B' has a rigorous monitoring and rationalisation program, sound team knowledge of the facilities and have the ability to tune controllers.

A comparison was conducted between CPF's 2016 alarm log in Table 17, and results obtained in 2013, showing company 'B' has improved their alarm system. In 2013 the total alarms by type per 24 hour period was 426, compared to 2016 weekly report shows 294 alarms per day (average). Note, is basic comparison does not present all the internal and external factors or process conditions for each years snap shot, however it is an improvement.

Included in the alarm reports are the 10 most active tagged alarm combinations that appeared to the Operator by alarm type (Figure 18) and most frequent alarms by tag (Figure 19).

CPF - CPF

7/03/2013 6:00:00AM — 8/03/2013 6:00:00AM



Alarm Type	Number of Alarms	% Contribution
OFFNORM	151	35.45
PVLO	139	32.63
PVHI	52	12.21
BADPV	31	7.28
ALARM	21	4.93
PVLL	11	2.58
UNCEVT	7	1.64
OPHI	6	1.41
PVHH	5	1.17
BADCTL	1	0.23
Others	**2**	**0.47**
Total:	**426**	

Figure 18: Historic (2013) alarm type data of the CPF (Company “B”, 2013)

The most frequent alarms in the last day graph (Figure 19) indicates 90 alarms are caused by 4HC8677 going off is considered normal state and 4PI6008 process value (PV) falling below its low (LO) set point. Initial assessment suggests a work order be created for 4PI6008.PVLO assigning maintenance corrective and 4HC8677.OFFNORM could be researched further and depending on findings consider a case to rationalise a different strategy for this alarm.

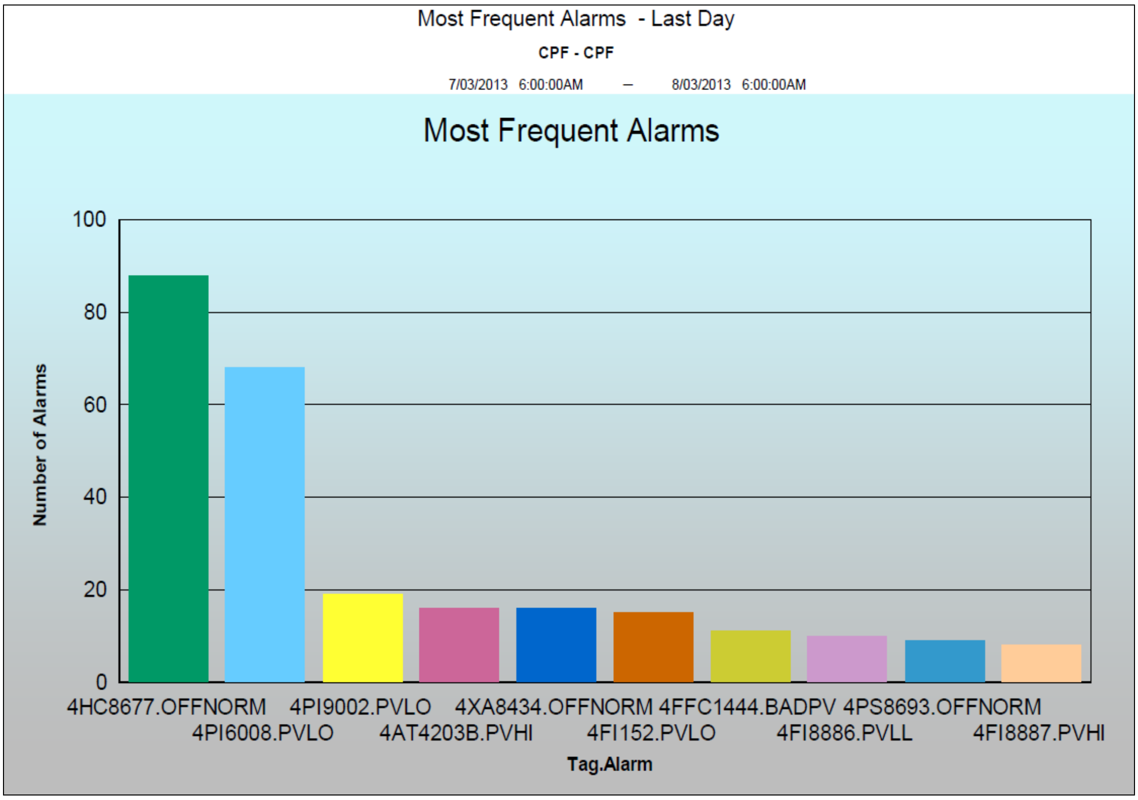
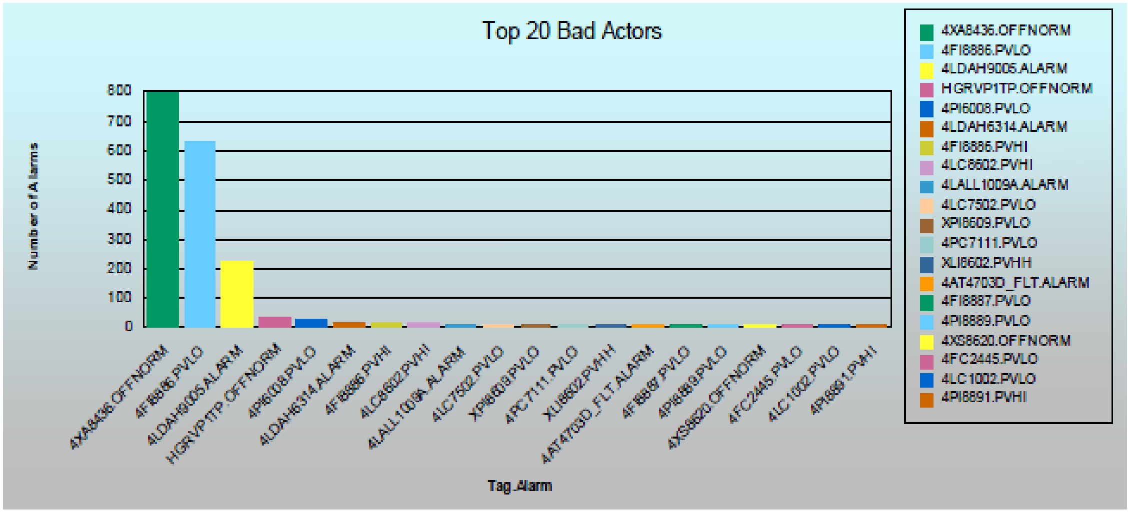


Figure 19: Historic 24 hour most frequent alarms dated 2013 (Company "B", 2013)

Figure 20 lists CPFs top 20 bad actor alarms, clearly identified are field instruments and controller improvement opportunities. If dedicated resources from a maintenance and engineering were provided, this bad actor alarm rate would reduce, over what period such an improvement would make could only be determined by a sample period average and a small dedicated team.

CPF - CPF

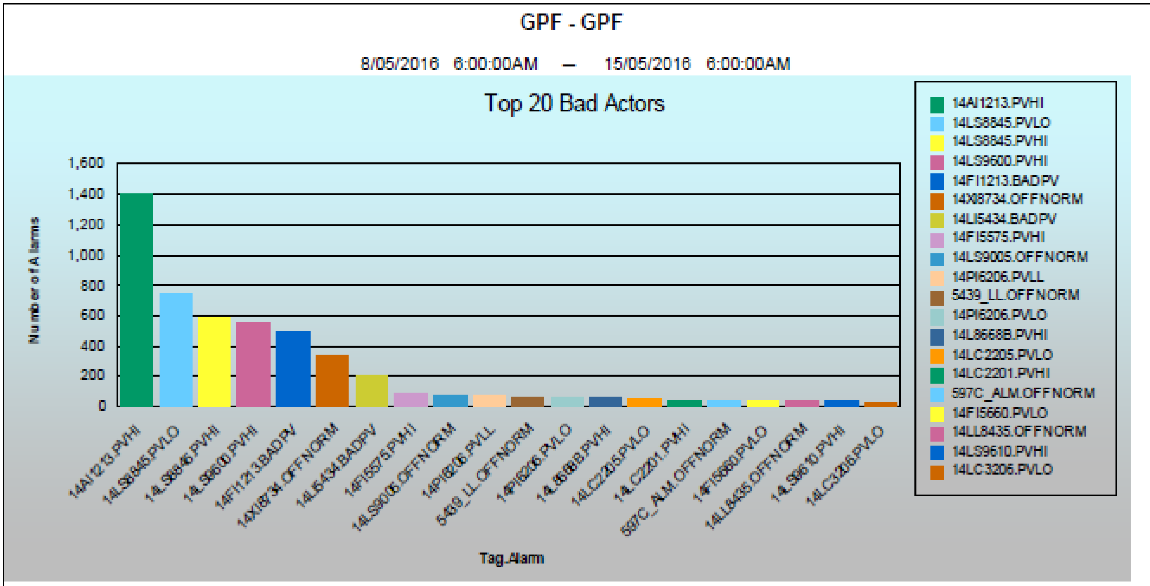
8/05/2016 6:00:00AM — 15/05/2016 6:00:00AM



Tag.Alarm	Description	# of Alarms	% Contribution
4XA8436.OFFNORM	INCINERATOR COMMON FAULT	793	36.7
4FI8886.PVLO	HYDROCYCLONE A FLOW	635	29.4
4LDAH9005.ALARM	HP FLARE K.O DRUM 4V3100A DIFFERENCIAL	223	10.3
HGRVP1TP.OFFNORM	HGCP COND RVP L1 T/POINT	32	1.5
4PI6008.PVLO	TANKS D,E,F FLARE GAS	27	1.3
4LDAH6314.ALARM	Crude Oil Storage Tank 4T2200C Level Discrepancy	17	0.8
4FI8886.PVHI	HYDROCYCLONE A FLOW	16	0.7
4LC8602.PVHI	INJECTION H20 SURGE TANK	14	0.6
4LALL1009A.ALARM	INLET SEPARATOR A OIL/WATER INTERFACE LEVEL	12	0.6
4LC7502.PVLO	TEST SEP. A OIL/WATER	10	0.5
XPI8609.PVLO	INJECT PUMP SUCTION PRES	10	0.5
4PC7111.PVLO	AGOGO INLET MANIFOLD	9	0.4
XLI8602.PVHH	INJECT H2O SURGE TANK	9	0.4
4AT4703D_FLT.ALARM	TEGD GAS DET	7	0.3
4FI8887.PVLO	HYDROCYCLONE B FLOW	7	0.3
4PI8889.PVLO	HYDROCYC B DISCH PRESS	7	0.3
4XS8620.OFFNORM	INJ PMP B COMMON TRIP	7	0.3
4FC2445.PVLO	B REBLR FUEL GAS FLOW	6	0.3
4LC1002.PVLO	INLET SEP PRODUCED H2O	6	0.3
4PI8891.PVHI	HYDROCYC A DISCH PRESS	6	0.3
Others		**307**	**14.2**

Figure 20: CPF weekly top 20 bad actor alarms (Company “B”, 2016)

Reviewing GPF weekly top twenty “Bad Actor” alarms presents a similar picture to CPF. GPF’s data is more concerning given there appears to be safety equipment i.e. electric fire pump, flame detectors and blank gas low level trip alarms performing poorly (highly active or faulty). This brings to question why priority codes are not included (Critical, High, and Low etc.) into all reports. This may not change the company’s approach to its current alarm system state however, those responsible for the alarm management system may direct maintenance to prioritise high priority alarms over lower, even if for example the high priority alarms is 18th on the list.



Tag.Alarm	Description	# of Alarms	% Contribution
14AI1213.PVHI	PROD SEP A OIL DENSITY	1,410	24.2
14LS8845.PVLO	GAS FLOT UNIT WATER LVL	738	12.6
14LS8845.PVHI	GAS FLOT UNIT WATER LVL	576	9.9
14LS9600.PVHI	GM PIG LAUNCHER SUMP LVL	552	9.5
14FI1213.BADPV	PROD SEP A OIL FLOW	486	8.3
14XI8734.OFFNORM	ELEC FIRE PUMP 3700B STA	339	5.8
14LI5434.BADPV	FILTER 2300B UPPER LVL	200	3.4
14FI5575.PVHI	F/GAS TO TEGB FLOW	82	1.4
14LS9005.OFFNORM	FLARE KO DRUM HI LEVEL	68	1.2
14PI6206.PVLL	TANK B BLANKET GAS PRESS	65	1.1
5439_LL.OFFNORM	F2300B LOWER LEVEL	51	0.9
14PI6206.PVLO	TANK B BLANKET GAS PRESS	49	0.8
14L8668B.PVHI	OILY WATER TREAT OIL LVL	44	0.8
14LC2205.PVLO	PROD SEP B LEVEL	42	0.7
14LC2201.PVHI	PROD SEP B I/FACE LEVEL	28	0.5
597C_ALM.OFFNORM	ME2300B FLAME DETECT ALM	28	0.5
14FI5660.PVLO	LEAN GLYCOL 2304B FLOW	26	0.4
14LL8435.OFFNORM	INJ WATER SURG TK LL LVL	25	0.4
14LS9610.PVHI	SEG PIG LAUNCHR SUMP LVL	25	0.4
14LC3206.PVLO	PROD SEP C LEVEL W/SEP	19	0.3
Others		**984**	**16.9**

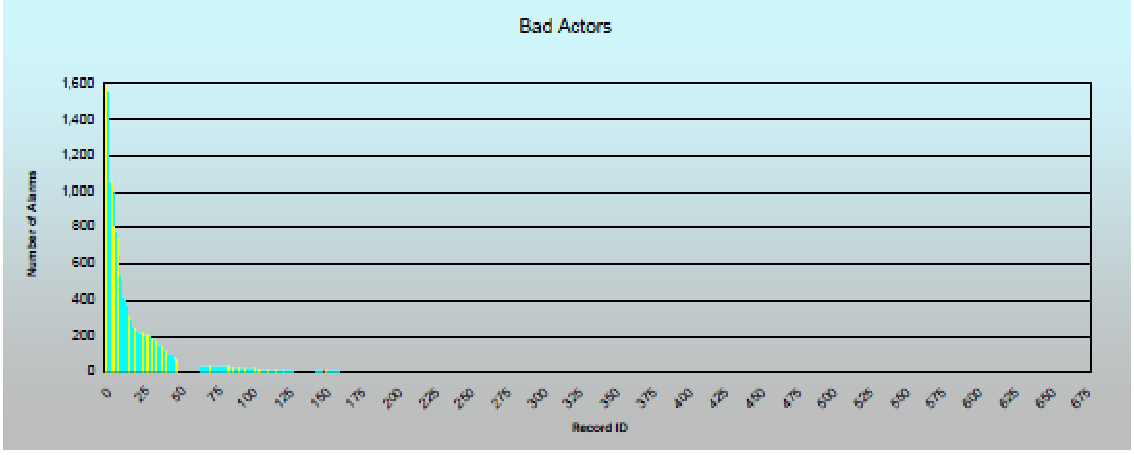
Figure 21: GPF weekly top 20 bad actor alarms (Company “B”, 2016)

Lastly the figure 22 (spaning 2 pages) is a 3 week historic view of APF’s alarm system in 2014. Unfortunately, when compared to 2016’s weekly alarm data, there has not been an improvement to alarm counts. Most concerning is 2014 had a dangerously high rate of high priority alarms performing badly however, the improvement noted is this report includes alarm priority which demonstrates the ease in which one can identify high priority alarms.

APF - APF

6/05/2014 6:00:00AM – 1/06/2014 6:00:00AM

Tag.Alarms with Number of Alarms >= 1



ID	Tag.Alarm	Description	Priority	# of Alarms	% Contribution
0	85FI0802.PVLL	SEM GAS LIFT LINE	High	1,582	6.7
1	85FALL0802.OFFNORM	GAS LIFT LOLO FLOW	Low	1,561	6.6
2	288LI2619.BADPV	FG B FILTER SEP LEVEL	Low	1,519	6.4
3	85LI0602.PVHI	SEM SEP WTR LEVEL	Low	1,054	4.5
4	85LI0602.BADPV	SEM SEP WTR LEVEL	High	1,051	4.5
5	207XA3021.OFFNORM	BACKUP FIRE WATER PUMP	Low	1,001	4.2
6	288DI2417.PVHI	MORAN 2 SEP OIL DENSITY	High	802	3.4
7	207PDA1091.PVHI	HP 2ST COOLER DISCHARGE	Low	779	3.3
8	85LAL0602.OFFNORM	SEM SEP WAT LVL LO LO	High	743	3.1
9	85JI0543.PVLO	SEM BRIDGE VALVE SITE 2	Low	539	2.3
10	85PDC0610.PVLO	SEM SEPARATOR DIFF PRESS	Low	530	2.2
11	88XIC1153.UNCEVT	AIR COMP 88C3502	Low	503	2.1
12	206TAH4957.OFFNORM	MOR12 HYD SEP TEMP HIGH	Low	424	1.8
13	288FY2580.BADPV	LP B 2ST FLOW	Low	413	1.8
14	207FY1000.BADPV	MORAN INJECTION GAS	Low	374	1.6
15	207FZ1000.BADPV	MORAN INJECTION GAS	Low	373	1.6
16	85LAL0608.OFFNORM	SEM SEP OIL LVL LO LO	High	304	1.3
17	206PI4906.PVHI	MORAN 12 DOWN HOLE PRESS	Low	296	1.3
18	207TI4625.BADPV	AGOGO TEST SEP WTR TEMP	Low	261	1.1
19	288DI2417.BADPV	MORAN 2 SEP OIL DENSITY	Low	252	1.1
20	207FI4625.PVHI	AGOGO TEST SEP WTR FLOW	High	242	1.0
21	207DI2266.PVHI	MORAN 1 SEP OIL DENSITY	High	229	1.0
22	206LAL4980.OFFNORM	MOR12 HYDRATE SEP LVL	Low	229	1.0
23	88LC571.PVLO	LP A 1ST SUCTION DRUM	Low	221	0.9

Continued

ID	Tag.Alarm	Description	Priority	# of Alarms	% Contribution
24	207FI1000.BADPV	MORAN INJECTION GAS	Low	213	0.9
25	207DI4525.PVLO	AGOGO TEST SEP WTR DENSI	High	210	0.9
26	207TI4526.BADPV	AGOGO TEST SEP OIL TEMP	Low	208	0.9
27	85FI0802.PVLO	SEM GAS LIFT LINE	Low	208	0.9
28	288DI2416.PVLO	MORAN 2 SEP WATER DENS	High	204	0.9
29	207DI4525.PVHI	AGOGO TEST SEP OIL DENSI	High	201	0.9
30	207TC3325.PVLO	TEG C - REFLUX CONDENSER	Low	201	0.9
31	206JI4450.PVLO	INTERM VLV SITE 1 EPT	Low	198	0.8
32	207FI4524.PVHI	AGOGO TEST SEP GAS FLOW	High	191	0.8
33	207TI4524.BADPV	AGOGO TEST SEP GAS TEMP	Low	188	0.8
34	207FI4526.PVHI	AGOGO TEST SEP OIL FLOW	High	169	0.7
35	85DGASALARM.OFFNORM	COMP D GAS DETEC ALARM	High	167	0.7
36	88LDA571.PVHI	LP A 1ST SUCTION DRUM	Low	142	0.6
37	88FI386.PVHI	TEG-A LEAN GLYCOL FLOW	Low	141	0.6
38	COMP_COMMON_ALM.OFFNORM	GAS COMPRESSOR FAULT ALM	Urgent	139	0.6
39	207LC401.PVLO	AGOGO TEST SEP OIL	High	133	0.6
40	206PAH4956.OFFNORM	MOR12 HYD SEP PRESS HIGH	Low	126	0.5
41	207LC2201.PVLO	AGOGO PROD SEPARATOR OIL	High	122	0.5
42	207XA3011.OFFNORM	PRIMARY FIRE WATER PUMP	Low	100	0.4
43	286TAHH2318.OFFNORM	TEGB REBLR TEMP HI HI	Low	100	0.4
44	85FAL0335.OFFNORM	CORR INHIB P5107E/F FLW	Low	97	0.4
45	85FALL0335.OFFNORM	P5107E/F LOLO	Low	97	0.4
46	85TC0416B.OFFNORM	ME5102 TMP CNTRL	Low	88	0.4
47	207LDA401.PVHI	PVHI HIGH DISCREPANCY LEV PS	High	85	0.4
48	207PC3235.PVLO	SEPARATOR GAS MANIFOLD	Low	78	0.3
49	207PC1307.PVLO	FUEL GAS TO HP TURBINE	High	71	0.3
50	88LC571.PVHI	LP A 1ST SUCTION DRUM	Urgent	69	0.3
51	207HPD609.OFFNORM	HP FAST STOP LOCKOUT	Low	65	0.3
52	206ZA4905.OFFNORM	MOR12 PROD CHOKE DISC	Low	63	0.3
53	207XI3011.UNCEVT	PRIMARY FIRE WATER PUMP	Low	63	0.3
54	88LI571B.BADPV	LP A 1ST SUCTION DRUM	Low	63	0.3
55	288PDI2043.PVHI	OWS TRANSFER DIFF PRESS	High	62	0.3
56	85LI0608.PVLO	SEM SEP OIL LEVEL	Low	52	0.2
57	88PI143B.PVROCN	TRFR PMP C SEAL POT NDE	Low	52	0.2
58	206PI4002.PVLO	INSTRUMENT GAS PRESSURE	Low	50	0.2
59	206PI4102.PVLO	WELL 6/9 INSTRUMENT GAS	Low	50	0.2
60	85DI0612.PVLO	SEM SEPERATOR WATER	Low	50	0.2
61	88LAHH571B.OFFNORM	LP A 1STG SUCT DRUM LVL	Urgent	49	0.2
62	207HPD006.OFFNORM	HP LUBE OIL HEADER PRESS	Low	48	0.2
63	85PI0522.PVLO	SEM INST G PRES	Low	46	0.2
64	207LC2202.PVLO	AGOGO PROD SEP. WATER	High	45	0.2
65	288LC2402.PVLO	MORAN NO 2 SEP WATER LVL	High	45	0.2
66	88LDA571.BADPV	LP A 1ST SUCTION DRUM	Low	45	0.2
67	206FY4277.BADPV	MORAN 5X INJECTION GAS	Low	43	0.2
68	85LDA0603.PVHI	SEM SEP WATER LEVEL DIFF	Low	42	0.2
69	207DI2265.PVLO	MORAN 1 SEP WATER DENS	High	41	0.2

Figure 22: APF 3 weekly bad actor alarms (Company "B", 2014)

In summarising the two companies reviewed. Company "B" is a great example of a mature company and facilities which is experiencing high alarm rates due to the aging field and system which is expected. Wear and tear in a mature plant can be difficult to control in an alarms system. Based this evidence, infant Company 'A' should ensure all resources are available to effectively implement, maintain, manage and monitor their control and alarm system. This will ensure the process is optimised and limit major liability. Importantly demonstrated by both companies is measuring and reporting the right information ensure correct decisions and actions are made during the alarm systems lifecycle.

4.0 Methodology

4.1 Methodology

The goal of this research project was to identify best practice management of industrial process control alarm floods. Research suggests most modern control systems will experience alarm floods to some degree. Therefore, the underlying problem remains.

EEMUA 191 suggests advanced intelligent alarm flood processing is an active area of research however, to explore such a solution in this research project would require greater time than available, in depth software skills to develop software to interact with vendor control system as well as provide product lifecycle support. Considering also the functional requirements to annunciate alarms, any high alarm frequency rate filter, algorithm or other method (similar to an electronics low pass filter) limits the reaction times of an operator and may not be effective during a large number simultaneous alarms within a short period of time. Therefore, the concept of exploring a high alarm frequency suppression system at this point seems to present risk, however exploring better design options via a rationalisation process based on alarm performance analysis has merit.

Organising alarms, sorted by alarm type or function also has merit by reducing alarms to the operator. Better organising methods entails assigning alarms affecting the process or requiring some action by the operator be considered production alarms, other maintenance, pre-emptive condition or diagnostic alarms from smart instruments allocated to a maintenance / control system administrator alarm log or shelved for action by a dedicated person in an assigned monitoring role. Although these maintenance alarms may have some pending impact to production, they often do not require immediate attention by the operator and therefore should not be routed to the operator console. Implementing an additional alarm log system for maintenance alarms requires caution in term of monitoring. For example a redundant communication network having a primary communication line failure results in no redundancy, although this could be considered a system alarm not requiring the operators attention, the potential should the redundant communication line fail, will affect production or the safety system, therefore this alarm should be considered a medium to high priority alarm and annunciate in the operators console for recording and action if a maintenance system is unmonitored during after business hours.

EEMUA 191 focuses on applying first principle strategies to better develop and manage alarm systems and by default, reduce alarms floods. In addition, provides performance metrics for benchmarking user systems data by comparison. Areas where EEMUA 191 and ISA 18.2 could provide more information is when developing or presenting KPIs and analysis techniques. Analysis techniques using various software platforms based on industry scenarios will assist other operators and engineers the opportunity to learn and better understand their systems, ultimately improving alarm management systems by mutual recognition. The importance in reporting techniques is similar to grey scale graphics, where too much detail masks the problem however tool little downplays the situation.

Alarm performance data provides a holistic view on an alarm management system. A poor performance report highlights the need for more resources, focused rationalisation workshops, more specific performance metrics and other analysis techniques that will improve and aid the user during normal day to day operations. Often alarm system analysis is carried out retrospectively months or years after the alarm events, loss of production or catastrophe occurs. This retrospective analysis often identifies areas for improvement after the fact, therefore if improved within the day to day operation, problematic areas can managed before they escalate.
The need to develop and test, key performance indicators (KPI) to provide meaningful information to targeted audiences at all levels of an organisation enables the audience to adequately understand the problem. This is vital in gaining support for a solution. Other benefits of effective analysis and KPIs reporting can include monitoring subtle areas of poor performance that would otherwise not be considered important in the day to day production. Subtle data can often be of interest to other departments i.e. maintenance performance, reoccurring breakdowns, condition monitoring mechanical reliability (spurious vibration alarm occurring over a period less than when scheduled monitoring is planned, could indicate premature failure, associated system control problems or prompt heighten monitoring techniques).

Operator KPIs aid in the development of operators and help companies manage risk. This is achieved through well organised data and training scenario simulations, testing not only the various levels of alarm loads but also allows the operator and company to gauge assumptions in time to respond and operator workload. In a training program environment, operators can be exposed to various scenarios, providing some familiarity of how to handle a situation. KPIs provide feedback on an operator's performance. This information should only be used for development of the operator not a demotion. KPIs also help identify specialised discipline knowledgebase support; during poor performance events KPIs helping build a strong case and evidence for a rationalisation workshop. Also real-time performance statistics and projected flag similar events should they occur warranting a review or perceived event intervention.

A quantitative and qualitative analysis methodology was used to measure the alarm system performance against EEMUA 191 and ISA 18.2 metrics (Table 20). Other methods of analysing alarms and event data were employed as identified to help explore and identify other alarm system improvement opportunities.

Utilising quantitative and qualitative analysis methods, raw alarms system data was taken and analysed to be measured against current standard benchmarks outlined in the literature review, company alarm philosophies and established reporting formats. Due to the unavailability of the PSS software, the analysis tools utilised was Microsoft excel. The aim was to analyse the alarm data, determine methods that replicate the vendor software package analysis tools and reporting..

The benefit of manually developing analysis techniques provided the opportunity to discover other improvement opportunities while dissecting the alarm data, in comparison to vendor alarm analysis packages and reports presented. Furthermore, using common software with a data analysis package like Microsoft excel, makes the analysis techniques available for other alarm system analysers who may not have the capital to afford expensive alarm analysis tools and packages or the access.

The steps used to analyse the alarm data included –

1. Identifying KPIs in relation to EEMUA 191 and ISA 18.2 (Table 20).
2. Developing analysis methods using common software
3. Processing and analysing alarm data
4. Comparing the analysed data against the identified metric KPIs to identify non-conformance

ISA 18.2 - Alarm performance metrics based on at least 30 days of data		
Metric	**Target value**	
Annunciated alarms per time	**Target value: Very likely to be acceptable**	**Target value: Maximum manageable**
Annunciated alarms per day per operating position	150 alarms per day	300 alarms per day
Annunciated alarms per hour per operating position	6 (average)	12 (average)
Annunciated alarms per 10 min per operating position	1 (average)	2 (average)
Metric	**Target value**	
Percentage of hours with >30 alarms	< 1%	
Percentage of 10-min periods with >10 alarms	< 1%	
Maximum number of alarms in a 10-min period	<= 10	
Percentage of time the system is in a flood condition	< 1%	
Percentage contribution of the top 10 most frequent alarms to the overall alarm load	< 1% to 5% maximum, with action plan to address deficiencies	
Quantity of chattering and fleeting alarms	Zero, develop action plans to correct any that occur	
Stale alarms	< 5 per day, with action plan to address	
Annunciated priority distribution	If using three priorities: 80% low, 15% medium, 5% high	
	If using four priorities: 80% low, 15% medium, 5% high, < 1% ‘highest’	
	Other special-purpose priorities are excluded from the calculation	
Unauthorised alarm suppression	Zero alarms suppressed outside of controlled or approved methodologies	
Unauthorised alarm attribute changes	Zero alarm attribute changes outside of approved methodologies or management of change (MOC)	

Table 20: ISA 18.2 – Performance standard (ISA 18.2, 2009)

In addition to comparing the alarm data against Table 20 metrics. Other analysis methods were employed to determine other improvements areas or results not identified. These included the techniques as listed below –

1. Statistically (min, max, span, mean, medium and standard deviation)
2. Cross correlation between data samples and events
3. Histograms of alarms and events
4. Alarm count
5. Time correlation between events and or alarms
6. Trending alarms based on time.
7. Manipulation (removing bad actors or high frequency alarms to analyse data)
8. Develop a report to display findings and analysis conclusions

In some cases, the analysis results did not produce useable information. In other cases, the analysis provided a basis for further exploration or an explanation to help other analysis personnel.

4.2 Resources

The primary resource identified to analyse the data was a customised alarm management software suite developed by a company called PAS product titled Plant State Suite (PSS). PAS PSS is an alarm analysis software package and readily available to industry if purchased. Company "A" selected PAS PSS software tool for its corporate alarm management analysis and reporting function. PAS PSS tool analyses the alarm and event data via remote terminal database (RTDB) at each of its remote facilities using fibre or satellite communications. The downloaded data from the respective RTDB's using fibre or satellite will be as close to real-time as possible for processing (time lag yet to be measured due to construction delays).

The intent was to use the PAS PSS software tool to develop KPI's and analysis strategy tools to produce meaningful correlation between alarms, events and other alarm analysis areas of interest. However, due to the project delays access to PSS to analyse company 'A' alarm and event data was not possible. Unfortunately data from company "B" although it may be used to analyse the effectiveness of KPIs and reporting methods developed in PSS the approvals from company A could not be justified. The intent being to allow comparisons with companies 'B' current reported information to company A analysis reports.

The backup resource software selected was MATLAB and Microsoft excel, identified during the project risk assessment. Given the resources situation presented both software packages were tested to determine analysis suitability, with Microsoft excel proving to be the preferred software package. The benefit of being commonly available software package make developing methods potentially beneficial to other alarm system data analysers who cannot access larger vendor alarm management packages.

The techniques used to develop excel into an alarm analysing system or processor is captured in appendix B.

The project timeline, risk assessment, analysis of consequences and ethical implications are provided in the appendixes.

5.0 Analysis

The alarm analysis in this section refers to the methodology and findings outlined in pervious sections. In some cases the graphs and tables relate providing graphical and statistical information.

5.1 Percentage contribution to overall alarm load

The percentage contribution to overall alarm load is considered a secondary KPI in EEMUA 191. This metric requires analysis the alarm data to determines the overall alarm frequency rate and load each alarm rate places on the alarm system. ISA 18.2 specifies the percentage contribution of each alarm should not exceed ~ < 1% to 5% of the overall alarm load for >30 days of alarm data.

Based on the 92 days of alarm data obtained and analysed, the high frequency alarm percentage contribution (figure 23) shows four dominant alarms among the total alarms annunciated totalling 32033.

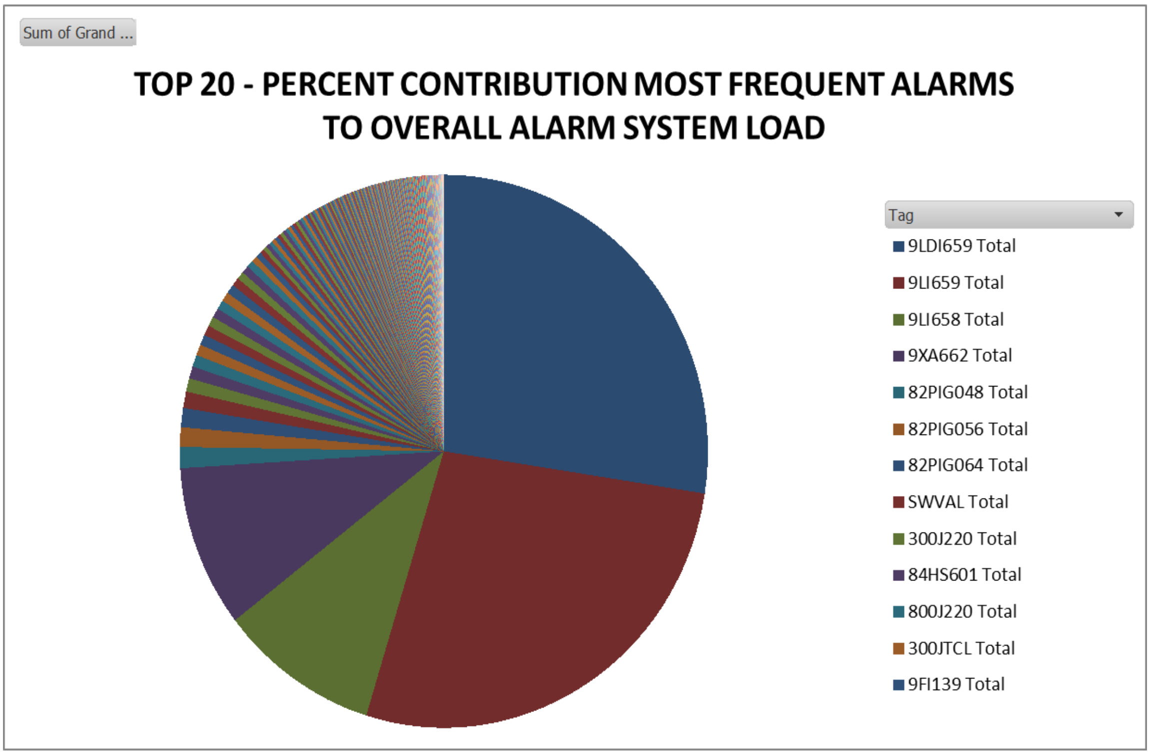


Figure 23: top 20 alarms – Percent contribution most frequent alarm to overall alarm system load

The percentage contribution of each alarm was calculated and displayed in table 21. The two right hand side columns in Table 21 show individual percent contribution per alarm tag and the accumulated alarm system load percentage working down the list. The top 7 alarms exceed the metrics 1%. A contribution to total alarm counts

The calculated results identify 7 alarms that require immediate attention to determine cause and rectify the problem to remove the load on the alarms system and distraction to the operator.

Accumulating the percentage load the top ten alarms account for eighty percent of the total alarm load. Repairing these top ten alarms will have a dramatic effect on the systems performance.

TOP 20 MOST FREQUENT ALARMS				
TOP 20	**TAG**	**ALARM COUNT**	**% CONTRIBUTION TO TOTAL ALARM LOAD**	**ACCCUMULATED % ALARM LOAD**
1	9LDI659 Total	8792	27.45%	27.45%
2	9LI659 Total	8745	27.30%	54.75%
3	9LI658 Total	3133	9.78%	64.53%
4	9XA662 Total	3040	9.49%	74.02%
5	82PIG048 Total	394	1.23%	75.25%
6	82PIG056 Total	367	1.15%	76.39%
7	82PIG064 Total	358	1.12%	77.51%
8	SWVAL Total	306	0.96%	78.47%
9	300J220 Total	251	0.78%	79.25%
10	84HS601 Total	227	0.71%	79.96%
11	800J220 Total	224	0.70%	80.66%
12	300JTCL Total	206	0.64%	81.30%
13	9FI139 Total	197	0.61%	81.92%
14	14HS520 Total	187	0.58%	82.50%
15	9XA687 Total	181	0.57%	83.06%
16	83HS600 Total	180	0.56%	83.63%
17	81FUELLOS Total	175	0.55%	84.17%
18	81PDH301S Total	173	0.54%	84.71%
19	9FI140 Total	173	0.54%	85.25%
20	KI_PRES Total	158	0.49%	85.75%
GRAND TOTAL OF ALL ALARMS FOR SAMPLE PERIOD		**32033**		

Table 21: Top 20 alarms – Percent contribution most frequent alarm to overall alarm system load

In the event maintenance and engineering staff are able to resolve the 7 most frequent alarms, then the alarm system percentage distribution will resemble a more equally distributed alarm loaded system (Figure 24).

However, the projected changes to the KPI measuring alarm loads < 1%, shows removing the 7 top bad actors will see an increase in the number of alarms whose percentage alarm load is greater than >1% (see Table 22). Initially 7 top bad actor alarms >1% in table 21, now changes to >20 top bad actor alarms >1% of total alarm load Table 22. Although there is a considerable reduction in alarms reduced from 32033 to 7204, any KPI reports representing bad actor (percentage load of alarms) would show a significant increase from 7 to now >20 top alarms whose percentage alarm loads >1%.

This projection highlights the importance of understanding proposed changes and the need to communicate anticipated results to key stakeholders before implementing.

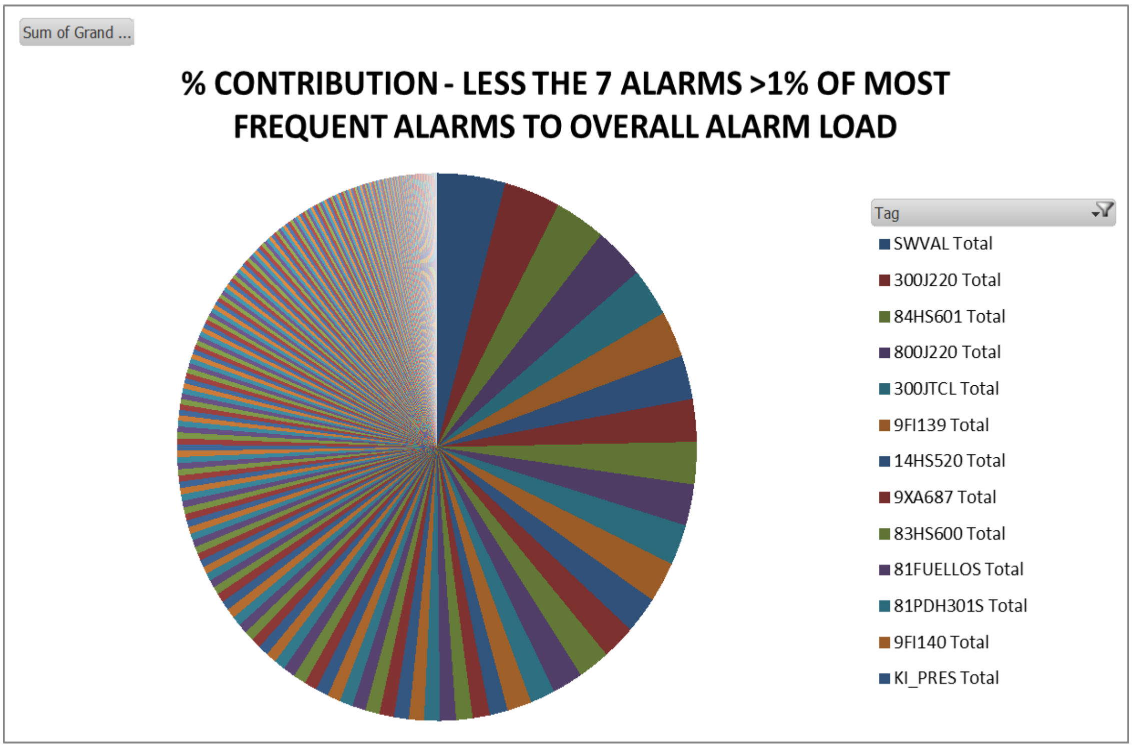


Figure 24: Top 20 percentage contribution alarms – After >1% most frequent alarm where removed

IF IMPROVED - TOP 20 MOST FREQUENT ALARMS				
TOP 20	**TAG**	**ALARM COUNT**	**% CONTRIBUTION TO TOTAL ALARM LOAD**	**ACCCUMULATED % ALARM LOAD**
1	SWVAL Total	306	4.25%	4.25%
2	300J220 Total	251	3.48%	7.73%
3	84HS601 Total	227	3.15%	10.88%
4	800J220 Total	224	3.11%	13.99%
5	300JTCL Total	206	2.86%	16.85%
6	9FI139 Total	197	2.73%	19.59%
7	14HS520 Total	187	2.60%	22.18%
8	9XA687 Total	181	2.51%	24.69%
9	83HS600 Total	180	2.50%	27.19%
10	81FUELLOS Total	175	2.43%	29.62%
11	81PDH301S Total	173	2.40%	32.02%
12	9FI140 Total	173	2.40%	34.43%
13	KI_PRES Total	158	2.19%	36.62%
14	14HS521 Total	148	2.05%	38.67%
15	KO_PRES Total	142	1.97%	40.64%
16	14PDH525 Total	137	1.90%	42.55%
17	9PI319 Total	111	1.54%	44.09%
18	84IC1PIR Total	109	1.51%	45.60%
19	84QA604 Total	81	1.12%	46.72%
20	$CONSOLE01 Total	77	1.07%	47.79%
GRAND TOTAL OF ALL ALARMS FOR SAMPLE PERIOD		**32033**	**Less >1% MOST FREQUENT THE TOTAL COUNT BECOMES**	**7204**

Table 22: Top 20 alarms – After >1% original top 7 most frequent alarms removed

5.2 Annunciated alarms per day per operating position

ISA 18.2 states the manageable rate of alarms per day per operating position is 150 - 300 alarms per day. Table 23 show the day alarm rate for the month of February 2016 however also includes the alarm priority distribution based on the ISA 18 performance metric. The priority columns are configured to change colour based on the limits specified at the top of the columns or as per ISA 18.2, 80% low, 15% medium, 5% high and < 1% 'highest' (Urgent). Green indicates healthy and within desired limits, yellow is marginal encroaching upper limit and red indicates the upper limit has been reached or exceeded. The colours are the same for each of the four priority columns. The column labelled journal priority, is not annunciated to the operator, however is of interest for analysis/ monitoring purposes and therefore captured in the events log. The tally for journals alarms is low and could be utilised more.

Based on the colour changes, the observer can easily identify poor performance areas and where necessary further analyse. As can be seen Figure 23 most of February alarm rates exceed the KPI's with the majority of alarms high priority. The same can be viewed in Figure 24 and 25.

DAILY ALARM ANALYSIS											
ALARM DATA PER DAY							ANALYSIS TO ISA 18.2 STANDARD				
FLOOR 1hr	Time	High	Journal	Low	Urgent	Grand Total	KPI 150-300 ALM/day	High < 5%	Journal = N/A	Low < 80%	Urgent < 1%
Grand Total	1/02/2016	32	11	414		457	457	7.00%	2.41%	90.59%	0.00%
Grand Total	2/02/2016	1	8	5		14	14	7.14%	57.14%	35.71%	0.00%
Grand Total	3/02/2016	39	15	156	1	211	211	18.48%	7.11%	73.93%	0.47%
Grand Total	4/02/2016	104	21	390	1	516	516	20.16%	4.07%	75.58%	0.19%
Grand Total	5/02/2016	116	35	154	1	306	306	37.91%	11.44%	50.33%	0.33%
Grand Total	6/02/2016	160	20	237	1	418	418	38.28%	4.78%	56.70%	0.24%
Grand Total	7/02/2016	169	22	206	1	398	398	42.46%	5.53%	51.76%	0.25%
Grand Total	8/02/2016	152	4	205		361	361	42.11%	1.11%	56.79%	0.00%
Grand Total	9/02/2016	107	5	173	2	287	287	37.28%	1.74%	60.28%	0.70%
Grand Total	10/02/2016	111	10	127		248	248	44.76%	4.03%	51.21%	0.00%
Grand Total	11/02/2016	98	18	116	1	233	233	42.06%	7.73%	49.79%	0.43%
Grand Total	12/02/2016	97	5	90		192	192	50.52%	2.60%	46.88%	0.00%
Grand Total	13/02/2016	195	9	242		446	446	43.72%	2.02%	54.26%	0.00%
Grand Total	14/02/2016	42	10	45		97	97	43.30%	10.31%	46.39%	0.00%
Grand Total	15/02/2016	115	18	188	4	325	325	35.38%	5.54%	57.85%	1.23%
Grand Total	16/02/2016	168	26	162		356	356	47.19%	7.30%	45.51%	0.00%
Grand Total	17/02/2016	251	19	266		536	536	46.83%	3.54%	49.63%	0.00%
Grand Total	18/02/2016	269	12	271	1	553	553	48.64%	2.17%	49.01%	0.18%
Grand Total	19/02/2016	383	10	406		799	799	47.93%	1.25%	50.81%	0.00%
Grand Total	20/02/2016	182	3	183		368	368	49.46%	0.82%	49.73%	0.00%
Grand Total	21/02/2016	27	9	68		104	104	25.96%	8.65%	65.38%	0.00%
Grand Total	22/02/2016	17	18	31	1	67	67	25.37%	26.87%	46.27%	1.49%
Grand Total	23/02/2016	21	15	37	2	75	75	28.00%	20.00%	49.33%	2.67%
Grand Total	24/02/2016	158	6	188		352	352	44.89%	1.70%	53.41%	0.00%
Grand Total	25/02/2016	412	8	565		985	985	41.83%	0.81%	57.36%	0.00%
Grand Total	26/02/2016	387	13	496		896	896	43.19%	1.45%	55.36%	0.00%
Grand Total	27/02/2016	149	14	169		332	332	44.88%	4.22%	50.90%	0.00%
Grand Total	28/02/2016	54	5	64		123	123	43.90%	4.07%	52.03%	0.00%
Grand Total	29/02/2016	23	31	58	1	113	113	20.35%	27.43%	51.33%	0.88%
FEBRUARY MONTHLY AVERAGE							350.62069	36.86%	8.20%	54.62%	0.31%

Table 23: Total alarms per day and alarm priority distribution per day for February 2016

For comparison purposes, Figure 25 bar graph with limit line was created to show the same data as Table 22.

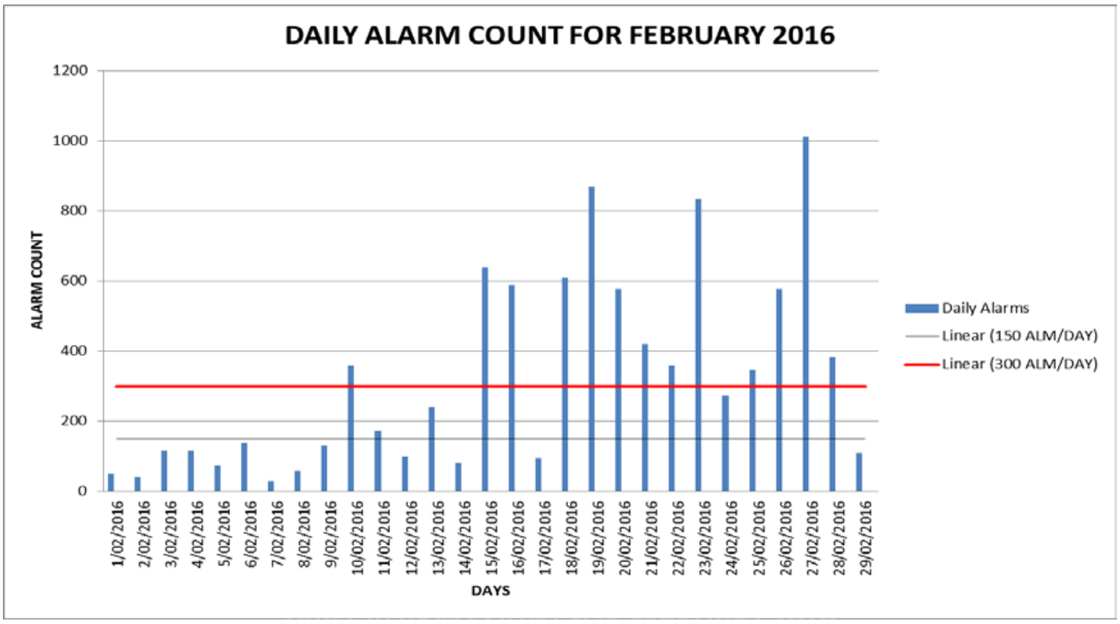


Figure 25: Daily total alarms per day for February 2016

DAILY ALARM ANALYSIS											
ALARM DATA PER DAY							ANALYSIS TO ISA 18.2 STANDARD				
FLOOR 1hr	Time	High	Journal	Low	Urgent	Grand Total	KPI 150-300 ALM/day	High < 5%	Journal = N/A	Low < 80%	Urgent < 1%
Grand Total	1/03/2016	6	13	31	1	51	51	11.76%	25.49%	60.78%	1.96%
Grand Total	2/03/2016	4	8	29		41	41	9.76%	19.51%	70.73%	0.00%
Grand Total	3/03/2016	29	22	66		117	117	24.79%	18.80%	56.41%	0.00%
Grand Total	4/03/2016	40	7	69		116	116	34.48%	6.03%	59.48%	0.00%
Grand Total	5/03/2016	16	16	41		73	73	21.92%	21.92%	56.16%	0.00%
Grand Total	6/03/2016	25	35	78		138	138	18.12%	25.36%	56.52%	0.00%
Grand Total	7/03/2016	4	4	20	1	29	29	13.79%	13.79%	68.97%	3.45%
Grand Total	8/03/2016	14	9	36		59	59	23.73%	15.25%	61.02%	0.00%
Grand Total	9/03/2016	45	14	73		132	132	34.09%	10.61%	55.30%	0.00%
Grand Total	10/03/2016	107	23	225	4	359	359	29.81%	6.41%	62.67%	1.11%
Grand Total	11/03/2016	46	15	113		174	174	26.44%	8.62%	64.94%	0.00%
Grand Total	12/03/2016	28	12	60		100	100	28.00%	12.00%	60.00%	0.00%
Grand Total	13/03/2016	93	20	126	1	240	240	38.75%	8.33%	52.50%	0.42%
Grand Total	14/03/2016	26	13	41	2	82	82	31.71%	15.85%	50.00%	2.44%
Grand Total	15/03/2016	45	30	565		640	640	7.03%	4.69%	88.28%	0.00%
Grand Total	16/03/2016	57	19	513		589	589	9.68%	3.23%	87.10%	0.00%
Grand Total	17/03/2016	24	19	52		95	95	25.26%	20.00%	54.74%	0.00%
Grand Total	18/03/2016	33	24	552		609	609	5.42%	3.94%	90.64%	0.00%
Grand Total	19/03/2016	183	6	680		869	869	21.06%	0.69%	78.25%	0.00%
Grand Total	20/03/2016	114	39	426		579	579	19.69%	6.74%	73.58%	0.00%
Grand Total	21/03/2016	191	7	222		420	420	45.48%	1.67%	52.86%	0.00%
Grand Total	22/03/2016	120	31	207		358	358	33.52%	8.66%	57.82%	0.00%
Grand Total	23/03/2016	371	36	427	1	835	835	44.43%	4.31%	51.14%	0.12%
Grand Total	24/03/2016	50	57	166		273	273	18.32%	20.88%	60.81%	0.00%
Grand Total	25/03/2016	34	19	288	4	345	345	9.86%	5.51%	83.48%	1.16%
Grand Total	26/03/2016	137	17	425		579	579	23.66%	2.94%	73.40%	0.00%
Grand Total	27/03/2016	388	31	592	1	1012	1012	38.34%	3.06%	58.50%	0.10%
Grand Total	28/03/2016	138	38	205	2	383	383	36.03%	9.92%	53.52%	0.52%
Grand Total	29/03/2016	24	15	68	2	109	109	22.02%	13.76%	62.39%	1.83%
Grand Total	30/03/2016	25	17	30		72	72	34.72%	23.61%	41.67%	0.00%
Grand Total	31/03/2016	157	80	217		454	454	34.58%	17.62%	47.80%	0.00%
MARCH MONTHLY AVERAGE							320.387097	25.04%	11.59%	62.95%	0.42%

Table 24: Total alarms per day and alarm priority distribution per day for March 2016

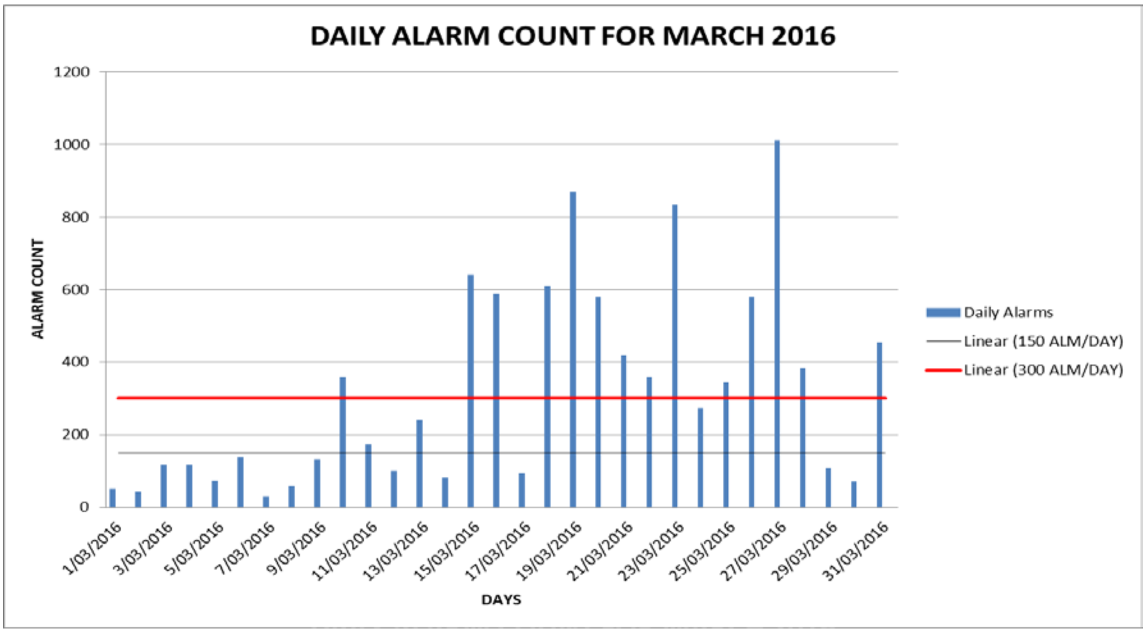


Figure 26: Daily total alarms per day for February 2016

DAILY ALARM ANALYSIS											
ALARM DATA PER DAY							ANALYSIS TO ISA 18.2 STANDARD				
FLOOR 1hr	Time	High	Journal	Low	Urgent	Grand Total	KPI 150-300 ALM/day	High < 5%	Journal = N/A	Low < 80%	Urgent < 1%
Grand Total	1/04/2016	259	25	347		631	631	41.05%	3.96%	54.99%	0.00%
Grand Total	2/04/2016	188	50	287		525	525	35.81%	9.52%	54.67%	0.00%
Grand Total	3/04/2016	317	12	423	1	753	753	42.10%	1.59%	56.18%	0.13%
Grand Total	4/04/2016	442	21	832	1	1296	1296	34.10%	1.62%	64.20%	0.08%
Grand Total	5/04/2016	363	3	850		1216	1216	29.85%	0.25%	69.90%	0.00%
Grand Total	6/04/2016	347	15	677		1039	1039	33.40%	1.44%	65.16%	0.00%
Grand Total	7/04/2016	294	11	708	2	1015	1015	28.97%	1.08%	69.75%	0.20%
Grand Total	8/04/2016	457	21	850		1328	1328	34.41%	1.58%	64.01%	0.00%
Grand Total	9/04/2016	400	20	612	2	1034	1034	38.68%	1.93%	59.19%	0.19%
Grand Total	10/04/2016	221	24	323	2	570	570	38.77%	4.21%	56.67%	0.35%
Grand Total	11/04/2016	57	27	74		158	158	36.08%	17.09%	46.84%	0.00%
Grand Total	12/04/2016	29	49	57	1	136	136	21.32%	36.03%	41.91%	0.74%
Grand Total	13/04/2016	49	15	96	3	163	163	30.06%	9.20%	58.90%	1.84%
Grand Total	14/04/2016	8	11	32		51	51	15.69%	21.57%	62.75%	0.00%
Grand Total	15/04/2016	15	30	22		67	67	22.39%	44.78%	32.84%	0.00%
Grand Total	16/04/2016	43	22	87	1	153	153	28.10%	14.38%	56.86%	0.65%
Grand Total	17/04/2016	54	38	167	7	266	266	20.30%	14.29%	62.78%	2.63%
Grand Total	18/04/2016	40	28	115		183	183	21.86%	15.30%	62.84%	0.00%
Grand Total	19/04/2016	25	268	404		697	697	3.59%	38.45%	57.96%	0.00%
Grand Total	20/04/2016	52	39	91	1	183	183	28.42%	21.31%	49.73%	0.55%
Grand Total	21/04/2016	15	58	35	1	109	109	13.76%	53.21%	32.11%	0.92%
Grand Total	22/04/2016	5	5	14		24	24	20.83%	20.83%	58.33%	0.00%
Grand Total	23/04/2016	15	2	23		40	40	37.50%	5.00%	57.50%	0.00%
Grand Total	24/04/2016	49	90	315	9	463	463	10.58%	19.44%	68.03%	1.94%
Grand Total	25/04/2016	21	17	32		70	70	30.00%	24.29%	45.71%	0.00%
Grand Total	26/04/2016	31	9	32		72	72	43.06%	12.50%	44.44%	0.00%
Grand Total	27/04/2016	25	25	32	1	83	83	30.12%	30.12%	38.55%	1.20%
Grand Total	28/04/2016	4	21	5		30	30	13.33%	70.00%	16.67%	0.00%
Grand Total	29/04/2016	97	17	18		132	132	73.48%	12.88%	13.64%	0.00%
APRIL MONTHLY AVERAGE							430.586207	29.57%	17.51%	52.52%	0.39%

Table 25: Total alarms per day and alarm priority distribution per day for April 2016

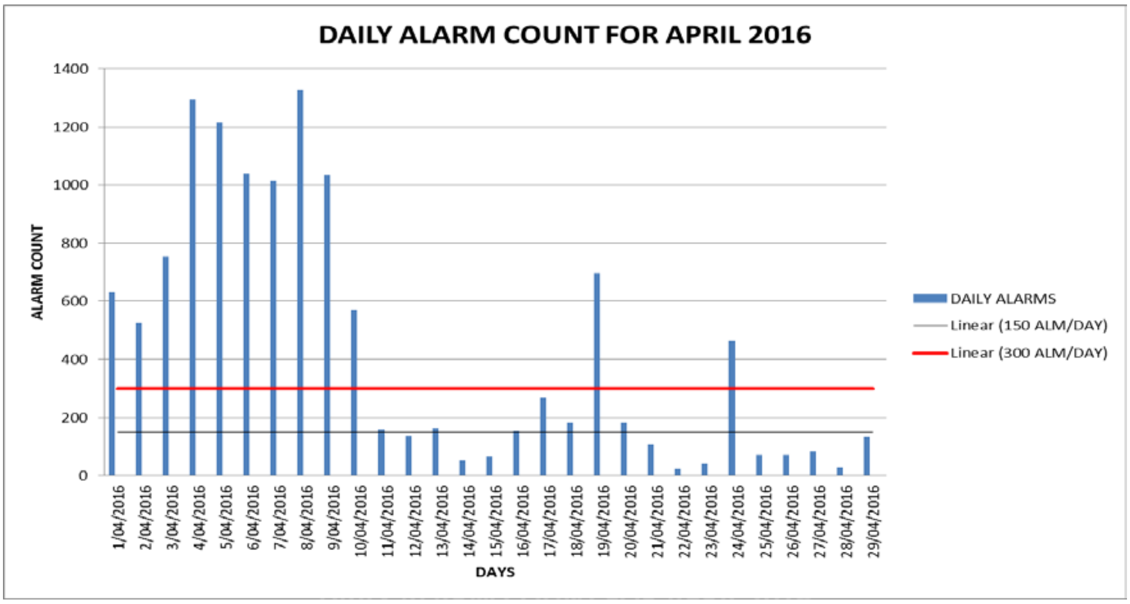


Figure 27: Daily total alarms per day for February 2016

Of the 92 days sampled 53% or 49 days, the alarm rate was under ISA 18.2 metric of maximum manageable alarms < 300 alarms per day (see Figure 28 and Table 26). Therefore, 47% of the sample period or 43 days are considered unmanageable, given they exceed the 300 alarms per day.

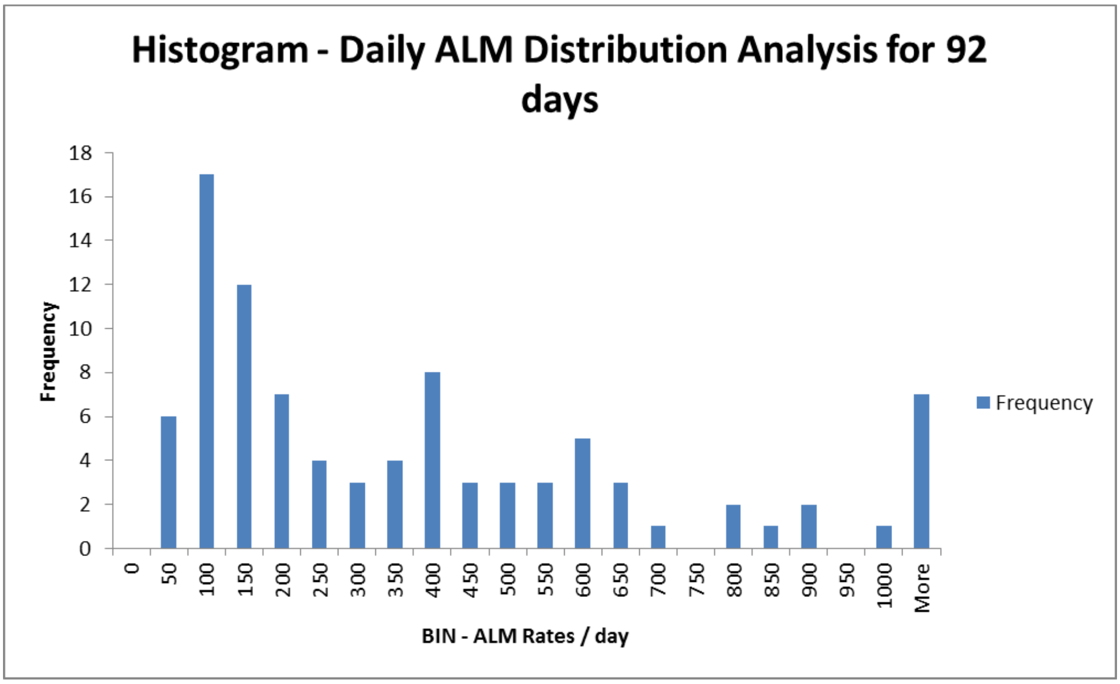


Figure 28: Surveyed period daily alarm rate distribution

Referencing Table 26, 7.6% of daily alarm rates over the 92 days have an alarm rate above 1000 alarms per day.

ALARM DISTRIBUTION PER DAY FOR 92 DAYS			
BIN - ALM Rate/ day distribution	Frequency over days surveyed	Frequency % total days surveyed	% Accumulated total
0	0	0.00%	0.00%
50	6	6.52%	6.52%
100	17	18.48%	25.00%
150	12	13.04%	38.04%
200	7	7.61%	45.65%
250	4	4.35%	50.00%
300	3	3.26%	53.26%
350	4	4.35%	57.61%
400	8	8.70%	66.30%
450	3	3.26%	69.57%
500	3	3.26%	72.83%
550	3	3.26%	76.09%
600	5	5.43%	81.52%
650	3	3.26%	84.78%
700	1	1.09%	85.87%
750	0	0.00%	85.87%
800	2	2.17%	88.04%
850	1	1.09%	89.13%
900	2	2.17%	91.30%
950	0	0.00%	91.30%
1000	1	1.09%	92.39%
More	7	7.61%	100.00%
Total Days Surveyed	92		

Table 26: Surveyed period daily alarm rate distribution

Based the results in Table 26 it seems reasonable to expect the monthly alarm average analysis in Table 27 to shows the distribution of alarms and with month experienced the higher alarm rates. The KPI column 150-300 alarms / day are exceeded for all three months. The high alarm priority expected to be < 5% averages from 25% to 36% for the 3 months and the low priority is underutilised having capacity of 80% yet only registers 50-60% low priority alarms. Based on the results further analysis is required to determine if the alarm priorities can be reallocated to improve the alarm priority distribution.

MONTHLY ALARM AVERAGE ANALYSIS					
ALARM DATA PER MONTH	ANALYSIS TO ISA 18.2 STANDARD				
	KPI 150-300 ALM/day	High < 5%	Journal = N/A	Low < 80%	Urgent < 1%
FEBRUARY MONTHLY AVERAGE	350.62069	36.86%	8.20%	54.62%	0.31%
MARCH MONTHLY AVERAGE	320.387097	25.04%	11.59%	62.95%	0.42%
APRIL MONTHLY AVERAGE	430.586207	29.57%	17.51%	52.52%	0.39%

Table 27: Monthly average of alarms per day

In terms of drawing the observer's attention to areas of interest, the coloured tables present poor performances with greater impact than the bar charts. Although the daily alarm average not set to change colour when limits are exceeded provides a reasonable quick glance overview of the systems performance.

5.3 Annunciated alarms per hour per operating position

The next performance metric from 18.2 is the annunciated alarms per hour per operating position, targeting ~6 to ~12 alarms per hour (average). Similar to the daily analysis, the hourly analysis enables the observer focus on hours of non-conformance. This is particularly useful in pinpointing the hours requiring for specific trending / analysis.

Note – Only the hours where an alarm has occurred are included in the table analysed.

HOURLY ALARM ANALYSIS											
ALARM DATA PER PER HOUR							ANALYSIS TO ISA 18.2 STANDARD				
FLOOR 1	Time	High	Journal	Low	Urgent	Grand To	KPI 6-12 ALM/H	High < 5	Journal = N	Low < 80	Urgent <
0:00	1/02/2016	8		8		16	16	50.00%	0.00%	50.00%	0.00%
1:00	1/02/2016	4		5		9	9	44.44%	0.00%	55.56%	0.00%
2:00	1/02/2016		1			1	1	0.00%	100.00%	0.00%	0.00%
6:00	1/02/2016	1	8			9	9	11.11%	88.89%	0.00%	0.00%
9:00	1/02/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%
15:00	1/02/2016	6		150		156	156	3.85%	0.00%	96.15%	0.00%
16:00	1/02/2016	10		250		260	260	3.85%	0.00%	96.15%	0.00%
17:00	1/02/2016		2			2	2	0.00%	100.00%	0.00%	0.00%
19:00	1/02/2016	2				2	2	100.00%	0.00%	0.00%	0.00%
0:00	2/02/2016		6	2		8	8	0.00%	75.00%	25.00%	0.00%
14:00	2/02/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%
16:00	2/02/2016			2		2	2	0.00%	0.00%	100.00%	0.00%
23:00	2/02/2016		2			2	2	0.00%	100.00%	0.00%	0.00%
5:00	3/02/2016			1		1	1	0.00%	0.00%	100.00%	0.00%
8:00	3/02/2016	6	2	103		111	111	5.41%	1.80%	92.79%	0.00%
9:00	3/02/2016	14		21		35	35	40.00%	0.00%	60.00%	0.00%
10:00	3/02/2016			1		1	1	0.00%	0.00%	100.00%	0.00%
13:00	3/02/2016	2				2	2	100.00%	0.00%	0.00%	0.00%
14:00	3/02/2016			2		2	2	0.00%	0.00%	100.00%	0.00%
15:00	3/02/2016		1			1	1	0.00%	100.00%	0.00%	0.00%
16:00	3/02/2016		2	2		4	4	0.00%	50.00%	50.00%	0.00%
17:00	3/02/2016	2		2		4	4	50.00%	0.00%	50.00%	0.00%
18:00	3/02/2016	11	6	17	1	35	35	31.43%	17.14%	48.57%	2.86%
19:00	3/02/2016	2	4	7		13	13	15.38%	30.77%	53.85%	0.00%
21:00	3/02/2016	2				2	2	100.00%	0.00%	0.00%	0.00%

Table 28: Snap shot #1 - alarms per hour with alarm priority distribution

HOURLY ALARM ANALYSIS											
ALARM DATA PER PER HOUR							ANALYSIS TO ISA 18.2 STANDARD				
FLOOR 1	Time	High	Journal	Low	Urgent	Grand To	KPI 6-12 ALM/H	High < 5	Journal = N	Low < 80	Urgent <
0:00	25/02/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%
1:00	25/02/2016	28	2	36		66	66	42.42%	3.03%	54.55%	0.00%
2:00	25/02/2016	29		50		79	79	36.71%	0.00%	63.29%	0.00%
3:00	25/02/2016	26		33		59	59	44.07%	0.00%	55.93%	0.00%
4:00	25/02/2016	22		27		49	49	44.90%	0.00%	55.10%	0.00%
5:00	25/02/2016	24		40		64	64	37.50%	0.00%	62.50%	0.00%
6:00	25/02/2016	41		64		105	105	39.05%	0.00%	60.95%	0.00%
7:00	25/02/2016	30		33		63	63	47.62%	0.00%	52.38%	0.00%
8:00	25/02/2016	6		6		12	12	50.00%	0.00%	50.00%	0.00%
9:00	25/02/2016	1				1	1	100.00%	0.00%	0.00%	0.00%
10:00	25/02/2016	1	2			3	3	33.33%	66.67%	0.00%	0.00%
13:00	25/02/2016	2		4		6	6	33.33%	0.00%	66.67%	0.00%
14:00	25/02/2016	29	2	35		66	66	43.94%	3.03%	53.03%	0.00%
15:00	25/02/2016	34	2	50		86	86	39.53%	2.33%	58.14%	0.00%
16:00	25/02/2016	28		40		68	68	41.18%	0.00%	58.82%	0.00%
17:00	25/02/2016	28		36		64	64	43.75%	0.00%	56.25%	0.00%
18:00	25/02/2016	36		51		87	87	41.38%	0.00%	58.62%	0.00%
19:00	25/02/2016	33		46		79	79	41.77%	0.00%	58.23%	0.00%
20:00	25/02/2016	12		12		24	24	50.00%	0.00%	50.00%	0.00%
21:00	25/02/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%
0:00	26/02/2016	1	1	1		3	3	33.33%	33.33%	33.33%	0.00%
1:00	26/02/2016	5	2	5		12	12	41.67%	16.67%	41.67%	0.00%
2:00	26/02/2016	33		39		72	72	45.83%	0.00%	54.17%	0.00%
3:00	26/02/2016	31		36		67	67	46.27%	0.00%	53.73%	0.00%
4:00	26/02/2016	25		40		65	65	38.46%	0.00%	61.54%	0.00%
5:00	26/02/2016	35		50		85	85	41.18%	0.00%	58.82%	0.00%
6:00	26/02/2016	30	1	43		74	74	40.54%	1.35%	58.11%	0.00%
7:00	26/02/2016	31		33		64	64	48.44%	0.00%	51.56%	0.00%
8:00	26/02/2016	4	1	6		11	11	36.36%	9.09%	54.55%	0.00%
10:00	26/02/2016			2		2	2	0.00%	0.00%	100.00%	0.00%
13:00	26/02/2016	2	1	2		5	5	40.00%	20.00%	40.00%	0.00%
14:00	26/02/2016	6		7		13	13	46.15%	0.00%	53.85%	0.00%
15:00	26/02/2016	50	6	62		118	118	42.37%	5.08%	52.54%	0.00%
16:00	26/02/2016	24	1	40		65	65	36.92%	1.54%	61.54%	0.00%
17:00	26/02/2016	30		38		68	68	44.12%	0.00%	55.88%	0.00%
18:00	26/02/2016	28		33		61	61	45.90%	0.00%	54.10%	0.00%
19:00	26/02/2016	40		47		87	87	45.98%	0.00%	54.02%	0.00%
20:00	26/02/2016	12		12		24	24	50.00%	0.00%	50.00%	0.00%

Table 29: Snap shot #2 - alarms per hour with alarm priority distribution

Given only the hours having alarms were compiled to provide results for comparison against the KPI (Tables 28, 29 and 30), this could be misinterpreted as an indication of the complete period. When comparing the alarm rate averages against the total hour periods (24 per day) for each month the average, as expected falls dramatically (Table 31) and April is now within hourly KPI tolerance. Comparing Tables 30 and 31, demonstrates the pitfalls of averages. In terms of best practice alarm management Table 30 provide a true reflection of the average alarm rate during the hour periods when an alarm occurs. In contrast to Table 31, Aprils alarm rate is manageable (9.32 alarms / hour) yet February and March just unmanageable (13.3 and 14.6 alarms / hour).

MONTHLY HOURLY ALARM AVERAGE ANALYSIS					
ALARM DATA PER HOUR PER MONTH	ANALYSIS TO ISA 18.2 STANDARD				
	KPI 6-12 ALM/Hr	High < 5%	Journal = N/A	Low < 80%	Urgent < 1%
FEBRUARY HOURLY AVERAGE	21.7730193	36.11%	13.28%	50.24%	0.37%
MARCH HOURLY AVERAGE	18.5992509	22.62%	14.67%	62.41%	0.30%
APRIL HOURLY AVERAGE	25.6934156	26.69%	18.98%	53.60%	0.72%

Table 30: Monthly average alarm rate per hour

MONTHLY HOURLY ALARM AVERAGE ANALYSIS					
ALARM DATA PER HOUR PER MONTH	ANALYSIS TO ISA 18.2 STANDARD				
	KPI 6-12 ALM/Hr	High < 5%	Journal = N/A	Low < 80%	Urgent < 1%
FEBRUARY HOURLY AVERAGE (ALL HOURS PER MONTH INLCUDED)	14.6091954	24.23%	8.91%	33.71%	0.25%
MARCH HOURLY AVERAGE (ALL HOURS PER MONTH INLCUDED)	13.3494624	16.23%	10.53%	44.79%	0.22%
APRIL HOURLY AVERAGE (ALL HOURS PER MONTH INLCUDED)	9.32160734	11.33%	7.35%	31.28%	0.15%

Table 31: Monthly alarms averaged over the total 24 hour periods per month

Based on the above, further data analysis was conducted to determine the distribution of hourly alarms rates. This was achieved using a histogram (Figure 29) distributing the one hourly alarm rates over the 92 day sample period. The frequency of alarm rate per hour referencing the manageable target ~6 to ~12 alarms per hour (average) accounts for 60% of alarms rates (table 32). Surprisingly, the histogram shows an increase in alarm distribution around the 48-96 alarms per hour, this blemish attracts attention for further investigation to find out why this alarm rate increased when it should have be tapering off left to right as the alarm rates increase.

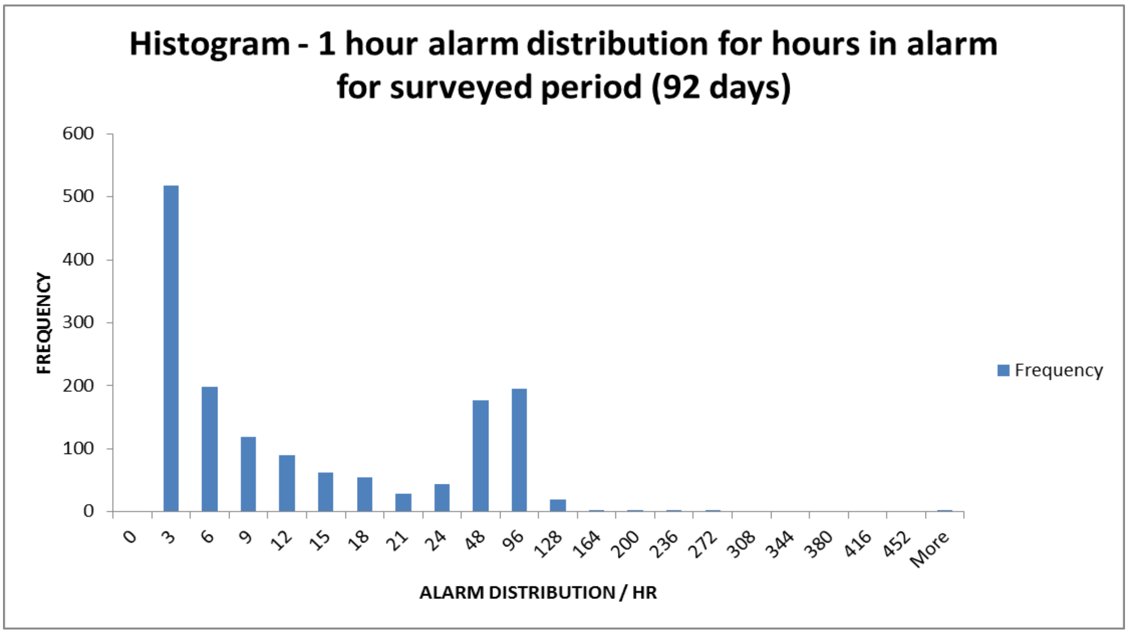


Figure 29: Hourly alarm rate distribution histogram for surveyed duration

ALARM DISTRIBUTION PER 1 HR FOR 92 DAYS			
ALARM DISTRIBUTION / HR	FREQUENCY	Frequency % distribution / BIN	Accumulated total
0	0	0.00%	0.00%
3	518	34.01%	34.01%
6	199	13.07%	47.08%
9	119	7.81%	54.89%
12	90	5.91%	60.80%
15	62	4.07%	64.87%
18	54	3.55%	68.42%
21	29	1.90%	70.32%
24	44	2.89%	73.21%
48	177	11.62%	84.83%
96	195	12.80%	97.64%
128	20	1.31%	98.95%
164	3	0.20%	99.15%
200	3	0.20%	99.34%
236	3	0.20%	99.54%
272	3	0.20%	99.74%
308	1	0.07%	99.80%
344	0	0.00%	99.80%
380	0	0.00%	99.80%
416	0	0.00%	99.80%
452	1	0.07%	99.87%
More	2	0.13%	100.00%
Sample Count	**1523**		

Table 32: Hourly alarm distribution with accumulated percentage

The hourly alarm rate demonstrates its effectiveness in narrowing high alarm rates to hour periods. However use caution when averaging alarm rates over time as demonstrated the results may appear good or bad.

5.4 Percentage of hours with >30 alarms

Using the hourly data periods from above, a comparison to the hourly alarm rate provides the percentage of hours with alarm rates > 30 alarms per hour. The target is less than < 1%.
The results in Table 33 show excessively high percentage of alarms > 30 alarms per hour in comparison to the < 1% target.

Percentage of hours with >30 alarms - target <1%			
Month	February	March	April
Hours >30 Alarms	122	82	149
Hours / month	696	744	696
Percentage	**17.53%**	**11.02%**	**21.41%**

Table 33: Percentage of hours with >30 alarms per hour

5.5 Annunciated alarms per 10 min per operating position

Analysing the annunciated alarms per 10 min per operating position, gauging the acceptable alarm rate < 1 alarm/ 10mins or maximum manageable alarm rate of < 2 alarms / 10mins both averaged.

The 10 min. period performance metric tables include an additional metric column to highlight alarm floods. The alarm flood column identified by the amber box determines alarms for each 10 min. period, if the alarm rates greater that10 alarms per 10 min. the alarm system is in flood. The amber column signifies alarm floods and is set to change colour to allow the observer to see which 10 minute periods during the day are in alarm flood.

10 MINUTE ALARM ANALYSIS												
ALARM DATA PER 10MIN INTERVALS							ANALYSIS TO ISA 18.2 STANDARD					
FLOOR 10min	Time	High	Journal	Low	Urgent	Grand Total	ALM ~1-2 / 10min	High < 5%	Journal (N/A)	Low < 80%	Urgent > 1%	ALM > 10 / 10min
0:50	1/02/16	8		8		16	16	50.00%	0.00%	50.00%	0.00%	16
1:00	1/02/16	4		5		9	9	44.44%	0.00%	55.56%	0.00%	9
2:40	1/02/16		1			1	1	0.00%	100.00%	0.00%	0.00%	1
6:40	1/02/16	1	8			9	9	11.11%	88.89%	0.00%	0.00%	9
9:00	1/02/16			1		1	1	0.00%	0.00%	100.00%	0.00%	1
9:10	1/02/16	1				1	1	100.00%	0.00%	0.00%	0.00%	1
15:40	1/02/16			23		23	23	0.00%	0.00%	100.00%	0.00%	23
15:50	1/02/16	6		127		133	133	4.51%	0.00%	95.49%	0.00%	133
16:00	1/02/16	5		131		136	136	3.68%	0.00%	96.32%	0.00%	136
16:10	1/02/16	5		119		124	124	4.03%	0.00%	95.97%	0.00%	124
17:10	1/02/16		2			2	2	0.00%	100.00%	0.00%	0.00%	2
19:40	1/02/16	2				2	2	100.00%	0.00%	0.00%	0.00%	2
0:30	2/02/16		6	2		8	8	0.00%	75.00%	25.00%	0.00%	8
14:40	2/02/16	1		1		2	2	50.00%	0.00%	50.00%	0.00%	2
16:40	2/02/16			2		2	2	0.00%	0.00%	100.00%	0.00%	2
23:00	2/02/16		2			2	2	0.00%	100.00%	0.00%	0.00%	2
5:50	3/02/16			1		1	1	0.00%	0.00%	100.00%	0.00%	1
8:40	3/02/16			47		47	47	0.00%	0.00%	100.00%	0.00%	47
8:50	3/02/16	6	2	56		64	64	9.38%	3.13%	87.50%	0.00%	64
9:00	3/02/16	8		10		18	18	44.44%	0.00%	55.56%	0.00%	18
9:10	3/02/16	6		10		16	16	37.50%	0.00%	62.50%	0.00%	16
9:20	3/02/16			1		1	1	0.00%	0.00%	100.00%	0.00%	1
10:20	3/02/16			1		1	1	0.00%	0.00%	100.00%	0.00%	1
13:50	3/02/16	2				2	2	100.00%	0.00%	0.00%	0.00%	2
14:00	3/02/16			2		2	2	0.00%	0.00%	100.00%	0.00%	2
15:30	3/02/16		1			1	1	0.00%	100.00%	0.00%	0.00%	1
16:20	3/02/16		2	2		4	4	0.00%	50.00%	50.00%	0.00%	4
17:20	3/02/16	1		2		3	3	33.33%	0.00%	66.67%	0.00%	3
17:50	3/02/16	1				1	1	100.00%	0.00%	0.00%	0.00%	1
18:10	3/02/16			1		1	1	0.00%	0.00%	100.00%	0.00%	1
18:20	3/02/16	4		4		8	8	50.00%	0.00%	50.00%	0.00%	8
18:30	3/02/16	2	2	2		6	6	33.33%	33.33%	33.33%	0.00%	6
18:40	3/02/16	5	4	10	1	20	20	25.00%	20.00%	50.00%	5.00%	20
19:00	3/02/16		1	6		7	7	0.00%	14.29%	85.71%	0.00%	7
19:40	3/02/16	2	3	1		6	6	33.33%	50.00%	16.67%	0.00%	6
21:20	3/02/16	1				1	1	100.00%	0.00%	0.00%	0.00%	1
21:50	3/02/16	1				1	1	100.00%	0.00%	0.00%	0.00%	1

Table 34: Annunciated alarms per 10 min per operating position (3 days in February analysis sample)

The next two tables (Table 34 and 35) highlight the contrast between alarms rates and alarm floods. The beginning of April appears more active in comparison to March.

10 MINUTE ALARM ANALYSIS												
ALARM DATA PER 10MIN INTERVALS							ANALYSIS TO ISA 18.2 STANDARD					
FLOOR 10min	Time	High	Journal	Low	Urgent	Grand Total	ALM ~1-2 / 10min	High < 5%	Journal (N/A)	Low < 80%	Urgent > 1%	ALM > 10 / 10min
0:50:00	1/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
1:50:00	1/03/2016		2			2	2	0.00%	100.00%	0.00%	0.00%	2
2:30:00	1/03/2016		2			2	2	0.00%	100.00%	0.00%	0.00%	2
2:40:00	1/03/2016			1		1	1	0.00%	0.00%	100.00%	0.00%	1
3:40:00	1/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
5:40:00	1/03/2016			1		1	1	0.00%	0.00%	100.00%	0.00%	1
5:50:00	1/03/2016			1		1	1	0.00%	0.00%	100.00%	0.00%	1
7:00:00	1/03/2016		1			1	1	0.00%	100.00%	0.00%	0.00%	1
7:10:00	1/03/2016		2			2	2	0.00%	100.00%	0.00%	0.00%	2
7:20:00	1/03/2016		1			1	1	0.00%	100.00%	0.00%	0.00%	1
7:30:00	1/03/2016	1	1			2	2	50.00%	50.00%	0.00%	0.00%	2
7:50:00	1/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
8:10:00	1/03/2016	2		1		3	3	66.67%	0.00%	33.33%	0.00%	3
8:30:00	1/03/2016	2				2	2	100.00%	0.00%	0.00%	0.00%	2
8:40:00	1/03/2016	1				1	1	100.00%	0.00%	0.00%	0.00%	1
9:00:00	1/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
10:50:00	1/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
11:30:00	1/03/2016		2	8	1	11	11	0.00%	18.18%	72.73%	9.09%	11
12:20:00	1/03/2016		2	3		5	5	0.00%	40.00%	60.00%	0.00%	5
12:40:00	1/03/2016			1		1	1	0.00%	0.00%	100.00%	0.00%	1
15:20:00	1/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
20:50:00	1/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
23:50:00	1/03/2016			1		1	1	0.00%	0.00%	100.00%	0.00%	1
1:20:00	2/03/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%	2
2:40:00	2/03/2016			1		1	1	0.00%	0.00%	100.00%	0.00%	1
3:50:00	2/03/2016			1		1	1	0.00%	0.00%	100.00%	0.00%	1
12:00:00	2/03/2016		2			2	2	0.00%	100.00%	0.00%	0.00%	2
13:10:00	2/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
15:10:00	2/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
17:10:00	2/03/2016			1		1	1	0.00%	0.00%	100.00%	0.00%	1
19:30:00	2/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
20:20:00	2/03/2016	1		2		3	3	33.33%	0.00%	66.67%	0.00%	3
20:30:00	2/03/2016			4		4	4	0.00%	0.00%	100.00%	0.00%	4
20:40:00	2/03/2016		2	3		5	5	0.00%	40.00%	60.00%	0.00%	5
21:00:00	2/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
21:10:00	2/03/2016		2	3		5	5	0.00%	40.00%	60.00%	0.00%	5
21:40:00	2/03/2016	1		5		6	6	16.67%	0.00%	83.33%	0.00%	6
22:10:00	2/03/2016	1				1	1	100.00%	0.00%	0.00%	0.00%	1
23:50:00	2/03/2016		2			2	2	0.00%	100.00%	0.00%	0.00%	2
3:50:00	3/03/2016		1			1	1	0.00%	100.00%	0.00%	0.00%	1
4:20:00	3/03/2016	1				1	1	100.00%	0.00%	0.00%	0.00%	1
6:50:00	3/03/2016	1	1			2	2	50.00%	50.00%	0.00%	0.00%	2
7:00:00	3/03/2016	1	1			2	2	50.00%	50.00%	0.00%	0.00%	2
7:10:00	3/03/2016		1			1	1	0.00%	100.00%	0.00%	0.00%	1
7:50:00	3/03/2016	2	3			5	5	40.00%	60.00%	0.00%	0.00%	5
8:00:00	3/03/2016	1				1	1	100.00%	0.00%	0.00%	0.00%	1
8:40:00	3/03/2016		1			1	1	0.00%	100.00%	0.00%	0.00%	1
8:50:00	3/03/2016	1	1			2	2	50.00%	50.00%	0.00%	0.00%	2
11:40:00	3/03/2016	1		2		3	3	33.33%	0.00%	66.67%	0.00%	3
11:50:00	3/03/2016	1		2		3	3	33.33%	0.00%	66.67%	0.00%	3
12:00:00	3/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
12:20:00	3/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
12:30:00	3/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
13:00:00	3/03/2016		2			2	2	0.00%	100.00%	0.00%	0.00%	2
13:10:00	3/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
13:20:00	3/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
13:30:00	3/03/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
13:40:00	3/03/2016	1		4		5	5	20.00%	0.00%	80.00%	0.00%	5

Table 35: Annunciated alarms per 10 min per operating position (3 days in March analysis sample)

10 MINUTE ALARM ANALYSIS												
ALARM DATA PER 10MIN INTERVALS							ANALYSIS TO ISA 18.2 STANDARD					
FLOOR 10min	Time	High	Journal	Low	Urgent	Grand Total	ALM ~1-2 / 10min	High < 5%	Journal (N/A)	Low < 80%	Urgent > 1%	ALM > 10 / 10min
0:00	1/04/2016	7		10		17	17	41.18%	0.00%	58.82%	0.00%	17
0:10	1/04/2016	6		6		12	12	50.00%	0.00%	50.00%	0.00%	12
0:20	1/04/2016	8		8		16	16	50.00%	0.00%	50.00%	0.00%	16
0:30	1/04/2016	6		6		12	12	50.00%	0.00%	50.00%	0.00%	12
0:40	1/04/2016	4		5		9	9	44.44%	0.00%	55.56%	0.00%	9
0:50	1/04/2016	2		2		4	4	50.00%	0.00%	50.00%	0.00%	4
1:00	1/04/2016	2		2		4	4	50.00%	0.00%	50.00%	0.00%	4
1:10	1/04/2016	3		3		6	6	50.00%	0.00%	50.00%	0.00%	6
1:20	1/04/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%	2
1:30	1/04/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%	2
1:40	1/04/2016	1		2		3	3	33.33%	0.00%	66.67%	0.00%	3
8:10	1/04/2016		1	2		3	3	0.00%	33.33%	66.67%	0.00%	3
8:20	1/04/2016		1	1		2	2	0.00%	50.00%	50.00%	0.00%	2
9:50	1/04/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%	2
10:00	1/04/2016	2		1		3	3	66.67%	0.00%	33.33%	0.00%	3
10:10	1/04/2016	2		3		5	5	40.00%	0.00%	60.00%	0.00%	5
10:20	1/04/2016	5		6		11	11	45.45%	0.00%	54.55%	0.00%	11
10:30	1/04/2016	2		3		5	5	40.00%	0.00%	60.00%	0.00%	5
10:40	1/04/2016	2		2		4	4	50.00%	0.00%	50.00%	0.00%	4
10:50	1/04/2016	6		7		13	13	46.15%	0.00%	53.85%	0.00%	13
11:00	1/04/2016	9		9		18	18	50.00%	0.00%	50.00%	0.00%	18
11:10	1/04/2016	8		8		16	16	50.00%	0.00%	50.00%	0.00%	16
11:20	1/04/2016	2		3		5	5	40.00%	0.00%	60.00%	0.00%	5
11:30	1/04/2016	2		2		4	4	50.00%	0.00%	50.00%	0.00%	4
11:40	1/04/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%	2
11:50	1/04/2016	5		6		11	11	45.45%	0.00%	54.55%	0.00%	11
12:00	1/04/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%	2
12:10	1/04/2016	2		2		4	4	50.00%	0.00%	50.00%	0.00%	4
12:20	1/04/2016	4		5		9	9	44.44%	0.00%	55.56%	0.00%	9
12:30	1/04/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%	2
12:40	1/04/2016	3		3		6	6	50.00%	0.00%	50.00%	0.00%	6
12:50	1/04/2016	7		9		16	16	43.75%	0.00%	56.25%	0.00%	16
13:00	1/04/2016	3		3		6	6	50.00%	0.00%	50.00%	0.00%	6
13:10	1/04/2016	4		4		8	8	50.00%	0.00%	50.00%	0.00%	8
13:20	1/04/2016	7		11		18	18	38.89%	0.00%	61.11%	0.00%	18
13:30	1/04/2016	4		6		10	10	40.00%	0.00%	60.00%	0.00%	10
13:40	1/04/2016	5		6		11	11	45.45%	0.00%	54.55%	0.00%	11
13:50	1/04/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%	2
14:00	1/04/2016	9		12		21	21	42.86%	0.00%	57.14%	0.00%	21
14:10	1/04/2016	4		5		9	9	44.44%	0.00%	55.56%	0.00%	9
14:20	1/04/2016	8		10		18	18	44.44%	0.00%	55.56%	0.00%	18
14:30	1/04/2016	3		4		7	7	42.86%	0.00%	57.14%	0.00%	7
14:40	1/04/2016	4		5		9	9	44.44%	0.00%	55.56%	0.00%	9
14:50	1/04/2016	2	3	4		9	9	22.22%	33.33%	44.44%	0.00%	9
15:00	1/04/2016	4		4		8	8	50.00%	0.00%	50.00%	0.00%	8
15:10	1/04/2016	3		5		8	8	37.50%	0.00%	62.50%	0.00%	8
15:20	1/04/2016	2	2	8		12	12	16.67%	16.67%	66.67%	0.00%	12
15:30	1/04/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
15:40	1/04/2016		2			2	2	0.00%	100.00%	0.00%	0.00%	2
15:50	1/04/2016	4		4		8	8	50.00%	0.00%	50.00%	0.00%	8
16:00	1/04/2016		2			2	2	0.00%	100.00%	0.00%	0.00%	2
16:10	1/04/2016	1		1		2	2	50.00%	0.00%	50.00%	0.00%	2
16:20	1/04/2016		2	4		6	6	0.00%	33.33%	66.67%	0.00%	6
16:30	1/04/2016	2		1		3	3	66.67%	0.00%	33.33%	0.00%	3
16:40	1/04/2016	2	2	5		9	9	22.22%	22.22%	55.56%	0.00%	9
16:50	1/04/2016		2	1		3	3	0.00%	66.67%	33.33%	0.00%	3
17:00	1/04/2016			4		4	4	0.00%	0.00%	100.00%	0.00%	4
17:10	1/04/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
17:30	1/04/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2
17:50	1/04/2016		2			2	2	0.00%	100.00%	0.00%	0.00%	2
18:00	1/04/2016			2		2	2	0.00%	0.00%	100.00%	0.00%	2

Table 36: Annunciated alarms per 10 min per operating position (1st of April analysis sample)

Analysing the monthly data using an average for each month summarises the alarm systems performance as poor (Table 37). However, based on the maximum manageable alarm rate of 2 alarms per 10 min. if the current monthly average alarms rates per 10 min. are divided between 4 operators (3.78 operators calculated then rounded up) the facility would meet this performance standard. The text in Table 37 has been set to change to gauge the effect of drawing ones attention to values in excess of the standard.

MONTHLY 10min ALARM AVERAGE ANALYSIS							
ALARM DATA PER 10min PER MONTH	ANALYSIS TO ISA 18.2 STANDARD						
	Maximum Alarms /10min (=<10)	ALM ~1-2 / 10min (Avg)	Alarm Prioirty Distribution				ALM > 10 / 10min (~<1%)
			High < 5%	Journal = N/A	Low < 80%	Urgent < 1%	
FEBRUARY MONTHLY AVERAGE	136	7.57675112	38.89%	8.22%	52.57%	0.31%	10.37%
MARCH MONTHLY AVERAGE	144	6.5745583	25.94%	13.70%	60.08%	0.28%	5.51%
APRIL MONTHLY AVERAGE	66	7.64476886	29.70%	11.86%	58.14%	0.31%	12.27%

Table 37: Summarised 10min alarm average monthly analysis

To better understand the alarm rate distribution per time interval, a histogram was used to visually display common trends in alarm rates for 10min periods. Fortunately, 77% of the alarm rates were within the 0-12 alarms / 10min interval spanning the 92 days (Table 38), therefore if the other 23% (high alarm rate periods) can be eliminated the system should remain mostly under the alarm flood performance metric.

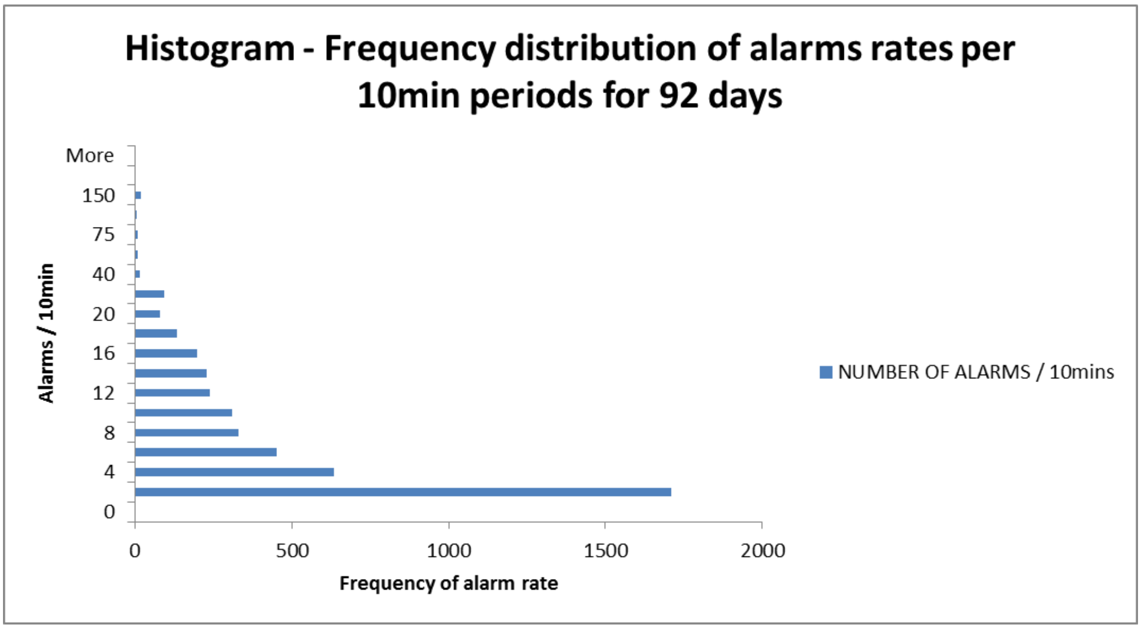


Figure 30: Histogram – Frequency distribution of alarm rates per 10 min. period over 92days

ALARM DISTRIBUTION PER 10 min PERIOD FOR 92 DAYS			
NUMBER OF ALARMS / 10mins	FREQUENCY	% distribution / BIN	Accumulated total
0	0	0.00%	0.00%
2	1710	38.32%	38.32%
4	633	14.19%	52.51%
6	451	10.11%	62.62%
8	331	7.42%	70.04%
10	309	6.93%	76.96%
12	240	5.38%	82.34%
14	227	5.09%	87.43%
16	199	4.46%	91.89%
18	135	3.03%	94.91%
20	78	1.75%	96.66%
30	94	2.11%	98.77%
40	17	0.38%	99.15%
50	7	0.16%	99.31%
75	7	0.16%	99.46%
100	5	0.11%	99.57%
150	19	0.43%	100.00%
200	0	0.00%	100.00%
More	0	0.00%	100.00%
Sample count	**4462**		

Table 38: Alarm rate per 10min period with alarm system percentage distribution

In reviewing the contrast between in information provided in Tables 34, 35 and 36 and Figure 31, displaying the alarm rates / performance a more traditional bar graph. The drawback in using the bar graph approach is the limited ability to draw ones attention the standards and the differences compared. Also when a high alarm rate period occurs the vertical scale changes, this may cause the observer to overlook the other time periods exceeding the performance metrics for 10min periods on account of the attention drawn to the three high rate alarm periods between 7:40am and 9:00am shown in Figure 32.

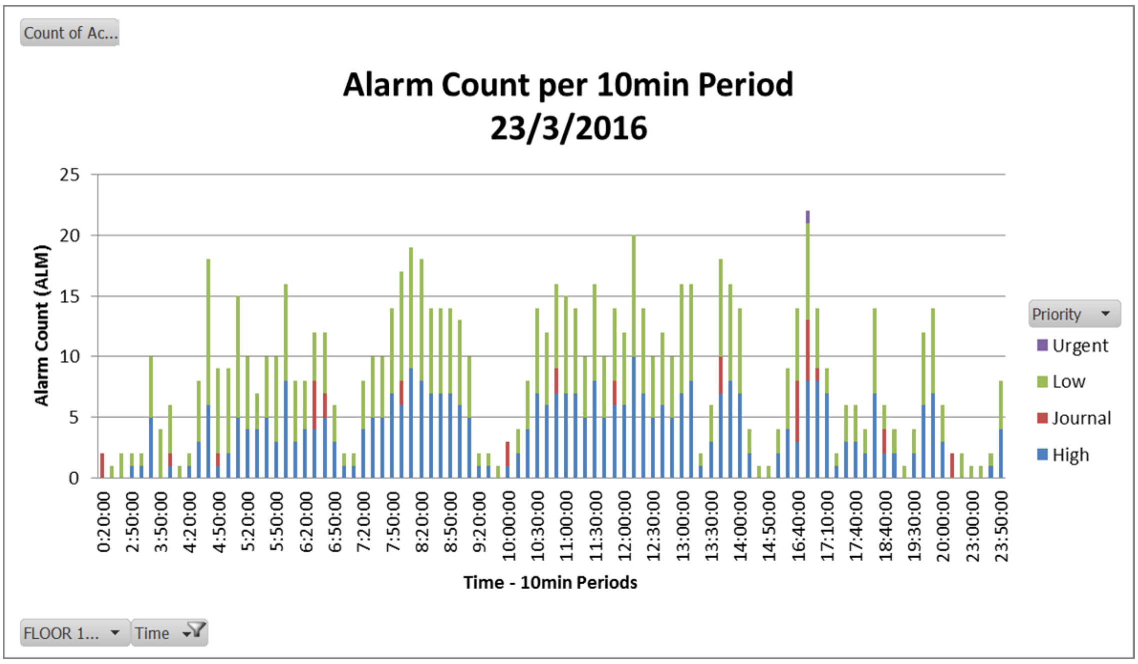


Figure 31: Daily alarm count graph in 10min periods

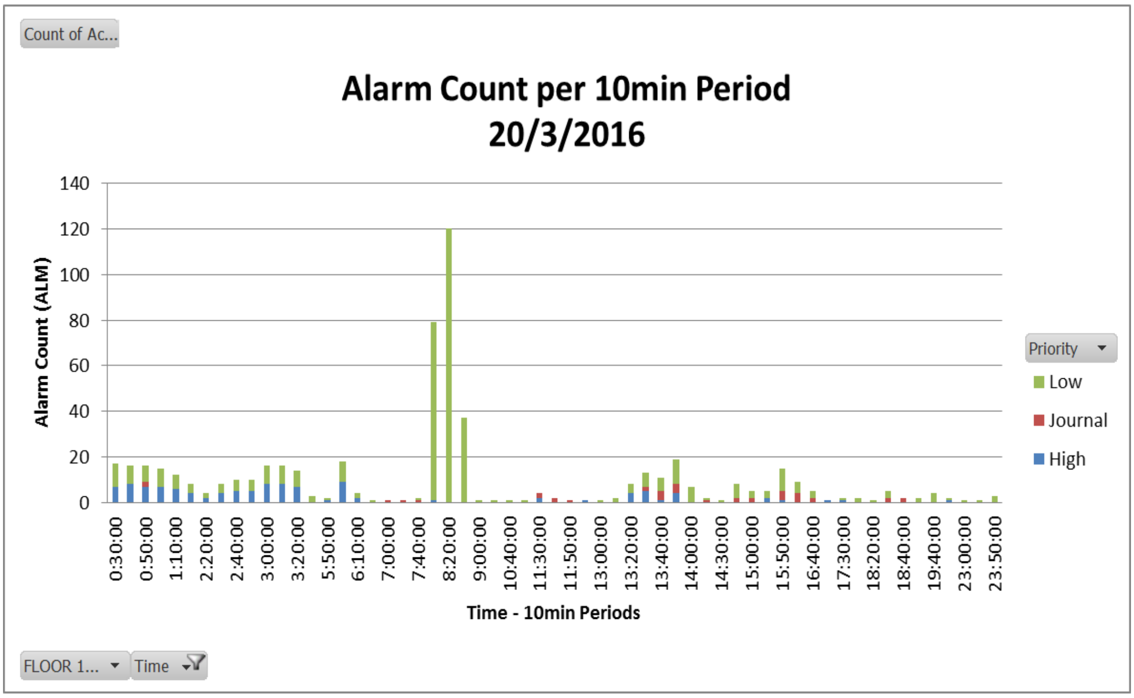


Figure 32: Daily alarm count graph in 10min periods

In summary, the monthly, daily, hourly and 10min analysis provides an effective evaluation and variations of alarm data when assessing the performance of an alarm system. This variation prompts further investigation by the analyser, where in non-conformance problem are identified, however the monthly, daily, hourly and 10min period should be analysed based on the problem found with averaging.

5.6 Stale alarms

Stale alarms are described as an alarm that remains in the alarm state for an extended period of time (e.g. 12, 24 hours). Stale alarms performance target is < 5 per day, should this be exceeded action plans to address these alarms should be in place. The analysis was shortened to >12 hours based on most operator panels spanning a12 hour shift. Analysing this metric also showed some concerning trends by way of the included examples of prolonged periods where high and urgent alarms remaining in alarm (see Figure 33 and Table 39).

The analysis per tag calculates time and days in alarm, some of these alarms occur twice or more during the 18th February to 8th March. This performance metric captures the backlog of active alarms in the system, analysis generally focuses on what's entering the system, not the number of alarms remaining or missed in the system.

Although the targets stale alarms < 5 alarms per day, this metric could include the number of days an alarm remains stale, escalating weight with each day the stale alarm remains. All alarms should be actioned, even if this includes, shelving, disabling the alarm under an out of service or management of change action until the alarm is required or returned to service.

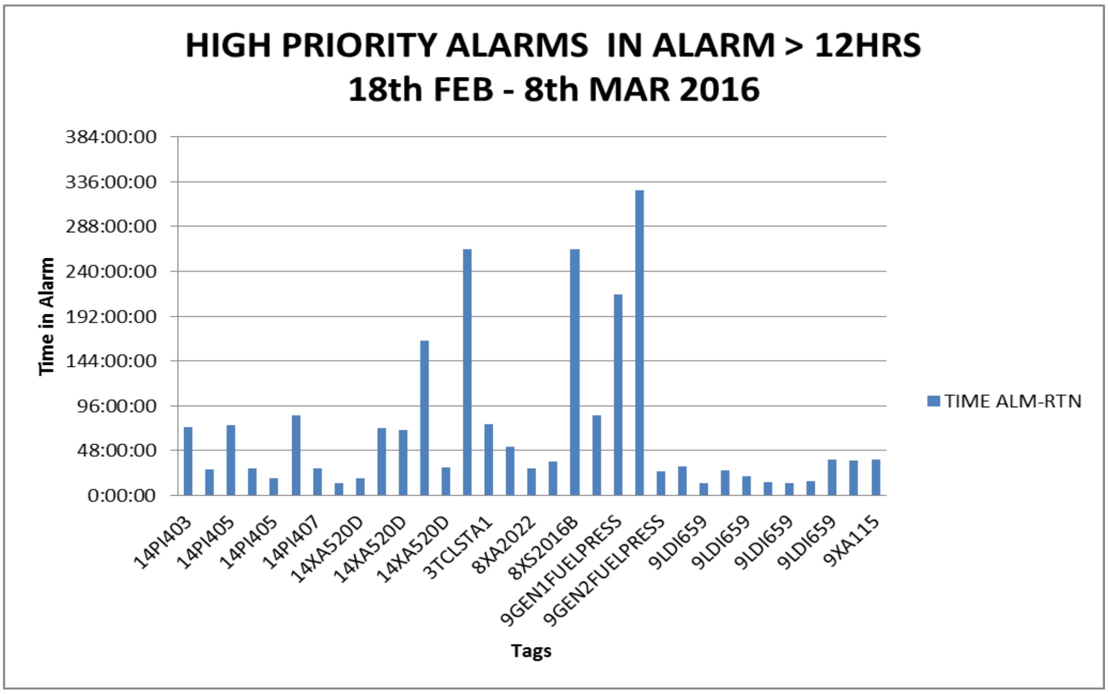


Figure 33: Stale alarms graph (High Priority)

Stale Alarms - High Prioirty				
Tag1	Time	RTN	TIME ALM-RTN	High
14PI403	22/02/2016 3:30:40 PM	1	73:16:40	1
14PI403	2/03/2016 12:21:30 PM	1	27:51:00	1
14PI405	22/02/2016 5:23:31 PM	1	75:07:30	1
14PI405	2/03/2016 1:38:21 PM	1	29:04:20	1
14PI405	7/03/2016 5:39:41 AM	1	18:40:50	1
14PI407	23/02/2016 3:52:50 AM	1	85:37:10	1
14PI407	2/03/2016 1:46:10 PM	1	29:02:40	1
14PI407	3/03/2016 9:12:40 AM	1	12:52:30	1
14XA520D	19/02/2016 2:44:41 PM	1	18:29:17	1
14XA520D	22/02/2016 2:52:51 PM	1	72:08:03	1
14XA520D	25/02/2016 1:37:45 PM	1	70:17:59	1
14XA520D	3/03/2016 3:06:20 PM	1	166:11:00	1
14XA520D	4/03/2016 9:02:18 PM	1	29:55:50	1
14XAPMPA	29/02/2016 7:22:31 PM	1	263:08:40	1
3TCLSTA1	29/02/2016 7:46:09 PM	1	76:16:45	1
8XA2022	24/02/2016 7:14:54 PM	1	52:03:40	1
8XA2022	4/03/2016 8:35:29 PM	1	29:28:35	1
8XA2022	6/03/2016 9:02:44 AM	1	35:59:45	1
8XS2016B	29/02/2016 7:39:12 PM	1	263:08:16	1
9GEN1FUELPRESS	23/02/2016 7:57:46 AM	1	85:52:07	1
9GEN1FUELPRESS	3/03/2016 6:54:35 AM	1	214:56:10	1
9GEN2FUELPRESS	4/03/2016 8:19:52 AM	1	326:21:01	1
9GEN2FUELPRESS	5/03/2016 10:15:13 AM	1	25:54:59	1
9GEN2FUELPRESS	6/03/2016 5:03:50 PM	1	30:48:34	1
9LDI659	24/02/2016 2:41:53 AM	1	12:46:19	1
9LDI659	2/03/2016 1:20:58 AM	1	26:58:49	1
9LDI659	2/03/2016 9:49:25 PM	1	20:25:11	1
9LDI659	3/03/2016 11:45:49 AM	1	13:56:23	1
9LDI659	5/03/2016 11:39:53 AM	1	12:43:23	1
9LDI659	6/03/2016 3:05:31 AM	1	15:25:27	1
9LDI659	8/03/2016 5:26:23 AM	1	38:11:20	1
9XA114	28/02/2016 6:59:07 AM	1	37:21:29	1
9XA115	28/02/2016 7:23:26 AM	1	38:11:02	1
		ALM ACTIVE >12HRS		33

Table 39: Stale alarms (High Priority)

Analysis reveals 2 urgent priority alarms that remained stale (Figure 34) for over a week (Table 40) demonstrating the need to assess the backlog of active alarms.

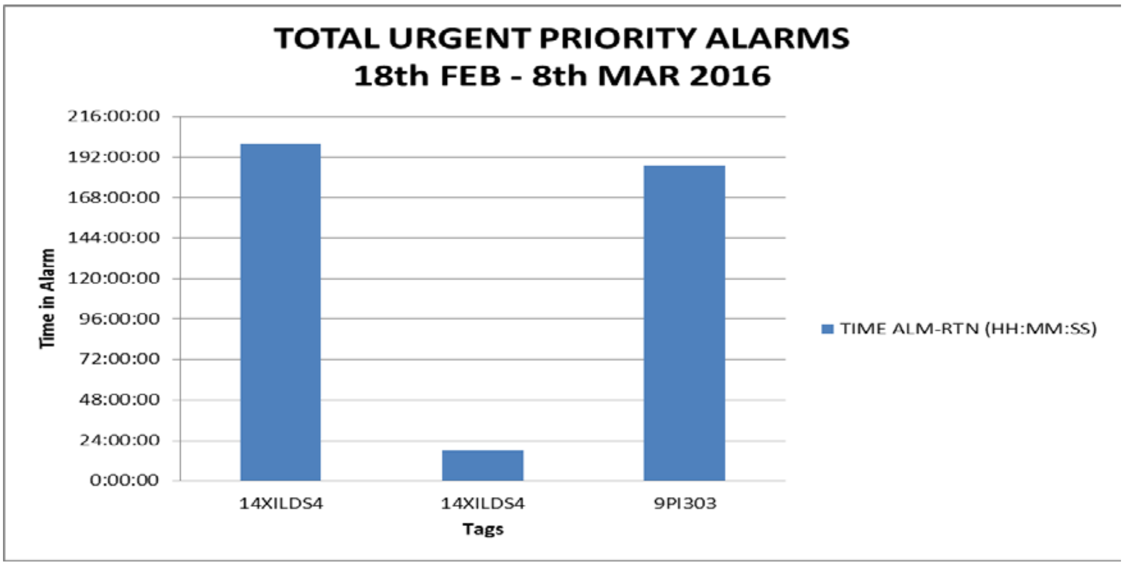


Figure 34: Stale alarms graph (Urgent Priority)

Stale Alarms - Urgent Prioirty					
Tag1	Time	RTN	TIME ALM-RTN (HH:MM:SS)	Days	High
14XILDS4	1/03/2016 5:11:40 PM	1	200:05:19	8:20	1
14XILDS4	8/03/2016 5:42:20 AM	1	18:00:10	0:45	1
9PI303	26/02/2016 3:48:33 PM	1	187:13:03	7:48	1
		ALM ACTIVE >12HRS			3

Table 40: Stale alarms (Urgent Priority)

The stale alarm results reflect various situations –

1. The operator was overwhelmed with alarms causing the oversight and the alarms were buried with high influx of alarms
2. The alarms are not important require an MOC and inclusion for the next alarm rationalisation workshop.
3. The equipment is out of service or in standby mode therefore not actioned. (See item 4 & 5)
4. Operator re-training to help recognise, prioritise and address stale alarms
5. Forgot to shelve the alarms
6. Lack of support or backup for the operator by supervision or engineering monitoring and assessment.

This performance metric if introduced to operations daily monitoring and reporting during a shift handover would ensure operators and supervising staff capture and address stale alarms.

5.7 Shelved Alarms

Shelving of alarms is a technique used to temporally suppress an alarm often used during periods of maintenance or high alarm rates to limit the distraction to the operator. Shelving of alarms should be accompanied with written permission in the form of an override certificate or MOC to acknowledge management's approval to the change.

Monitoring shelved alarms provides an overview of alarms that were suppressed using this method and will help determine if unauthorised alarm suppression has occurred. ISA 18.2 targets zero alarms suppressed outside of controlled or approved methodology, the monitor would be required to check suppressed alarms against a register to confirm both override and shelved lists align.

No review of suppression documentation or certificates was undertaken as these are generally company specific.

Alarms Sheleved and Unshelved									
01-02-2016 to 17-02-2016									
Tags	Alarms Suppression				Priority Distribution				
	ALM	SHELVED	UNSHELVED	Grand Total	High	Journal	Low	Urgent	(blank)
9LDI659	1488	68	68	1624	1488				136
9LI659	1462	67	67	1596			1462		134
9XA662	703	2	2	707			703		4
9LI658	142	23	23	188			142		46
84HS601	120	3	3	126			120		6
82PIG048	86			86			86		
82PIG056	77			77	77				
82PIG064	73			73	73				
9M354101	61			61			61		
9LAL629	46	2	2	50			46		4
9PI319	40			40			40		
14HS521	32			32			32		
14HS520	22			22			22		
9PI677	21			21		21			
7PY1063	21			21		21			
9PI676	21			21		21			
9LI413	20			20	20				
84HS600	20			20			20		
9FI140	20			20			20		
SWVAL	18			18			18		
9PI301	17			17			17		
MTPIGCNT	17			17	17				
9HS624	17			17		17			
09HS695	16			16		16			
84IC2COM	15			15			15		
84QA604	14			14	14				
84MR601	12			12			12		
9XI612	12			12	12				
7FY1025	12			12		12			
8XA2022	12			12		12			
3TCLSTA1	11			11	11				
09GD811_MOS	10			10	10				
9XI611	10			10		10			
8XS2016B	10			10		10			
9FI653	9			9				9	
9FI139	9			9	9				
9PI303	9			9			9		
09MOS_KEY_SWITCH	8			8	6				2
81QL605S	8			8		8			
14PI405	8			8		8			
85QL605	8			8	8				
09FI111_10K_DCS	7			7			8		
9XI108A	7			7			7		
800J217H	7			7			7		
9XI108B	7			7	7				
84IC1ENT	7			7			7		
84IC1PIR	7			7		7			
8XI2023A	6			6			7		
84QA601	6	1	1	8			6		
84MR600	6			6			6		

Table 41: Alarm Shelving Analysis

Due to 9LDI659 high alarm frequency and suppression, interest in the behaviour of the operator and actions taken to manage this problem was investigated further. Although a slight side track, Figure 35 shows the time distribution pattern between alarms and their frequency. A cluster pattern of alarms start around the 5s and spans to 4 min. mark before tapering off until the 15min. period. Although is information appears random, it could be possible a process or environmental effect is causing the sensor input alarm type “BADPV” to be a nuisance alarm.

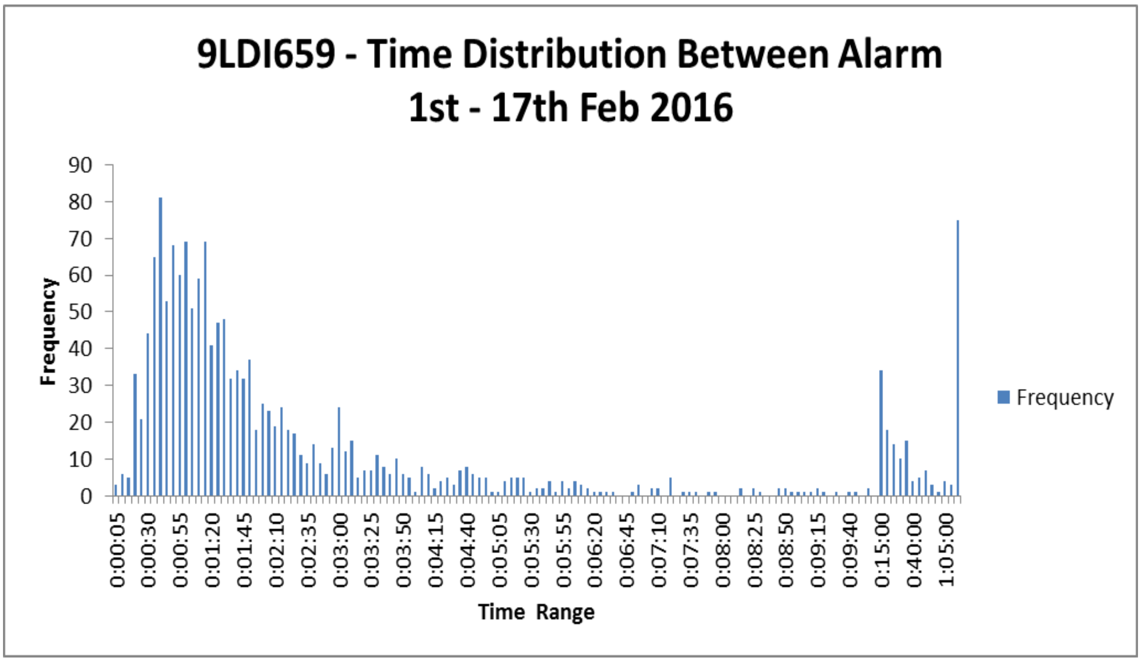


Figure 35: 9LDI659 – Time between alarms

However, the downside of the nuisance alarm is the distraction to the operator. Based on the time patterns in Figure 36, there appears to be a time pattern to un-shelved alarms, the operators appear to have a tolerance of 30 min. before re-shelving. However, the shelved period range is less than expected with the majority time being 2 hours and 30minutes (Figure 37) indicating by frequency the alarms was a point of focus to the operators.

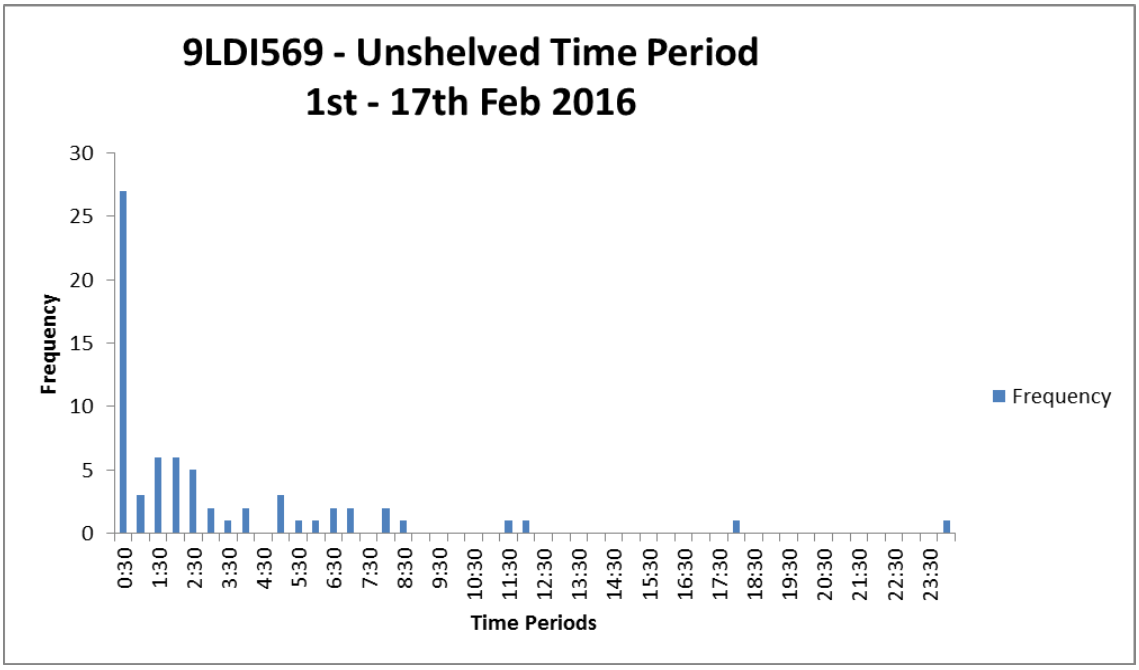


Figure 36: 9LDI659 – Frequency of Time Periods Un-shelved

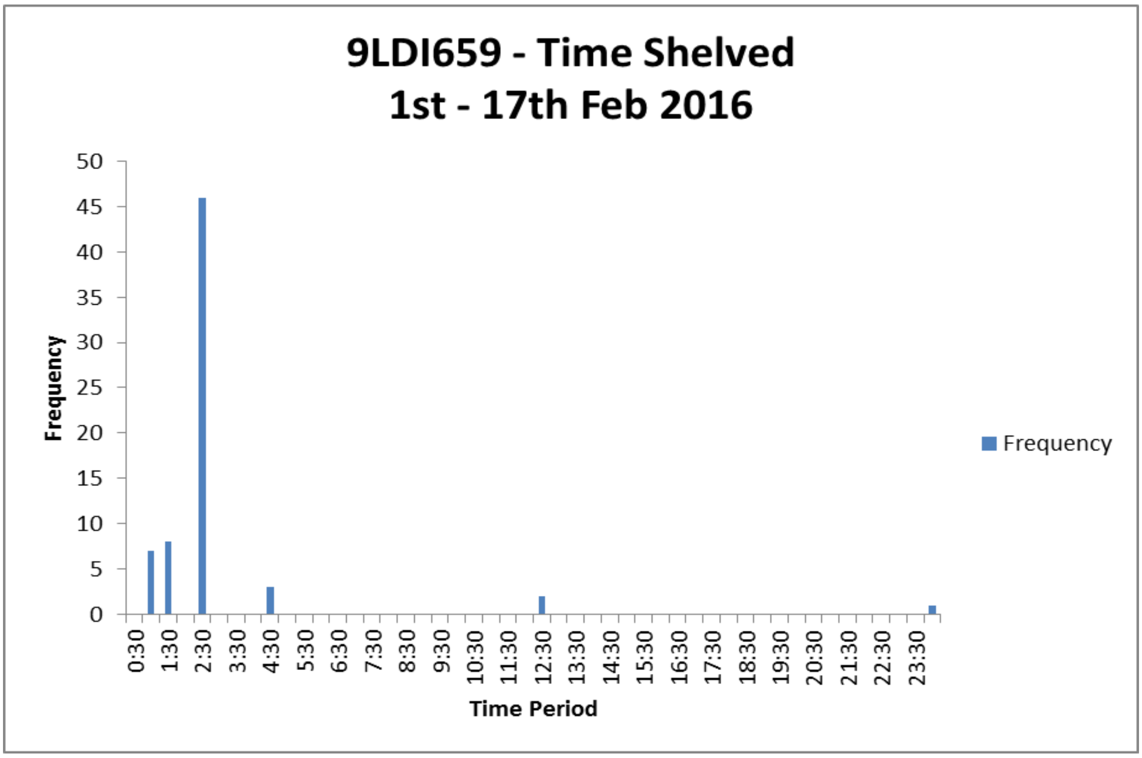


Figure 37: 9LDI659 – Frequency of Time Periods Shelved

5.8 Advanced Analysis

5.8.1 Time Analysis

As per an alarm system specification each alarm or event is time stamped along with other information such as priority, alarm acknowledgement or returning to normal. ISA 18.2 and EEMUA 191 state the work rate (W) of an operator can be measured by the average alarm rate (R) multiplied by the average time to respond. Using these time stamps and attempt to complete time analysis to measure the alarm (ALM), acknowledge (ACK) and return to normal (RTN) time periods.

Note –due to the amount of alarm data over the 92 days, the data was divided into smaller manageable files to limit excel crashing on account of being overloaded.

5.8.2 Analysing time between ALM – ACK

First analysis tests the distribution of time from ALM-ACK using 1 min. intervals over 60 mins. The results in the figure above show 93% of alarms are acknowledged within first minute of activation (Figure 38 and Table 42).

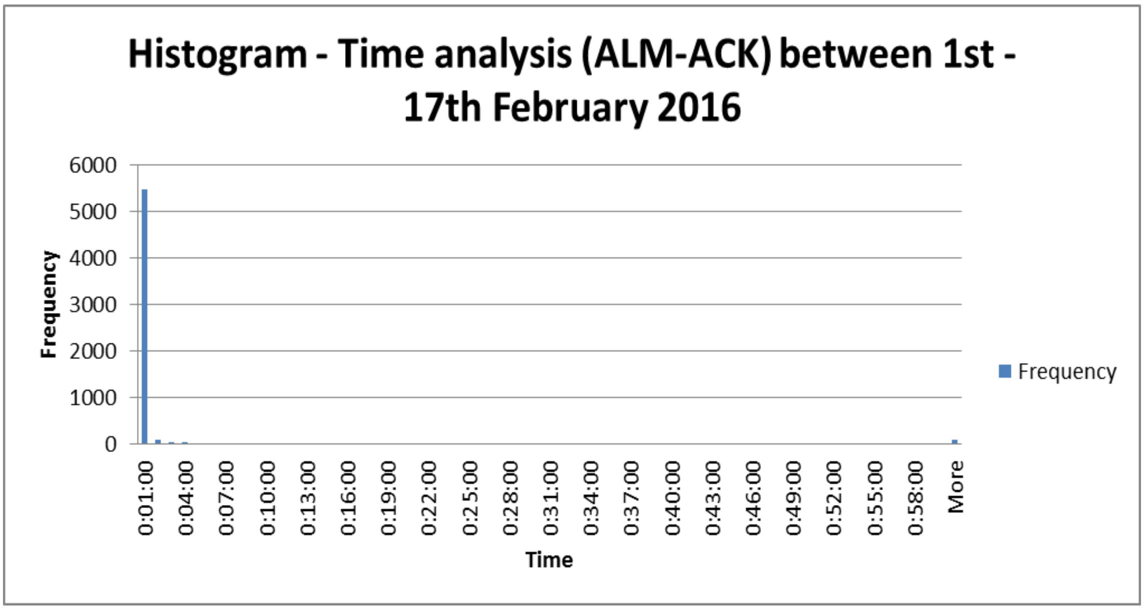


Figure 38: Time Analysis (ALM-ACK) (1 – 60 mins)

Note – The alarm acknowledge pushbutton events range from 1-4 during some time stamps. This creates a difference between ALM and ACK by increasing the sum total of ACK. To simplify analysis all acknowledge events have been set to ACK =1, bring the ACK total = 5831. Considered explanations for the additional ACK numbers per time event included the ACK button being depressed for an extended duration of time either out of frustration with alarm frequency, sticky contact on button and or an electronic de-bounce problem. If 24hr monitoring and reporting was in place, the problem would have been identified and through conversation with operator resolved the issue.

TIME ANALYSIS ALM-ACK (1st - 17th Feb 2016)			
TIME ALM-ACK	OCCURANCE FREQUENCY	% ALM-ACK PER TIME PERIOD	ACCUMULATING %
0:01:00	5476	93.91%	93.91%
0:02:00	82	1.41%	95.32%
0:03:00	42	0.72%	96.04%
0:04:00	29	0.50%	96.54%
0:05:00	23	0.39%	96.93%
0:06:00	13	0.22%	97.15%
0:07:00	7	0.12%	97.27%
0:08:00	7	0.12%	97.39%
0:09:00	7	0.12%	97.51%
0:10:00	6	0.10%	97.62%

Table 42: Time Analysis (ALM-ACK) (1min-60min)

Considering 93% of the ALM-ACK events occur in less than 1min, the interval of 1s to 4 min. is employed to analyse the data. In this instant 86% of alarms are acknowledges within 5s.

Errors occur for the times between 0:00:00 to 0:00:01 or 40% of the total ALM-ACK events (Figure 39 and Table 43). This error is due to splitting the data between spreadsheets due to the size of data files. Hence, the accumulated time between alarm and acknowledge does not carry over from the last alarm to acknowledge event where the accumulated time is recorded in the respective excel cell.

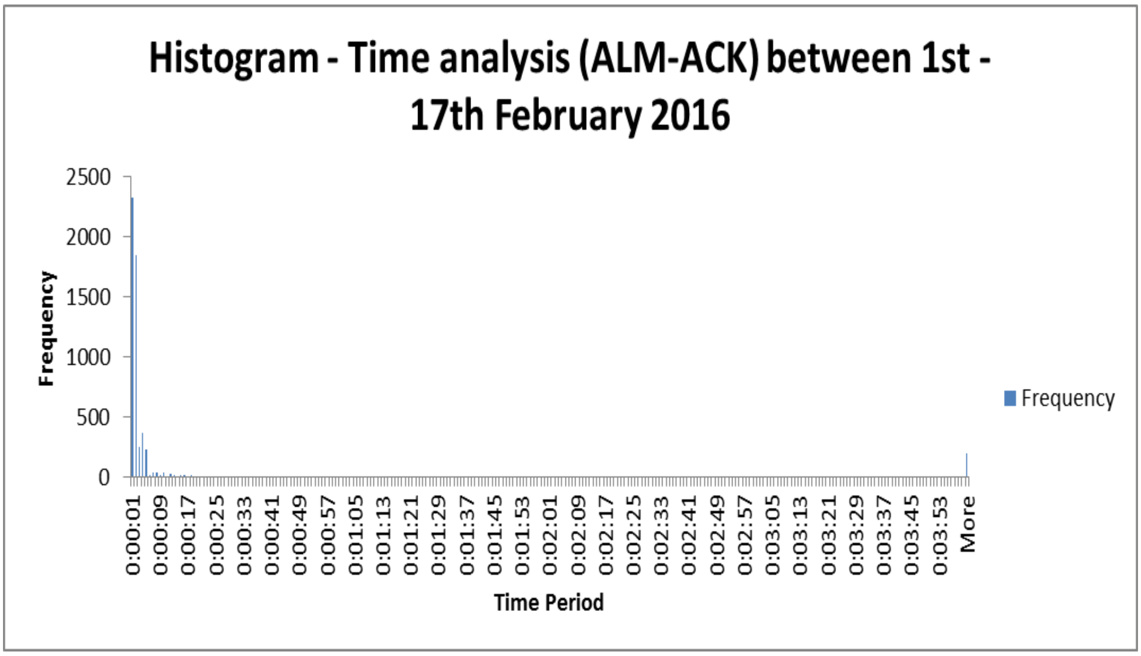


Figure 39: Time Analysis (ALM-ACK) (1s-4min)

TIME ANALYSIS ALM-ACK (1st - 17th Feb 2016)			
TIME ALM-ACK	OCCURANCE FREQUENCY	% ALM-ACK PER TIME PERIOD	ACCUMULATING %
0:00:01	2322	39.82%	39.82%
0:00:02	1842	31.59%	71.41%
0:00:03	254	4.36%	75.77%
0:00:04	367	6.29%	82.06%
0:00:05	235	4.03%	86.09%
0:00:06	24	0.41%	86.50%
0:00:07	36	0.62%	87.12%
0:00:08	43	0.74%	87.86%
0:00:09	16	0.27%	88.13%
0:00:10	37	0.63%	88.77%
0:00:11	12	0.21%	88.97%
0:00:12	30	0.51%	89.49%
0:00:13	23	0.39%	89.88%
0:00:14	7	0.12%	90.00%
0:00:15	24	0.41%	90.41%
0:00:16	23	0.39%	90.81%
0:00:17	3	0.05%	90.86%
0:00:18	17	0.29%	91.15%
0:00:19	2	0.03%	91.19%
0:00:20	13	0.22%	91.41%
…	…	…	…
…	…	…	…
…	…	…	…
0:03:59	0	0.00%	0.00%
0:04:00	0	0.00%	0.00%
More	202	3.46%	3.46%

Table 43: Time Analysis (ALM-ACK) (1s-4min)

Utilising the percentage time period against the total time for which the alarm data was taken an estimate of the work rate (W) can be calculated. If the maximum manageable alarm rate per person is 2 alarms/ 10min. or Work Rate = 2 per 10 min.

Given the average alarm rate for February is 7.56 alarms per 10 min. multiplying this by the ALM-ACK timeframes spread over a 17day period equates to a work rate of 3.9358 per 10 min for February. This equates to a work rate of 1.97 times the advised manageable work rate for February. The work rate calculation could be used to predict operator alarm workloads, thus assist in determining the number of panel operators required to safety distribute the work load to maintain a safe and manageable work rate.

Caution should be used or a correction factor added given the possibly of additional ACK events being logged per time event due to sticky contacts in a keypad which would produce an error.

5.8.3 Analysing time between ALM – RTN

Having determined the ALM-ACK time, it seemed worthwhile analysing the time between alarm (ALM) annunciation and variable returning to normal (RTN). This measure being considered a measure of the effectiveness of control system and the operator's combined response. Analysis shown in Figure 40 and equated in Table 44 for the duration of the 1st to the 17th February 2016, determined 71% of the 4943 alarms returned to normal within 1 min. of activation and 91% in the first 10 min. This could suggest the control system is considered effective, slightly sluggish due to aged or process conditions have changed therefore requiring a further review based only on this statistical analysis.

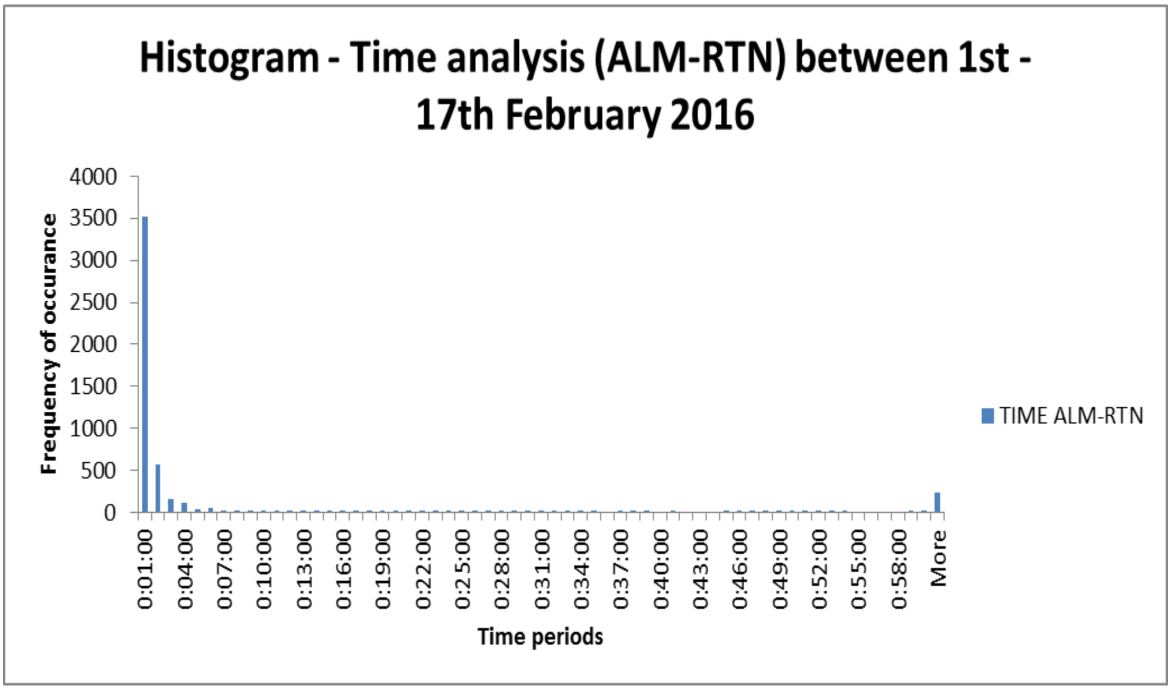


Figure 40: ALM-RTN Histogram (1min - 60min)

TIME ANALYSIS ALM-RTN (1st - 17th Feb 2016)			
TIME ALM-RTN	OCCURANCE FREQUENCY	% ALM-RTN PER TIME PERIOD	ACCUMULATING %
0:01:00	3523	71.2725066	71.2725066
0:02:00	571	11.5516893	82.8241958
0:03:00	163	3.29759256	86.1217884
0:04:00	118	2.38721424	88.5090026
0:05:00	35	0.70807202	89.2170747
0:06:00	49	0.99130083	90.2083755
0:07:00	24	0.4855351	90.6939106
0:08:00	21	0.42484321	91.1187538
0:09:00	14	0.28322881	91.4019826
0:10:00	17	0.3439207	91.7459033
0:11:00	14	0.28322881	92.0291321
0:12:00	9	0.18207566	92.2112078
0:13:00	6	0.12138378	92.3325915
0:14:00	16	0.32369007	92.6562816
0:15:00	10	0.20230629	92.8585879
0:16:00	3	0.06069189	92.9192798
0:17:00	5	0.10115315	93.0204329
0:18:00	5	0.10115315	93.1215861
0:19:00	1	0.02023063	93.1418167
0:20:00	7	0.1416144	93.2834311
…	…	…	…
…	…	…	…
…	…	…	…
1:00:00	1	0.02023063	94.6995752
More	233	4.7137366	99.4133118

Table 44: ALM-RTN Analysis (1min – 60min)

Further analysis into the distribution of ALM-RTN time periods shows 30% of the total alarms annunciate and return to normal within a 5s period (Figure 41 and Table 45). It would be fair to assume this return to normal is faster than a panel operator can respond.

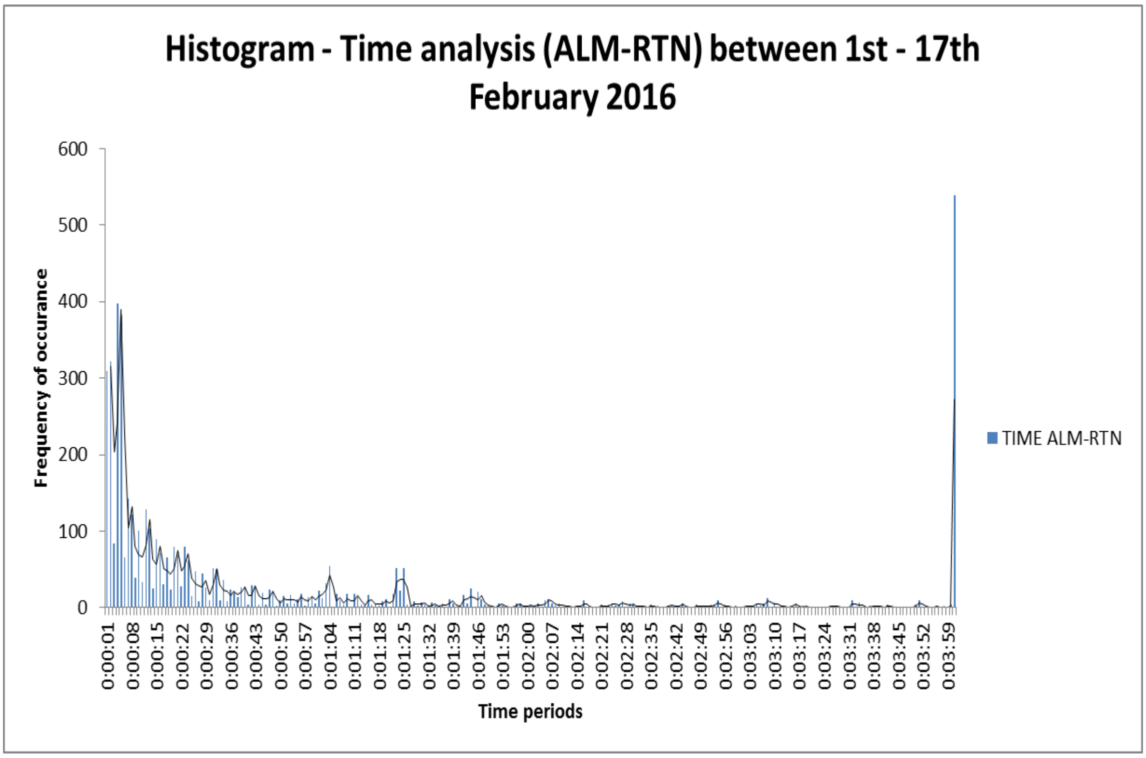


Figure 41: ALM-RTN Histogram (1s - 4min)

Table 45 quantifies the individual and accumulated extent of time between alarm and the alarm returning to its normal state.

Filtering the time period and grouping each tag quantifies the alarms affected. Based on the 0 - 5 s time period, 145 separate alarms could potentially be affected if some form of suppression was applied to the identified alarms. The major benefit is the potential 30% reduction in alarms.

The improvements increase as an accumulating percentage in Table 45. Highlighted shows the 10 seconds after alarm annunciates 39% of alarms have occurred.

TIME ANALYSIS ALM-RTN (1st - 17th Feb 2016)			
TIME ALM-RTN	OCCURANCE FREQUENCY	% ALM-RTN PER TIME PERIOD	ACCUMULATING %
0:00:01	310	6.27%	6.27%
0:00:02	322	6.51%	12.79%
0:00:03	84	1.70%	14.49%
0:00:04	398	8.05%	22.54%
0:00:05	382	7.73%	30.27%
0:00:06	66	1.34%	31.60%
0:00:07	143	2.89%	34.49%
0:00:08	122	2.47%	36.96%
0:00:09	39	0.79%	37.75%
0:00:10	100	2.02%	39.77%
0:00:11	34	0.69%	40.46%
0:00:12	129	2.61%	43.07%
0:00:13	103	2.08%	45.15%
0:00:14	25	0.51%	45.66%
0:00:15	89	1.80%	47.46%
0:00:16	71	1.44%	48.90%
0:00:17	30	0.61%	49.50%
0:00:18	65	1.31%	50.82%
0:00:19	23	0.47%	51.28%
0:00:20	80	1.62%	52.90%
0:00:21	69	1.40%	54.30%
0:00:22	28	0.57%	54.87%
0:00:23	80	1.62%	56.48%
0:00:24	61	1.23%	57.72%
0:00:25	15	0.30%	58.02%
0:00:26	48	0.97%	58.99%
0:00:27	8	0.16%	59.15%
0:00:28	45	0.91%	60.06%
0:00:29	26	0.53%	60.59%
0:00:30	9	0.18%	60.77%
…	…	…	…
…	…	…	…
…	…	…	…
0:04:00	4	0.08%	88.51%
More	539	10.90%	99.41%

Table 45: ALM-RTN Analysis (1s - 4min)

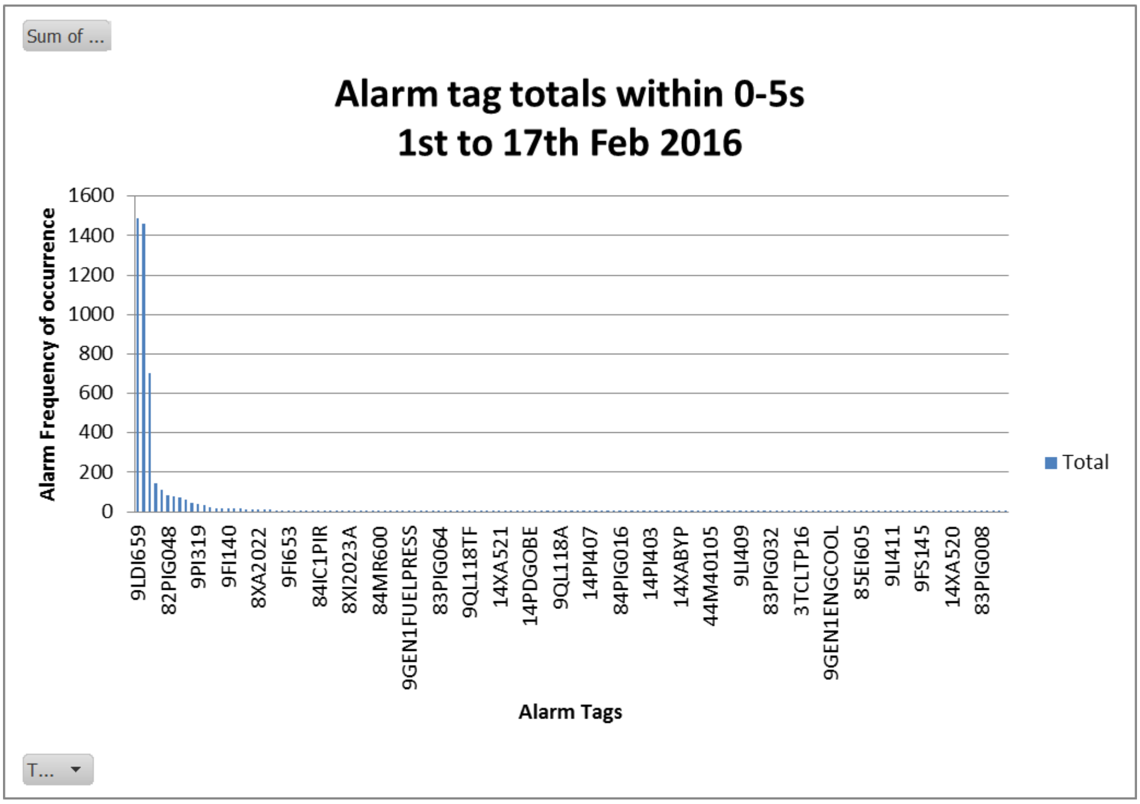


Figure 42: Time filter (0-5s)

TOP 20 - ALM-RTN (0-5s) 1st to 17th Feb 2016		
Item	TAGS	ALM-RTN COUNT
1	9LDI659	1488
2	9LI659	1462
3	9XA662	703
4	9LI658	142
5	84HS601	114
6	82PIG048	86
7	82PIG056	77
8	82PIG064	73
9	9M354101	61
10	9LAL629	46
11	9PI319	40
12	14HS521	32
13	14HS520	22
14	9LI413	20
15	84HS600	19
16	9FI140	18
17	9PI301	17
18	84IC2COM	15
19	84QA604	14
20	84MR601	12
Total TAGS		145

Table 46: Top 20 – ALM-RTN tags within (0-5s)

Based on the potential improvement provided by a suppression time delay of 0-5s, the alarm data was rearranged into monthly groups to quantify the improvement per month.

Table 47 calculates for the month of February an improvement of 5% or 10 less tags will alarm and return to normal (ALM-RTN) in comparison to the original ALM-RTN data.

The difference for February between annunciated alarms (ALM) and original ALM-RTN is 4.16%. Where the initial projected improvement of 30% in Table 45 is over 17 days a more realistic 26% for February remains a realistic improvement as per Table 47 February results.

MONTHLY IMPROVEMENT WITH 5s DELAY TO IDENTIFIED TAGS											
MONTH	AS FOUND					FORECAST IMPROVEMENT - 5s DELAY TO SELECTED TAGS					
	No. ALARMS	No. ALM-RTN	No. ALM-RTN TAGS	Δ % ALM-RTN	Δ No. ALM-RTN	No. RTNs	Δ % AS FOUND to DELAY	Δ ALM-RTN	Δ No.TAGS	Δ % TAGS	Δ No. TAGS
FEBRUARY	10051	9633	189	4.16%	-418	7125	26.04%	-2508	179	5.29%	-10
MARCH	9478	9714	240	-2.49%	236	6219	35.98%	-3495	226	5.83%	-14
APRIL	12436	12051	261	3.10%	-385	10374	13.92%	-1677	244	6.51%	-17

Table 47: Suppression (5s) Monthly Improvement

Quantifying the alarm tags affected by the 5s delay is included as an example. A total of 58 tags will improve by alarming less and 51 alarms improve more than 10%. Interestingly, the spread of improvement is across 30% of the alarm tags.

FEBRUARY 5s DELAY IMPROVEMENT PER TAG		
TAGs	Sum of RTN	TAG % IMPROVEMEN
9LI659	1615	20.21%
9LDI659	1587	20.17%
9LI658	295	13.49%
SWVAL	156	31.58%
83HS600	126	16.00%
84HS601	40	4.76%
14HS521	39	7.14%
14HS520	37	11.90%
84HS600	26	7.14%
84IC2PIR	26	3.70%
7FY1025	18	10.00%
9XA687	14	17.65%
81QL605S	13	7.14%
84MR600	12	14.29%
84MR601	12	14.29%
9XA662	11	99.53%
9FI111	11	8.33%
9FY116	11	8.33%
14PI403	10	16.67%
14PI405	10	16.67%
14PI407	9	18.18%
MT_ACCUM	6	40.00%
9UA623	6	33.33%
84IC2ENT	6	14.29%
84IC2SOL	6	14.29%

Table 48: 5s Delay tag improvement for February

Other suppression strategies could include applying different time delays to different priorities alarms. For example high priority alarm that ALM-RTN with a 0-5s timeframe is suppress whereas low priority ALM-RTN could be extended to 0-10s. All these suppression strategies require undergoing an alarm rationalisation workshop and MOC approval before being implemented. Importantly, where alarm delays are used, the alarm should be captured in the events journal on first triggered. Capturing this trigger event ensures the sequence of events log is accurate regardless of when the alarm annunciates to the operator and aids any other analysis or reviews.

5.8.4 Correlation

The following example analysis demonstrates the used of correlation analysis technique. Correlation coefficient (a value between -1 and +1) identifies how strongly two variables are related to each other. Auto and cross-correlation are statistical techniques for analysing time varying signals to identify underlying patterns that may be hidden in noise.

Microsoft excel has a CORREL function or activating the Analysis Tool Pak add-in will help find the correlation coefficient between two variables. The correlation coefficient of +1 indicates a perfect positive correlation where variables X and Y increase or decrease together. A correlation coefficient of -1 indicates a perfect negative correlation where variable X increases, variable Z decreases or variable X decreases and variable Z increases. A correlation coefficient tending towards 0 indicates no correlation hence correlation values of < 0.5 will be considered unrelated.

Errors where experienced using this technique. Firstly, noise from the top 4 bad actors masked alarms correlating to each other, hence were removed for correlation. Second time stamping to seconds prevented relationships being discovered, therefore the alarms where grouped into minimum time intervals of 10 min.

Using correlation analysis appears effective in identifying relationships however requires time to further investigate the relationship based on their variables to determine if such a relationship truly exists. Using the instruments variable sensor data as opposed to alarms will confirm relationships i.e. high flow from an upstream transmitter cause a pressure or level transmitter downstream to activate.

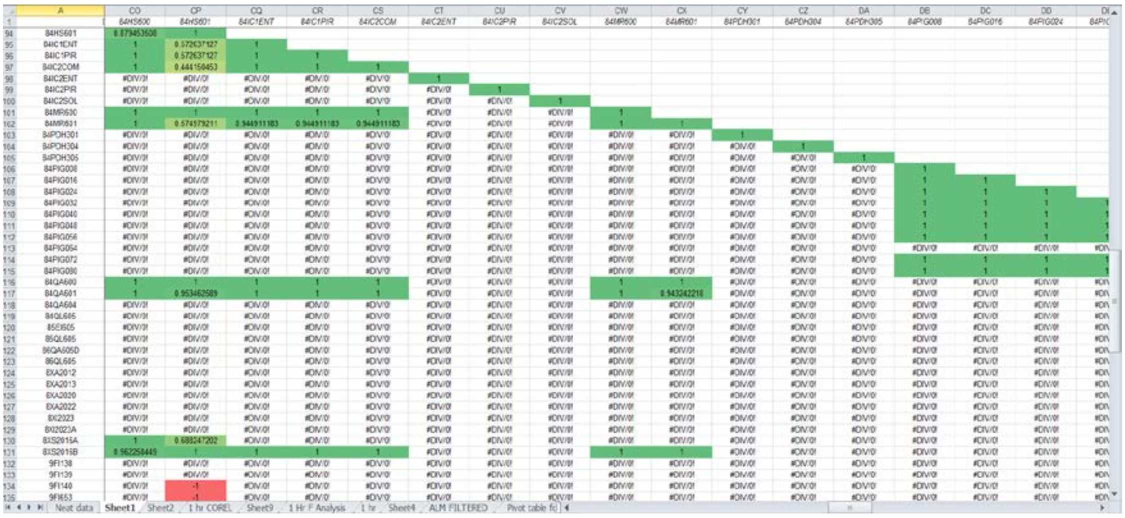


Figure 43: Correlation analysis of data (10 min. interval)

Shown below is a negative relationship where 9GEN1FUELPRESS and 82PIG048 have a negative opposing relationship. The two transmitters are completely separate and hence their relationship is disregarded.

	A	BU	BV	BW	BX	BY
1		82PIG048	82PIG056	82PIG064	82PIG072	82PIG080
136	9FS145	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
137	9FS146	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
138	9GEN1ENGCOOL	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
139	9GEN1FUELPRESS	-1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
140	9GEN2ENGCOOL	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
141	9GEN2ENGSPEED	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
142	9GEN2FFR	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
143	9GEN2FUELPRESS	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
144	9HS2003	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
145	9HS624	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
146	9JITGEN1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
147	9LAL629	-0.5	-0.5	#DIV/0!	#DIV/0!	#DIV/0!
148	9LDAH405	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
149	9LI402	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
150	9LI409	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
151	9LI410	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
152	9LI411	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
153	9LI412	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
154	9LI413	1	1	#DIV/0!	#DIV/0!	#DIV/0!
155	9LI416	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
156	9LI658	-0.087342859	0.018124211	0.073372489	#DIV/0!	#DIV/0!
157	9M09000Z	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
158	9M353050	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
159	9M354101	-0.56423203	-0.534113921	-0.561089372	#DIV/0!	#DIV/0!
160	9M354102	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
161	9PAK314	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
162	9PAL662	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
163	9PI301	-0.196116135	-0.049029034	0.080064077	#DIV/0!	#DIV/0!
164	9PI303	-0.440958552	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
165	9PI314	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
166	9PI319	0.203355313	0.187936394	0.186543063	#DIV/0!	#DIV/0!
167	9PI676	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
168	9PI677	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
169	9QL118A	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
170	9QL118TF	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
171	9UA613A	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
172	9UA623	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
173	9XA1000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
174	9XA114	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
175	9XA115	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
176	9XI107B	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
177	9XI108A	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Neat data | Sheet1 | Sheet2 | 1 hr COREL | Sheet9 | 1 Hr F Analysis | 1 hr | Sheet

Ready

Figure 44: Correlation analysis related however physically unrelated variable (10 min. interval)

5.9 Errors and Assumptions

Considered errors during analysis include alarm event calculations that do not carryover between data files. Due to the size of the alarm data, separate files were created into smaller data blocks to prevent the PC from crashing. The considered error occurs when an alarm occurs but does not return to normal within the data file, hence the calculated value remains uncalculated. For the sake of this thesis this error was considered minor in terms of affecting the outcome of the analysis based on the strong trends and results. In the case where a PC having access to the alarm systems database, a customised vendor supplied alarm system analysis software package also connected to the alarm database, greater filtering or continuity in alarms and events or results over time periods is made easier and reduces such errors.

Assumptions based the analysis performance results; these may portray a poor alarm system state even though the alarm system, plant and operators are content with the alarms systems. This assumption can only be confirmed through a perception survey (Appendix F). A survey is generally conducted on a needs basis or a frequency deemed suitable.

The periods of high alarm rates, an alarm placed into a shelved state will not annunciate to the operator. However, the alarms are recorded in the alarms and events log, therefore any shelved alarms were not be excluded in the analysis as they were considered relevant in determining the alarm systems performance and alarms requiring scrutiny.

Averaging results can mask poor performances or high alarm rates occurring in short time periods. Where required, averaging flaws were identified to caution users when monitoring and assessing performance standards.

5.10 Analysis Summary

Applying all performance metrics and advanced analysis methods to the surveyed alarm data, the results demonstrate the need for companies to constantly monitor and assess their alarm systems. The high frequency alarms, bad actors or nuisance alarms can be considered as noise and hence corrupt the analysis. Standards and Guidelines suggest removing these alarms for analysis; however on removing 7 bad actors in the alarm data another 20 surfaced exceeding the performance metric. Predicting changes before implementation is vital as improvements may be masked by other degraded measurements which appeared fine in its original condition.

Analysing time between ALM-ACK proved an operator work rate can be calculated, errors considered. Exploring the time between ALM-RTN proved to be a beneficial measure of performance. Capturing ALM-RTN times allows analysis of the control system or an operator’s physical ability to respond based on clearance times. All alarms must have a purpose and a response according to the standards, therefore alarms that fall into considered time limits can then be scrutinised and managed. In cases this may include, re-tuning, supressing based on priority however in all cases any change shall be executed as part of an MOC and undergo alarm rationalisation workshop to review and approve the change.

The software package analysis methods developed in Microsoft Excel (Appendix B) and analysis examples provided this section produce all the necessary results that can be tailored to monitor, assess and report alarm systems conditions to successfully support justification for change or resources. Or as the case may be develop evidence to present to an alarm rationalisation workshop to facilitate targeted outcomes as opposed to a generalised review approach.

The various graphical representations used to present the analysis results has hopefully inspired new ideas for those considering new ways to present information.

The work has hopefully demonstrated and/or provided examples of the needs and benefits of performance metrics that companies can adopt or implement to ensure their systems are operating as per the specified standards.

6.0 Conclusion

Alarms attract attention and present information in many different ways for example audible sounds, visual indications (flashing lights and text), background or text colour changes, graphic or pictorial changes and messages. Modern technology has evolved in complexity, allowing many different types of alarms to be easily configured within a control system to monitor and on activation, alert operators or engineers of the alarm state. It is the ease of implementing an alarm, the relative low cost and sheer number of various alarms a control system offer, can cause an information overload where simultaneous alarms occur in a short space of time commonly referred to as an alarm flood.

Based on the evidence presented in this report, an alarm system operating within its manageable performance limits creates a safe operational envelope and layer of protection between variable and hazardous state. Allowing suitable amount of response time for the operator to return the alarm back to its normal (alarm cleared) state is crucial as the response time help the operator diagnose the alarm condition, implement the response and monitor. These actions prevent the escalation of a hazardous situation; however they also help prevent losses in profit due to unplanned shutdowns, equipment damage or off specification product. Efficient operation also reduces wear to equipment machinery from stress caused to equipment when safety protection devices operate returning the monitored process variable back to within safe operating range.

Industrial incidents account for US$10- 20 billion dollars per year in losses (EEMUA, 2013). In many cases incident investigations associated process control system alarm floods or badly designed or performing alarms systems as a contributing causal factor to an incident event. This is often due to alarms floods overwhelming the operator preventing them from diagnosing and responding efficiently to contain or prevent the abnormal situation escalation. However the rate or the way in which alarms are presented may not always be the contributing cause. Human factors contribute another variable in an alarm systems functional design, having various effects on an operator’s ability to perform. Human performance shaping factors (PSF) can be influenced both externally and internally to the workplace. It is important operators present fit-for-work or advise their supervisors or managers of any factors affecting their ability to perform. Equally it is important for the supervisors and or managers to support and foster open communication, as this is often the only means in determining ones state of mind and is particularly relevant when operating highly hazardous facilities such as nuclear, chemical, pesticide or hydrocarbons to name a few.

Alarm management standards and guidelines are very well defined documents that, in cases like EEMUA 191, read like book. EEMUA 191 provides examples and information necessary to purchase, develop and maintain an effective alarm management system. ISA 18.2 and IEC-62682 specify the lifecycle aspects of an alarms system, as well as providing benchmark performance standards. The standards also specify the functionality of a control system providing manufactures the necessary information to develop technology to enable operators, maintenance personnel and engineers the ability within their alarm system to monitor various alarm states, types, priority and conditions. This enables specified or specific areas of interest or concern to trigger an alarm, bringing attention to a perceived or known problem or hazard. The alignment of standards and guidelines by the companies alarm management system surveyed, demonstrated the effectiveness of the standards and guidelines to deliver a consistent message, however more importantly the willingness of these companies to seek and implement considered best practice alarm management standards and guidelines. In all cases the surveyed companies had attempted more stringent performance levels than the standards and reporting

Reviewing the surveyed companies alarm standards, procedures and alarm data, identified opportunities to improve monitoring and assessment. Suggested changes include changing the KPI reporting format to ensure all aspects of the performance standards are monitored for the specified time periods 10 min. 1 hour, 12 hour (operator shift), 24 hour and monthly. Completing performance comparisons against all performance variables will identify any specific areas of interest that exceed the performance limits and can be presented in an overview report to other targeted audiences depending on their needs and technical understanding.

Benefits of multiple performance standards comparisons having analysed the alarm data highlighted other areas for improvement. The data showed overuse of the high priority alarm, often 5 to 6 times the specified target (< 5 %). Another area of improvement was operator work rate; the calculated work rate for 17 days in February was 1.9 times higher than the maximum manageable work rate. This suggests an opportunity review the alarms between current operators, employ another operator, reduce alarm rates or shut down the process and repair the problems. The elevation shutdown decision KPI was specified in company 'A' alarm management procedure. This approach provides guidelines for staff to follow based on an elevated KPI value (Tables 13 and 14).

Interestingly EEMUA 191 places the top 10 load percentage as secondary KPI. Analysis demonstrated high alarm rates seen as noise corrupt the alarm analysis results. And is effective in targeting alarms who's load contributes more an >1% of the total alarm load.

Human factors in relation to the time between alarm and acknowledge (ALM-ACK) as shown in Figure 40 where most of the alarms are acknowledged within a few seconds, improving the alarm system should see more acknowledge events distributed across the time axis demonstrating operator confidence and less alarm load. Generally low priority acknowledgement timelines will be greater than high priority, aligning to an alarm priority matrix response time criteria. Importantly short acknowledge times with no obvious operator response may be an indication that the operator is finding that many alarms are of little operational value in the present process state or is accepting them without significant investigation.

In analysing the time between alarm and the alarm returning-to-normal (ALM-RTN) (not a standard or company specified performance metric), the analysis identified a considerable number of ALM-RTN events within a short period (Table 47 or Figure 41). Returning to the first principles of an alarm, every alarm requires a response (ISA 18.2, 2009). Hence, there is little chance of an operator reviewing and responding an alarm that will clear within short time period i.e. 5 seconds. This raises the question could these short duration alarms be suppressed. Implementing for example, 5 second suppression for only the identified ALM-RTN alarms would reduce the annunciation of the total alarm count by 26%. While allowing alarms to annunciate after 5 seconds providing they are still active. This type of approach could include time based suppression based on alarm priority and periods i.e. 10s suppression for low priority alarms and 5s for high priority alarms. The measure also captures the control system, by identifying alarms that potentially require tuning or maintenance or flagging process changes where engineering design review may be warranted i.e. resizing a valve or change the heating capacity of a heat exchange.

Where resources and technology permit, implementing an automated report for the end of each operator’s shift (12 hours) outlining key performance metrics would engage conversations, familiarity and focus on the alarm system. Importantly, stale or shelved alarms could be recognised and handed over to the incoming shift for action for follow up.

As demonstrated by the outcomes identified for Company B, the standards and guidelines provide industry with the necessary information to effectively implement and manage a safe, reliable and efficient alarm system. The research evidence supports organisations allocating resources to reduce and maintain alarm rates to within the performance matric limits specified, which in the long term, provide greater profit returns and a safer operation.

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Appendix A – ENG4111/4112 Research Project Specification

For :	Ross Guy
Title :	Best practice management of industrial process control alarm floods
Major :	BENG – Instrumentation and Control Engineering
Supervisors :	Mrs Catherine Hills, (tentative TBA – Employer engineering team are interested in supporting and or providing guidance towards the research topic)
Sponsorship :	Employer is interested in assisting to what capacity is TBA.
Confidentiality:	Possible masking of data, titles, terms or references may be required where company information is used.
Enrolment :	BENG – Instrumentation and Control Engineering
Project Aim :	Investigate causes of industrial process control alarm floods and recommend approaches to preventing and managing these events.

Programme : Issue label ‘B’ – 30th March 2016

1. Research alarm flood background information within the context of process control systems.
2. Study the underlying attributes and purpose of an alarm, including human factors impacting the alarm management system.
3. Investigate current company employed control system technology, alarm philosophy, alarm flood management techniques and alarm flood control methodology.
4. Make recommendations for best practices in managing alarm floods in real time under all operating conditions.

As time permits:

5. Develop, model and or design improved methods to manage alarm floods in association with EEMUA Publication 191, ISA 18.2 and other identified resources.

Appendix B – Analysis Tool Methods

Microsoft Excel – Alarm Data Methods

The Microsoft Excel data analysis methods described below outline some of the methods used to help analyse the alarm data.

Tidy the alarm data removing all blanks columns and rows. Ensure the text formatting sizes column width are the same.

EEMUA 191 and ISA 18.2 require alarms analysed in 1 hour and 10 min. periods. This can be achieved in two ways. Create reference tables for the time periods show below in figures 45 and 46. In first column enter the minimum time and in the second column titled range enter the code to create a text cell for the range of time the VLOOKUP will display with the said worksheet.

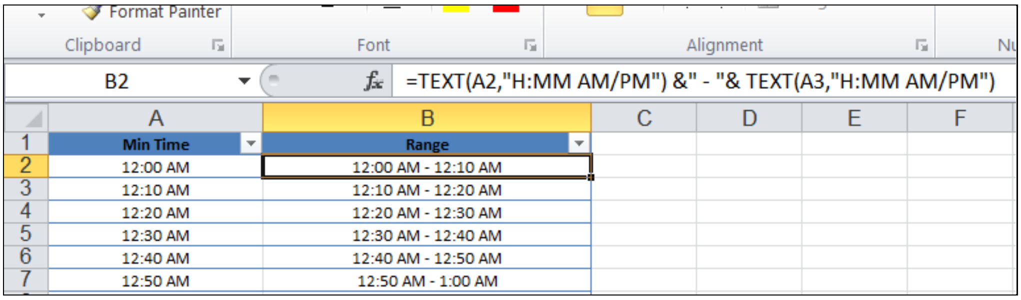


Figure 45: Excel time 10min periods

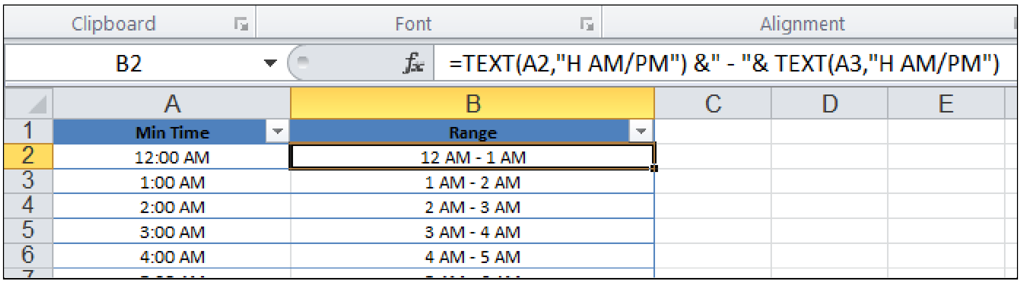


Figure 46: Excel time 1 hour periods

It is also important to name the table and worksheet for inter-spreadsheet referencing Figure 47.

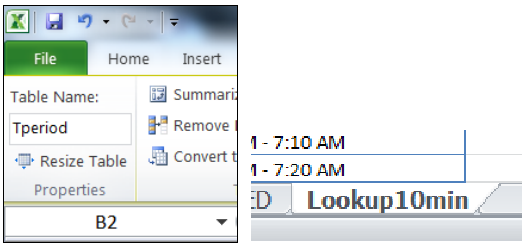
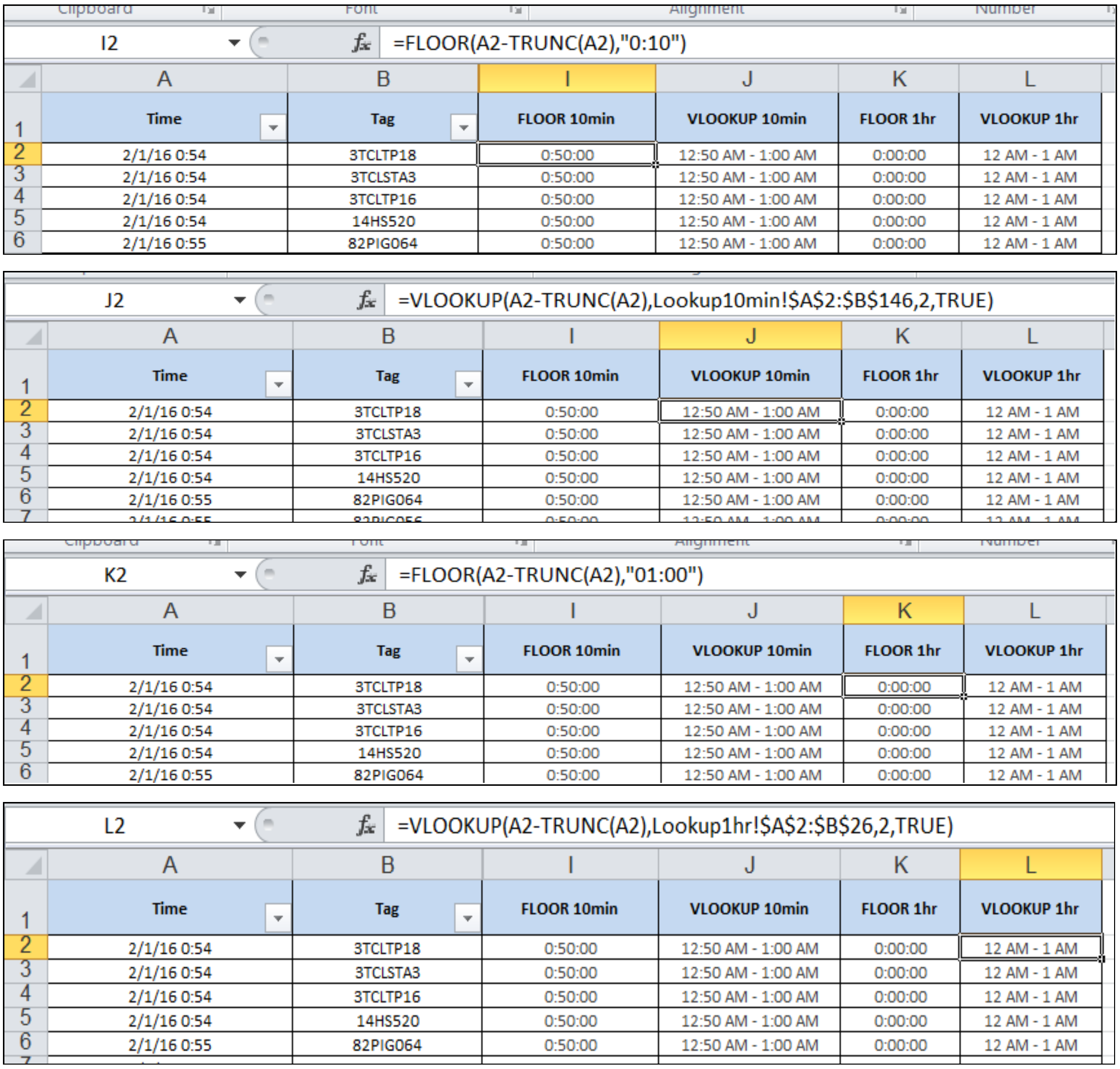


Figure 47: Excel Worksheet reference

Other option is to use a FLOOR function; both FLOOR and VLOOKUP have been used in the data analysis. Group each time stamped alarm into 10 min. and 1 hour periods. Create four columns FLOOR and VLOOKUP for 10 min. and 1 hour time groups. Each columns cell code is shown in function tab for reference.



I2 =FLOOR(A2-TRUNC(A2),"0:10")

	A	B	I	J	K	L
1	Time	Tag	FLOOR 10min	VLOOKUP 10min	FLOOR 1hr	VLOOKUP 1hr
2	2/1/16 0:54	3TCLTP18	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
3	2/1/16 0:54	3TCLSTA3	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
4	2/1/16 0:54	3TCLTP16	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
5	2/1/16 0:54	14HS520	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
6	2/1/16 0:55	82PIG064	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM

J2 =VLOOKUP(A2-TRUNC(A2),Lookup10min!$A$2:$B$146,2,TRUE)

	A	B	I	J	K	L
1	Time	Tag	FLOOR 10min	VLOOKUP 10min	FLOOR 1hr	VLOOKUP 1hr
2	2/1/16 0:54	3TCLTP18	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
3	2/1/16 0:54	3TCLSTA3	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
4	2/1/16 0:54	3TCLTP16	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
5	2/1/16 0:54	14HS520	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
6	2/1/16 0:55	82PIG064	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM

K2 =FLOOR(A2-TRUNC(A2),"01:00")

	A	B	I	J	K	L
1	Time	Tag	FLOOR 10min	VLOOKUP 10min	FLOOR 1hr	VLOOKUP 1hr
2	2/1/16 0:54	3TCLTP18	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
3	2/1/16 0:54	3TCLSTA3	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
4	2/1/16 0:54	3TCLTP16	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
5	2/1/16 0:54	14HS520	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
6	2/1/16 0:55	82PIG064	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM

L2 =VLOOKUP(A2-TRUNC(A2),Lookup1hr!$A$2:$B$26,2,TRUE)

	A	B	I	J	K	L
1	Time	Tag	FLOOR 10min	VLOOKUP 10min	FLOOR 1hr	VLOOKUP 1hr
2	2/1/16 0:54	3TCLTP18	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
3	2/1/16 0:54	3TCLSTA3	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
4	2/1/16 0:54	3TCLTP16	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
5	2/1/16 0:54	14HS520	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM
6	2/1/16 0:55	82PIG064	0:50:00	12:50 AM - 1:00 AM	0:00:00	12 AM - 1 AM

Figure 48: Excel filters for 10 min and 1 hour periods

An easy way to manipulate data is to create a Pivot Table by selecting the alarm data of interest within the worksheet. Once created select PivotTable field list items of interest and drag them to the field areas below. Note – use caution as large amount of data take time to process.

The user can then filter fields based in interest or add combinations to obtain data layouts for further analysis on another worksheet. Figure 49 is an example of a PivotTable using the FLOOR10min data set showing all the alarms within each 10min. period for the time period analysed.

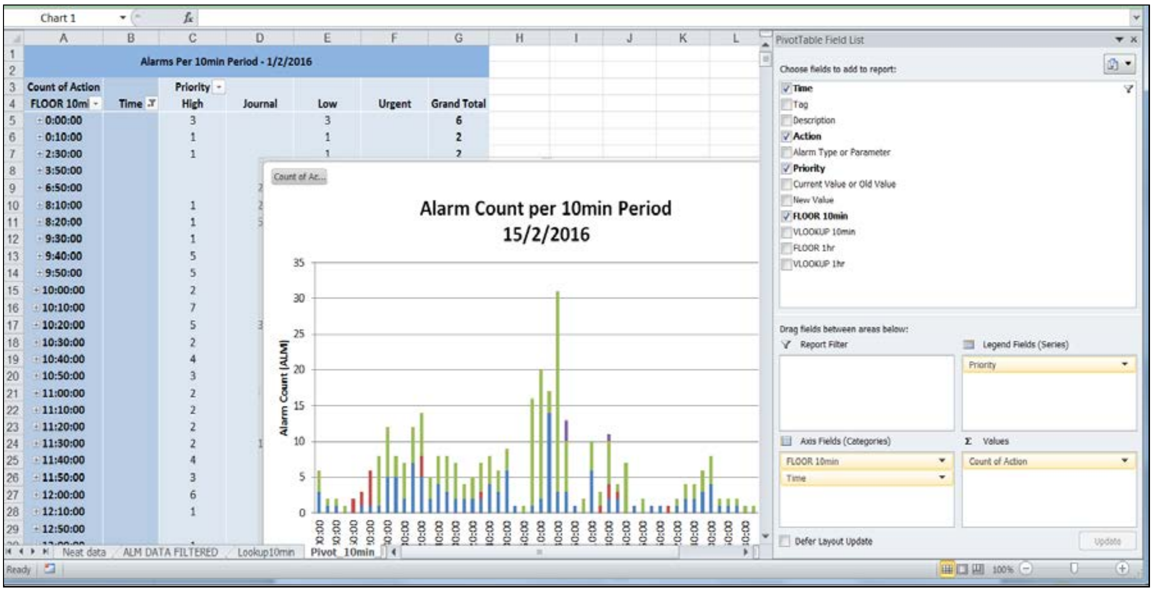


Figure 49: Excel pivot table data analysis and filtering

In Figure 50, the PivotTable has merged row cells together linking the next columns to the first column. To separate the merged cells data to individual cells for further processing in a separate worksheet, a Visual Basic Application (VBA) module script was used (see figure 50 and 51) to create a worksheet function. The function when typed into a cell =GetMergedValue() reads the assigned merged cell data and displays it in its residing cell (see figure XX below).

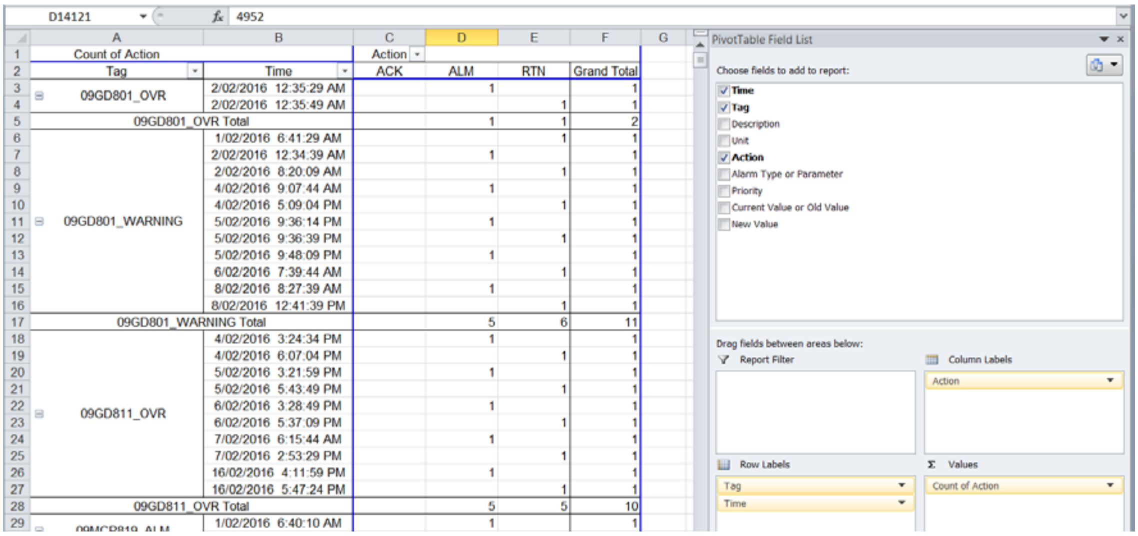


Figure 50: Excel pivot table data analysis and filtering

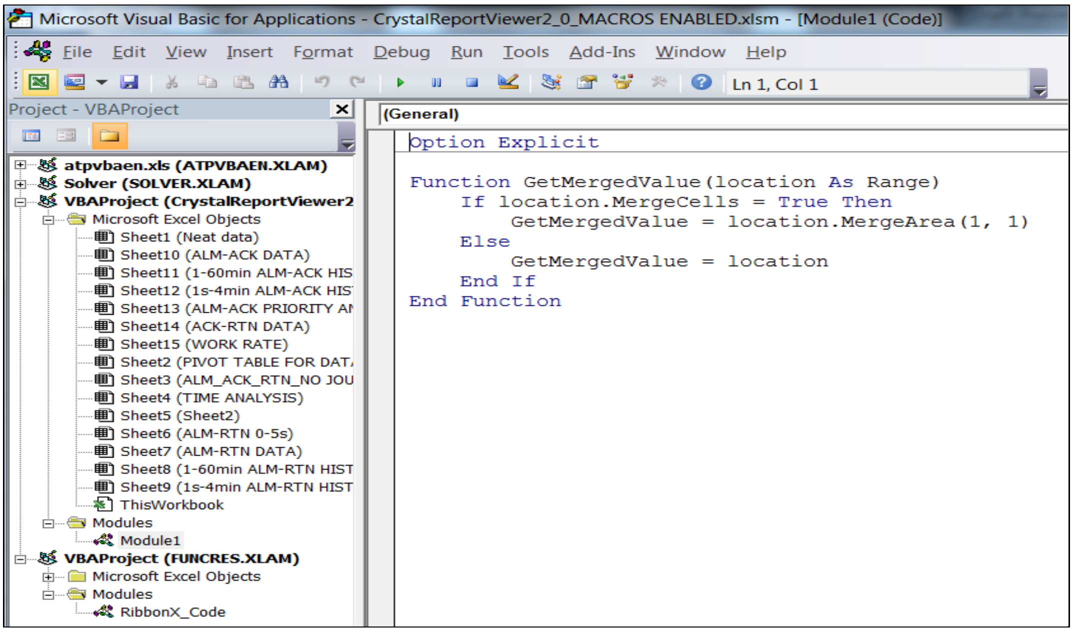


Figure 51: Excel VBA script to get merged cell values

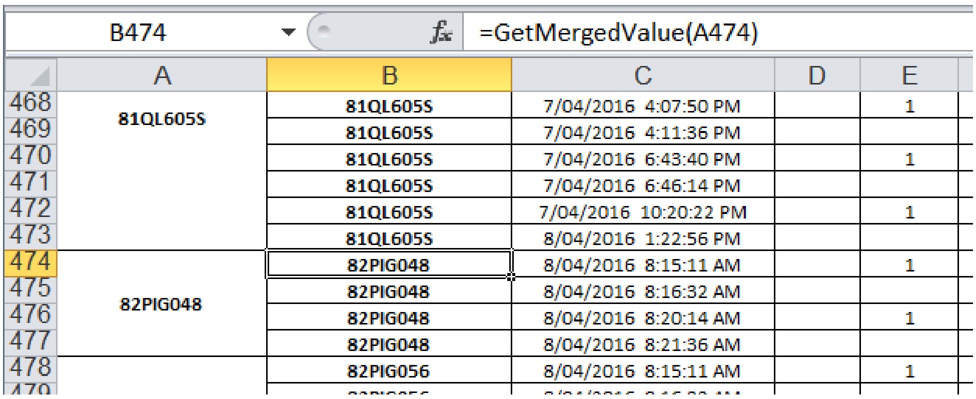


Figure 52: Excel VBA script cell function to get merged cell values

Step 5 - Another problem encountered was tallying merged cells to quantify a number of alarm tags with separate alarm events. Using another VBA script (see figure 53) to create a worksheet function “=CountMerged()” when entered into a cell counts the merged cells within a set range.

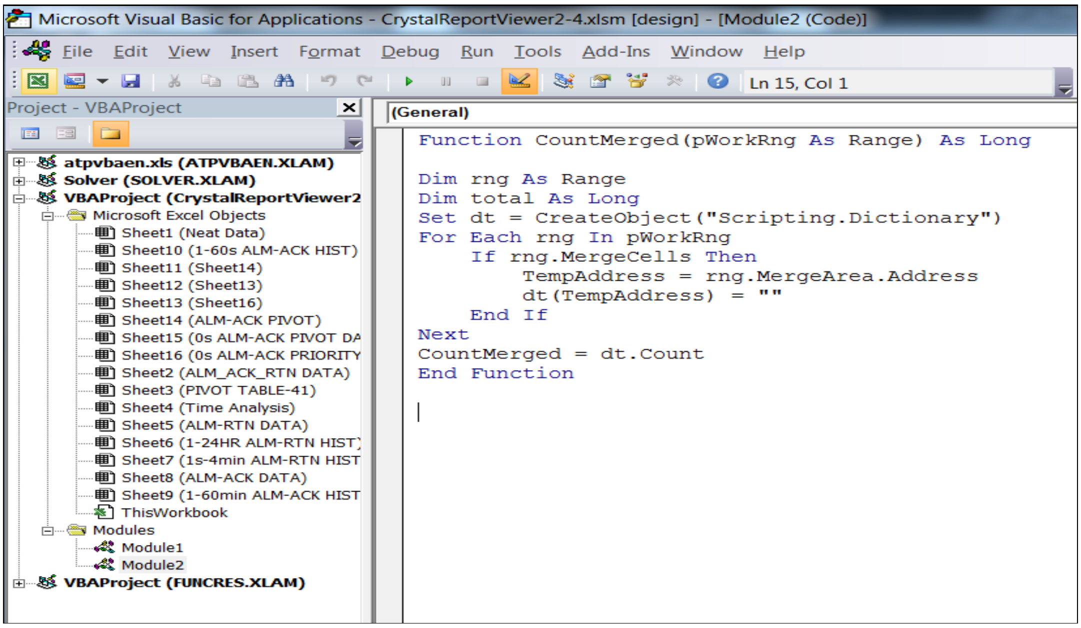


Figure 53: Excel VBA script to count merged cells

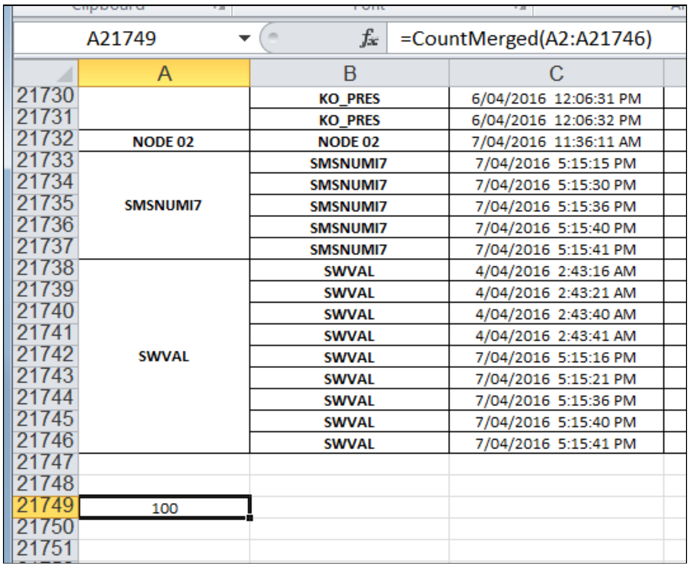
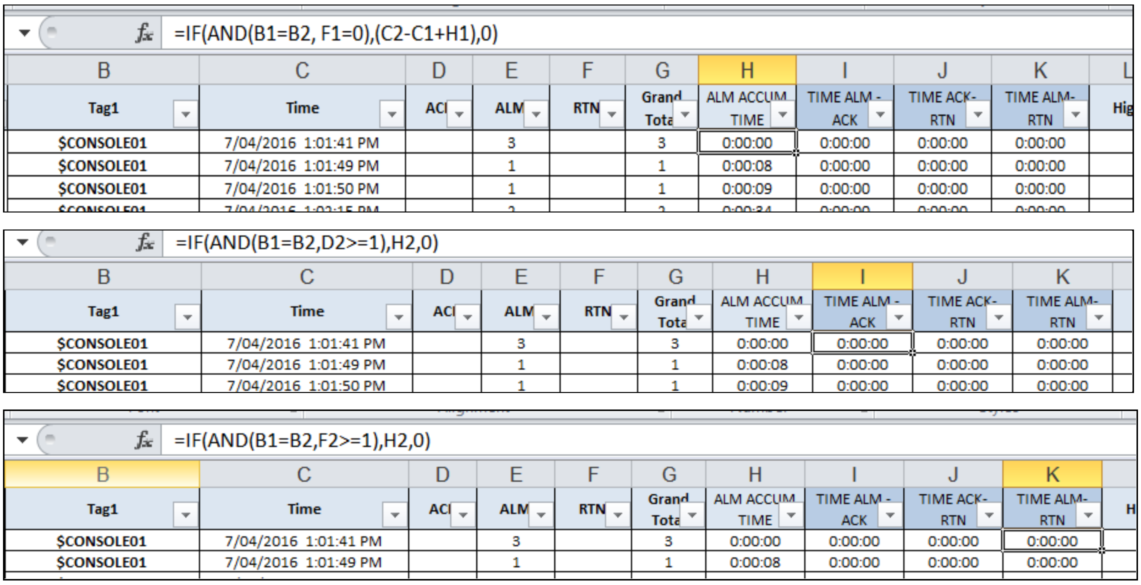


Figure 54: Excel VBA script cell function to count a range of merged cells

Step 6 – Time analysis. Method used was to group the tags, accumulate time and read accumulated time based on flags (ALM, ACK, and RTN). Using the IF() function and combinations of AND() and OR() functions within the IF() function. Figure 55 shows the various cells



=IF(AND(B1=B2, F1=0),(C2-C1+H1),0)

Tag1	Time	ACI	ALM	RTN	Grand Tota	ALM ACCUM TIME	TIME ALM - ACK	TIME ACK-RTN	TIME ALM-RTN
$CONSOLE01	7/04/2016 1:01:41 PM		3		3	0:00:00	0:00:00	0:00:00	0:00:00
$CONSOLE01	7/04/2016 1:01:49 PM		1		1	0:00:08	0:00:00	0:00:00	0:00:00
$CONSOLE01	7/04/2016 1:01:50 PM		1		1	0:00:09	0:00:00	0:00:00	0:00:00

=IF(AND(B1=B2,D2>=1),H2,0)

Tag1	Time	ACI	ALM	RTN	Grand Tota	ALM ACCUM TIME	TIME ALM - ACK	TIME ACK-RTN	TIME ALM-RTN
$CONSOLE01	7/04/2016 1:01:41 PM		3		3	0:00:00	0:00:00	0:00:00	0:00:00
$CONSOLE01	7/04/2016 1:01:49 PM		1		1	0:00:08	0:00:00	0:00:00	0:00:00
$CONSOLE01	7/04/2016 1:01:50 PM		1		1	0:00:09	0:00:00	0:00:00	0:00:00

=IF(AND(B1=B2,F2>=1),H2,0)

Tag1	Time	ACI	ALM	RTN	Grand Tota	ALM ACCUM TIME	TIME ALM - ACK	TIME ACK-RTN	TIME ALM-RTN
$CONSOLE01	7/04/2016 1:01:41 PM		3		3	0:00:00	0:00:00	0:00:00	0:00:00
$CONSOLE01	7/04/2016 1:01:49 PM		1		1	0:00:08	0:00:00	0:00:00	0:00:00

Figure 55: Excel condition based time calculation

Appendix C – Results % CONTRIBUTION

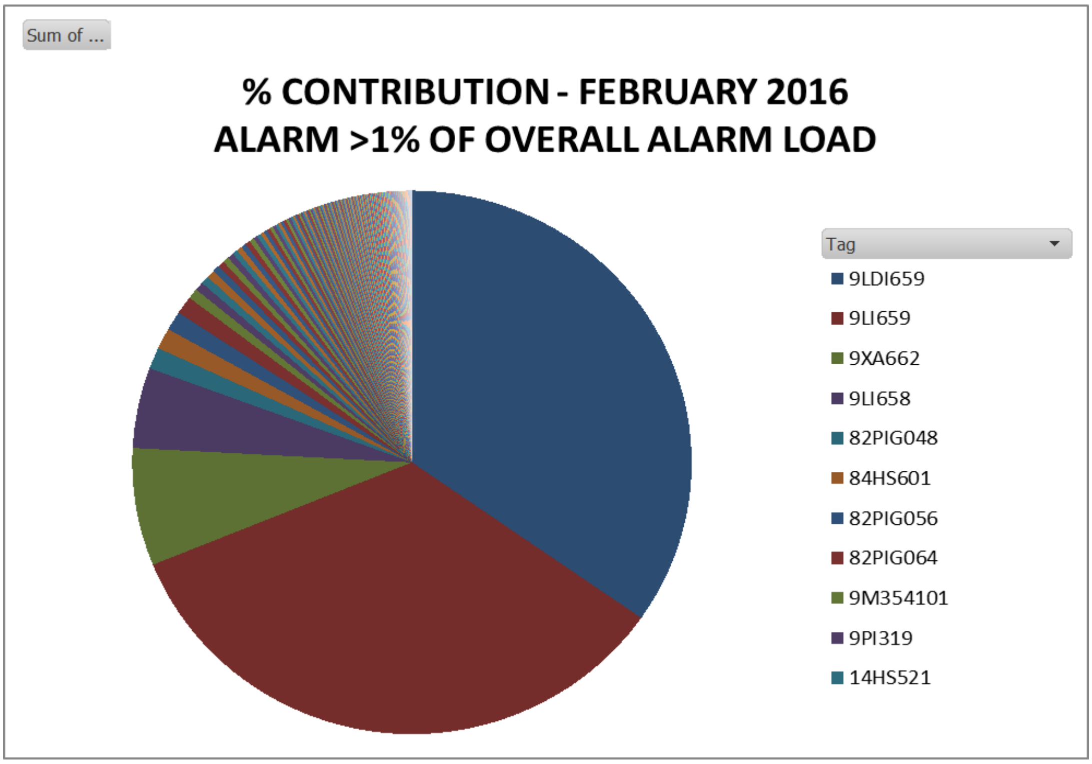


Figure 56: February alarm load % contribution

FEBRUARY 2016 - TOP 20 MOST FREQUENT ALARMS				
TOP 20	TAG	ALARM COUNT	% CONTRIBUTION TO TOTAL ALARM LOAD	ACCCUMULATED % ALARM LOAD
1	9LDI659	3488	34.70%	34.70%
2	9LI659	3432	34.14%	68.84%
3	9XA662	703	6.99%	75.84%
4	9LI658	481	4.79%	80.62%
5	82PIG048	128	1.27%	81.89%
6	84HS601	126	1.25%	83.15%
7	82PIG056	113	1.12%	84.27%
8	82PIG064	108	1.07%	85.35%
9	9M354101	62	0.62%	85.96%
10	9PI319	51	0.51%	86.47%
11	14HS521	48	0.48%	86.95%
12	9LAL629	47	0.47%	87.42%
13	14HS520	43	0.43%	87.84%
14	SWVAL	37	0.37%	88.21%
15	9PI677	36	0.36%	88.57%
16	9PI676	36	0.36%	88.93%
17	9PI301	31	0.31%	89.24%
18	7PY1063	31	0.31%	89.54%
19	84IC1PIR	30	0.30%	89.84%
20	84QA604	29	0.29%	90.13%
...	...	...	...	...
...	...	...	...	...
210	9XA1000	1	0.01%	99.97%
211	09UV803_OVR	1	0.01%	99.98%
212	09UV803_DO	1	0.01%	99.99%
Grand Total		10051		

Table 49: February alarm load % contribution

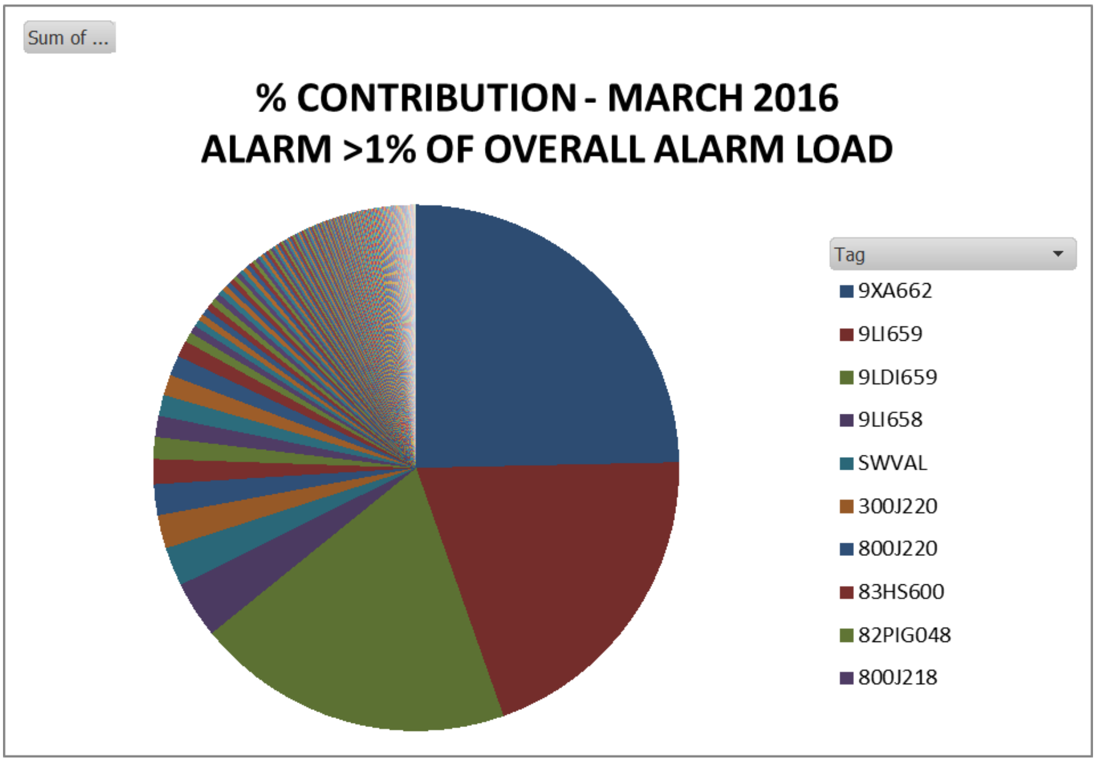


Figure 57: March alarm load % contribution

MARCH 2016 - TOP 20 MOST FREQUENT ALARMS				
TOP 20	TAG	ALARM COUNT	% CONTRIBUTION TO TOTAL ALARM LOAD	ACCCUMULATED % ALARM LOAD
1	9XA662	2337	24.66%	24.66%
2	9LI659	1891	19.95%	44.61%
3	9LDI659	1855	19.57%	64.18%
4	9LI658	330	3.48%	67.66%
5	SWVAL	227	2.40%	70.06%
6	300J220	194	2.05%	72.10%
7	800J220	180	1.90%	74.00%
8	83HS600	146	1.54%	75.54%
9	82PIG048	127	1.34%	76.88%
10	800J218	123	1.30%	78.18%
11	GOBE_ESD	123	1.30%	79.48%
12	82PIG056	120	1.27%	80.74%
13	82PIG064	117	1.23%	81.98%
14	300JTCL	95	1.00%	82.98%
15	800J219	58	0.61%	83.59%
16	14PDH525	46	0.49%	84.08%
17	14HS520	40	0.42%	84.50%
18	9PI676	39	0.41%	84.91%
19	9PI677	39	0.41%	85.32%
20	84HS601	38	0.40%	85.72%
...	...	...	...	...
...	...	...	...	...
259	09UV804_OVR	1	0.01%	99.98%
260	85QA605D	1	0.01%	99.99%
261	14XA520	1	0.01%	100.00%
Grand Total		10051		

Table 50: March alarm load % contribution

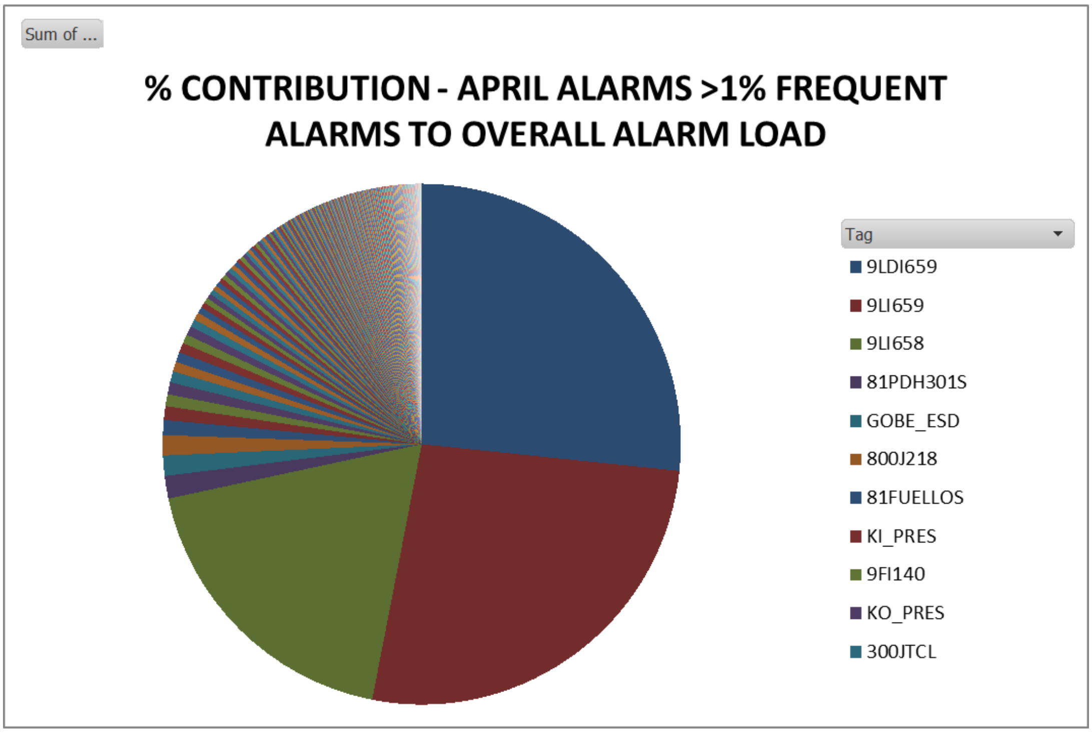


Figure 58: April alarm load % contribution

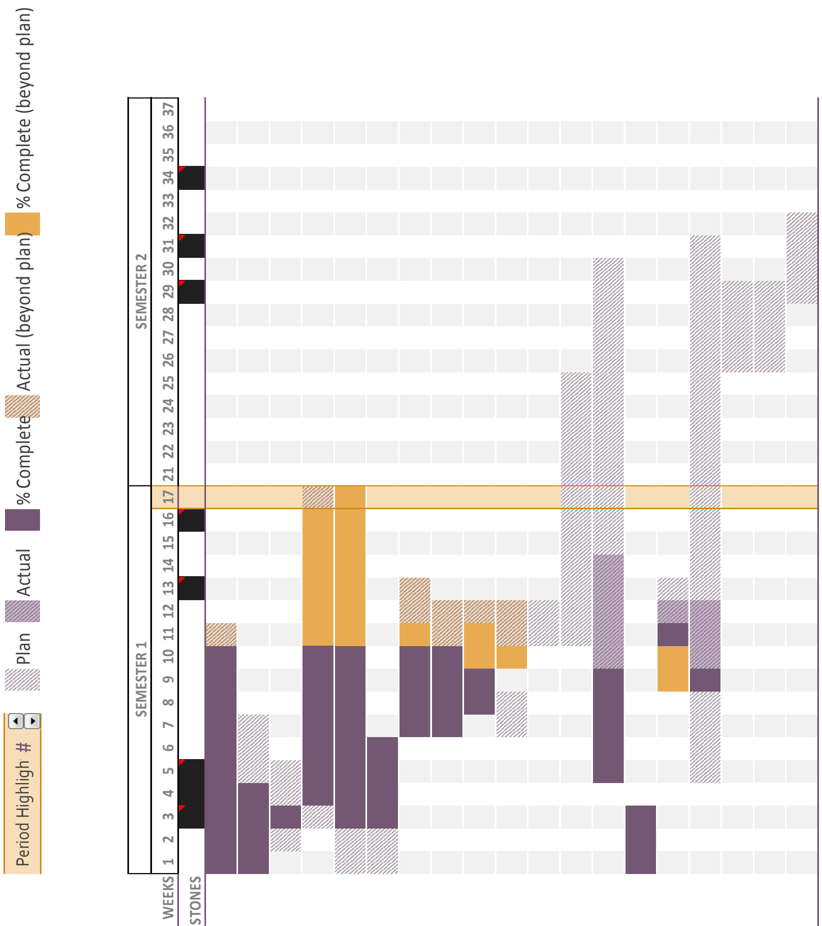
APRIL 2016 - TOP 20 MOST FREQUENT ALARMS				
TOP 20	**TAG**	**ALARM COUNT**	**% CONTRIBUTION TO TOTAL ALARM LOAD**	**ACCCUMULATED % ALARM LOAD**
1	9LDI659	3313	**26.64%**	**26.64%**
2	9LI659	3286	**26.42%**	**53.06%**
3	9LI658	2311	**18.58%**	**71.65%**
4	81PDH301S	173	**1.39%**	**73.04%**
5	GOBE_ESD	157	**1.26%**	**74.30%**
6	800J218	156	**1.25%**	**75.55%**
7	81FUELLOS	116	**0.93%**	**76.49%**
8	KI_PRES	106	**0.85%**	**77.34%**
9	9FI140	92	**0.74%**	**78.08%**
10	KO_PRES	92	**0.74%**	**78.82%**
11	300JTCL	86	**0.69%**	**79.51%**
12	$CONSOLE01	77	**0.62%**	**80.13%**
13	82PIG048	76	**0.61%**	**80.74%**
14	14PDH525	75	**0.60%**	**81.34%**
15	82PIG056	70	**0.56%**	**81.91%**
16	82PIG064	68	**0.55%**	**82.45%**
17	9XA687	62	**0.50%**	**82.95%**
18	81HS602S	58	**0.47%**	**83.42%**
19	MU_PRES	49	**0.39%**	**83.81%**
20	81EI602AS	42	**0.34%**	**84.15%**
…	…	…	**…**	**…**
…	…	…	**…**	**…**
300	83FUELLO	1	**0.01%**	**99.98%**
301	09GD801_OVR	1	**0.01%**	**99.99%**
302	44M41523	1	**0.01%**	**100.00%**
Grand Total		**12436**		

Table 51: April alarm load % contribution

APPENDIX D – Project Planner / Timeline

Project Planner

	ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
1	Research Phase	1	10	1	11	97%
1.1	Background	1	7	1	4	100%
1.2	Standards	2	4	3	1	100%
1.3	Obtain Data	3	8	4	15	90%
1.4	Control systems	1	10	3	15	100%
1.5	ID Resources	1	6	3	4	100%
2	Analysis Phase	7	4	7	7	85%
2.1	Corrolate Info	7	4	7	6	70%
2.2	ID solution	8	2	8	5	85%
2.3	Comparisons	7	2	10	3	60%
3	Testing Phase	11	2	0	0	0%
3.1	Develop Test ?	11	15			
4	Write Up Phase	5	26	5	10	50%
4.1	Specification	1	3	1	3	100%
4.2	Prelim Report	11	3	9	4	95%
4.3	Draft Dissertation	5	27	9	4	20%
4.4	Presentation	26	4	0	0	0%
4.5	Partial Draft	26	4	0	0	
4.6	Final Submission	29	4	0	0	0%



APPENDIX E – Project Risk assessment

This risk assessment considers foreseeable risks associated with researching the "Best practice management of industrial process control alarm floods", during and post report submission. Where new risks are identified during the project research, these risks shall be captured and entered into this live risk assessment document as well as current risk monitored and reviewed during the course of the project.

The method follows Australian / New Zealand Standards 4360:1999 Risk Management. This method has been selected based on the country the study originates.

Risk assessment overview

The research into alarm floods considers how best to analyse alarm data without jeopardising the safe operation of an industrial processing plant by suppressing alarms communicating dangerous situations that could potentially cause harm.

Based on the risk matrix below the following other classification of risk is utilised as a subset to the risk assessment to further specify a considered risk or hazard rationale associated with the description, taken from Australian Standards 1999.

a) *Diseases*—affecting humans, animals and plants.
b) *Economic perils*—e.g. currency fluctuations, interest rates, share market.
c) *Environnemental*—e.g. noise, contamination, pollution.
d) *Financial*—e.g. contractual risks, misappropriation of funds, fraud, fines.
e) *Human perils*—e.g. explosions, riots, strikes, sabotage.
f) *Natural perils*—e.g. climatic conditions, earthquakes, bushfires, vermin, and volcanic activity.
g) *Occupational health and safety*—e.g. inadequate safety measures, poor safety management.
h) *Product liability* —e.g. design error, substandard quality control, inadequate testing.
i) *Professional liability* —e.g. wrong advice, negligence, design error.
j) *Property damage*—e.g. fire, water damage, earthquakes, contamination, human error.
k) *Public liability*—e.g. public access, egress and safety.
l) *Security* —e.g. cash arrangements, vandalism, theft, misappropriation of information, illegal entry.
m) *Technology*—e.g. obsolescence, advances and failure.

Risk Matrix

The following tables (Tables 52, 53 & 54) are used to create a level number that has been transferred to the risk matrix in order to risk rank the identified risks or hazards associated with the project.

Qualitative measures of likelihood		
Level	**Descriptor**	**Description**
5	Almost certain	The event is expected to occur in most circumstances
4	Likely	The event will probably occur in most circumstances
3	Moderate	The event should occur at some time
2	Unlikely	The event could occur at some time
1	Rare	The event may occur only in exceptional circumstances

Table 52- Qualitative measures of risk likelihood

Qualitative measures of consequence or impact		
Level	**Descriptor**	**Description**
5	Insignificant	No injuries, low financial loss
4	Minor	First aid treatment, on-site release immediately contained, medium financial loss
3	Moderate	Medical treatment required, on-site release contained with outside assistance, high financial loss
2	Major	Extensive injuries, loss of production capability, off-site release with no detrimental effects, major financial loss
1	Catastrophic	Death, toxic release off-site with detrimental effect, huge financial loss

Table 53 - Qualitative measures of risk consequence or impact

Risk Matrix

E = Extreme risk - require redesign or detailed plan
H = High Risk – require senior management acceptance / sign off
M = Medium Risk – Specify action and assign management responsible
L = Low Risk – managed through procedures

	Consequence				
Environment	Expected release through normal operation	On-site release immediately contained	On-site release contained with outside assistance	Off-site release with no detrimental effects	Toxic release off-site with detrimental effect
People	No injuries	First aid treatment	Medical treatment required	Extensive injuries	Death / treat to life
Reputation	Internal Controlled	Internal audits preventing escalation	External investigation required	Public or Political Significance	Negative Publicity
Business Processes and systems	Minor system or process errors that require corrective action	Failure of procedure or process	One or more responsibility requirement no met	Strategies not in accordance business plan	Critical failure / bad policy
Financial % of budget	Low financial loss 1%	Medium financial loss 2.5%	High financial loss >5%	Major financial loss >10%	Huge financial loss >25%
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**

Likelihood	**Probability**	**Historical**	**Level**		**1**	**2**	**3**	**4**	**5**
	>1 in 10	The event is expected to occur in most circumstances	**5**	**Almost Certain**	**M**	**H**	**H**	**E**	**E**
	1 in 10 - 100	The event will probably occur in most circumstances	**4**	**Likely**	**M**	**M**	**H**	**H**	**E**
	1 in 100 - 1000	The event should occur at some time	**3**	**Possible**	**L**	**M**	**M**	**H**	**E**
	1 in 1000 - 10000	The event could occur at some time	**2**	**Unlikely**	**L**	**M**	**M**	**H**	**H**
	1 in 10000 - 1000000	The event may occur only in exceptional circumstances	**1**	**Rare**	**L**	**L**	**M**	**H**	**H**

Table 54 - Risk Matrix

Risk Assessment

Risk Assessment

Item	Risk or Hazard	Risk Classification	Likelihood	Consequence	Uncontrolled Risk rating	Risk mitigation controls	Likelihood	Consequence	Controlled risk rating
1	Exposing operators to high alarm rates	Human stress	3	1	**L**	Testing will be completed in a simulation testing environment as part of an operators training. Operators will be advised of the scenario testing. Testing will cover performance metrics from EEMUA 191 and ISA 18.2.	3	1	**L**
2	Errors in alarm analysis and conclusions	Product Liability Professional Liability	3 1	1 2	**L** **L**	Analysis and interpretation of results are part of a research dissertation and therefore require careful scrutiny through a thorough alarm rationalisation process to ensure any changes are peer and multidiscipline reviewed under a management of change process	1	1	**L**
3	Companies associated to research project	Reputation Security	1 1	1 1	**L** **L**	All reference to company data and information shall be deleted, referenced where applicable and or identity kept private. The information and data where company data is used is only for research / analysis for this project and not a company commissioned project for public scrutiny.	1	1	**L**
4	Software and other products implicated	Reputation	3	1	**L**	The intended the dissertation is not to review software produces and other analysis tools but mealy utilise there	1	1	**L**

						function to aid the example of how to best implement “Best practice management of industrial process control alarm floods”			
5	Failure to achieve desired analysis results due to limitations or access to resources or tools	Stress Financial	3	2	**M**	Allow plenty of time through effective use of the GANTT chart noting milestones. Converse with supervisor. Identify other tools available e.g. MS excel, Matlab, Mathcad to assist in analysing data. Reach out to other colleagues.	3	1	**L**
6									
7									

Table 55 – Risk Assessment

APPENDIX F – Operator Questionnaire Example

Location:	'Plant location'		
Plant:	'Plant name'		
Date:			
Name:			
Role:			
1. How long have you worked with the present control/alarm systems? (E)			
	Years		Months
Have you worked with other systems? If so, which ones?			
What features of the other systems do you like?			
2. About your control/alarm systems			
Control System details (Name/ Manufacturer/ Model/ MMI/ Year installed)			
Is the alarm system part of the control system?			
Are there fixed annunciator panels?			
What other systems generate alarms you respond to?			
3. How well do the alarm systems support you in normal steady operations? (E)			
Very good	OK	Poor	Very poor
What series of operations do you do when an alarm is activated?			

Figure 59: Operator Questionnaire ((EEMUA 191, 2013, Appendix 9 pg 181)

4. How well do the alarm systems support you during plant fault or trips? (E)			
Very good	OK	Poor	Very poor
What is your impression of the number of alarms generated when equipment trips or communications fails?			
Is there more than one operator who accepts/responds to the alarms? If so, how many?			
Are alarms grouped say by plant area, equipment for each operator?			

5. What about the total number of alarms in the system? (E)			
Too many alarms	Many but necessary	Few but adequate	Too few alarms

Can you distinguish between alarms generated from different parts of the system?	Yes/Not at all/In part

What generates most alarms? (1- being the highest)				
Process	Equipment	DCS system	Communications	Instrument faults

6. How many alarms do you get in normal steady operation? (E)		
PER HOUR		
Guess		Per hour
Actual		Per hour

7. How often do you find that an alarm that comes up is a repeat of an alarm you have already seen in the last five minutes? (E)			
70-100% of alarms	40-70% of alarms	20-40% of alarms	Under 20% of alarms

8. Do you suffer from the following 'nuisance' alarms?			
	Often	Sometimes	Rarely
Alarms that are wrongly prioritised.(E)			
Alarms from plant that is shut down.(E)			
Two or more alarms occurring at the same time that mean the same.(E)			
Alarms occurring in a trip which are only relevant in steady operation.(E)			

9. What proportion of alarms are useful to you in operating the plant? (E)			
All essential	Most useful	Few useful	Very few useful

10. Do you fully understand each alarm message and know what action to take? (E)		
Always	Mostly	Sometimes

Figure 60: Operator Questionnaire ((EEMUA 191, 2013, Appendix 9 pg 182)

11. Consider a normal operating situation and 10 typical alarms. How many of the 10 alarms:-	
Require you to take positive action, e.g. operate a valve, or speak to an assistant?(E)	
Cause you to bring up a display/format and monitor something closely?(E)	
Are noted as useful information?(E)	
Are read and quickly forgotten?(E)	

12. How many alarms would you get during a large plant fault or trip? (E)		
In the first minute	In the next ten minutes	In the next hour
What facilities help you manage alarms during a large plant upset?		
What facilities would help you if there were a large amount of alarms during a plant upset?		

13. Do you keep an alarm list permanently displayed during a large plant fault or trip? (E)			
Yes		No	

14. How often do you look through the alarm list display during a large plant fault or trip? (E)			
Several times a minute	Once every couple of minutes	Once every 10 minutes	Less than once every 10 minutes

15. How often in a large plant fault or trip do the alarms come too fast for you to take them in? (E)		
Mostly	Sometimes	Rarely

16. How often in a large plant fault or trip are you forced to accept alarms without having time to read and understand them? (E)			
Always	Quite often	Sometimes	Never

17. Does the alarm system help you to pick out key safety related events during a large plant fault or trip?			
Very well	Some help	Little help	A nuisance

Figure 61: Operator Questionnaire ((EEMUA 191, 2013, Appendix 9 pg 183)

APPENDIX G – Consequences

The consequences resulting from data analysis results will have pros and cons –

Pros – Implementing methods to better analyse alarm data improves plant reliability and collaborates success by minimising company and public exposure to poor performing control systems and production overheads. By investing in KPI's and analysis methodologies, companies and industry are better positioned to assess, identify, manage or predict events and provide statistical direction of poorly performing alarm systems considered invaluable information during alarm rationalisation workshops. The better information provided to a rationalisation workshop enhances the outcome by reducing time, cost in resources committed to rationalisation workshops and is often a rare event. However, by not analysing data, searching for and implementing improvements leaves the alarms system vulnerable to alarm floods, poor performance and potentially a major event. Finally the most important point of effective alarm analysis is to protect personnel, the environment, public and plant.

Cons – Analysing any random data is susceptible to error or misleading information based on results obtained. Often a high probability of coincidence in alarm annunciation at or around similar events could be perceived as a possible relationship between alarm tags. The consequence of such could lead to an alarm being suppressed unnecessarily. Therefore relationships require in depth scrutiny by the engineering team. This scrutiny requires time and can be costly. However, must be considered before deciding to suppress the alarms around an identified alarm event or flood. Where careful scrutiny does not identify and remove the relationship of alarm tags to a random coincidence, the secondary alarms could be suppressed to an event journal and not the operator’s attention.

APPENDIX H – Project Ethics

Engineering students working towards becoming a professional engineer are expected by the University of Southern Queensland (USQ) to align with the Engineers of Australia code of ethics. As an engineering student all work contained in this report or conduct throughout this project follows EA code of ethics and conduct.

The EA code of ethics enables EA pathways for disciplinary processes against members and students who breach the code. Chartered members and registrants on the various registers administered by the national engineering registration board are specifically required to practice in accordance with the code of ethics. Furthermore, EA code of ethics provides engineers and students with the core values that must be adhere to ensuring ethical decisions are made strengthening the profession and reputation of EA. All members are required to practice and demonstrate integrity, practice competently, exercise leadership and promote sustainability. For more information on EA code of ethics please visit the webpage and or document referenced.