AC 2010-608: AN ALARMING EXPERIENCE: RESULTS OF AN UNDERGRADUATE CHEMICAL PROCESS ALARM LAB MODULE

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Abstract

Since the introduction of the Distributed Control System (DCS), process plant alarms have become essentially free, resulting in a tendency for the process engineer to implement more and more process alarms. The problem with over alarming a chemical process is that the operators, whose main responsibility is the safe operation of the process, will have to sift through the alarms to distinguish which are more important and require immediate action. This alarming problem has been identified as a contributing factor in numerous chemical process incidents, such as the Texaco Pembroke Refinery in the UK and others on the Gulf Coast.

Alarm issues are caused when newly minted chemical engineering graduates become process engineers and are asked to suggest alarm settings for their projects without having an understanding of alarm management principles. Therefore we have developed this Alarm Documentation and Rationalization (D&R) Module to introduce alarm management concepts to undergraduate students.

In this paper we describe our experience exposing undergraduate students to this D&R module and allowing them to implement and test their alarm settings on an actual DCS. Groups of four to five students were assigned to perform a D&R study on the process alarms for a reformate stabilizer column simulated in HYSYS and similar to such columns at many refineries. Students were asked to perform one of the following roles: process engineer, process control engineer, superintendent, or operator. Then, aided with D&R instructional material, including sample alarm configurations provided by local industry, they were tasked with rationalizing the alarms for this system. The module concluded by allowing the students to implement the alarms and test their operation on an actual DCS system.

Selected Acronyms

BNC	A small device for connecting coaxial cables with a snap-lock architecture which keeps the plug firmly in its socket
CAT5	Category 5 cable defined in ANSI/TIA/EIA-568-A
D&R	Documentation and Rationalization
DCS	Distributed Control System
HAZOP	Hazard and Operability Study
LOPA	Layer of Protection Analysis
PSA	Process Safety Analysis
PV	Measured Process Variable
PVHH	High-High PV Alarm Setpoint
PVHI	High PV Alarm Setpoint
PVLL	Low-Low PV Alarm Setpoint
PVLO	Low PV Alarm Setpoint
TDC3000	Honeywell DCS Common in Refining and Petrochemical Industries

Lamar University Process Control Lab

The Lamar University Process Control Lab (CHEN 4150) course is a required one-hour course which supplements the Process Control I (CHEN 4331) undergraduate course. It includes five process control modules plus this newly developed alarm rationalization module. The students are divided into groups of four or five students for most of these exercises including the alarm rationalization module. During the Spring 2009 semester this class had a total of 22 students (5 groups) who rotated to a different process control module each week until each group had performed all six modules. Students were graded as a group and for individual contributions during the course of the semester.

The alarm Documentation & Rationalization (D&R) module was developed using the Chemical Engineering Department's new Distributed Control System (DCS) demonstration unit. This DCS is being developed to provide students with a better understanding of the modern chemical manufacturing environment. Because alarms are critically important to modern industrial operation, their use as part of the operating environment must be understood by all plant personnel, especially engineers. As an integral part of the operating culture these alarm practices can vary depending on the particular plant; however, in recent years alarm management best practices have been developed and adopted by many of the leading chemical manufacturers.[1] Since these practices include alarm rationalization principles designed to improve safety and reliability for operating companies, we wanted to incorporate those principles into the alarm module developed for this class.

In this module we stress the types of analysis used to determine alarm settings. The role playing is an attempt to get the students to think in terms of the different perspectives that will be present in the plant environment. They must understand the conditions under which they operate as engineers. Things that they do affect the operation of the unit and the better they understand how the unit is affected by their activities the better they can make judgments on how to make changes. This module provides students with an in-depth understanding of modern manufacturing that cannot be achieved simply by lecturing at them.

DCS Demonstration Lab Overview

We use an industrial quality DCS system with all of the alarming capabilities of typical systems used by the chemical process industries. A Honeywell Experion DCS system was purchased for this purpose. This DCS system is much less bulky than its predecessor, the TDC3000, which uses predominantly 10base5 cable with BNC connectors, and is commonly found in many refineries and chemical plants. A major factor contributing to this reduction in bulkiness is the Honeywell Experion's use of CAT5 Ethernet cable in place of the TDC3000's bulky and stiff 10base5 coaxial cable connectors, which allows this system to be implemented using equipment found in a typical campus computer lab. The refining or chemical process is represented by a HYSYS^{TM} dynamic simulation that is automated and connected to the DCS much like the actual plant is connected to the DCS system in industry. DCS tags and graphics are constructed for the process and those tags' alarm settings are configured by the students during the completion of this module.

Alarms are more of a problem now than they were in the pneumatic days when an alarm had to be hard wired into an alarm panel with a lighted square behind every alarm. Now an alarm is essentially zero cost to configure on a conventional DCS, leading to a crisis in the number of alarms that must be answered by operators on a daily basis. When alarms were more expensive and difficult much more thought and consideration were given to placing an alarm. Now with alarms costing virtually nothing, suggesting and implementing new alarms to address items in an incident report is easy. In fact, rare indeed is the modern minor incident report that does NOT suggest a new alarm setting that could help the operator prevent future reoccurrences of the incident.

The typical DCS alarm is configured for an existing DCS tag that is connected to a field measurement from the process being controlled. It consists of a priority and a setpoint. Typically two high alarms (PVHI and PVHH) and two low alarms (PVLO and PVLL) are available for each process measurement. The priority for each alarm can be set to Journal (log only), or to enunciate with Low, High, or Urgent priority. The DCS system typically stores the date and time that all alarm events occur including the initial alarm, its acknowledgment by the operator, and when the alarm returns to normal. This information is available for inspection by the control engineers and others as needed.

One of the tasks of process engineers during Layer of Protection Analysis (LOPA) studies for their projects is to suggest alarms based on Process Safety Analysis (PSA) analysis to determine which potential alarms are critical and which are not. The purpose of our D&R module is to provide our process engineering graduates with a better understanding of the role of alarms in modern chemical manufacturing.

Alarm D&R Background

The D&R process is used to document existing alarms including the reasons for those alarms and compare them with a strategy document that is used to determine whether alarms are appropriate for each case. Prominent cases that demonstrate the need for such a process include the Texaco Pembroke Refinery disaster in the UK on 24 July 1994, and the BP Texas City Refinery isomerization unit explosion on 23 March 2005. In the Pembroke case, a lack of alarm rationalization led to a "barrage" of alarms which contributed to the extent of the incident.[2] In the BP incident, a liquid level alarm was acknowledged by operators, but the redundant hard-wired high level alarm was broken. The soft level reading increased to above 100%, and the high level alarm stayed on and acknowledged. Two shift changes later, this broken hard alarm plus the single static acknowledged soft alarm led to overfilling of the tower, which contributed to the discharge to the atmosphere of hot hydrocarbons, which were ultimately ignited.[3]

The premise of the modern alarm D&R approach is that alarms should be based on operator needs. In other words, each alarm should lead to some action by some operator. It is useless for an alarm to be created that the operator does not have any control over and that does not affect the way that he is working. Countless screens filled with nuisance alarms obscuring the really important alarms requiring a response in times of critical operation are inherently dangerous. These nuisance alarms can make the operator's job a very tedious affair and desensitize him to alarms which can be very dangerous when a true emergency arises. Chattering alarms lead to the

"Just push the yellow button" complex where alarms are ignored while business is conducted that is presumed to be more important. This also leads to numerous standing alarms that stay in the alarm state for days at a time and can distract from potentially important alarms, as in the BP incident referenced above.

Potential alarms should be evaluated based on the operator response time required and the severity of the consequence if no action is taken when the alarm occurs. The following D&R matrix[4] was provided for the students to classify the alarms in this module:

Maximum Time To Respond	Consequence Severity: MINOR	Consequence Severity: MAJOR	Consequence Severity: SEVERE
> 30 Minutes	No Alarm	No Alarm	No Alarm
10 to 30 Minutes	Low	Low	High
3 to 10 Minutes	Low	High	High
< 3 Minutes	High	Urgent	Urgent

The students were also provided with the following table[5] to help them determine the consequence severity if the operator took no action when the potential alarm occurred:

Category	Consequence Severity: MINOR	Consequence Severity: MAJOR	Consequence Severity: SEVERE
Personnel Safety	Slight injury (first aid) or health effect No disability No lost time recordable	Injury affects work performance maximum one week Reversible health effects (such as skin irritation)	Lost time injury > 1 week, or worker disabling or severe injuries, or Life Threatening
Public or Environmental	Local environmental effect Does not cross fence line Contained release Little, if any, clean-up Negligible financial consequence Internal or routine reporting requirements only	Contamination causes some non-permanent damage Single complaint Single exceedance of statutory or prescribed limit Reporting required at the local or state agency level	Limited or extensive toxic release Crosses fence line Impact involving the community Repeated exceedances Uncontained release of hazardous materials with major environmental impact and 3rd party impact Extensive cleanup measures at the state or federal level
Costs/ Production	Event costing < \$10,000.	Event costing \$10,000 to \$100,000	Event costing > \$100,000

Loss/ Down time / Quality	Reporting required only at the department level	Reporting required at the site level	Reporting required above the site level

This module focuses on a critical area of interaction between engineers and operators. The alarms are frequently based on both engineering limits for the plants (the engineering perspective) as well as operational perspectives on how to respect those limits with the existing facility and personnel and operating procedures.

In a perfect world the number of alarms could be reduced to just those critical few that are necessary to inform the operator when actions should be taken; however, because real world instruments and their associated alarms can fail for various reasons it is not uncommon to have more than one alarm configured to address the same concern. For example, a column overhead temperature alarm may be configured to backup an analyzer alarm because the analyzer data is more unreliable than the temperature readings. In addition, it is a very small consolation that the unit was shut down because the operator was not monitoring the process sufficiently when an additional alarm would have brought the urgency of the situation to his attention. Although the argument is frequently made that if all alarms were based on imminent operator requirements operators would be more likely to treat each alarm as requiring action, turning down a reasonable request for an additional alarm can be very difficult if it might reasonably be expected to help avoid a unit shut-down. Therefore, the alarm policies encompassed by these tables are not written in stone and there is generally some flexibility to allow for common sense.

D&R Module Organization

The student learning outcomes for this module are as follows:

1. Classify potential alarms and choose an appropriate alarm priority based on operator response time and consequence of inaction
2. Use the DCS tools to review chemical process data and DCS event history
3. Determine if alarms should be enunciated and the appropriate alarm setpoint
4. Appreciate the importance of this module for their education

Assessments for these outcomes were based on written tests following the module and on a written report submitted by each group. A student satisfaction outcome was measured by a Likert scale survey administered after the module.

Notes provided to each student at the beginning of the semester contain detailed instruction on how to perform the D&R activity. These notes also describe the various roles that students will be expected to play in the D&R process. The personnel represented by these roles each have a stake in the development and maintenance of alarms. This is true in any industrial operation that multidisciplinary teams of employees and sometimes contractors form to accomplish company objectives. For the D&R process the team typically consists of a process control engineer, a process engineer, an operator, and an operations supervisor. All of these roles are important for engineering students to understand in order for them to succeed in industry.

Students must learn to interact with other team members in the conditions that exist in the modern control room. In this lab we are able to duplicate those conditions in a classroom setting, as shown in Figure 1. Only by experience can they gain the type of insight necessary to guide those decisions that affect operations. This helps our students attain ABET Criterion 3 Program Outcome (d): an ability to function of multidisciplinary teams.[6]

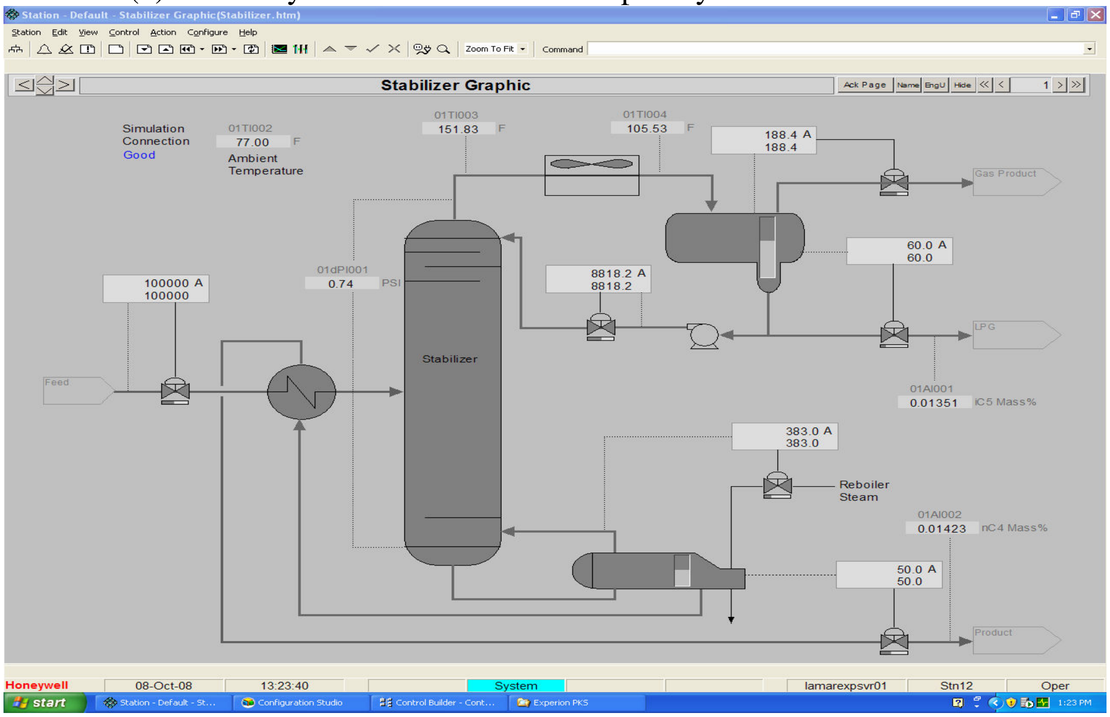

Figure 1. Screen capture of Reformate Stabilizer DCS Graphic

The process engineers must carefully consider the alarms that should be placed on any project that is being developed for operations. Especially during the HAZOP phase the reasons for potential alarms are reviewed while trying to make sure that potentially hazardous situations are mitigated by process safety systems. Obviously, the operators have a stake in alarm implementations because they are responsible for the safe operation of the process and are at the front lines of a chemical processing operation. They want alarms that provide understanding of the actual failure and indicate the appropriate response. Supervisors typically have a strong overall understanding of the process unit and are responsible for meeting specifications and reporting to the next level of plant supervision. They can usually make very good arguments for or against certain alarms based on their overall understanding of the appropriate response for various operating conditions. Process control engineers implement the alarms in the DCS system and generally have the best idea of how the controls and dynamics of the process will respond to given conditions. This usually makes the process control engineer an ideal person for the team.

We want the students to appreciate the criticality of these alarms. Students should understand that their settings and values can and do have a direct safety implication for both the personnel operating the unit and the surrounding community in addition to the obvious economic implications to the company. If the information being provided does not require the operators to make a move to correct the alarm, then the alarm becomes static, thereby quickly decreasing the value of such information. Students have to understand the distinction between information that is useful to engineers, information that is useful for operations and information that is required to operate the unit. For example, a poor alarm rationalization strategy might produce the alarm summary display shown in Figure 2. After rationalization, only the necessary alarms would be displayed as shown in Figure 3.

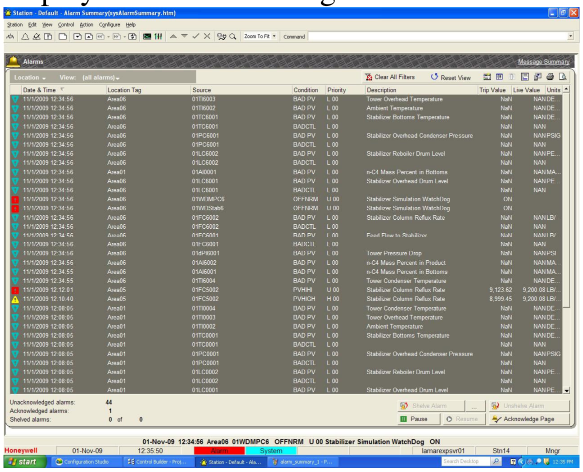

Figure 2. A poor alarm rationalization strategy may result in many static standing alarms.

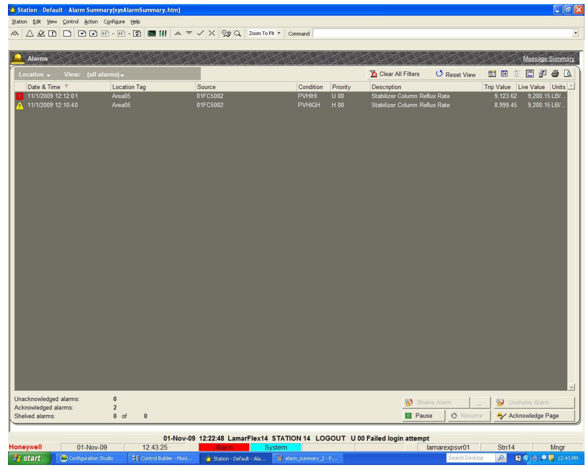

Figure 3. A corresponding good alarm rationalization strategy may result in fewer alarms.

Students are instructed that alarm setpoints should be set at the point of process upset when the operator's attention is required to make adjustments. Obviously, alarms should not be set to enunciate after the operator should have already responded. This is equivalent to the high temperature car alarm light that appears after the driver has been forced to pull over because the car's engine has already been damaged. However, alarms that enunciate too soon before operator action is required may also cause the operator to fail to respond. The operator may have already forgotten about the alarm by the time the response is finally needed.

Evaluation

The students' performance following this module was measured by using a rubric to evaluate their justification of their alarm settings on a submitted written report (Items 1 and 2) as well as a test (Item 3) to measure their understanding of when alarms should be enunciated and how to determine the appropriate alarm setpoints. The results of the performance assessment for the current cohort of students are displayed in Table 1.

Table 1. Student Performance Assessment

Item	Assessment Description	Performance 0-5.0 Average ± Standard Deviation
1	Ability to classify potential alarms and choose an appropriate alarm priority based on operator response time and consequence of inaction	4.2 ± 0.8
2	Ability to use the DCS tools to review chemical process data and DCS event history	2.8 ± 1.3
3	Ability to determine if alarms should be enunciated and how to determine the appropriate alarm setpoint	4.1 ± 0.7

The students were also asked questions to measure their satisfaction with the assignment. The results of this survey are shown in Table 2.

Table 2. Student Satisfaction Survey Results

Item	Survey Statement	Satisfaction 0-5.0 Average ± Standard Deviation
1	All members participated in the process	4.6 ± 0.9
2	The group was able to stay on track	4.5 ± 0.6
3	Implementing alarms on the DCS improved understanding	4.5 ± 0.7
4	Using DCS and event history improve understanding	4.1 ± 1.0
5	Group seemed to understand	4.2 ± 0.9

Conclusions

Results from the first cohort show satisfactory results for all student learning outcomes except Student Performance Assessment Item 2. The assessment of this item was based on each individual's contribution to the team's report. Unfortunately, each team member did not perform the steps necessary to obtain credit for the performance of these tasks. In future implementation to improve the performance on this critical item we plan to offer an outline for the report so that students must address each area that is required for this performance evaluation. The students' ability to use DCS system tools to retrieve event and historical data and interpret it is critical to their ability to perform troubleshooting in the field.

Future Work

We plan to implement troubleshooting scenarios using this equipment to address the unsatisfactory results of our first cohort on Student Performance Assessment Item 2. In particular, we'll assign the team to an incident investigation so that they will have to use the DCS historical data and event history information to diagnose and determine the corrective action for a simulated incident. The troubleshooting cases will be adapted from those used in McMaster University's troubleshooting class.[7]

Acknowledgments

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