INTELLIGENT ALARM MANAGEMENT THROUGH SUPPRESSING NUISANCE ALARMS AND PROVIDING OPERATOR ADVICE

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Abstract: Nuisance alarms often clutter and obscure an operator’s view of critical and important information. In this paper, an intelligent alarm management system for a refinery plant is presented. Its function includes nuisance alarm suppression, intelligent advisory information to guide operator response and recovery mechanism in case of system failure. This system is implemented on Distributed Control System (DCS) and validated through online plant tests. The results show that nuisance alarms are effectively suppressed and the DCS alarm system becomes more helpful.

Key words: Alarm filtering, DCS, Expert System, Chemical Process, Safety

1. INTRODUCTION

The introduction of Distributed Control Systems (DCS) with easily programmable alarm settings has resulted in large numbers of alarm signals being configured on many sites in order to provide plant information to the operator. Alarm systems have consequently become an important tool used by operators to maintain safe plant operation (Andow, 1998; Wilson, 1998). However, recent studies of alarm systems (Bransby and Jenkinson, 1998) in chemical and power industries indicate that the convenience offered by these alarm systems has in many cases been annulled by operators being overloaded with a large number of alarms both during steady-state operation and plant upsets. Many of these alarms are of low operational importance and are considered to be nuisance alarms (Liu, et al., 2000a; Li, et al., 2000).

Nuisance alarms often cause important alarms to be missed by the operator – with potentially severe consequences. This problem becomes worse during plant upsets. A recent study by the Health & Safety Executive (HSE) in the UK reported incidents where such failure of alarm systems put lives at risk and contributed to major plant damage, production loss, and environmental damage, leading to millions of pounds of losses that are avoidable with better alarm systems. The prevalence of inadequate alarm management as a crucial problem is testified by similar findings in other countries as well (Nimmo, 1995). This paper addresses this important problem and describes an Intelligent Alarm Management System (IAMS) for suppressing nuisance alarms and providing valuable advisory information to help the panel operator focus quickly on important alarm information and take correct and quick action. IAMS has been running successfully in a refinery since June 2000 (Liu, et al., 2000b). Results show that nuisance alarms can be effectively suppressed by IAMS, thus making the alarm system in the refinery more efficient.

This paper is organized as follows. In Section 2, the requirements for an alarm management system are outlined. A detailed description of the intelligent alarm management system is provided in Section 3. Results for the improvement in nuisance alarm suppression and conclusions are given in Section 4.

2. REQUIREMENTS OF A PRACTICAL ALARM MANAGEMENT SYSTEM

Consider a chemical plant burdened with an alarm management problem where a new alarm occurs every two minutes (industry average as per HSE survey). For each alarm, the panel operator has to comprehend the information provided by the alarm, decide if it requires any action and take necessary actions to maintain the safe operation of the plant.

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This cognitive challenge is usually coupled with uncertainties about the importance of the alarm. An alarm indicating that a variable is out of transmitter range may be critical and forebode imminent danger if the process variable is actually at its limit but is a nuisance if it is caused by a faulty instrument. In this safety-critical situation, a deluge of alarms and the short time within which crucial decisions have to be made makes the tasks of operators extremely difficult.

An intelligent alarm management system (IAMS) can assist operators tremendously through nuisance alarm suppression and providing context-sensitive, intelligent, advisory information. The guiding principle in any IAMS is that it should function conservatively by suppressing nuisance information while ensuring that information that could be useful to the operator is not affected. A real-time alarm management system has to run continuously on a stand-alone computer communicating with the DCS through the network. Therefore, an important consideration is the provision for graceful recovery from failures – either in the computer running IAMS or in the network communications. One key consideration in any alarm management system is the availability of a user-friendly graphical interface to support the operator through context-sensitive information. Panel operators would thus benefit from the alarm management system where only the critical messages are displayed. In particular, information such as statistical summaries, the efficacy of alarm suppression, reports of broken instruments, etc are very useful and beneficiary to engineers, supervisors and maintenance staff. All these should be accounted for when designing and implementing a practical AMS.

3. IAMS DESCRIPTION

The primary objective of this project was to develop an Intelligent Alarm Management System (IAMS) to be used in a refinery in Singapore. At the start of the project, the refinery used to record, on an average, one alarm every 50 seconds during normal operation and one alarm every 10 seconds during plant upsets. IAMS was implemented primarily to reduce this large number of alarms from an industrial standard of “likely to be over-demanding” level to a more “manageable” level. The main features of IAMS are described in the following subsections.

3.1 Overview

IAMS is developed with Microsoft Visual C++ and is based on application-specific algorithms, process knowledge and control system expertise. IAMS runs round-the-clock on a dedicated Windows NT PC - Human Interface Station. Fig. 1 shows the IAMS framework.

Fig. 1. Framework of IAMS

IAMS communicates with the DCS through a data I/O function block. This block reads real-time process trend data and alarm messages from the DCS using an OLE for Process Control (OPC) bridge. The alarm handling function blocks of IAMS (Alarm/Trend/Knowledge Database, Statistical Analysis, Nuisance HI/LO Analysis, IOP Analysis, Criticality Analysis, Standing Alarm Analysis, Monitor & Recover) build up the database, perform alarm analysis and make decisions. After analysis, IAMS uses the OPC bridge to communicate the new alarm settings to the DCS through data I/O block. The system suppresses nuisance alarms and provides on-line advisory information to the operator through graphical user interface.

To guarantee safe operation, a failure protection system (FPS) is developed to automatically restore all alarm settings changed by IAMS to their original values in the event that IAMS breaks down.

3.2 Nuisance Alarm Suppression

Two major types of nuisance alarms occur in the refinery: repeating alarms where the same alarm continuously arises and clears over a period of time and standing alarms where the alarm signal persists for a long time due to the dead band although the original triggering condition is no longer valid. Repeating nuisance alarms includes repeating process high/low alarm as well as repeating Input Open (IOP) alarm. They are the most common form of nuisance alarms. In a typical plant, they may account for up to 50% of the alarm annunciation. Dead-band (difference between alarm occurring level and alarm recovering level) is commonly used in DCS alarm system to reduce repeating nuisance alarms, as shown in Fig. 2, where PH is the process high alarm limit
and D is the dead band (2% of the scale). Without the dead-band, each time the process value crosses the PH level, there would be a HI alarm and the number of alarms would increase. However, dead-band also causes time delay in alarm recovery. This will sometimes result in standing false alarm or nuisance alarms as shown in Fig. 3, where the process value has been lower than the process high alarm limit for several hours but didn’t recover due to the dead-band (also 2% of the scale). Panel operators are usually not interested in these alarms. The choice of the dead-band size is thus critical. If it is too small, there will be a lot of repeating nuisance alarms. If it is too large, the alarms will take a long time to recover and there will be a lot of standing nuisance alarms.

Fig. 2. Repeating nuisance alarm

Most DCS alarm management systems have a dead-band of 2% (of full scale). At this level, there are still many repeating HI/LO nuisance alarms, as well as some standing nuisance alarms. Advanced solutions have to be developed to further suppress these repeating nuisance alarms and standing nuisance alarms.

The approach to suppress these nuisance alarms is based on dynamically reconfiguring the alarm settings. Different solutions are required to suppress process high/low alarms and IOP alarms as their generation mechanisms are different.

For suppressing repeating process high/low nuisance alarms, an algorithm has been developed that automatically changes the process high/low alarm limit based on the variable’s moving average and standard deviation so as to keep the process variable in alarm status (Liu, et al., 2000b). The change in alarm limit is temporary and the original alarm limit would be restored if it can be determined that for a given period of time, this alarm will not set and clear repeatedly with the original alarm limit. In this way, repeating process high/low alarms can be reduced without compromising safety. Fig. 4 shows an example on how the algorithm works on one of the process tag in the refinery. The implementation of the algorithm has resulted in a huge reduction in the number of alarms for this particular tag. The number of alarms has reduced from 53 to only 3 for that time period (from 01:34:01 to 03:39:05 on Aug. 4, 2000) and from 390 to 90 for that particular day.

For suppressing repeating IOP nuisance alarms, an algorithm that identifies IOP nuisance alarms suitable for masking has been developed. Once an IOP nuisance alarm has been identified, the operator is given a choice to put the corresponding tags into alarm-off status in order to mask them. Those tags will be put back to alarm-on status automatically if it can be determined that the inputs go back to normal status (within scale range) for a period of time, as shown in Fig. 5. The operator can also manually turn an IOP alarm to the alarm-on status whenever desired. Again, this will ensure plant safety.

Fig. 3. Standing nuisance alarm

Fig. 4. An example depicting the suppression of repeating process high/low nuisance alarms

Fig. 5. Recovery of nuisance IOP alarm
When there is a plant upset or shutdown, there are a lot of IOP/IOP- alarms. These nuisance IOP alarms fill up operator’s panel and actually make operator’s task more difficult. Even in normal operation, there may be nuisance IOP alarms due to faulty instruments. Fig. 6 shows the total number of IOP alarms and the total number of process analog alarms over several months. The total number of process analog alarms on Aug. 1, 2000 is 860 in which one tag contributed 343 IOP alarms, which could be reduced to 34 with IOP suppression.

Suppressing a standing nuisance alarm is achieved by resetting it automatically - temporally changing the alarm limit to counteract dead band effect and then changing back quickly to its original value. In this way, standing nuisance alarm can be removed from the standing alarm list on the panel without any negative effect.

3.3 Intelligent Advisory Information

Intelligent advisory information is designed to provide advice to the panel operators when encountering different alarm situations. Some advisory information which are useful to plant operators and engineers includes: identification of important alarms, early warning of ramping alarms, status change of control loops requiring attention, statistical information, alarm management overview, fault detection and maintenance report. This advisory information is mainly based on heuristics from experienced plant engineers and the study of different alarms in the refinery.

Advisory information helps the operator to differentiate between a process value that is out of range and nuisance signals caused by faulty instruments as shown in Figs. 7 and 8 respectively.

Advisory information to help the operator during shift changes (handover) is provided through reports on status change of control loops requiring attention. On-line maintenance reports on bad transmitters, broken wires and outdated alarm setting are also provided to the operators. The advisory system also provides complete statistical function about alarm numbers that is useful for analysis, evaluation and reconfiguration. An overview of the alarm suppression results is also provided on-line to inform the operator which types of alarms occur frequently and which alarms are currently suppressed.
3.4 Failure Protection

In order to guarantee the safe operation of the plant in the event of hardware, software or network failure that affect IAMS functioning, the original static alarm settings have to be restored to the DCS. Such graceful recovery is achieved through an IAMS watchdog function added on the DCS and a dedicated Failure Protection System (FPS). FPS is developed in Microsoft Visual C++ and automatically restores all alarm settings changed by IAMS to their original values in case of breakdowns. FPS runs on another NT station or server of DCS and communicates with IAMS through the Ethernet. Fig. 10 shows this hardware environment.

![Fig. 10. Hardware environment](image)

The alarm management system will send the previous alarm settings to the FPS whenever it changes an alarm setting on the DCS. IAMS will also check the connection status with FPS regularly. If the connection is lost, IAMS restores all the alarm settings that it has changed, switches off all nuisance alarm suppression functions automatically and informs the operator. As soon as the connection is re-established, IAMS resumes the nuisance alarm suppression functions again automatically.

The failure protection system also checks the IAMS watchdog tag on the DCS. When IAMS fails to communicate with the DCS, the watchdog tag on the DCS will not be updated. This is detected by the FPS, which will then restore the changed alarm settings in IAMS to their original values according to the original alarm settings stored in the FPS. The alarm management system will run continuously providing on-line guidance information while nuisance alarm suppression function of IAMS can be switched on/off through operator or automatically when FPS is restarted/down.

4. RESULTS AND CONCLUSIONS

In this section, we present results to highlight the improvement in reduction of alarms since the installation of the intelligent alarm management system in a major refinery in Singapore. The IAMS has been in continuous operation since June 2000, managing thousands of process variables in the refinery. It has performed successfully and has gained the acceptance from plant operators. Improvement achieved is illustrated in Fig. 11, where x-axis is the date and y-axis is the total process alarm number for that day. Series “With IAMS” represents real alarm number recorded by DCS while IAMS is running. Series “Without IAMS” represents alarm number if IAMS were not running. On Nov 9, 2000, the whole aromatic plant was shutdown while on Apr 15, 2000, some parts of the plant were being starting up. The data for the other days corresponds to upset and normal operation conditions.

![Fig. 11. Alarm numbers with and without IAMS](image)

From Fig. 11, it can be seen that without IAMS, number of process alarms would increase by at least 50% to 80% for both normal and abnormal conditions. This is a conservative estimate and the actual reduction could be even greater as the number of possible alarms without IAMS is estimated from original alarm settings on DCS and the trend data collected by IAMS from DCS. Since, collection of trend data through the OPC bridge can never be as fast as the generation of alarms on the DCS, some alarms might be missed when estimating using the trend data.

We now compare the number of process alarms before and after the implementation of IAMS. Process alarm number for the last two years is shown in Fig. 12. In normal operating condition before the implementation of IAMS, the average number of process alarm is about 2000+ per day (about 1 alarm per 1.5 minutes per station, close to industrial average of 1 alarm per 2 minutes). After the installation of IAMS, the average number of process alarm is about 1000 per day in normal condition (about 1 alarm per 3 minutes per station - should be manageable according to HSE survey). The alarm reduction is thus about 50%.
On Nov 9, 2000 (at 14:04), the aromatic plant had an emergency shutdown due to power loss resulting in a spike in the number of alarms as shown in Fig. 11. IAMS was running online at that time and made a significant contribution in reducing the number of alarms on that day. With IAMS online, the total number of process alarms was 5629 (5333 alarms during shutdown from 14:04 to 24:00). Without IAMS, the total number of process alarms would have been at least 9750 (an increase of 73%). As a comparison, a similar emergency shutdown in the same aromatic plant on Aug 22, 1999, prior to IAMS’ commissioning, resulted in 11246 alarms.

An Intelligent Alarm Management System (IAMS) has been installed on a major refinery in Singapore. The system helps operators focus on important alarms through nuisance alarm suppression and enhances the operator ability to detect process faults and take corrective action through intelligent advisory support. The alarm rate has on average reduced by 30% to 50%, bringing the number of alarms from the industrial level of “likely to be over-demanding” to the level of “should be manageable”. Plant personnel have also evaluated IAMS guidance information to be useful. Results show that IAMS works effectively during normal, shutdown/startup as well as upset conditions and may play an important role in the prevention of potential incidents and economic loss.

REFERENCES


