Reduction of alerts in automated systems based on a combined analysis of process connectivity and alarm logs

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Abstract

Process alarm management systems alert the operator when normal operation limits are exceeded. Single disturbances can lead to an abundance of consequent alarm messages, and the alarm messages may overload the user by presenting many redundant alarms. This unwanted situation is called an alarm flood. The aim of the work presented in the paper is to reduce the number of alerts presented to the operator. If alarms are related to one another, those alarms should be presented as one alarm problem. For the realization of the ideas, a software prototype is developed to perform this reduction automatically. The analysis process starts with the alarm history which is a log containing all alarm messages. This is combined with the process topology of the controlled system and a rule framework describing interrelations between those alarm messages. The combination of these three parts gives an effective alarm management strategy that will help users to comply with standards for alarm management such as ANSI/ISA 18.2 (2009) and EEMUA 191 (2007) which set limits on the number of alarms per unit time for an operator.

Keywords: alarm flood, alarm management, ISA 18.2, EEMUA 191, rule-based system, IEC 62424.

1. Introduction

From their conception, large chemical, refining, power generation, and other processing plants require the use of a control system to keep the process operating successfully within the boundaries specified by the process designers. Exceeding these boundaries might endanger the quality of the product, the stability of the process, or even the safety of the plant. Therefore, the operators in the control room are notified by alarm messages when certain alarm limits are violated, and they are expected to take appropriate action. In the case of a plant disturbance, usually several process variables (such as pressure, level, flow, temperature) are affected simultaneously and the operator is confronted with several alarm messages within a short time interval, and might not be able to act correctly. Therefore, alarm management concepts are under development which aim at reducing the number of alarms shown to the operator, in order to improve the operator’s capability to react properly.

One approach is to determine which alarms originate from a common root cause. For example, a low level of cooling water (level low alarm) might result in a higher temperature in a reactor (high temperature alarm) and thus a higher pressure in the same reactor (high pressure alarm). They stem from a single cause and should be dealt with in a single operator action. Preferably, these alarms should not be displayed as individual
alarms to the operator but in combination, thus reducing the number of alarms without suppressing valid information.

The manual analysis of the interrelations between physical variables in a plant can take time and be prone to error, hence there is a motivation for an automated, computer-based analysis. This requires (i) a computer-accessible representation of the physical structure of the plant, and (ii) knowledge about causal dependencies of process variables. This article shows how the conditions (i) and (ii) can be fulfilled in an automated system and reports a pilot project where the concepts have been implemented and applied to real plant data.

The novel feature of the work compared to state-of-the-art industrial systems is the use of computer-readable process topology information in the analysis. The work fits into an overall context of industrial and academic activity in alarm management. Basic alarm design is broadly established in the Standards ANSI/ISA 18.2 (2009) and EEMUA 191 (2007), and best practice is captured in text books such as Hollifield and Habibi (2006). Techniques of real-time alarm management include deadbands, delay-timers, and filtering to reduce false, chattering or nuisance alarms (Izadi et. al., 2009; Adnan et al., 2011), and data-driven methods including correlation analysis (e.g. Yang et al., 2010a). Signal analysis extends to determination of cause-effect relationships and the use of signed digraphs (Yang et al., 2010b), or hybrids of data-driven and rule-based systems (Aizpuria et. al, 2009).

2. Methods

The components of the alarm analysis system are illustrated in Fig 1. They comprise a process alarm log, a description of plant topology in the form of a process schematic or P&ID, and a set of rules which specify when alarms can be grouped.

2.1. Plant topology models and alarm logs.

Object-oriented representations of processes and plants are becoming widely available with modern CAD tools. P&IDs can now be exported into a vendor independent and XML-based data format, giving a portable text file that describes all relevant equipments, their properties and the connections between them. One standard for plant topology models is described in IEC 62424 (2008) which specifies an XML schema for information exchange called CAEX (Computer Aided Engineering Exchange). CAEX describes items of equipment in the plant such as tanks, pipes, valves and instruments and how they are linked together physically and/or through electronic control signals.

The alarm system in a typical plant control system creates an alarm log. It is a machine-readable text file showing timing and location information about the alarm and the nature of the alarm (too high, too low).

Figure 1. Components of the alarm analysis system. Top: The alarm log. Middle: The P&ID. Bottom: Alarm rule library.
Importantly for this analysis, the CAEX file contains the tag names (the unique identifiers for process variables) which are also used in the alarm system. Every alarm which occurs in the plant can thus be related to an object such as a sensor or an actuator in the plant topology model. The idea is to analyze the topology model to determine whether there is a link between the locations of two alarms either through the process or via electronic signals. The aim is to impose some structure into the alarm log to make it easier to understand the causes of the alarms.

The algorithm must analyze the plant topology model for a connection between a pair of alarms which is done by searching for directional paths in the topology. It can be done several ways and the details are not the main focus of the work. In previous work (e.g. Thambirajah et al, 2009) the XML was parsed to create a connectivity matrix which could be used to find paths between plant items. In this case, connectivity was detected by direct parsing of the XML text to build up information about paths through the plant.

2.2. Rules to relate alarms in plants

Fig. 2 illustrates the rules. They include (i) the elapsed time between alarms, (ii) the types of alarms that can be grouped, (iii) the type of connection (e.g. a process product line or a signal connection), and (iv) the number and types of items of equipment in the process that can be in between the locations of the alarms. Rules about the types of alarms that can be grouped are based on process knowledge and understanding. Other aspects such as the allowed items between the alarms locations are tuneable parameters which affect the extent of the alarm grouping.

The analysis examines any pair of two alarm messages to determine whether there is interrelation between them. For illustration, two pressure alarms probably have the same cause if they also comply with some further conditions such as occurring in a short time interval and having a physical process path connecting them. Some excluded items are not allowed on this path. For example a pump may not be allowed between two pressure alarms as this could indicate different alarm causes. If two alarms trigger the rule then they can be assigned to one collective alarm problem.

Altogether, 18 rules have been collected which relate a sensor process variable alarm either with another sensor process variable alarm or with an actuator process variable alarm. An example for the latter is a valve alarm (i.e. a stuck valve) in combination with a pressure alarm. The rules have been stored using a pre-defined XML schema. Thus, they are available for the computer-based analysis algorithm and can easily be modified by the user. A rule editor has also been developed which allows users to modify existing and/or to add new rules (Fig. 3).
2.3. Analysis algorithms
The complete algorithm is depicted in Figure 5. It shows the loading of the required information followed by loops to do systematic checking against the rules. There are decisions about matching of the type of the alarms and whether the time frames are close enough to consider the alarms as related. If two alarms are grouped then other alarms are checked to see if they also belong to the group. The final outcome is a structured alarm log which contains all the information of the original log but showing the groups detected by the analysis.

Figure 3. The analysis algorithm

3. Prototype and case study
The analysis algorithm has been implemented in a software tool that is realized in the object oriented programming language C# within the Microsoft .NET Framework. This platform enabled the reuse of single software parts and includes interfaces to Microsoft Excel and XML. The developed tools were applied on an alarm log from a turbine section of a gas storage facility. Fig 1 shows the P&I diagram of this plant which was encoded as a CAEX file to make it available for the computerized analysis. Several alarm log files from this plant were analyzed by the computer-based algorithm. The structured alarm log in Figure 4 showed a 74% reduction in the original alarms by grouping the alarms. The flat operator alarm log list has been converted to a tree structure. The alarms which occurred first and last are in bold font. Other related alarms in the same group can be observed by clicking on the first alarm, these are shown in a lighter grey font.

Figure 4. The alarm log after analysis. It contains the same alarms as the original but now structured according to the groupings detected by the new alarm analysis algorithm.

4. Discussion and summary
This paper has presented practical tools for grouping alarms in an industrial process control system. Potential uses include:
- Offline mode using alarm logs to find alarms which have (most probably) common causes. These findings can be used to optimize the configuration of the alarm system to reduce the number of nuisance alarms for the operator of this plant in future.
- Online mode in the operator station. Whenever a new alarm arises, it is analyzed in combination with all previous alarms to identify if this alarm has a common cause...
with an earlier alarm or alarm group. Use of groups of related alarms will present the operator with a more compact problem to solve and should reduce overload during alarm floods.

Key features presented which have the potential to achieve the above uses are:

- A combined analysis of alarm logs and plant topology to manage alarm messages. The connection between all available data is described by interrelation rules. These rules allow the grouping of individual alarm messages into fewer groups that give a more comprehensive insight into alarm problems.
- Interrelation rules specify the search criteria for alarms likely to have the same cause. The rules consider temporal connection, type of the alarm and spatial and functional structure which can be found in the plant topology.
- The concept has been implemented in a software prototype which manages the alarm log, plant model and interrelation rules. The software analyses the resources and presents them in an interactive alarm display. The result is a compact alarm display with fewer alarm messages but a higher information density. A rule editor is also provided to create and capture new rules.
- The finished analyzer has been used to evaluate industrial case studies (Schleburg, 2011), one of which is reported in this article. The reduction of alarms after analysis was significant.

References


