Collaborative Operations Using Process Alarm Monitoring

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Abstract. We discuss alarm monitoring in process control supported by best practice used and standards implemented into recently developed engineering tools. Our paper describes aspects of a joint project development in the specific engineering company and VSB-Technical University of Ostrava. Our work focuses on monitoring assets and viewing status of conditions with help of data files acquired during commissioning process implementing the technology into practice. Alarm and event data received from technology process were analyzed according to standardized approaches with the aim to point out further limitations of alarm reports and develop an engineering tool for configuration of event and alarm limits of monitored variables in a control system during the commissioning phase under operation conditions.

Keywords: Alarms, Commissioning, Data, Monitoring, Project, Process.

1 Introduction to Collaborative Operations

In many engineering systems, the ability to anticipate and provide well-defined alarm of an impending critical event is of great importance. Various critical events can have different degrees of severity and in fact may occur during normal operation of the system. According to (Rodney, M., 2004) "An alarm may be given for any number of thermal sensation complaint events that occur over a specified time period. As such, an optimal alarm system can be designed to warn facility managers of impending complaints that might occur within a specified time period, to aid them in making critical decisions about building operations."

Diagnostics, error detection and its further processing bring other points of view at the critical state or situation monitoring. Errors or failures can occur on hardware parts of control systems, as well as in the software operating systems and programming logic controllers (PLCs), user application software or the behavior of a controlled process. Standardized procedures (Tiegelkamp, J., 2010) provide reports indicating system response to various conditions of error or malfunction. The new generation PLC has standardized basic functionality and engineers use highly sophisticated tools to program it for a variety of applications. Standardization also supports ability to integrate systems

adfa, p. 1, 2011.

assembled from standardized software components such as editors, compilers, and export and import utilities, with open interfaces for repeated functionality. Tools that were previously provided as separate and distinct modules, for example, human-machine interfaces (HMIs), simulation and/or visualization modules are now standardized interfaces of control systems, see the photo in Fig.1 showing the control room with operators and their workstations.

Fig. 1. Illustrative photo of a control room with operators and their workstations running applications with HMI (Source: A photo from a project)

During engineering practice, new knowledge constantly comes from the observed phenomena during operation and production, and the observation shows that events in many cases repeat. By storing information about these events into database allows us to access those records later and process historical data files through familiar and proven methodologies for data processing. The standardized steps ensure that the data is accurate and relevant in order to validate the data processing. Furthermore, these steps correct the data processing and organize it in sequence and/or in different files, then sort the data or put them into categories (classification), reduce the details of data into their main points (summarization), combine multiple pieces of data (aggregation), collect, organize, analyze, interpret and present data into reports. This is the way, in which the knowledge is born from data (Hýl, R., Wagnerová, R., 2016).

Knowledge Discovery and Data Mining (KDD) is an interdisciplinary field focused on methodologies for extracting useful knowledge from data. These methodologies further develop mainly due to the rapid growth of online data access and due to the widespread use of the Internet and databases. The role of extracting knowledge from data originated from research. The further development is supported, among others, by the field of statistics, but the pattern recognition, machine learning, and data visualization earns its importance as well. Areas of monitoring and control, scheduling and diagnostics represent the increasing availability of large amounts of sensor data, due to different sensors or connection to processes, its high dimensionality and variety, and complete nature of manufacturing optimization problems (Wuest, 2015).

Knowledge which comes from processed data measured during repeated observations, and evaluate common patterns, carries the added value to any development of reporting tools. The limitations of traditional Statistical Process Control (SPC) used in quality problem detection are well recognized. According to (IBM, 2012): "*Specifically, traditional SPC is largely reactive in nature, results in a large number of cumulative defects produced before alerting, and suffers from high rates of false alarms*". Assuming the subject of observation is a control system operation, its evaluation focuses on the part of the data emerging during configuration of alarm limit states of monitored variables. Then a wide area of knowledge opens, which combines the knowledge and experience in the field of industrial automation, statistical process control, and knowledge and experience of people, operators, who work with these processes and in this operation (Grabot, B., et al., 2014).

2 Standardization in Integrated Process Control Systems

The compliance with standards and principles during design of operator workstations and supervisory control system configuration process have a direct impact on innovation processes and reflect development of new requirements for control system functionalities (Brand, K.-P., 2010). The shift occurred when a standardized means of communication and technology started to be dominated by the industrial Ethernet followed by IEC 61850 standard.

Capacity of today's communication networks allows us to work with current and voltage in the so-called digital world of zeros and ones by sensors directly at the measuring element of the system, at the switch. The measured and monitored value is heading as a data entry with its time stamp directly to plants processing this item.

Although IEC 61131 standard prescribes to every PLC programmer to follow standardized procedures (Karl-Heinz J. and Tiegelkamp M., 2001), another area that must be taken into consideration when designing the control system is the functional safety of machinery, equipment and its units. In terms of production process, this part is implemented in the machine and process control with the use of control algorithms and is performed automatically. Therefore, with large and distributed control systems, the role of supervision at operator workplaces gets much higher attention and growing importance than in the past.

Data acquisition from production and technological units along with the monitored values of variables set to reporting their limits expand sources of information used in decision-making and production management. This binds the now standardized aspects of the safety of people and the environment in the area, according to the standards IEC 61508 and EN 61511, and thus generally increases complexity of control systems connected to the aspect of human behavior.

Data acquired from the technology system with system architecture structured according to ISA95 Standard (Khedher A.B., Henry S., and Bouras A., 2011) during commissioning phase provides us with data log files that contain items that hold information about each triggered alarm, see also Fig. 3. The ISA95 organizes individual parameters of specific equipment, on which alarm settings are configured for process control, and these show the information from the log files divided accordingly (MESA, 2013).

3 Real Time Data Acquisition From Control System Operation

As an example of supervisory control, we describe here the area of an alarm management system. Such system is dealing with alarm logs giving a feedback for better understanding at the level of the human-machine interface in order to improve and support the engineering work on the design, configuration and implementation of the system for an operator supervising the production and managing alarms.

1	Priorit	State	ActiveTime	ObjectName	ObjectDescription	Message	Conditio	SubConditio	Class	Severity
2	1	ACT	07 17:08:26:771	7430Q07511	SCRUBBER 1 GAS NOX	HIGH HIGH LEVEL	HH	HH	27	900
3	1	ACT	07 17:07:10:166	6414V06415	ME 4 FUEL OIL FEED VISCOSITY	HIGH HIGH LEVEL	HH	HH	18	900
4	2	ACT	07 17:03:54:268	6514L06501	ME 1 LO SYSTEM TANK LEVEL	HIGH HIGH LEVEL	HH	HH	12	650
5	2	ACT	07 17:03:29:563	6111U01734	ME2 COMMON ENGINE ALRM	ALARM	VALUE	VALUE	7	650
6	1	ACT	07 17:03:24:266	6414V06413	ME 3 FUEL OIL FEED VISCOSITY	HIGH HIGH LEVEL	HH	HH	18	900
7	2	ACT	07 17:02:33:037	8241P08124	BT1 LUB OIL PRESS LOW	ALARM	VALUE	VALUE	11	650

System | MAS | MasDataOnlyAlarm | MASdata | MASgrafy | HVAC | HVACdata | ...

Fig. 2. Data fragment directly exported from a log file used for the alarm data analysis: Priority, State, ActiveTime, ObjectName, ObjectDescription, Message, Condition, Subcondition, Class, and Severity (Source: Authors' data processing files)

The alarms as well as other data are acquired during the data acquisition process with data collection functions. The data acquisition functions determine the data acquisition processing functions. Those are the function, which are consequently applied for consolidation and the identification of the data source(s).

The database provides consistent and always up-to-date data and must be optimized in order to minimize the waiting time for the data retrieval from database into reports for the user. Process data is automatically acquired from the process as real time raw data - the primary logs - acquisition of data entries of the same time base pertaining to one specific item, the stop logs and maintenance counters. Stop logs and maintenance counters are needed for downtime management, for troubleshooting and maintenance, and they are not further compressed or consolidated. Primary logs are compressed to save space when archived, and to speed-up trend graphical display.

The compressed data is stored in the database as compressed logs. In addition, primary logs are used to create secondary logs for hourly, shift, daily, weekly, monthly and yearly data. The creation of secondary logs is referred to as data consolidation process.

As described above, the control systems save readings and history about monitored variable courses into logs, events and alarms. An **event** is recorded when the variable changes its value within the defined working interval, while **alarm** is identified as a change regarding the exceeding limit of the working interval.

The alarm logs inform us about the time, value, frequency of reaching or exceeding maximum or minimum limits set for the monitored variable during the observed time interval. Both the maximum and minimum limits can be defined at levels of severity, for example high (H) and very high (HH), low (L) and very low (LL).

In our work we dealt with system modules determined for alarm handling and alarm management and focused on operator performance, when alarm is raised, what actions need to be done, metrics and benchmark values for design principles. The files with data regarding the time, values, set limits, acknowledgment status, frequency of events, date of last reset interval, alarm log creation, and similar information were acquired from the exported data from the control system alarm logs and elaborated as described further.

4 Implementing Control Systems in Operation With the Support of Human-Machine Interface

The problems occurring during implementing control systems into operation will show and can be identified based on looking into data from the control system during the commissioning phase of a project and talking to the operators of the technological process at the customer site. Discussions with the operators about the system implementation and further alarm performance analysis from the real time operation is also supported by using methodology from approved standards, such as the ISA 18.2 and EEMUA 191 (ANSI/ISA–18.2, 2009). These two standards prescribe the function of alarm systems and recommend their design. (Emerson Process Management, 2015). Together with the definition for specific areas, they also set the average number of alarms per day, and the maximum number of received alarms per 10 minute period. The operator should not be overloaded with more than 1 or 2 alarms within 10 minutes. The overloaded operator is then defined as the operator working under condition, when more than 10 alarms are received and displayed at an operator workstation within a 10 minute time period. According to the EEMUA 191 standard, alarm performance parameters, such as:

- Average alarm intensity
- Maximum alarm intensity
- Percentage of alarm intensity beyond reasonable target

can be set for each 10 minute period. The ISA 18.2 Standard further recommends not using more than 3 or 4 types of alarm priorities and more than 5% of alarms set for the highest priority (Honeywell Process Solutions, 2011).

Having these parameters defined and standardized in a process industry, it is possible to analyse data logs in several ways. For example, looking at the problems occurring during implementing control systems into operation and during the Functional Acceptance Test (FAT), the acceptance testing conducted at the site determines if the requirements of a specification or contract are met, which involve performance tests.

By acquiring data from the control system during this phase of a project, the commissioning engineers realize that the same data logs indicate and provide much more information about the real time operation. This motivated us to analyze alarm logs from different technological processes and corresponding operator responses from the supervisory control system in plants, where the control system was implemented (Urban, P. and Landryová, L., 2016).

5 Designing and Testing the Engineering Tool for HMI Part of the Control System

The first step to design the analysis procedure was the data preparation by calculation done with the data files with the aim to determine time intervals for logs according to the Alarm Rate definition.

Table 1. The Example Of Calculated Frequency Of Alarms For Each Equipment And Defined Interval (Source: Authors' data processing files)

Equipment	*Different time [min]*	*Time of generation one alarm [min]*	*10 [min]*	*20 [min]*	*30 [min]*	----	----	*160 [min]*	*170 [min]*	*180 [min]*
L21/00	*154115*	*180,00*	*0*	*0*	*0*			*0*	*0*	*1*

For example, the time difference between the last reset of the equipment *L21/00*, date in *Reset date* column, and the log creation, date in *Create log date* column of Table 1, was 154115 minutes. For this equipment data log, 854 alarms correspond to the given time interval; The average time calculated for events logged into the equipment was 180 min., the result was written to the Table 1 and this step was applied for other equipment and their data logs.

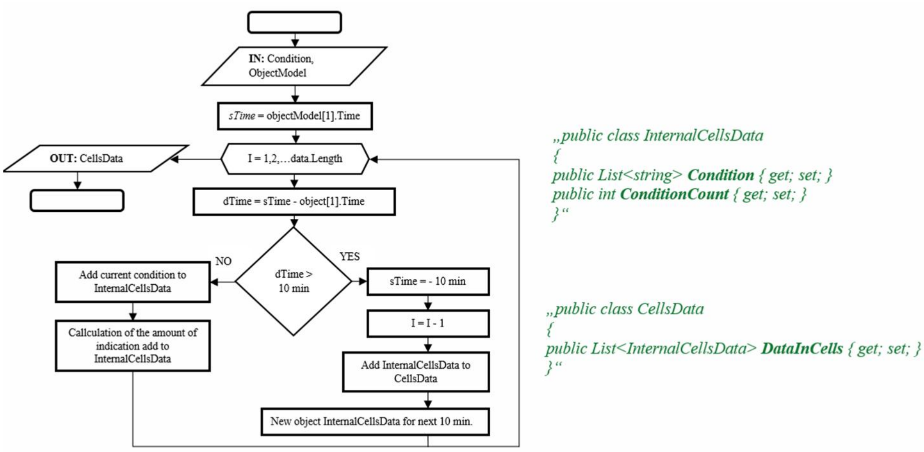

Fig. 3. A flowchart and a part of the code for the design of the engineering tool algorithm (Source: Authors' design of algorithm)

The Fig. 3 shows a flowchart for the code, based on which the engineering tool was built. The results were tested and compared with the manual calculations and verified the correct function. The commissioning engineer can now import the log file from a control system into this tool, and the program code will prepare the alarm model with the help of its Array Mapper according to the standards described above. The algorithm will then create the time intervals and will process the alarm data into form ready for graphical format according to the EEMUA 191 standard.

6 Conclusion

The main objectives of this work were to address the extensive amount of analyzed data logs and develop and provide a tool for engineering, which will help project commissioning engineers and process systems operators to manage alarms in control systems and meet the standards. The engineering tool developed for the purpose of alarm system analyses enables now a commissioning engineer to analyze the newly configured control system before it runs in full operation on various technology and protects the operators from alarm overload defined in the EEMUA 191 standard.

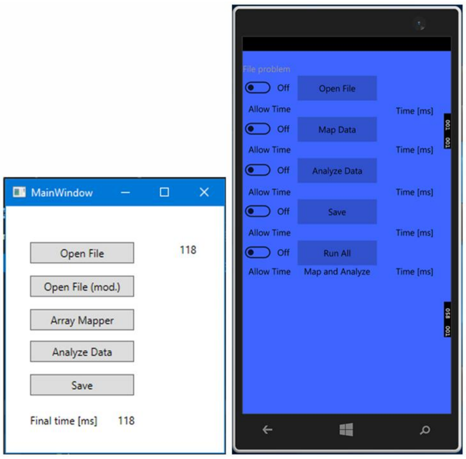

Fig. 4. Engineering Tool was tested as a console application for PC user interface and a smart phone user (Source: Authors' scan and a photo of a mobile phone)

The engineering tool now joins the group of tools used in the practice and enables interoperability of control systems and human operators, defined as the component of an intelligent production company management communicating by IoT (Internet of Things) and IoS (Internet of Services). Using this tool provides the "virtualization", as it gives the ability of interconnecting the physical systems and a virtual model with a simulation during commissioning phase before the system is in a full time operation. Furthermore, the tool supports the decentralization idea for decision-making in subsystems and the ability of working in real-time, which is the key factor for any communication, decision-making and control of process systems. Finally yet importantly, the newly developed tool configurability and modularity comprehend the Industry 4.0.

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