Alarm and Event Analysis for Batch Process Improvement

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KEYWORDS
Alarm and Event Analysis, Batch Event, Event Balance, Productivity Improvement

ABSTRACT

Alarm and event analysis has long been used for improving process operation. However, since alarms are usually generated and displayed based on physical equipment, alarm analysis has been difficult to perform on a batch basis.

In this paper, we focus on the interrelation of alarm/message notification and operator reaction in a batch process and analyze them systematically according to S88.01 Models and Terminology. Balance patterns of alarm/message notification and operator reactions are visually analyzed. Batch based analysis is done by grouping and filtering alarm and event data by master recipe, procedural hierarchy, and batch unit. This makes it easy to find and improve spurious alarms and inefficient operator habits.

In a brief experience in a pharmaceutical plant, spurious alarms have been reduced by approximately 30% and smoother operation procedures have been implemented.
INTRODUCTION

Lonza's Riverside plant manufactures bulk active ingredients for the pharmaceutical industry. A new, fully automated multipurpose reactor train was installed in early 1996. This train includes ten 500 to 1500 gallon vessels used for reaction, distillation, phase separation and crystallization; two centrifuges for isolating finished products; and two dryers. Automated support equipment includes a bulk metering station, five vacuum pumps, four process scrubbers, and four weigh scales. In order for producing a variety of products, approximately 20-30 batch processes are concurrently running on this train. We have been investigating the alarm and event history of this train since Sept. 1998 for improving the operation efficiency. We started investigating the relation between the alarm notification and the operators reactions. In order to analyze their relation numerically, we measured the frequency of message notification and operator actions in the historical event database. As the investigation proceeded, we have found that the frequency increase patterns of alarm notification and operators’ reaction are interrelated. Furthermore, some increase patterns are synchronously found with specific recipe operation/phases duration. A similar frequency increase pattern shows a possible area for improvement activity. A different pattern in a save phase of a batch shows a batch specific problem area.

EVIL OF EXCESSIVE ALARM NOTIFICATION

A fine chemical plant is producing variety of products at the same time. Although all the batch procedures are automated and controlled by DCS systems, operators still need to watch the process and manually initiate each sequence. The control system notifies operators with alarm messages to direct their attention to unexpected situations. Guidance messages are also often used to prompt operators for permission to proceed with the next step in a procedure. Because a number of recipes are loaded on the system and cycle times are critical, precise and timely operators reactions are essential to keep the plant productivity, and the controllers alarm and guidance message notification is important. But as the system grows and the process become complex, the number of alarm detection points increases and operators are often overloaded with the excessive alarm notification. Operators tend to ignore excessive alarm notification and may miss an important alarm message among less important messages. It is difficult to keep adequate message frequency level for operators in order to maintain high level of productivity.

EVENT BALANCE OF PROCESS REQUEST AND OPERATOR ACTIONS

Alarm messages are notified to operators to react in some way. In this sense they are “Process Request” of which the production process requests for the operators’ reaction. Because the operators start their actions by watching the console messages, the number of operator actions should be interrelated with the number of message notifications. On the other hand, there are the cases that the
alarm message notification increases when the operators action is not adequate. In both cases, Process Request and Operator actions are interrelated.

Figure 1 shows an event balance trend chart of a day in the train. By counting messages notification for each divided time period, the message frequency can be quantified and visualized as a trend graph. Operator action frequency can be also quantified by counting the operation records. By comparing message notification frequency and operation frequency on a balance trend graph, whether the operator was busy for dealing with alarms or not can be viewed. It shows the balancing event frequency for each ten-minute period for a day. The bar size for the upper direction shows the process request message (alarm, guidance) count per minutes. The bar size for the down direction shows the manual operation frequency per minutes for each 10 minute period.

![Event Balance Trend Graph](image)

Figure 1. Event Balance Trend Graph

As shown in this graph, the process request frequency and the operator action frequency show interrelations. It is easy to find out when the operators were busy (7:00-9:00 for example). At 11:00 there was a process request peak, but the operators reaction frequency was not increased. By investigating message records in this period, we found that high pressure alarm messages were repeatedly generated because the nitrogen pressure controller’s range setting was not adequate. In this way, the meaningful message and spurious messages can be distinguished easily by comparing with operator reaction frequency.
EVENT BALANCE ANALYSIS OF A BATCH PROCESS

As the next step, we applied this balance analysis method to a batch process. Figure 2 shows how an event balance trend graph for a batch process is made. Figure 1 shows the event balance of process request and operator action trend for a day. A batch graph is expanded its start/end time range from a day to the batch start/end time. The center box in Figure 2 shows one day event balance on 3/5, and its start/end period is expanded to whole 22-9DAP batch period (from 3/2 13:00 – 3/7 17:00). Then only 22-9DAP batch related events (event messages tagged with the batch-ID) are retrieved for calculating the process request and operator action frequency.

![Figure 2. Expand Daily Event Balance Trend Graph to Batch Start/End period](image)

This batch has 4 unit procedures. In order to compare the relative timing relationship with the batch procedure, 4 box bars are added on the graph to show the unit procedure duration as a Gantt chart form as shown in Figure 3. By looking at this figure, the process request peak and the operation peak are synchronous with a specific operation of a batch procedure. Figure 4 shows 9DAP recipe structure and a part of SFC chart of No.1 Unit procedure and No.2 Unit procedure. They are also marked as “Operation R160 and R260” in the balance chart. In that period, the balance chart shows there were some process request messages and operator reactions. In this phase, the operators must confirm the material status with their eyes and manually open/close the transfer valves. At 17:00 on the balance chart, there was a rush of manual operations. The operator has to manually adjust the plow position to remove the cake which is dried in a centrifuge.

In these ways, the combination of a batch event balance chart and unit procedure duration blocks makes it easier to review a batch process.
Figure 3. Batch Event Balance Trend Graph (1)

Figure 4. 9DAP Recipe Structure and its SFC(partial)
Figure 5 shows another batch balance trend graph. Because the procedure (recipe) of this batch is the same recipe shown in Figure 3, the balance peak patterns show similarity. By comparing several balance charts, similar process request peaks and operation peaks occur synchronously with a certain operation/phase of the batch procedure.

Figure 6 also shows another batch event balance trend graph of the same recipe. Some differences can be noticed in this chart. Primary there was a rush of answerback error messages at 4:00 on 3/11. This was caused by a problem with a non-critical field device leading to a large number of answerback alarms. Also there was a larger number of manual operations during the execution of Unit No3. This was due to a more difficult cake removal operation in the centrifuge.
We found those repeating answerback errors are not as meaningful for the operators as other messages among that period. The answerback timer can be adjusted in the controller function block for the field device and by making this adjustment we eliminated these spurious answerback errors so that the operators may not miss more important alarms.

**APPROACH TO A PROBLEM AREA**

In order to approach to a problem area, finding a key event among huge number of event records is important. In order to find out problem areas introduced in this paper, we used the following filtering key in the event database.

- Event Time Stamp
- Batch ID
- Operation/Phase ID
- Physical Equipment ID (Tag, Unit)
- Plant Hierarchical ID (Area, Cell)

By narrowing down the balance trend graph with these filter keys, a specific problem area can be found easily. For example as shown in Figure 7, F4272PDI36 (Pressure Differential Indicator) was turned to be generating spurious alarms in a certain situation.

![Alarm Frequency of F4272PDI36](image)

Through our investigation, we found the following 5 problem areas:

1) **Inadequate Alarm Set Point (high/low limit)**

   When the high/low limits for the indicator are not set well, high/low limit alarm can be generated frequently which may not be essential. There are also some cases that high limit and high high (extreme high) limit values are set closely, which cause high and high high alarms to be generated together. This problem was mainly detected in the material transfer phase between reactor units.
2) **Invalid Scale Range**

    If the instruments are operated in a range close to its limit value, “Input Open” errors are detected often and operators are disturbed. In this case, it is desirable to tune the indicators scale range adequately.

3) **Invalid Timer Setting**

    In the stirring phases, frequent answerback error were notified for changing the motor speed. This was due to the invalid timer setting of the controller, and we adjusted the response timer settings.

4) **Redundant Alarms**

    When some equipment indicators/controllers are integrated as one unit, a unit alarm may represent the substantial indicators/controllers alarming state. But there are some cases that the underling blocks generate an alarm message together with the representing alarm messages.

5) **Manual Operations**

    Some operations required much more operator intervention than what had been expected – perhaps a machine or field device is not working properly, a loop is poorly tuned, or a phase was poorly designed. The event balance trend graph could quickly reveal such operations and lead to improvement actions.

By eliminating these spurious alarms, approximately 30% of alarm messages are reduced (about 350 alarms / day were reduced to 250-300). Because the spurious alarm was causing the operators confusion, operation procedure become smoother after the improvement efforts.

**CONCLUSION**

It is not easy to keep the productivity of a batch plant consistent because many batch procedures are concurrently running and their recipes are changed often. Even once an improvement measure is installed, its effectiveness may not last long. The key to increase batch productivity is to find the problem area as quickly as possible and to apply countermeasures immediately. We found the event balance trend graph of a batch process shows exact problem areas to be fixed. “Process Request” and “Operator Action” frequency should be balancing and a problem can be found where they are not balanced. Overlaying the unit procedure execution period on a batch event balance trend can narrow down the exact operation/phase in the procedure to be improved. The analysis can lead to ideas for automation schemes that have a dramatic impact on the amount of operator interaction required to operate plant equipment. Improvement is possible from both directions – both the reduction of spurious alarms/messages and the reduction of unprompted, unexpected manual operations.