Control Room Information for Batch Processes

Milton Crofts  
Aroma and Fragrance Chemicals (AFC)  
Widnes, UK  
Phone:  
Email: Milton_Crofts@afchemicals.com

KEY WORDS

ABSTRACT

The way information is displayed in control rooms in the process industry has developed a long way from the original gauges, chart recorders and lamps to the sophisticated windows based Graphical User Interfaces (GUI) of today. But does the increased ability to acquire and to display more data mean that better information is conveyed than before? This paper describes how the technology available recently has not been used to its full potential in control rooms. A methodology is then developed to make use of the available technology in order to assist in the delivery of information to control room operators. In particular the paper addresses the problems in the presentation of plant data in the context of batch processes.

1. Introduction

The way information is displayed in control rooms in the process industry has developed a long way from the original gauges, chart recorders and lamps to the sophisticated windows based Graphical User Interfaces (GUI) of today. But does the increased ability to acquire and to display more data mean that better information is conveyed than before? This paper describes how the technology available recently has not been used to its full potential in control rooms. A methodology is then developed to make use of the available technology in order to assist in the delivery of information to control room operators. In particular the paper addresses the problems in the presentation of plant data in the context of batch processes.
2. A brief history of data acquisition and display

From the early 1980s, developments in computer technology brought down the costs and made it widely available. Primitive graphical representations of processes started to become available around this time particularly with the introduction of DOS. From the mid 1980s the combination of PC based computing, colour graphics and the introduction of the Programmable Logic Controller (PLC), gave rise to cost-effective data acquisition and display capability suddenly available across the process industry.

The DOS based displays were limited in the amount of data that could be displayed. This limitation, however, forced designers to think carefully about how displays were configured and arranged. Usually, there would be a series of overview displays from which lower level plant and instrumentation type displays could be accessed. The manipulation of data into information at the display level was difficult, however, and the display of raw data predominated. There was no real consensus about best practice regarding the layout of displays, neither was there even any standardisation of colour schemes. Only a handful of colours were available but even so colour schemes tended to vary from company to company.

Apart from the ambiguity of information conveyed through colour there was also an overuse of alarm data. The developments in DCS and PLC technology not only meant that more data could be acquired but in addition a series of attributes, including alarms, could now be associated with each signal. Those involved in the configuration of these plant control systems tended to set alarm limits on all signals, often at quite arbitrary levels. Thought was rarely given to the kind of action the operator may need to take on receiving such an alarm. The assumption, if only a subconscious one, was that more equals better. The result, however, was that a large number of alarms were raised on some kind of alarm banner that held no meaning whatsoever to the operator. Worse still, where useful alarms did exist they tended to be buried within a stream of irrelevant data.

The absence of standardisation or even of a clear idea of best practice was further complicated by the introduction of windows based displays at the end of the 1980’s. Of course windows and Microsoft in particular brought much-needed standardisation to control systems hardware, software and networking. But the even greater flexibility in the presentation of data caused other problems.

Now there is in practice an infinite number of colours available, multiple windows, three-dimensional and animation effects, video imaging and much more functionality. When asking a designer why he employs a particular technique in the configuration of a graphic he is quite likely to reply “because I can”. Glancing at the marketing documentation of any control systems vendor one can find an abundance of all of the functionality described above and more brought together in multi-coloured and multi-faceted displays. But have all these developments in technology necessarily improved the efficiency of conveying information to the process operator? For example, does a sophisticated three-dimensional representation of a valve convey any more information than a simple ISA symbol? These questions will be addressed in the following sections.

3. The Process Operator
The role of the operator has changed in many instances over the years from one of active engagement with the process on a manual plant to one of relatively passive monitoring of an automated plant. This is not to say that the role of the process operator has been diminished. Indeed, with the enhancements in the ability to acquire and to display data, the operator has more potential than ever to keep processes in control. Operator response to an abnormal situation is a key factor in loss prevention and therefore in the profitability of the company.

The abundance of data, however, and the lack of useful alarm information has meant that the operator can in practice still only operate a small number of processes. This is because the operator must monitor large amounts of data in order to determine the current status of the processes for which he is responsible. Clearly the operator can only assimilate so much data and it is this that limits his scope of responsibility. In a situation where operators are deployed to be dedicated to a particular process then it is likely to be the case that they will have to perform both control room and field operations and this can further undermine the ability to use limited resources efficiently. In Figure 1 the changes in the level of information required is shown with respect to the number of process operators per process and the level of automation.

The technology now available has the potential to deliver information to the operator in a far more efficient manner than in the past but this implies a significant change in the mode of operation. Or, to put it the other way round, pressure to reduce operator head count has meant that new modes of operation need to be found and this is forcing changes to the way that plant data are displayed. Best practice in the industry points to using dedicated control room and field operators but also recommends rotating operators between processes and between control room and field operations.
In the mode of operation proposed above the control room operators would need to monitor many more processes than on the traditional site. To achieve this, mechanisms need to be found to deliver information to the operator rather than the operator having to scan data.

4. A methodology for improved delivery of information

With modern plant control systems there is enormous flexibility in how data can be presented. In practice the tools are now available for the designer to achieve almost any display format that he can imagine. Add to this the sophisticated alarm handling functionality that is generally available then it should be possible to deliver information reliably and in a timely fashion to the control room operator.

The methodology proposed here seeks to apply the technology available and the current thinking in best practice in order to address the following issues:

- Display Colour
- Display Hierarchy
- Overview Displays
- Operation Displays
- Alarm Handling

The interest here is focused on batch processes. The proposed methodology pre-supposes that the processes in question are highly automated and are controlled by use of a modern batch management system. Normal operation should entail little operator intervention in the control room apart from having to respond to various prompts to select plant or to input data.

4.1 Display Colour

In the industry a consensus is emerging about best practice in the use of colour for operator displays. In general a cool screen approach should be adopted. The cool screen avoids the use of bright colours but utilises greys, blues and greens for normal operating conditions.

Abnormal situations should be brought to the attention of the operator by the use of small areas of bright colour, typically yellow or red. It is possible to provide additional focus by flashing an unacknowledged alert.  

With batch processes pattern recognition seems to play an important part, not just to identify plant status, but also to assist in the awareness of sequencing. For this, changing the distribution of colour is a very effective method to inform the operator precisely which stage of a process is active.
Contemporary discussion often focuses on the ergonomics of control rooms and some of the issues surrounding this are brought into current thinking on use of display colours. For example it is recommended to design displays to be of low contrast in order to avoid eye strain. In addition a light background is recommended to help optimise the overall lighting effects of the control room. Although it is the case that displays designed along these lines can be pleasing to the eye, care should be taken not to lose important information. For example there may be several identical processing units, in which case prominent labeling would be required in order to avoid confusion and mistakes. Also, it has been found desirable to be able to identify process variables quickly on a display. Both of these examples require high contrast areas within displays. Other objects may be of low contrast. For example level or temperature switches can blend into the background unless in the alarm state.

It is clear, then, that it is necessary to take a balanced outlook with respect to the use of colour. On the one hand take into account current guidelines. On the other hand never lose sight of the overall objective to convey information.

4.2 Display Hierarchy

The objective is to develop a display structure that facilitates an expansion of the scope of operator responsibility. To achieve this the number of displays per process must be reduced as the operator can only assimilate information from a limited number of screens. This suggests a layered, hierarchical approach whereby detail is increased towards the lower levels of the structure.

In principle the hierarchy can have many layers from site overview down to individual device. The number of layers, however, is dependent on the individual application and on the type of process. Reporting by exception should be employed as far as possible whereby the operator should only be alerted to a particular process when a problem is occurring. Batch processes, however, have the added complexity of sequencing and the need for the operator to know which stage of the process is currently active. A control room operator may well be coordinating a team of field operators, so field operations such as sampling need to be scheduled. To achieve this the control room operator needs to be aware of the sequence at unit level, and this effectively sets the top layer of the display hierarchy for the operator workstations in batch processes.

For batch processes there may well be higher level displays that are appropriate for supervisors and production management. In addition a site overview may be useful to show which plants are active and to indicate whether or not they are healthy. A technique sometimes adopted is to display a site overview on a large wall mounted screen. Here we will develop a methodology with respect to the operator workstation and, as such, use the unit process as the highest display level. The methodology may be expanded easily to a multi-layered structure using the same principles.

4.3 Overview Displays

In Figure 2 an overview display is shown for a reactor unit process. An overview should be of an abstract nature that assists in providing a conceptual view of the process similar to that of a process flow diagram. It is important to note that the overviews generally need to be process specific. In the experience of the author, to attempt to build a general reactor overview would tend to clutter the available space with information that is irrelevant to the process in question. A reactor such as the one shown may well be a multi-purpose unit used for a number of processes utilising a range of
associated vessels and services. A separate overview should be configured for each process rather than attempting to display everything on a single graphic. This approach undoubtedly adds to the engineering effort required for the configuration of the displays but it assists in the clarity of information.

The various objects on the display are ordered to reflect the process sequence and to indicate the various services available to the reactor such as temperature control and vacuum system. A banner is provided at the top of the display to give process description, summary batch information and some key process variables. The colour scheme is simple: Grey is inactive or normal; green is active; yellow (or yellow flashing) represents failed or alarm; different shades of grey are used to provide varying focus to different objects containing summary information. The colours of lines simply indicate whether or not the line is completely open. That is green for open and black for not open. For additional clarity it is useful for operation specific information to be visible only when the particular operation is active. In figure 1 the target and actual charge weights for material 2 are shown along with the time taken. This information disappears when the charge is complete.

Figure 1.
Each block on the display contains summary information pertaining to the underlying operation. For example the block labeled *Material 1* contains summary information regarding the charging of material 1 to the reactor. Specifically at this overview level the information should be the result of a comparison between the *intention* and the actual *outcome*. When there is no request to charge, then the block is deemed to be *inactive* and is colour coded grey. When a request for the charge is received then the block flashes yellow until such time as the line is fully open, at which point the block turns green to indicate *active*. If, at any time during the charge, the *outcome* no longer matches the *intention*, then the block is deemed to be *failed* or in *alarm* and flashes yellow. If the problem that has caused the charge to halt is due to one of the services then that block will also flash yellow.

As indicated already, the overview display contains summary information only. To diagnose the specific nature of a problem it is necessary to access a lower level, operation oriented display and this is achieved by clicking on the block of interest. Operation-oriented displays are described in the next section. It should be noted that the delivery of abnormal situation information is assisted by use of the system alarm handler. This facility is also described in a later section.

### 4.4 Operation Displays

Operation-oriented displays represent the layer in the display hierarchy below the process unit overview. These displays provide a detailed view of a particular process operation or service.

In Figure 3 the display is shown for the operation to transfer the contents of the stripper vessel to the reactor and may be accessed from the stripper block on the overview. The display is similar to a plant and instrumentation diagram in that it shows objects down to equipment level. It differs from a P&I diagram in that, instead of focusing on a single processing unit, it displays the relationship between two processing units. It shows all of the plant and instrumentation that is required to transfer the contents of the stripper to the reactor.
The colour scheme is similar to that of the overview: green for valve open, pump running, and line open; black for valve closed, pump stopped, and line closed; and yellow for failed. For status switches grey represents normal and flashing yellow for alarm. Process variables are displayed as green values on black backgrounds. These may also flash in alarm if configured to do so.

Often there can be other device attributes apart from open or closed that are desirable to be visible at a glance such as the following:

- Device interlocked
- Field or DCS mode selection
- Multi-state device

There are numerous examples of additional attributes that one could provide but in general it is a good idea to present these attributes as shaded areas of the main device symbol. In the example given an interlock is shown as a light grey shaded region of the pump or valve.

The level of detail on the operation display should be such that a quick diagnosis of any problem is possible. As a minimum any interlock that could prevent the operation from taking place should be shown. Where it would be too cumbersome to show a particular interlock, say because it was part of another subsystem, then a reference may be made to it by way of a block similar to those used on the
overview. In this example references are made to the vents of both vessels and to the condenser of the reactor. These are shown as blocks at the top of the screen. These blocks imply that there is one or more aspect of these sub-systems that may cause the transfer operation to fail. A high vent line temperature would be a typical example of this, and would be indicated by the block flashing yellow as on the overview.

Other supporting information may be incorporated. In this example the transfer is complete when the stripper vessel is empty. The test to determine that the stripper is empty is indicated by the three blocks on the left-hand side of the display. These three blocks show green while the transfer is taking place and all must go to grey for the system to decide that the transfer is complete.

Under normal operating conditions the display should exhibit a cool effect as shown. Flashing objects would then quickly attract the attention of the operator to a problem. Ideally, when the operation is inactive the display should remain cool. To make sure that nothing flashes when the operation is not active, however, can take a great deal of effort. Careful consideration should also be given to start-up or maintenance conditions in order to avoid spurious alarm information.

It is important not to make the displays too complicated. If detailed information about a particular object is required then this can be achieved by clicking on it. With Visual Basic for Applications now embedded in the display software of many control systems it is possible to exercise a great deal of control over the kind of information that is accessible. For example it is possible to click on an object to pull down a menu that would provide access to drawings, specifications, webcam, etc as well as a faceplate for operational purposes. Links to other displays or to other data sources are useful, but these should not clutter the display. If a large number of links are required then they could also be accessed from a drop-down menu. Three-dimensional objects should be used with care. If a three dimensional view of a valve is required, for example, then provide a link to a drawing from a drop-down menu and keep the valve symbol simple on the display.

4.5 Alarm Handling

It is first necessary to define what is meant by an alarm.

“An alarm is advice to the operator that immediate action is required.”

There has been great interest in the management of abnormal situations in recent years, particularly since the Milford Haven disaster in 19945. The focus has been on alarm system performance, alarm reduction techniques, and the display of alarm information in general. It is not the intention here to rehearse any of the arguments surrounding these issues but to place some of the ideas in the context of control room information.

Where operators have been dedicated to a particular process and where meaningful alarm information has been absent, it has been the operator who has acted as a de facto alarm system. With the luxury of many detailed views of the plant the operator has been able to identify abnormal situations as they develop. This is not to say that an operator in this situation would not have seen some benefit from meaningful alarm information. On the contrary, this is quite a risky mode of operation not least because the operator would not to be able to view the entire plant in this manner.
In addition if the operator was required to be absent from the control room for any reason then a colleague would have had to cover, often struggling to manage a process for which he may have received little or no training.

In the mode of operation proposed in this paper, alarm information becomes even more important. As the operator must monitor more processes, he cannot hope to view them all in detail. Now information must be delivered comprehensively to the operator.

The method of reporting by exception through operator displays described above needs to be complemented by an audible alarm facility and a system for managing alarms. Much has been written about the kind of facilities that should be available in an alarm management system. In fact any good DCS or SCADA system provides all of the recommended functionality in some form.

The practicality of designing and configuring an alarm system is far more problematic than selecting the best product. To make an alarm system effective, a great deal of intelligence must be built in to filter, enable and disable, dynamically adjust settings and otherwise manipulate individual points. This is exacerbated in batch processes due to the many and varied process states.

The key to a good design of an alarm system is first to design the alarms. Initially it is a good idea ruthlessly to remove any alarm that does not conform to the definition of an alarm quoted above. So, for each alarm there should be a written procedure that details the action that should be taken. There are those in the industry who propose that there should be an informative alarm that requires no action in itself but alerts the operator to a developing problem that may soon require action. This level of alarm certainly makes sense but it is better to get the main system working first and gain confidence in it as this then provides a good foundation for further refinements.

Traditionally the activation of a safety related hard-wired trip has been brought to the attention of the operator by use of hard-wired annunciator panels separate to the DCS. Although it is often the case that this category of alarm does not conform to the definition of an alarm given above, it is still necessary for the operator to be aware that a trip has occurred. It is desirable for the operator to check that the hard-wired trip has operated correctly for example. There is no real reason to keep the hard-wired annunciator panels, however, as the data could easily be incorporated into the alarm management system of the DCS and the panels themselves tend to clutter control rooms. The trip initiators should be connected into the DCS anyway such that they can be incorporated into interlock logic as a mimic of the hard-wired trip action.

5. Conclusion

Increased automation in the process industries has resulted in fewer process operators. These changes have resulted in a need to change the way that process plants are operated. In particular there have been changes in the way that process information needs to be presented to the operator.
The intention here has been to develop a generic methodology for the display of batch processing information in the control room. As such the methodology is not prescriptive in how this should be achieved but it is assumed that in a modern plant control system the necessary tools will be available to implement any design.

A philosophy of reporting by exception has been adopted such that control room operators may be quickly alerted to abnormal situations. The approach has been to adopt a layered structure for displays coupled with a well-designed and closely integrated system for alarm handling. Displays are kept as simple as possible throughout the structure and careful consideration is given to the use of colour. Where detailed information is required it should be accessed using navigational tools rather than cluttering main graphics.

Above all the emphasis has been on the delivery of key information to the control room. Data that are of no significance to the operator have no place on displays or in alarms and should be avoided. Information is about assisting the control room operator in his job. On a highly automated plant the job of a control room operator is to prevent loss by intervening to keep the process under control where it is not possible for the DCS to do so. In this sense the control room operator is only as good as the information he receives.

References

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