Refining reliability

Scott Stout, Nexus Engineering, Inc., USA, discusses reliability and operations management applications in hydrocarbon processing plants.

'A week of unscheduled downtime is worth a year of advanced process control benefits'.

Initially applied to narrowly focused applications in refineries, petrochemical and chemical plants, rules and procedural based software technologies are now being deployed for reliability and operations management applications in these plants to provide a broad range of operational benefits. These industries are a mix of older and newer technologies and facilities. The refining industry in general is a mature industry with older plants and technologies. Today's petrochemical plants are typically the result of the newer process technologies built or revamped over the last 15 years and positioned to quickly deploy the newer automation technologies. The newer units have the open architecture control systems and digital instrumentation to form the infrastructure for the high return advanced automation applications. The older units require migration strategies to the new architecture in order to become competitive.

The current generation of plant management have built their careers on leveraging the new process and automation technologies for competitive advantages. The investments in advanced control applications are no longer based on if the applications will work, but on where they should be applied to deliver the maximum return on investment. The plant operations philosophy has shifted from merely running the unit, to the management of the process operations.

Automation as a competitive strategy

Although hydrocarbon processing plants deploy various automation technologies, they are being deployed at different rates. Some companies are pursuing optimisation while others are still deploying the multivariable controller applications. As new technology becomes viable, it is eventually deployed throughout the industry. As a result, today's breakthrough technology becomes tomorrow's basic automation platform.

Among these plants, there is a 'pace setter' group comprising top performers, typically leading in a number of performance metrics in addition to automation.

The progression of deployed technologies contributes to the continual improvement in the median performance levels of hydrocarbon processing plants. Companies with moderate investment strategies merely remain in their industry position, while those with flat investments fall behind. The upward migration of the performance curves drives the need for deploying emerging technologies early in their lifecycles. The contribution to the company's performance relative to its industry peers is dependent upon how quickly the benefits were realised before they became the new base level of automation.

New issues have emerged as companies have become experienced with the automation technologies. The applications provided the expected benefits but they also exposed critical automation areas that remained unaddressed. The automation areas now being addressed are the reliability and operations management (R/OM) applications.

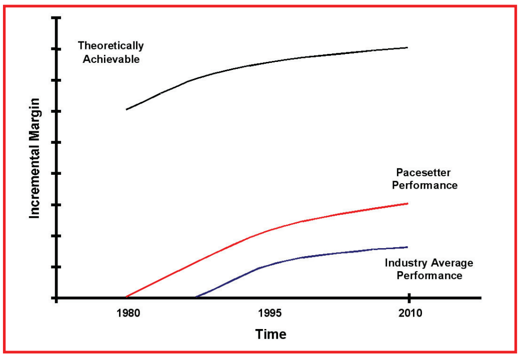

Figure 1. Industry automation trends.

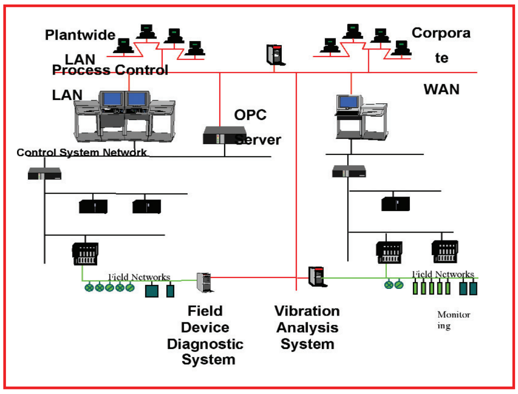

Figure 2. R/OM system server.

Reliability issues

The availability of operations performance information from the initial information technology and control projects increased management's awareness of actual operations economics. This improved understanding of the plant operations generated initiatives to improve the plant's reliability and safety. The initial reliability initiatives were focused on the maintenance and mechanical integrity of the equipment because the organisations driving these initiatives were more familiar with these aspects of the client's business.

With recent benchmarking data indicating that approximately 70% of reliability issues are process induced with the other 30% being mechanically induced[1], the plant reliability groups are now expanding their initiatives to address asset utilisation and process reliability. The reliability focus has enabled the sites to identify the historical performance, but has done little to provide the real time assessment of the issues in time for them to be impacted by the operations personnel. The issues were typically identified after the damage was done.

Operations issues

The newer distributed control systems (DCS) and the advanced control applications provided a wide range of benefits over the earlier operations environments, but they also created new operational issues:

- Operators initially were responsible for 30 - 50 loops with the older panel board with single loop controllers. The newer distributed control systems increased the typical loop counts to 100 - 125 per operator. The addition of the advanced control applications enabled the loop counts to c limb to more than 200 and in some cases over 350 loops per operator.

- Extensive alarm annunciation at predetermined points within the instrument range.
- Providing a platform for value added technologies such as multivariable control and real time optimisation.

Unfortunately, these strengths often make it more difficult to identify the root cause of process problems and develop appropriate responses. This has resulted in a less than optimal reliability factor for most processing facilities. Factors affecting this decline in reliability are:

- DCS alarms are typically limited to monitoring specific parameters at pre-assigned levels within the operations range. While this level of parametric alarming is important, it doesn't provide the complete picture of the problem. A more process focused diagnostics system is needed that correlates data to identify problems early in their severity level.
- Pre-defined alarm limits must be configured appropriately to prevent nuisance alarms over the full range of operation. Very little attention is given to performing diagnostics within the 'normal' operating range. Examples of where this causes problems are frozen or hung transmitters, or deviations within range that affect associated control loops.
- The parametric alarming function provides cryptic descriptions of the upset condition ('FIC101 High'). Operators waste time deciphering these alarms rather than focusing on taking the appropriate corrective actions.
- A larger concern is the very common occurrence of alarm flooding, whereby the operator receives excessive information about follow-on incidents. The operator is not provided with an indication of the root cause of the process problem. The operator must sort through the alarm information to discern what's actually happening, typically with inconsistent interpretation of the information.
- Very little information is provided to the operator on how to respond to process disturbances. When a disturbance occurs, the operator is immediately put into a reactionary mode. They must troubleshoot the problem and develop a solution. The operators experience level, alertness, and the way information is presented limit the degree with which operators can identify the problem and develop the correct response.
- The operator's scope of responsibility also increased with the increasing loop counts. Now the operator was responsible for not merely an entire unit, but multiple units, each with unique characteristics. The addition of the advanced control applications simplified the operators' interactions with the units during normal operations, but left the operator exposed when direct interaction with the control system was required during process upsets.

In response to the consequences of some of these issues, regulatory agencies required additional documentation on the process equipment, operating procedures, chemical compositions, and critical failure scenarios. The process safety initiatives generated additional information on the process units without addressing how the operations personnel could access and benefit from the information during a process upset. For example:

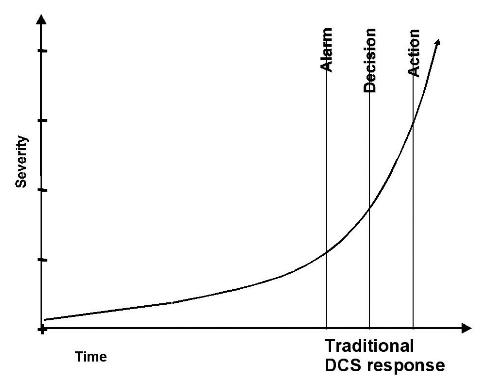

Figure 3. Traditional DCS response.

- Detailed problem definitions and action procedures resident in PSM documents are not effectively integrated into the operators' job function. Little has been done to position the information captured in OSHA mandated documentation to operators in an effective fashion. This investment and intellectual capital generally sits on the shelf and is not used effectively to make money for the organisation.
- The improved performance analysis available through the information and control systems enabled companies to identify significant variations in the operations practices between shifts. The focus on 'best practices' identified the need for operations tools to promote consistent procedure execution by the operations personnel but there was not a mechanism to deploy the information. Intellectual capital resident in experienced operations and engineering staff is not being digitised and captured. Furthermore, there is no way to deploy this intellectual capital across shifts, let alone across multiple plant assets.

These deficiencies in current automation technology result in the operator being unable to effectively manage upset conditions, nor operate the plant for maximum profit contribution.

Emerging technologies

As the control and information technology applications have become mainstream in the industry, expert system technologies are now emerging to address the middle-ware automation requirements. The rules and procedural based reasoning and inferential logic features inherent to expert systems technology are providing the core functions to a range of applications, facilitating the management of data between the information and control domains. Companies are now able to leverage from expert systems to implement more sophisticated and higher return applications on their existing control and information system infrastructures. The automation areas now being addressed are the use of expert systems in reliability and operations management applications (R/OM).

The R/OM applications are based on an expert system architecture to utilise the rules and procedures to provide the automation functions undeliverable by the advanced control and optimisation applications. The knowledge based rules incorporated into the system enable the operator to benefit from the unit operations information contained in the operating procedures, in addition to the contributions of the most experienced operations and engineering personnel.

System architecture

The system architecture uses industry standards such as ethernet networks, PC workstations, Windows NT 2000 operating system, XML and OPC communications to provide a high performance system integrated with the existing control system. The use of the industry standard applications, protocols and objects enables the application to integrate with legacy applications and systems while providing a consistent operations interface through the operator's control system consoles.

The architecture of the R/OM system addresses the production management domain of the console operator, while also integrating with applications to support the planning and scheduling, maintenance and engineering personnel. Integrating the document management systems, plant historian, equipment diagnostics server and fieldbus server enables the R/OM system to perform diagnostics across multiple systems. The integration with the wide area network or the remote access server enables the applications to be deployed and maintained from remote locations or with the client's centralised support groups.

The standards based architecture supports the integration of the system with other applications to yield a consistent operations interface at the control system console. The result is an operations support system which enables the operator to identify, assess, decide and respond to process upsets faster and more correctly than with the standard control system.

Reliability and operations system functions

The R/OM system takes a process level view of the diagnostics function. Rather than focus on electrical connections, and annunciation at predefined alarm limits, the system:

- Evaluates the health of the process on a real time basis.
- Identifies the root cause of process problems early (before the DCS alarm is activated).
- Couples diagnosis of the problem with a suggested action response to avoid the upset entirely.
- Provides advisory messaging to minimise the effects of upsets that do occur.

Components of the R/OM system diagnostics package are as follows:

- Sensor validation: algorithms supplement the sensor validation functions of the DCS by monitoring for changes within alarm limits, limit excursions, blips, spikes and most importantly, dead sensors.
- Cascade loop monitoring: monitors the variation between the 'remote set points' and 'process variables' for cascade loops. A deviation in this relationship could indicate a need for tuning of the loop or uncover an upstream process problem.
- Control loop modelling: models the relationship between the 'process variable' and 'output' of all control loops. This allows line plugging, windup conditions valve and instrument failure to be detected.
- Process data correlation: this function allows calculated values to be compared with actual signals to provide additional validation. For example, the level in a tank can be compared with a calculated value based on inflows, outflows and tank volume. Or analyser values can be correlated against the expected calculated values based on operating conditions.

The R/OM system diagnostics package adds value by identifying the problem early and coupling the diagnostics with advisory messaging to allow the operator to focus on corrective actions rather than process troubleshooting.

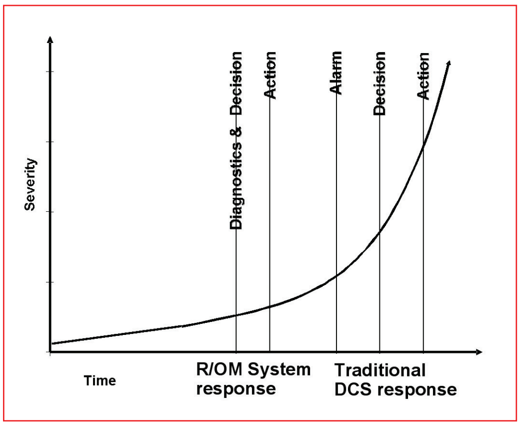

Figure 4. R/OM system response.

The operations management applications also address process unit level functions by monitoring for operating conditions that would adversely impact production. These rules are based on the standard operations procedures for the units, first principal models and the accumulated 'best practices' knowledge of the operations personnel. Examples of these diagnostics are:

- Operations diagnostics: distillation column flooding, furnace over firing, catalyst poisoning, filter plugging, etc.
- Operational changes: feed composition, cooling water and air temperature, foaming, plugged (frozen) pipes, fuel quality, etc.
- Utilities failures; electrical, air, cooling water, steam, fuel gas, etc.
- Equipment failures; pumps, compressors, heat exchangers, furnaces, columns, etc.

The R/OM system requirements are based on a hierarchy of requirements starting with sensor validation. At the basic level the sensor validation consisted of data analysis for the high/low limit checking, 'blipped', 'dead' and simple model inferences. Another benefit of the sensor validation is realised when the R/OM system is integrated with other applications such as the multivariable controls (MVC). Although most of the current MVC implementations use some form of gross error detection to check the process data, they are still vulnerable to the process upsets propagated by the inappropriate control response to a dead sensor. The demand for more rigorous sensor validation is increasing with the proliferation of the MVC applications as users strive to maintain the high service factors on which the applications were justified. The integration of the enterprise applications is creating additional demand for the sensor validation as the consequences of erroneous process data extend beyond the process unit or the site to the corporation.

The more advanced features of the system address fundamental chemical engineering principals, operational heuristics and the data response patterns. Although the benefits of the production management applications can be very significant, the real benefits of the system are in the reduction of process upsets. The benefits of the advanced control applications are based on incremental improvements to the process operation over long runtimes, high unit capacities and high application service factors. A week of unscheduled downtime will cost the refinery more than a year's worth of advanced control benefits. Process manufacturing companies are learning that the management of their abnormal situations provides greater benefits than their advanced process control (APC) applications by addressing a more fundamental function, keeping their process units running. Unlike the advanced control applications, the R/OM applications are targeting the reduction in unit downtime, which represents a total loss of production.

The operator advisory components provide the messaging and alarm management for the process analysis performed by the expert system rules. Clients have invested a significant amount of knowledge engineering effort and time in the development of these procedures in response to the OSHA process safety management initiatives. Incorporating this information into the operator advisory system would enable the documents to be more effectively accessed by the operators, during the abnormal operating situations, when they were needed most. The integration of the emergency response procedures enhances the operator's interface by presenting the appropriate procedure for a detected abnormal situation in real time. The system has established a new 'best practices' by providing a of change management environment for the OSHA required documents. The ability of the operator to effectively use and provide feedback for the documents is improving the quality of the documents and, more importantly, the value to the operations personnel.

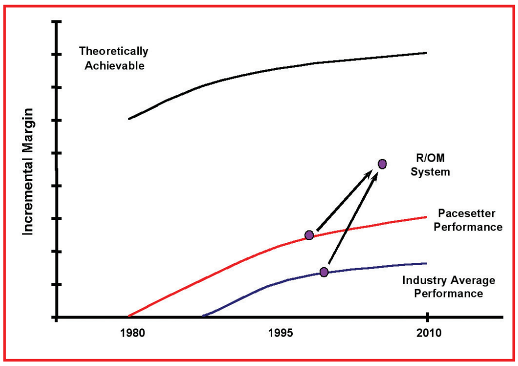

Figure 5. Industry automation trends.

Operations scenarios

An operator with a conventional control system is usually first aware of a process event when a process value has exceeded a predefined alarm limit, generating an alarm in the control system. The alarm may be specific to a single parameter issue or it might be one of many alarms.

The operator must then assess the alarms to determine what has occurred before deciding on the appropriate action. Assuming that the operator correctly assesses the situation, understands the numerous response possibilities and decides to take the 'best action'; the operator will then initiate a corrective response. Meanwhile the severity of the problem has escalated and a flood of alarms associated with subsequent, follow-on problems occur. The operator is left to discern what is actually happening, what caused the problem and what is an appropriate response.

This is a simplified view of the operator's world. The 'real world' scenario is that there are numerous other alarms on the control system at the same time. The operator may have observed the problem before, or may have heard about it occurring on another shift. The corrective response may have been recorded in the standard operations procedure for the unit, or in the emergency response procedures. The operator may decide to look-up the information either electronically or in the binder of documents stored near the control console, if this particular upset has been clearly referenced and documented. With time ticking away, the severity of the upset has continued to progress from merely an alarm condition toward a more severe condition. The operator is now responding to a more elevated situation over the initial alarm with process operation consequences of varying impacts.

The R/OM system takes a different approach by detecting process events before they reach the alarm conditions on the control system. The system monitors the status of the instrumentation, equipment, and the process unit operations. The sensor validation will identify suspect values before they can escalate into the larger process upsets. Before the control system experiences the alarm, a controller has gone out of control or reached its limit of control, permitting the process to move to an undesirable condition. If the operator or the operations engineer were closely monitoring that particular area of the process, they may have been able to observe and respond to the problem before the process triggered a limit alarm on the control system. In the 'real world', the operator's scope of responsibilities does not permit them to scrutinise the unit operations at this level.

As the operator selects the advisory message displayed on the control system console, the trended information related to the detected failure and the emergency response procedure are automatically displayed, advising the corrective action required. The diagnostics and suggested responses are presented to the operator in a clear, concise fashion, using descriptive language. Should the operator require additional information relative to the explanations and response procedures for an event or equipment type, the system automatically displays the appropriate OSHA documentation and highlights the correct response advisory text. The documents can be process safety management documents, material data safety sheets, HAZOPS procedures, etc. The significance of this function is that the R/OM system fully leverages the client's investment in OSHA regulatory compliance and environmental health and safety initiatives.

At the more advanced diagnostic levels, the rules in the system monitor for the symptoms that would indicate immanent process upsets of a more significant scale such distillation column flooding, overfiring a furnace, blocking in a running pump, catalyst poisoning, etc.

Benefits/casestudy

The R/OM system diagnoses process problems and couples operator advisory messaging to avoid process upsets. Furthermore, the system captures the best practices of operations, engineering and management staff and allows this knowledge to be deployed to operators on a 24/7 basis. The result is increased process uptime and reduced incidents, which expose personnel and the environment to potentially hazardous situations. The benefit areas the package addresses are detailed below:

Process availability

The R/OM system diagnoses reliability incidents and couple an appropriate operator response to avoid the upset condition and resulting downtime. This is especially important for those plants that have to deal with operator turnover and the resultant inexperienced operator responses.

Advanced automation technologies such as APC and optimisation have led to longer run times and fewer process upsets, whereby operators are often ill equipped to handle problems when they do occur.

One olefins manager recently commented that operators could even forget how to run the plant on a seasonal basis. More importantly, this manager commented on the amount of management support required to startup this unit. They see a great benefit in being able to capture operations know-how, and deploy it across the operations staff, to facilitate smoother startups.

Environmental, health and safety

The R/OM system will provide the right information, and guidance, to allow the operations staff to diagnose process problems and respond in a safe and orderly fashion.

As an example of how the system will address this key benefit area, a large ethylene complex recently experienced a power outage on one of their units. The operator of a nearby unit started receiving alarms at a rate of 60 alarms per minute. The operator acknowledged all the alarms including key alarms that should not have been acknowledged. A furnace fire ensued that put personnel in jeopardy and resulted in significant losses. The R/OM system would have:

- Ignored the alarms coming from the unit which was down.

- Identified the root cause of the problem.
- Focused the operators attention on those alarm conditions that mattered most.
- Suggested an appropriate response to avoid the catastrophe.

Increased production

The R/OM system advisory enables the operator to push production through the management of abnormal conditions as well as providing the guidance to allow operators manage the multivariable control applications. Operators are able to manage the process operations to operate closer to the correct constraints.

Intellectual property management

In a recent example, key supervisors were preparing to retire from a client's plants. The personnel were involved with the knowledge engineering phase of a R/OM project contributing to the definition of diagnostics to facilitate how they managed the process operations. These procedures were transposed into the R/OM system knowledge base and commissioned on the process unit. The client has not only retained the expertise of its best operations and technical personnel, but it has also provided a mechanism to impart this experience to benefit junior level operations staff.

The intellectual capital captured during the knowledge engineering phase is then available to support consistent operations across shifts and across the client's asset base. This allows the operations philosophy of an organisation to be propagated globally to facilitate consistently profitable operations and allow for support from a central location.

Economic benefits

Studies by the Abnormal Situation Management Consortium have indicated that 3 - 15% of maximum throughput capacity can be lost through lack of control during abnormal operating modes[2]. An average refinery of 115 000 bpd can see savings of over US$ 6.3 million per year by effectively controlling the process during incidents and transition events (startup, shutdown, feedstock changes, product quality changes, etc.).

A recent feasibility study with another olefins client showed that the deployment of the R/OM system would have addressed key safety issues and resulted in an increase in profitability of US$ 5.4 million over a 13 month period. Further analysis of the incident data indicated the application would have provided a three month payback by avoiding the first three incidents during that same time period. The reliability losses for the next year were expected to exceed an additional US$ 4 million.

Conclusion

Although the applications are considered to be an emerging technology, the initial R/OM systems have been online for more than eight years. The demonstrated performance of these applications has established the viability of the technology, system architecture, and the project methodology.

Additional systems are now underway with other major companies as the industry's benchmark automation has moved to a higher level. Companies are now pursuing R/OM strategies to realise a step change in the benefits over their competitive companies.

References

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