Reliability and Operations Management Applications: "A View from Both Sides of the Table"

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Abstract
Operational best practices have historically been defined and documented by companies in an attempt to leverage this intellectual property across the operations teams. Although intended to improve the operators' decision process, these procedures are primarily used in the post-mortem analysis of process upsets. The operator has little time to assess the process and alarm information from the control system to infer the unit's current operating state, determine the appropriate procedures and actions. It is not until the intellectual property is digitized through a knowledge-based application that it can be managed and deployed to deliver value in real-time while the operator can impact the outcome of the operations event. Reliability and Operations Management applications use the client's existing automation and IT infrastructures to deploy this digitized intellectual property through the operator's console to provide real-time diagnostics of the process and equipment operations. The successful deployment of these applications is enabled by a robust technology design, but delivered through the project execution methodologies. This paper provides a profile of a successful project that addressed both.

Biographies
Mike Schustereit is a control systems engineer at the BP Chemicals Greenlake Texas site. He has worked for BP in both production and engineering at the site for 10 years. He is currently the project manager for the Manufacturing Vision project that is embracing new controls software to enhance the competitive edge of the site. The author has a BS in EE from the University of North Dakota in Grand Forks, North Dakota.

Jack Stout is president and founder of Nexus Engineering, providing reliability and operations management solutions to clients in the hydrocarbon processing, chemicals, and power industries. He has held positions with Firestone, Fina Oil & Chemicals, Fisher Controls, Honeywell, and engineering service companies for more than 20 years. The diverse experiences in technical support, operations, plant management, marketing and engineering management have contributed to the knowledge-based applications being implemented through Nexus Engineering. The author has a BS ChE from Lamar University in Beaumont, Texas.

Project Background

BP's acquisition of Amoco at the end of 1999, sparked an initiative in Spring of 2000 to define, deploy, and demonstrate a suite of information and control technologies generating a high rate of return on the sites' operating assets. The initial BP Chemicals Vision initiatives demonstrated the benefits of various automation technologies deployed within multiple chemicals business units. Although most of the technologies had been previously implemented by the sites, the Nexus Oz™ operations advisory system was one of the newer technologies to be deployed. Having observed the deployed systems in the Phase I sites, BP's Greenlake site initiated a project during the Summer of 2001.

Operations Management Requirements

As companies develop their operations experience with their process units, there is an awareness that the intellectual property (IP) being created at the site is not merely in the engineering design of the units, but also in the operating procedures. The lack of viable knowledge management technologies made the management of this intellectual property difficult, until recently. The opportunity for the Reliability & Operations Management (R/OM) system is to leverage the collective experience of individuals in the operations team across the entire operations group. The system enables the operations personnel to benefit from the other experiences of the operations team while also addressing the imminent loss of expertise as operations personnel move to non-operations positions or retire from the company.

The site's concern with knowledge management is also applicable to the technical support resources. The limited technical support and the progression of engineers through their careers creates a continual turnover of technical support expertise with little ability to leverage their knowledge skills between personnel or other similar units within the business unit. The digitization of the knowledge enables the operations IP to be managed along with the other traditional proprietary process information and deployed across similar unit assets.

Traditional Operation Scenario

The growth of the historical board operator position into today's console operator has resulted in a ten-fold increase in the amount of assets managed by a single person. The impact of a single person's actions and the value of their operations knowledge is now a critical factor in the success of the process unit operation. Reliability benchmarking information indicates that 70%[(1)] of reliability issues are operations induced, versus the traditional mechanical integrity concerns. The demand for a system to digitize the operations knowledge into a manageable form will continue to grow as the current operations organizations experience turnover in personnel. The personnel turnover compounds the issue as companies increase the complexity of their process operations to capture the incremental process operating margins.

In the current console operator position with the traditional DCS, the operator may be watching critical values or trended information to observe process changes requiring operator intervention. They are 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 or it might be one of many as part of an "alarm flood".

The operator assesses the alarms to determine what has occurred before deciding on the appropriate action (fig. 1). 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 the appropriate response.

Operator Response with Traditional DCS

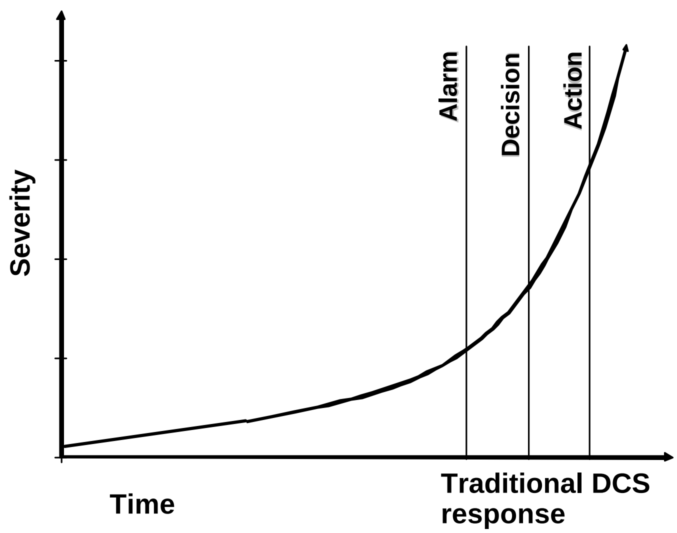

fig. 1

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 escalate from merely an alarm condition toward a more severe scenario. The operator is now responding to a more elevated situation over the initial alarm with process operation consequences of varying impacts. In each of these scenarios, the operator is required to infer the root cause from the raw data.

Reliability & Operations System Functions

The R/OM system takes a process and equipment perspective of the diagnostics function. The R/OM System diagnostics identify the problem early, coupling the diagnostics with advisory messaging to allow the operator to focus on corrective actions rather than process troubleshooting. Rather than merely annunciating at pre-defined alarm limits, the system:

- Evaluates the reliability of the process on a real time basis.
- Identifies the root cause of process problems early (typically 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 minimize the effects of upsets that do occur.
- Integrated operations procedures support a consistent response to the process upsets.

The R/OM system requirements are based on a hierarchy of diagnostics 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 realized 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 data reconciliation 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.

Control loop diagnostics monitor the relationship between the SP vs. PV, and the PV vs. OP, indicating a need for tuning of the loop or a number of process problems. The addition of modeled values and performance characterizations enables the system to also detect sensor drift, plugged impulse lines and sticking control valves. These diagnostics narrow the focus of the instrumentation technicians to the known problems requiring maintenance.

The use of process data correlations 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 to detect a level sensor error or an incorrect valve line-up. Another example is the correlation of analyzer values with the expected calculated values based on the current operating conditions.

The more advanced features of the system address fundamental chemical engineering principals, operational heuristics, and 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. While the advanced control applications contribute to incremental margins and throughputs, the R/OM applications are targeting the reduction in unit downtime, which represents a total loss of production.

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 & Air Temperature, Foaming, Plugged (Frozen) Pipes, Fuel Quality, etc.
- Utilities Diagnostics - Electrical, Air, Cooling Water, Steam, Fuel Gas, etc.
- Equipment Diagnostics - Pumps, Compressors, Heat Exchangers, Furnaces, columns, etc.

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 management of change environment for the OSHA required documents. The ability for 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.

Operation Scenario with R/OM system

The operator response with the R/OM system differs from the traditional DCS response 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 (fig. 2). The diagnostics are based on multiple variables, typically beyond the normal mode of operation on the standard operator console. 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 unreliable 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-based alarm on the control system. In the "real world", the operator's scope of responsibilities does not permit them to scrutinize the unit operations at this level of detail.

As the operator selects the advisory message displayed on the control system console, the trended information related to the detected failure and the operations 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.

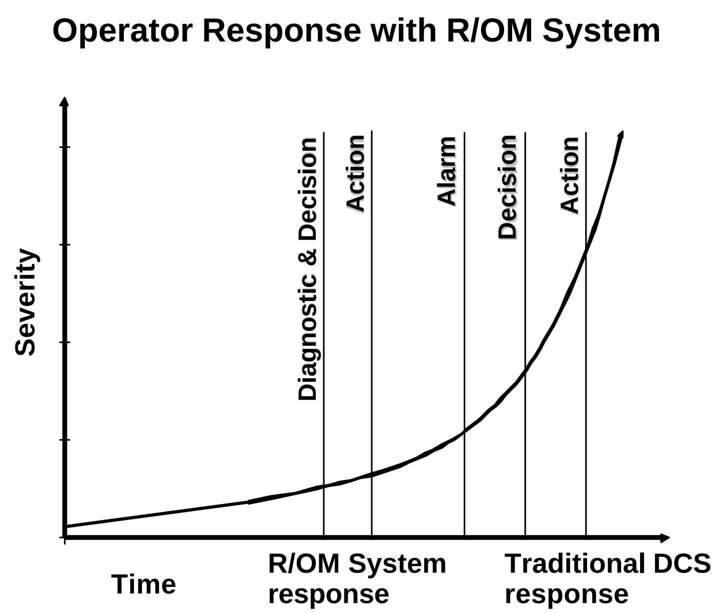

fig. 2

At the more advanced diagnostic levels, the rules in the system monitor for the symptoms that would indicate imminent process upsets of a more significant scale such distillation column flooding, over-firing a furnace, critical reactor operations, blocking in a running pump, catalyst poisoning, etc.

BP Greenlake Site Profile

The primary process at Greenlake Complex is an acrylonitrile unit. The process consists of an exothermic reaction followed by recovery and purification sections to yield the final products. The operation of the unit is a continuous state of degradation from start-up until the initiation of a turnaround to rebuild the equipment and repeat the cycle. Although there are numerous advanced control applications, the unit requires regular operator intervention to maintain reliable operating performance.

The operations personnel are very experienced, with many having started with the initial commissioning of the unit in 1981. The console operator position is not a fixed position, but is rotated every two weeks. The rotating schedule enables the operations team to maintain a shared perspective of the unit operations, but limits an individual operator's experience on the control system console. The consolidation of the console operator positions, over time has increased the areas of responsibility for this position.

Project Scope

The initial project scope addressed one third of the site, based on a single server addressing 2000 DCS tags (6000 - 7000 points) in the process area. The equipment includes:

9 Distillation Columns	2 Resin Beds
8 Heat Exchangers	13 Storage Tanks
1 Super Heater	Utilities
1 Feed Vaporizer	

The application was implemented on a Windows NT-based Yokogawa control system with Nexus Engineering's Nexus Oz™ software. The operations procedures were Microsoft Word-based documents, which were bookmarked and integrated with the Nexus Oz diagnostics. The process area also had a DMC plus application online, which was integrated with Nexus Oz.

The typical pilot project objectives are focused on validating the technology, demonstrating the benefits, and implementing quickly while counting on the second phase to deploy the more complex logic. The BP Greenlake project team decided not to just pursue the "low hanging fruit" but stretch the complexity of the deployed diagnostics to address operational issues experienced by the site over the previous 20 years. As a result this strategy, the deployed system used 95% of the functionality available in the Nexus Oz system at the time of the project. Diagnostic types included:

- Sensor Validation
- Control Loop Diagnostics

- Configured Smart Equipment Objects
- Knowledge Engineering Rules (Specific Rules)

The team developed more than 250 additional site specific rules addressing operations scenarios beyond those already configured within the application.

Project Strategy

An implementation strategy was developed that would accelerate the implementation of the R/OM system while developing the internal resources for longer-term maintenance and implementation support. A composite project team was developed with core personnel from the vendor and from BP's process automation group. This strategy enabled the vendor to manage the project and the technology while enabling the BP personnel to focus on their knowledge of the process versus being software programmers and debuggers.

The BP project team consisted of lead operations and engineering personnel, with access to additional operations, instrumentation and reliability personnel. A recently retired operations supervisor was employed as an additional operations resource on the project, due to his 33 years prior operating experience at the Greenlake and other global acrylonitrile sites.

Project Execution

The project kickoff meeting was mid-June 2001. During the first month, the server was ordered and the interface and configuration tools for the Yokogawa control system were developed while the BP personnel assembled the databases, documents and information for the project. The Nexus Oz product training was held onsite during August with the beginning implementation of the pilot application. The preliminary system configuration was reviewed with the operations staff during the conclusion of the training session to solicit additional input from the team as they became knowledgeable of the logic supported by the system.

The software was loaded on the server and configured with the database from the control system. The server was taken to the site in September and installed on the control system to perform a preliminary checkout of the OPC interface and to perform the sensor validation and controller diagnostics on the system. The results of these preliminary diagnostics enabled the instrumentation and control personnel to focus their maintenance efforts on the integrity of the control system necessary to support the application. The server was decommissioned and returned to the vendor's offices to complete the configuration process.

The knowledge engineering phase leveraged the information available through the operations procedures. These primarily consisted of the standard operating procedures (SOPs), event response procedures (HAZOPs), and other unit documents. Most of the documents were already available through the site's OSHA PSM initiatives. The operating philosophy for the operations team was to configure the application to enable the operator to have two opportunities to correct the operational issue before the process reached the hi/lo limit alarms in the control system.

In addition to the use of the documents, there were knowledge engineering (KE) sessions consisting of structured, focused discussions with the operations personnel to define the appropriate configuration requirements for the system and to define the custom rules required to address the unit operation. These KE sessions enabled the project team to include additional personnel as necessary to address the more specific issues. The KE sessions would typically require 3-5 days at either the vendor of the site location. With the completion of the training and the initial KE sessions, the site personnel were able to lead a large portion of the sessions. This strategy gave them easier access to the site personnel and contributed to a greater scrutiny of the rules to be developed, creating a sense of involvement and ownership throughout the project team.

Historical data from the unit operations was played back into the application to enable the system to be preliminarily tuned offline as the rules were being configured. This also enabled the team to play historical data from specific process upsets to verify that the configured rules would successfully diagnose an infrequent occurring event. This would also assure that diagnosis and response provided by the application would enable the operator to respond quickly and correctly to the event.

The configured system underwent a factory acceptance test, rigorously testing the execution of the configured application. The testing process was conducted with parallel teams simultaneously exercising the logic per the test plan. This process required four days to complete.

The configured, tested and documented system was taken to the site in mid-November. The site commissioning consisted of installing the server on the control system and tuning the application. Although the application was configured on real process data, it was not live, requiring incremental tuning at the site to enhance the system response to the unit dynamics. The vendor worked with the lead operator on the project team to develop the operator training class in a “train the trainer” arrangement. The vendor’s project personnel were available for technical support as the lead operator provided the training to the other operations personnel. The system was then monitored for an additional week after the training as the client signed off on the acceptance of the system.

Project Results

The project implementation was executed through a rigorous project management methodology, which optimized the use of the multiple resources and delivered a tested, commissioned, and documented system four weeks ahead of the seven-month schedule. The project was execution followed the initial GANTT chart provided to the client. The pilot project approach enabled the site to identify additional opportunities to be considered when the application is deployed on the remaining process areas. The following are areas that were identified:

Integrated Information & Control Systems Support
The expert system applications are running on control LANs that are integrated with the information systems and the control systems. Although the knowledge-based system is the responsibility of the automation group, the computing architecture is the responsibility of the information technology organization, which has its own priorities and accountabilities. The remote access support, which enables the vendor to provide remote technical support and email support for the application are key security issues to be resolved.

Maintenance Strategy
The lead operator for the pilot project initially provided the primary technical support and for the commissioned application. Maintenance resources need to be committed to maintain the application in an ongoing basis. Although it may be the partial allocation of the same personnel, it needs to be a primary responsibility to assure a priority focus on the application.

Timely Maintenance of the Instrumentation and Control Systems
The impact of faulty instrumentation on the operation of the process unit became more visible, requiring the instrumentation to be maintained more diligently.

Identified Additional I/O points to Support Additional Diagnostics
The initial application was deployed with the existing control system and instrumentation. Additional instrumentation was identified to support additional reliability and operations diagnostics logic, based on the initial results. The installation of the additional instrumentation will be considered for the next unit turnaround.

Application Tuning
In some cases, the "normal" operating range was too close to the safe limit to enable the application to generate two operations advisory responses. The tuning of the application is based on the system and unit response requirements. In some cases, the application required faster scan times to enable the diagnostics to execute and still provide the operator with the targeted response time.

Verification of Historical Incidents
The system is capable of detecting and responding to many abnormal situations that could occur. Among these scenarios, the situations that were addressed with additional confidence were those that had already occurred. The ability to playback the plant historian data file from a major incident, into the R/OM system, enabled the project team to verify and tune the diagnostics for these infrequent events. It also demonstrated the value the R/OM system would have contributed, had it been online earlier.

DCS Alarm Rationalization

The site is completing the alarm rationalization activities on the control system and are now observing the impacts in the significant reduction of DCS alarms. It is important to reassess the configuration of the control system alarms to minimize the nuisance and redundant alarms presented to the operator.

APC Integration

The application had a unique contribution to the Aspen DMC plus application, enabling the operators to understand the controller moves and keep it online. Complementary to the DMC plus application which is primarily a "hands off" application, Nexus Oz provides value during the "operator intervention" mode of unit operation.

Benefits Observed by the Site

The implementation of a new application technology impacts the sites operations in a number of areas as previously discussed. The use of the new technology as a tool to more effectively manage the process operation is demonstrated through the results generated by and attributed to the application.

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. Although the more experienced operators know how they should respond to the typical scenarios, they use Nexus Oz to look for next options that should be considered and for the unusual operational issues.

Intellectual Property Management

The use of key operations and engineering personnel define the diagnostics for the R/OM System enabled the site to retain the expertise of one of their best operations personnel and provided a mechanism to impart this experience to benefit junior level operations staff. The intellectual capital captured during the knowledge engineering phase is now available to support consistent operations across shifts and in addition to other similar BP process units. This allows the operations philosophy of the site to be propagated globally to facilitate consistently profitable operations.

Site Specific Operations Scenarios

The following are some specific examples of the major scenarios that have been averted by the Nexus Oz system since its installation:

- Nitrogen Management - Management of the nitrogen usage on various vessels to detect and prevent excessive blow through that would have been slow to detect otherwise.

- Resin Bed Dryers - Detected an inactive resin bed on one of the dryers preventing a production outage.
- Distillation Columns – Detected premature fouling in a lower tray section of the tower enabling operations to manage the unit operations until a shutdown could be scheduled.
- Reactor Area – Although the application was not initially applied to the reactors, one of the scenarios diagnosed in the recovery section indicated a problem initially undetected by the operator in the reactor area. The operator in the reactor area was able to recover from the process upset averting what would have been a reactor shutdown and a significant unit outage.

Project Key Success Factors

The success of the project was the result of numerous factors such as the technology, personnel, project scope, and the availability of the correct personnel. The following are the key factors contributing to the success of the project:

- Commitment of domain knowledgeable resources
- Engage operations staff early to create sense of ownership
- Develop short and long term support strategies with available and trained resources to preserve the investment in the application
- Commitment to uncover and implement new opportunities
- Contact application experts to resolve the 'difficult problems' and to maintain system integrity as needed

The commitment of the top operations personnel was critical to the success of the project. The deployment of this technology is a cultural change. The system does not merely replicate a tool that the operators had before but creates an enhanced operations environment. The acceptance of the application is enhanced by involvement of the operations personnel through the deployment of the system and in the maintenance to keep it current with the varying operations strategies and conditions.

The project team executed the project without constraints to assure the application delivered the expected benefits. Other projects have been implemented based on the strict compliance with a predefined specification, verifying that each rule was considered in or out of the project scope. Although executed successfully, these projects fail to deliver the expected benefits to the end users and are considered to be business failures. The Greenlake project team's focus on the delivery of functional value yielded an application that provided the anticipated value to the site, while following a diligent execution methodology to yield a robust, tested, documented, supportable application.

Conclusion

The results generated by the pilot project have enabled the site to position for the deployment of the technology on the remaining process units. The continued acceptance and support of the technology by the operations personnel and its integration with other applications at the site, such as the wireless PDAs for the field operators, will continue to enhance the sites management of its operations intellectual property amongst the numerous users to generate the expected operations performances from the process units.

(1) Birchfield, George, "Olefin Plant Reliability - A New Approach to Understanding Plant Reliability Underscores the Importance of Advanced Process Knowledge Management Systems", AspenWorld 2000 - Solomon Associates