OPERATOR ADVISOR SYSTEM FOR PROCEDURE MANAGEMENT

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Abstract

BP has developed and implemented an on-line knowledge-based system for improved management of planned transitions such as start-ups and shutdowns. The objective is to give the operator a better tool than paper-based checklists for improving the reliability of transitional operations. The system includes live process data monitoring, automatic record keeping, and a graphical user interface. It continuously monitors process data to verify normal completion or to advise the operator of unexpected conditions. The user interface provides a visual overview to the complete procedure and point-and-click access to specific details. The experience of installing the system for start-up of a grass roots unit will be described.

Introduction

Refinery process operations are primarily continuous, steady-state operations but do require procedures for start-up, shutdown, and maintenance. Industry standard practice is to use paper checklists to manage these operations.

The Operator Advisor System (OAS) that this paper describes has been developed and implemented for use by refinery operators and their supervisors to help manage transitional operations such as planned start-ups and shutdowns. This system was installed for the initial start-up of a diesel hydrotreater constructed in 1992/1993.

BP's Motivation

While the safety record of the refining industry is quite good and BP shares in that good performance, one of the highest risk times for plant operations is while executing procedures. One study (Rasmussen) of 190 accidents in chemical facilities found the top four causes were insufficient knowledge (34%), design errors (32%), procedure errors (24%), and operator errors (16%). A study (Butikofer) of accidents in petrochemical and refining identified the following causes: equipment and design failures (41%), operator and maintenance errors (41%), inadequate or improper procedures (11%), inadequate or improper inspection (5%), and miscellaneous causes (2%). The impact of improper procedure management can result in costly delays, damaged equipment, unexpected downtime, and even major disasters. The goal of OAS is to reduce the risk of procedure error during these operations.

Paper checklists have traditionally been the primary tool used to manage procedures. These are normal yet non-routine operations and are often a demanding and stressful job for operators. Because these transitions are infrequent and involve non-steady state operations, a typical operator may not have a great deal of experience in executing the procedure. Potential problems with procedure execution include lack of familiarity, widely distributed knowledge and experience, use of systems that are designed for steady state operation, and revisions to the process that result in procedure changes since the last time it was executed.

Although paper checklists can be effectively used to manage procedures, their use introduces a paper management task. Some of the problems with paper checklists are that they get outdated and they are sequential in nature. While an individual operator may only take one action at a time, we all know that many things are happening simultaneously during a start-up. There is always a lot of page flipping through the master copy to make sure that every item has been addressed. Some attempts to replicate the checklists electronically have been made but not all of the disadvantages can be addressed.

The potential for problems with procedures is complicated by the increased communication load between the operating parties and the systems that are largely designed for steady state operation. The operator's attention is often focused on a task at hand, not on the rest of the process that he would be closely monitoring during steady state operation. The control system's alarm functions do not usually have the ability to dynamically adjust for the changing conditions expected during transition operations and are not as useful during this time. In fact, the expected condition of many variables is often reversed from steady state and sometimes oscillates back and forth. Keeping up with unexpected conditions using the control system's alarm capabilities has not been successful. Increased verbal communication (via radio) is also a factor in complicating the execution of a procedure.

Many of the potential improvements directly map into the promise of knowledge based systems: scarce and distributed expertise, vigilant monitoring, centralized and maintainable knowledge, and 'natural' representation of the knowledge. It was with this apparent match between characteristics of appropriate KBS applications and the potential improvements that BP began applying knowledge-based systems to the procedure management problem.

Technical outline

The Operator Advisory System communicates with the control room operator through a computer terminal, mouse, and keyboard which are located alongside the DCS console. The OAS presently runs on a DEC VAX and is based on the G2 Expert System software marketed by the Gensym Corporation. G2 is a market leader in this area, with particular strengths in interfacing to live process data through standard distributed control systems and common process database systems.

Out of the box, G2 is a programming language with graphics tools, interfaces, inference capabilities and structure for a knowledge base. The objective of the development work was to produce a standard architecture and set of computer procedures within G2 suitable for configuring the start-up and shut-down operating procedures used within BP. This basic framework is the Operator Advisory System, providing tools to configure efficiently any particular procedure.

The two key features of the OAS are its structured operator interface and continuous monitoring. Figures 1 and 2 are examples of the operator interface. Figure 1 shows how the procedure is divided into a set of goals that have either been achieved, where work can be started or is in progress, or where pre-requisites have not yet been achieved so work cannot be started. The top row of the screen represents the entire start-up, with sub-goals represented down the page. The operators and supervisors can easily see where they are in the procedure.

Figure 2 shows the operator input area, where the system is seeking confirmation that a particular goal has been achieved. The operator enters his or her initials to indicate that a step is complete. A complete time-stamped record of each step with initials is kept in an audit file. Facilities are provided for the operators to input comments and to skip a step if a variation to the procedure is necessary. Again, these details are time-stamped, initialled, and stored in the audit file. For the first implementation, where PC's with on-line documentation were available in the control rooms, clicking on the question mark button causes the relevant part of the detailed procedure documentation to appear on the PC screen.

Behind the scenes, the OAS also continuously monitors process data to check if conditions are as expected. For the Figure 2 example, it will monitor the reactor section pressure and alert the operator if the pressure does not meet the procedure requirements. It will also alert the operator when the 30 minute time period is up. This kind of monitoring is very useful during start-up when the normal DCS alarm system limits are not valid. About 1/3 of the operator actions could make use of the live data coming from the DCS for on-line verification of the action. The intent was to record and verify proper execution but an unexpected benefit was instrument verification. Although loop checks had been done, there were two occasions where field operators verified actions through local gauges that were not replicated in the DCS values. The advisor caught the discrepancy and a potential incident was avoided.

One of the primary benefits of the system is monitoring for unexpected conditions outside the focus of the current task and beyond the capability of the DCS alarm system. It is easily possible for the operator's attention to be focused on completing the task at hand when an unrelated variable deviates from an expected condition. An example is that before filling a tower with liquid it would be the absence of a low level alarm that should be brought to the operator's attention. We experienced one example on this new construction unit when a valve failed and was replaced without incident. The expectation is that occurrences would be more frequent on older units.

Operators have the ability to enter comments regarding the procedure at any time. This is an attempt to capture the knowledge that is often scribbled in the margin of someone's copy of the procedure. All of the comments as well as messages and step completions are written into an electronic log. This would be valuable for incident investigation but also provides a mechanism to capture the experience gained during a transition and use it later to improve the procedure.

A more detailed description of the technology was presented at the Intelligent Systems in Process Engineering Conference (Beach and Knight).

Development Approach

Expert Systems development projects have been carried out in BP through the 1980's and into the 1990's. Discussions on the procedure management application began in 1990 with development of a framework in 1991 and 1992 with a refinery demonstration. The refinery application described in this paper was begun in 1992 and finished in 1993. The majority of the work was centrally funded.

The technical approach was to generalize the application as much as possible. Input from BP internal specialists, plant personnel and Ohio State University resulted in an object-oriented framework that should be capable of representing the majority of procedures and provides a wide range of monitoring tools. The aim was to minimize the work to build and maintain a particular application. This also proved to be a very productive approach as the interface design went through several iterations.

Throughout the development, the team sought input from the refiners. This ranged from VP level, Refinery Managers and Operation Managers. The resulting management buy-in and ownership carried the system through to the successful implementation described here and in continuing projects.

Implementation

BP Oil had a plan to demonstrate new technology such as the OAS in the major US projects that were underway in the early 1990's. The plan provided corporate engineering manpower for technology that could otherwise be supported by the major project. The site where the OAS was installed was selected for two reasons. First, the existing computer infrastructure would lower the cost and the local management had placed a high priority on upgrading, maintenance, and proper execution of procedures.

The OAS was implemented as part of the capital project for construction of the diesel hydrotreater. Implementing the system on a new construction unit provided special challenges and opportunities. The OAS was being developed at the same time that the procedures were being written. Each effort had an impact on the other. It was certainly a challenge to keep up with the constantly improving procedure. But an unexpected opportunity to impact the organization of the procedure surfaced due to the graphical view that the OAS provides. Many of the review sessions resulted in revising both the advisor and the written procedure.

Having the advisor as an identified piece for the capital project to deliver kept the visibility high. The development was started when the design contractor started to write the general procedure. Using the procedure to develop the OAS uncovered many of the inconsistencies early in the process.

Plant operations involvement was high from the beginning. This is always mentioned in descriptions of developing user interfaces but is worth repeating. Whenever possible, users were shown choices on the OAS using their procedure for developing the user interface. We found this approach worked better than a 'This is how it's going to look' dictation or a general discussion. Seeing their suggestions and decisions incorporated in the end design greatly increased the user buy-in. User buy-in was also increased by the development of a working team. The team consisted of local and corporate management, plant engineers, operators, and corporate engineers. The engineer installing the OAS had more control system, process, and instrumentation experience than expert systems or computer science. His ability to contribute to the more traditional DCS design and process activities aided his team membership and the OAS success. A wide skill set was more important than depth for this project.

As the procedures were written, the process we followed was to quickly build the OAS for that section and review it with the procedure authors. With the frequent revisions that came as the plant was being constructed, this may have taken a bit more time but waiting until the procedures were stable would have been too late. The reviews were primarily between the chief operator who was writing the procedures and the OAS developer. During the last 8 months of construction there were at least monthly reviews lasting for 3-4 half-days each.

With operators, the system was demonstrated and training carried out on the real refinery equipment. Training was a 1/2 day section of the standard DCS operator training.

Experience and Benefits

This application of the Operator Advisor System provided us with a proof-of-concept demonstration, a value-added application, and specifications for future enhancements. While we found it lacking in some areas, it provides the operator with a useful tool.

Careful incorporation of the operator’s concerns at the design stage, and well-designed training lead to good acceptance. They did not feel they were involved in an expert systems development project, but that they had another tool to use irrespective of the underlying technology.

Use of the system caused introduction of some new practices, in themselves beneficial. Early on, it was found that the operators would not individually enter their actions in a timely fashion, and this reflects some lessons learned in the deployment of outside operators. Having a single start-up co-ordinator on each shift, responsible for keeping the system up-to-date, improved performance of the procedure.

Another benefit was the access that other site personnel had to the system. We were able to network the system such that the supervisors and Operation Manager could access the system and scan around it independently of the operators. Only the operators could check off actions, but others could enter comments at any stage. It proved to be a valuable management tool in assessing the performance of the procedure.

The primary benefits that we observed are:

1. Graphical view of the procedure
2. Context-sensitive Data Monitoring
3. Comment capture
4. Automatic record keeping

The primary shortcomings were in two areas:

1. Integration with checklist documentation
2. User Interface (outside operators)

Beneficial applications can be delivered without resolving these limitations however they will have to be addressed for the technology to become in common use. There are some promising developments. Integration with a checklist version of the procedure may be addressed by on-line documentation tools. Perhaps mobile computing will have an impact on integrating the work that goes on outside the control rooms with the plant's computing networks.

The use of an on-line knowledge-based system is seen as having potential for reducing upsets and accidents during transitional operations. The hardware and software of the system were deemed manageable by the refinery support personnel. It was a great example of a diverse team involving management, engineering, and operations working together to accomplish a goal.

References

Beach, D.W. and Knight, M.J., “Refinery Implementation of an Operator Advisor System for Procedure Management”, Intelligent Systems for Process Engineering (IPSE) Conference, Snowmass, Colorado, July 1995.

B. Rasmussen, “Chemical Process Hazard Identification,” Reliability Engineering and System Safety, Vol 24, Elsevier Science Publishers Ltd., Great Britain, 1989, pp 11-20.

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Figure 1. Procedure Display

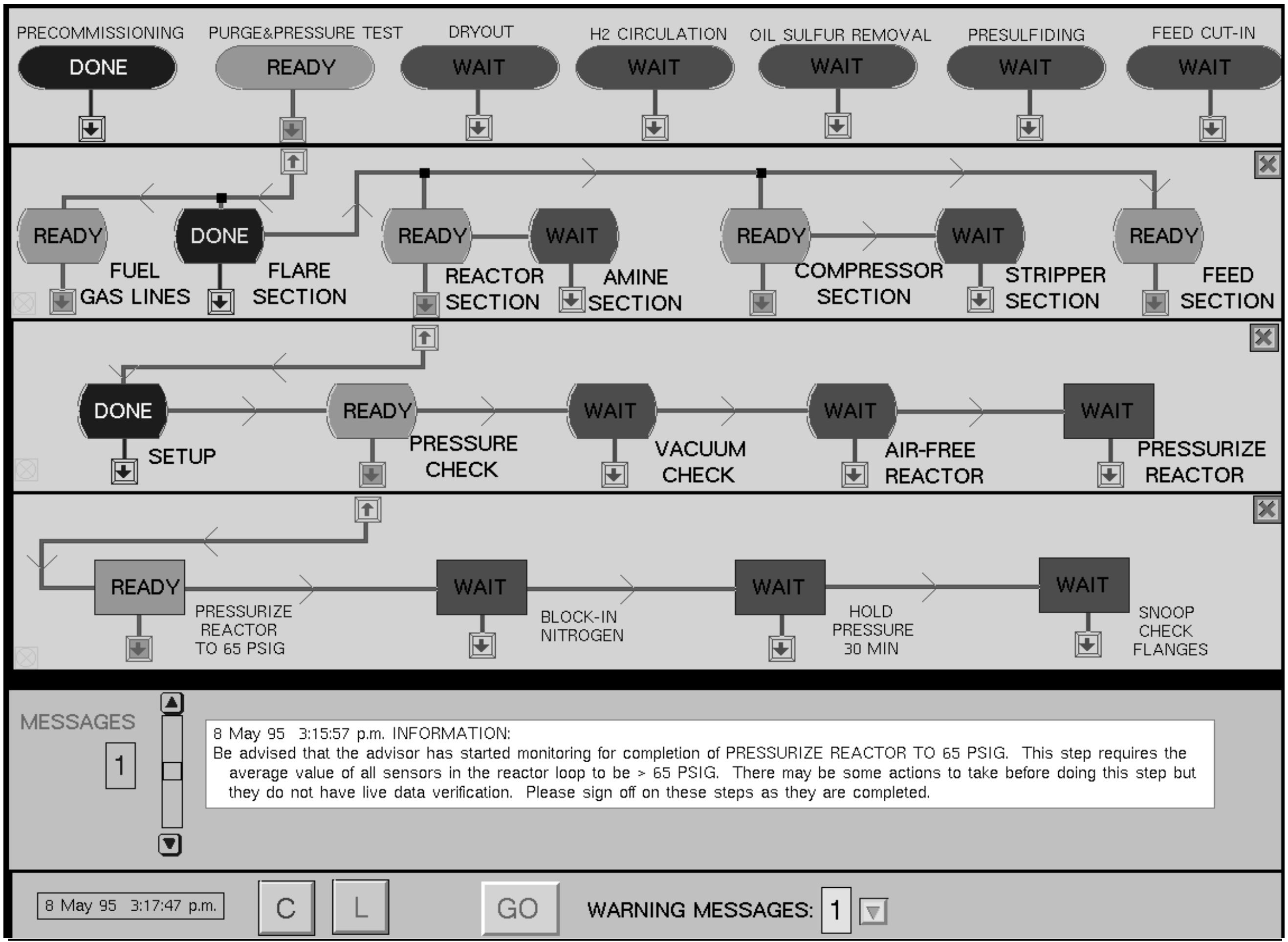

Figure 2. Operator Input Display