CRITIQUING TEAM PROCEDURE EXECUTION

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Critiquing is a form of decision support whereby a computer system monitors the actions of people to help prevent errors. Critiquing systems developed to date (spell checkers, problem-solving assistants, etc.) traditionally support a single person performing a static, non time-critical task. We have now developed a critiquing system in the more dynamic world of process control. Specifically, we support the execution of complex procedures in petrochemical plants with an on-line, executable dynamic procedures decision support system, where we introduce critiquing as a means to assist teams of operators as they execute procedures in real time.

INTRODUCTION

In process control, a critical and difficult time is during the startup and shutdown of large pieces of equipment or of an entire process. Startup and shutdown require a carefully executed sequence of actions by both a control system and a distributed team of operators, some who are in a control room, and some who are out in the field. Traditionally, operators use written procedures to guide the actions taken during this and other refinery tasks. This project aimed to develop and test an on-line, interactive procedure system that would support a team of operators as they execute complex procedures.

SITE INFORMATION

The design, development and testing of our prototype on-line procedure system was based on site visits and observations at a major petrochemical refinery. This refinery has two identical reactors in one part of their process. Every 2-3 months, it is necessary to shut down each of the reactors, to have maintenance change out the catalyst and do any other maintenance work that is needed, and then start back up again, usually one to three days later. The shutdown procedure takes about 6 hours and the startup procedure takes about 5 hours. Generally, two operators work together on the startup and shutdown procedures, the outside, "A" operator, and the control room "B" operator.

Because of the relatively frequent startup and shutdown of these reactors, we chose this unit to focus on for the design and test of our system. We were able to observe two startups and a shutdown early in the year, and use these observations to help define the requirements for the design of the system.

We observed several difficulties faced by operations teams that could perhaps be assisted by an on-line procedure system. Some of these difficulties are described below.

Operators working in a control room remote from the process need to coordinate their activities with outside field operators. The distributed nature of the team makes it difficult to assess where people are at in the procedure. Operators often call each other on the radio to ask if a step has been completed yet, or, despite the desire to do so, they do not call their fellow workers for fear of being annoying.

Some steps are time-critical, or dependent on the process conditions. For example, there are steps such as, "Close the block valves when the pressure reaches 400 psig." It is easy to forget to do a step at the appropriate time. We observed one start-up procedure where it was discovered by the incoming shift team that a critical step (exercising the reactor outlet valve) had not been completed.

This step needed to be done before the outlet valve could be opened and the reactor brought online. Meanwhile, pressure was building up in the reactor. By the time the step was completed and the valve was finally opened, the reactor pressure was higher than it should have been and continued to go higher. The control room operator struggled to bring the pressure back down again, narrowly avoiding a trip of the pressure relief valve.

For these reasons, it was hypothesized that a computer-based "smart" procedure system could enable better coordination of activities, and avoiding situations like the one just described.

CRITIQUING SYSTEMS

Critiquing is a form of decision support whereby a computer system monitors the actions of people to help prevent errors. Critiquing systems developed to date (spell checkers, problem-solving assistants, etc.) traditionally support static problem-solving tasks. For example, the systems developed by Guerlain, (1995), Fischer, Lemke, and Mastaglio (1990) and Silverman (1992) respectively support antibody identification, kitchen design, and probability problem-solving. In these domains, the information space is not changing while users are conducting their task. Furthermore, these systems aid one person working on a problem. For this project, we applied the critiquing approach to improve coordination of team members, and check for errors of omission and commission while executing a procedure on a dynamic process.

SYSTEM DESIGN

We introduced a computer-based system that allows a team of operators to simultaneously view the "same" copy of a procedure using a client-server architecture. The procedure is centrally managed on the server side and distributed to clients through a user interface that runs in any Java-enabled web browser. Figure 1 shows a sample shut down procedure that is in the middle of being executed.

By centrally managing the procedure, the system can track who has completed what steps, and allow all team members to see when other members check off steps. Live process values are shown in the context of the procedure for the user's benefit. The system includes critiquing functionality to help eliminate errors of commission, errors of omission, and procedural errors. The system monitors the execution of the procedure by the shift team, alerting operators to process parameters that go out of range, and alerting operators to tasks that need to be performed right away. For example, while pressuring up a reactor, a step such as, "Open the outlet block valve when the pressure reaches between 450 and 500 psi" will not become enabled until the pressure has reached 450psi, and will go to a critical, alert state when the pressure reaches close to the high end (490 psi). Steps that are dependent on previous steps will not become enabled until prerequisite steps have been completed. Finally, the system can verify user actions, to ensure that when a user says they closed a valve, for example, that the downstream flow has in fact stopped.

System Interaction

There are two kinds of steps contained in our procedures:

Action Steps. These are steps that have a defined action to take, such as, "Ensure that M&C pulls the depressuring and nitrogen blinds". Next to these steps is a checkbox, that, when active, should be checked off as the step is completed. The system will log the initials of whoever checked off the step, and other operators viewing the procedure online will see that the step has been completed. If a step is not yet ready to be performed (because preconditions have not been met) the checkbox is not displayed and the status area is grayed out. Once preconditions have been met, the status area is no longer grayed out and a checkbox appears. The checkbox itself is grayed out (unavailable) if the step is assigned to a different operator. If a task becomes critical, and has not yet been checked off, a red box highlights the step as needing operator attention.

Monitoring Steps. These are steps such as "Maintain 5PC61, flash drum pressure, above 300 psig". For these steps, we do not present a checkbox, as it is not appropriate to indicate when the step is "done" or "not done". Rather, the system monitors for that condition, and displays either "OK" if the condition is being met or "Alert" if the condition is not being met and needs to be adjusted by the user. In addition to displaying "Alert", a red box highlights the step as needing operator attention. If the period during which the monitoring needs to take place has not begun yet, there is nothing displayed next to that step. If the relevant monitoring period is over, the system displays "Done".

Whenever a procedure step references a measured process value, the live data is displayed within the step. This is particularly useful for the field operator who does not normally have the ability to see process parameters in the field. If the process value is being monitored by the computer and it is within acceptable range, then the data is displayed in green text enclosed in single brackets (along with the word "OK" displayed in the status box). If the process value is out of range, then the data is displayed in red text enclosed in double brackets (along with the word "Alert" displayed in a red status box). This context-sensitive monitoring functionality is a variation on the user-initiated notification concept as described in Guerlain and Bullemer (1996). Required process monitoring activities are off-loaded onto the computer system, relieving operators from having to constantly monitor for certain process conditions.

Steps that reference relevant documents or supporting information have a hyperlink available to support direct navigation to those details.

Operators can add a written comment to any procedure step, and can re-assign steps to others, if authorized.

Platforms of Use

Field operators access the procedure and check off steps as they are completed using a Personal Information Processing System (PIPS) as described in Guerlain, Lee, Kopischke, Romanko, Reutiman, and Nelson (1999). This PIPS system is a client-side wearable computer system with wireless access to server information. Control room operators access and use the system with a traditional desktop computer.

DISCUSSION

Teams of operators executing complex procedures such as starting up and shutting down large pieces of equipment need to coordinate their actions with each other and with the process, to ensure smooth, safe transitions. By centrally managing and distributing procedures, we have the ability to develop an interactive, "smart" procedure system, that can be sensitive to changes in the process, and monitor operator activities as steps in the procedure are being followed. Such a system has the potential to help remote operators stay coordinated with each other and with the current state of the process.

Despite the potential benefits, there are many challenges that must be overcome before such a system can have wide-spread applicability in the field. The foremost challenge is the need for the operators to interact with the system, faithfully checking off steps as soon as they are completed. Guerlain et al (1999) noted that in order for a critiquing system to be effective, it must have the ability to unobtrusively collect data about the user's actions in order to reason about their current level of activity. Signing off steps is a normal and required practice in petrochemical operations, but in practice, operators often execute several steps in a procedure before signing off those steps when it is convenient to do so. It would be much better if the system could detect automatically when an action was taken, rather than relying on the user to then check off the step. For some procedure actions this is possible, but others that require manual actions can not be directly monitored by the control system.

CONCLUSION

Critiquing systems have been demonstrated to be effective at reducing errors and improving overall performance in many static domains, assisting single operators as they perform a difficult task. For this project, we have developed a proof-of-concept critiquing system that can successfully detect errors of omission and errors of commission, as well as monitor for context-sensitive operating conditions in the dynamic process control domain. Although it is technologically feasible to provide this kind of a decision aid, plant cultural factors will prevent this type of a system from being of wide spread use until it becomes easy and unobtrusive for operators to sign off procedure steps immediately after being executed, or for the system to automatically detect when operator actions have been taken.

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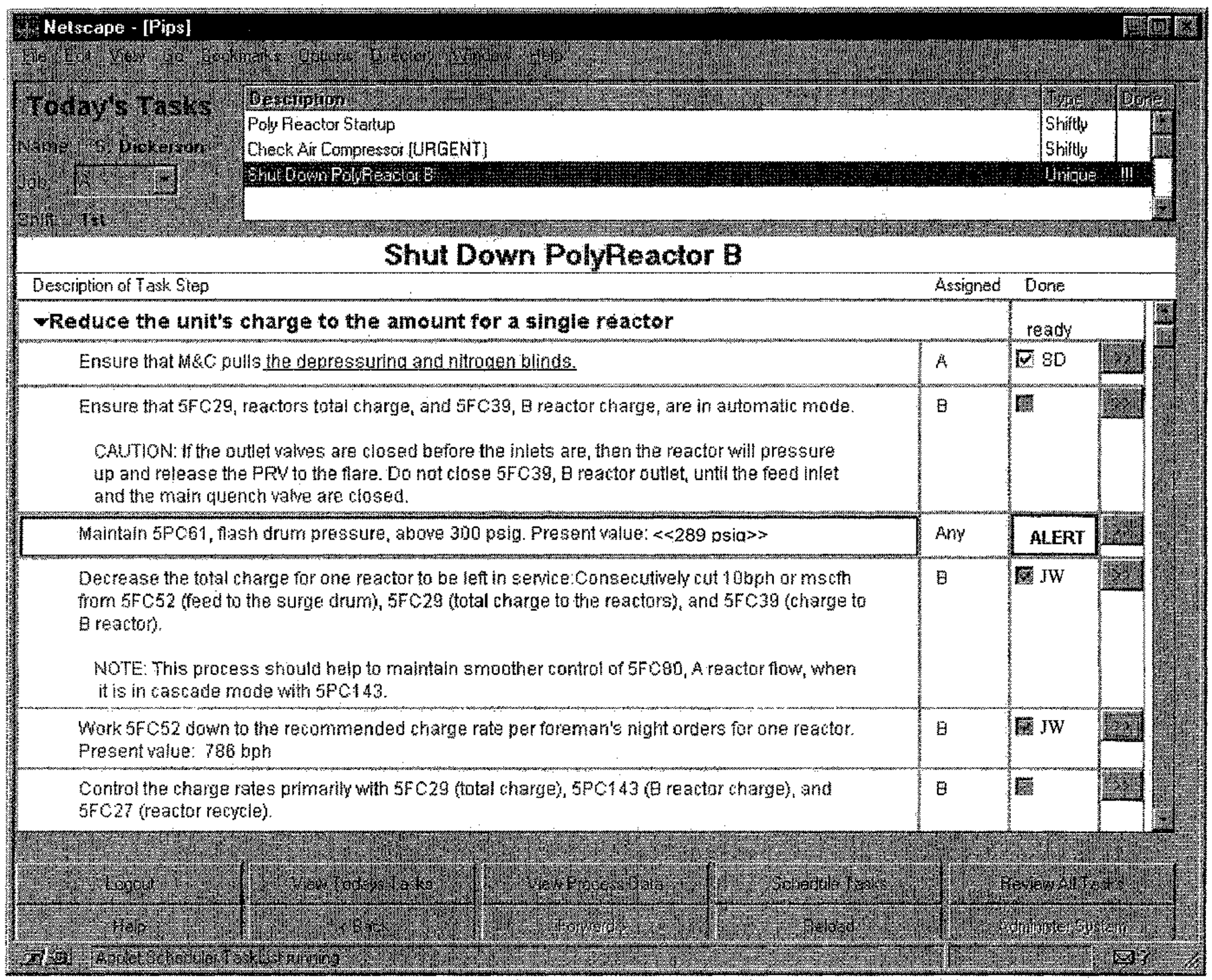

Figure 1. Sample Interactive Procedures Screen.