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Consider dynamic simulation tools when planning new plant startup

Simulation-based operator training uncovers potential process and operational problems before feed enters the unit

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An Operator Training System (OTS) is often a "point-solution," turnkey line item in projects. These systems are often developed with niche software, only suitable for use by OTS provider personnel.

Commercial dynamic simulation software has evolved. Consequently, the capability to model complex processes dynamically with engineering-grade commercial simulation software is transforming expectations from an OTS investment.

A recent BP Chemicals project demonstrates how a rigorous dynamic process simulation-based OTS can support many tasks before plant startup, and support processing improvements after commissioning. Development and study of dynamic models can:

- Enable rigorous understanding of complex plant process behavior
- Provide a realistic "virtual plant" to test the control system configuration against
- Deliver a dynamic model that may be used to develop and validate operating procedures prior to startup.

Maintainability of the OTS systems greatly improves through the utilization of a Windows-based, integrated steady-state and dynamic simulation engine. Plant personnel can use and maintain the dynamic models for additional engineering tasks after commissioning; since the commercial simulation engine is widely used by operating companies, engineering contractors and industry consultants. **Result:** The useful life of the OTS is longer, and the operating company receives additional long-term benefits from their dynamic simulation investment.

Strategic project decisions. In June 2001, BP Chemicals built a full-scale commercial ethyl acetate at the Saltend, Hull, UK complex. The 220,000-tpy plant is the world's largest single ethyl acetate production unit. The BP plant was initially commissioned and on-specification product was produced only two weeks after startup.

This project involved new process technology—a completely new chemical route. BP made a key decision to use dynamic simulation as part of the pre-commissioning engineering activities and to support operator training. The dynamic model of the complex process supported a variety of engineering and operational tasks in preparation for startup. The project was justified due to past successes with simulation projects, and the expectation that the dynamic models would be valuable tools for future engineering tasks.

FIG. 1. Personnel interacting with the operator training simulator.

Key business goals. The new project was a key business initiative, involving significant process innovation. To fulfill the need for a solid understanding of the process and control systems, and to train operators, BP developed a dynamic model of the *new* facility. This ethyl acetate process was new to both operating technicians as well as operations, control and process engineers. A high-fidelity simulator was critical for studying operational safety and issues that could prevent a smooth unit startup and achieve design output rates within the planned timeline.

Previously, BP successfully applied simulation to rigorously test and confirm DCS configuration. On this project, the key goals were control system configuration, controller tuning, development and testing of operating startup procedures, and familiarizing operating technicians with the underlying process and the control strategies.

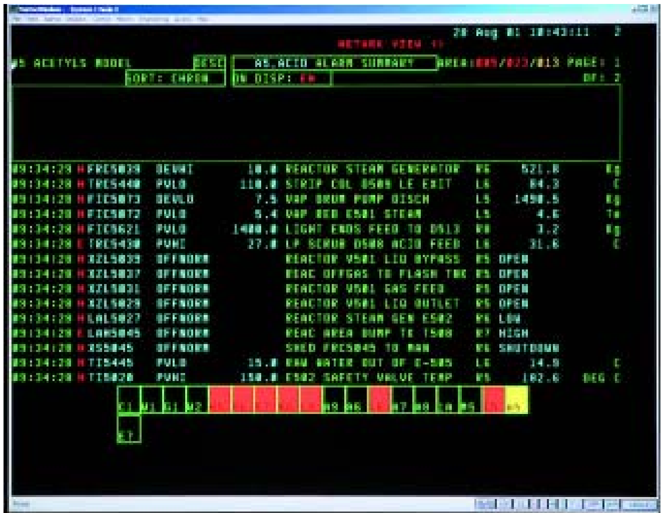

FIG. 2. **Operator graphical interface for operator training simulator.**

BP had extensive knowledge of this new process chemistry and thermodynamics stemming from intensive research. For this project, the commercial simulation had to transfer process knowledge from the project design team to operations personnel. A rigorous first-principles steadystate and dynamic process modeling software environment was selected. It could incorporate BP's vast chemistry and thermodynamic process knowledge into a dynamic model.

Cross-organizational usage of the simulator. The dynamic models were used across the project organization for many tasks. Some primary benefits to the team members included:

Process engineers: The simulator provided a broader understanding of the process operation during steadystate, as well as plant response during upsets and rate changes. It confirmed the process and safety system design.

Control engineers: Using the simulator, engineers were able to identify potential control problems prior to actual startup. The system discovered valves that were incorrectly specified, control valves that required resizing, and inappropriate transmitter span settings. Initial controller tuning parameters were calculated, with complex and critical loop tuning done on the simulator and then used on the actual plant successfully.

Operations: Operating technicians could review and validate operational, startup and shutdown procedures. An in-depth understanding of the process, control system, control strategies and operator interface was achieved through the simulation-based system. Operator graphics for the plant control system were tested during the factory acceptance test (FAT) on the DCS. The simulator provided more in-depth evaluation of these graphics following the DCS FAT. On connection to the rigorous dynamic model, a logbook was set up to capture errors upgrades identified when the operators started using the DCS operator graphics to "run" the dynamic model and make operational decisions.

DCS operator graphic information load and presentation were modified before startup; thus minimizing potential operator error stemming from poor operator graphics. "The latest control and online analysis technologies are used in the unit operation, allowing it to be efficiently managed by a small team of operators. The new plant is the first to be controlled from the Saltend site's new central control room. It is intended that all plant operators will eventually be located in this single state-of-the-art control room."[1]

The operating company was able to bring together the project team during pre-commissioning tasks using the simulator to build confidence in operations personnel who were starting up the ethyl acetate facility from the new central control room.

Benefits realized by project team. Compression of the learning curve for the process support engineers and operators was a key goal, achieved using the simulator. During startup, there were zero startup delays associated with a lack of operator understanding. No DCS configuration problems and no valve manipulation problems occurred. Operator knowledge gained on the simulator regarding the procedural aspects of the startup, the dynamics of the plant and how to progress the startup, and how to manage transitional operation of key columns through changing operating regimes, was proven.

The new unit quickly produced on-spec product. "Operator confidence was high and improved further as they started the new facility up using their experience from the simulator, and saw the plant respond as anticipated from their experiences with the simulator," said Peter Rutherford, BP Lead Engineer for the DCS Design, Implementation, and the Operator Training System for the project.

Design issues were uncovered as well using the same rigorous dynamic models, including limitations related to control valves (too large, too small, or wrong characteristics). Control strategy problems, particularly centered on the reactor, were identified during rate changes and low rate (60%) operation. Control strategies were revised to be more robust over a broader operating range by using the dynamic model as a virtual plant to devise new control techniques.

Startup procedures were tested in a step-by-step method and revised as process knowledge, control systems and trip system design understanding were brought together in the simulator. Some areas of the process had significant time constants and dead times that were discovered through trials conducted on the simulator. With this information, operating personnel could avoid "rushing" corrective action and startup on the actual plant. This level of process and control system understanding was vital to the successful startup efforts. This level of process and control system understanding was vital to the successful startup efforts, and was a result of the ability of the rigorous process model to represent complex process behavior with rigorous thermodynamics, simulation of three-phase distillation columns, and process equipment dynamics.

Operator acceptance of the simulator was very high. The simulator provided a low-risk environment to explore process and control system understanding before actual plant commissioning. All operators experienced about 15 days of training on the simulator. Ten operator shifts were trained via the simulator.

Another benefit realized concerned operational alarms. DCS systems come equipped with tremendous alarm capabilities. Unfortunately, many of these alarms can be spurious, posing a serious distraction and making the operator insensitive to real alarms.[2] The simulator provided a means to evaluate alarm settings and loading. BP engineers identified "nuisance" alarms and modified alarm ranges accordingly. A philosophy of zero alarms during "steady operations" was achieved via the simulator.

Using the simulator, key findings on how some control loops interacted with each other and prioritization of control loop

FIG. 3. Engineering and operations personnel interacting with simulator.

FIG. 4. Reviewing facility performance.

tuning in these situations was also possible. The dynamic model provided a rigorous representation of the process, enabling the control loops to interact wtih the process model, and thereby providing the process connection required to study interactions with other control loops.

Some control loops possessed multiple input options. When input options were modified, the control loop dynamics changed significantly in some instances. Having a rigorous thermodynamically-based model of the process enabled control engineers to schedule controller tuning changes within the plant control system—based on observed process dynamics from the simulator.

Some operational difficulties were identified with the simulator. Other operating challenges were uncovered with the pilot plant and then confirmed through the simulator. Due to the agreement between the pilot plant and simulator, engineers were able to confidently study these issues and identify both operational methods and control system changes to manage these challenging conditions safely.

Success and praise. The superior safety record of the project was recognized in April 2001. The BP VAM/Ethyl Acetate Alliance Project received an Award for Safety in Engineering Construction by the UK's National Joint Council for the Engineering Construction Industry. This award has only been given to nominated projects 12 times in the past 20 years, most recently in 1999.[1]

Rigorous simulation models are a lifecycle asset.

While the project startup was successful, the facility has already identified many applications to further exploit the dynamic models developed for the project. Additional engineering and operational value has been extracted from the project simulation efforts.

Additional potential applications include using the dynamic models for inferential sensing of key process variables, and evaluating the benefits of applying multivariable control to further improve plant performance. Dynamic models created using the same integrated steady state and dynamic modeling environment used for this project have been used successfully to evaluate and quantify the benefits of applying multi-variable control to a process, and then streamline the project implementation.[3]

Operational personnel were involved with procedure and alarm checkout during commissioning. These activities will also be undertaken on the simulator for new critical operational tasks and procedures. Future training will focus on setting up scenarios to replicate common operational problems observed in the plant, and abnormal situation alarm management will also be investigated using the simulator.

This project is an excellent example of how dynamic simulation and commercial process simulation software can provide tremendous benefits during design, commissioning, startup and post-commissioning phases. Using a consistent simulation environment across the project lifecycle ensures maximum capture and transfer of plant understanding and knowledge from the project team to operations and future engineering efforts. **HP**

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