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ESSENTIALS OF DYNAMIC SIMULATION
An Essentials Guide, by the editors of Control

About the Control Essentials Series
The mission of the Control Essentials series is to provide process industry professionals with an up-to-date, top-level understanding of a range of key process automation topics. Our intent is to present essential engineering concepts in a practical, non-commercial fashion, together with a review of the latest technology and marketplace drivers—all in a form factor well suited for onscreen consumption. Check in at ControlGlobal.com/Essentials for other installments in the series.

—The Control Editorial Team

This Control Essentials guide made possible by MynaH Technologies. See page 6 for more information on the company’s full range of simulation solutions.
The process industries are by nature a complex, risky business. And that risk can take many forms over a plant’s life cycle. First there’s schedule risk. From the first moment a new facility gets green-lighted, corporate stakeholders want the plant up and running as quickly as possible so they can start to realize a return on the investment they’ve approved. Project delays can mean revenue lost forever, as in the case of a patented pharmaceutical. And in the energy industry, earlier “time to first oil” can mean millions of dollars in cash flow. Then there are operational risks. Would an alternate control strategy make the process more efficient? Or would it give rise to instabilities or other unintended consequences? Are operators prepared to handle process upsets and tasks that are not often performed, such as start-ups and shutdowns? Then again, what happens when your most seasoned operators walk out the door, never to return?

Among all the software tools at the process manufacturer’s disposal, dynamic simulation is uniquely suited to help address these various sources of risk from the earliest stages of system design throughout a plant’s operating life. Dynamic simulation makes possible the early testing and troubleshooting of new control system code, when course corrections are easiest, fastest and least costly to make. Dynamic simulation makes possible the early hands-on training of process operators, which can be started even before the physical process is commissioned. Once a unit is up and running, dynamic simulation paired with an offline replica of the control system provides operators with experiential preparation for process upsets and procedures that are not often performed, such as start-ups and shutdowns — an impossible or impractical task when only the live production system is available. Dynamic simulation also is an effective tool for exploring the implications of potentially more optimal “what-if” scenarios — without putting actual production at risk.

And while the direct benefit of using a dynamic simulator is difficult to quantify, a recent survey by the Electric Power Research Institute (EPRI) indicated an average yearly saving of about $4,500 per megawatt of generating capacity. These savings are attributed to reduced training costs, improvements in plant availability, fewer environmental excursions and reduced damage to equipment. A little bit of math indicates a three-month payback for the typical power generation facility and begs the question: In what scenario would you not invest in a dynamic simulator? All dynamic simulation implementations, however, are not created equal. And on the pages that follow we’ll explore the key considerations.

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While every process simulation is based on underlying mathematical models, it’s important to remember that all models are not created with the same goals in mind. The models used for process design have their place, but typically are ill-suited to the dynamic requirements of control system testing and operator training. We’d hardly be surprised to hear that the workhorse CAD models for Boeing’s latest airplane don’t also drive the airplane’s flight simulator. So why should our industry be any different?

In contrast with most process design tools, the process models used for operator training and control system testing have to be dynamic and they must be executed in real-time. They must converge on a result every second and provide realistic results over a wide range of process conditions and transients. This isn’t to say that dynamic models are less rigorous than their steady-state counterparts; it’s just that the absolute accuracy of process variables takes a back seat to accurately depicting the dynamic behavior of the process over time.

As such, dynamic models used for operator training and control system testing still rely on chemical engineering “first principles.” That is, the thermodynamics, reaction kinetics and heat and mass transfer equations that govern process behavior. Within a dynamic simulation software package, basic and advanced function blocks model the dynamic behavior of valves, transmitters and entire unit operations — configurable with process-specific information such as known reaction kinetics. It’s also important to note that the same level of complexity need not be used to model all aspects of plant operation: a tank farm requires a simpler model than a series of interacting distillation towers. Using the appropriate model for each unit operation ultimately will provide the best balance of simulator performance, cost and future flexibility. Once operating experience has been gained, dynamic models can be further tuned using actual data. Models based solely on statistical correlations of process data, however, are unlikely to behave well throughout the full range of possible conditions, especially at the edges of the operating envelope such as during an upset, startup or shutdown, making them inappropriate for use in testing and training.

Industry standards such as the ISA/ANSI 77.02 specification on functional requirements for fossil fuel power plant simulators correctly apply a different accuracy standard to dynamic performance (20%) than to steady-state (2%). Further, the specification states that for a dynamic simulator the “observable change in parameters shall correspond in direction to those expected from a best estimate for the simulated transient and shall not violate the physical laws of nature” and that “the simulator shall not fail to cause an alarm or automatic action if the reference plant would have caused an alarm or automatic action, and, conversely, the simulator shall not cause an alarm or automatic action if the reference plant would not have caused an alarm or automatic action.” This is, after all, the true measure of a dynamic simulator’s utility: Does it correctly model the process behavior such that operators and process engineers can better understand how the process will react to specific actions and operator interventions?
The right choice of process model is only the first step in the successful application of a dynamic simulator. Just how the models are implemented and the manner in which the production control system is recreated offline will make or break how well the combined system works initially and how easily it can be maintained over the process life cycle.

Perhaps the most important architectural consideration is the logical separation of the dynamic simulation package from the offline replica of the production control system. Resist the temptation to wedge a dynamic simulator into the control system environment, or to emulate the control system within the dynamic simulator. Both functions will suffer — initially and into the future—from this sort of compromise. Process control systems are designed for control: they don’t include the tools needed to readily build and manage a dynamic simulation, and attempting to do so will likely cause the performance of the offline control system to diverge from its production counterpart. A dynamic simulator, in turn, will likely fall short in trying to emulate the subtleties of a given manufacturer’s process control system — initially and over the course of time.

Maintaining these domains as separate applications allows the offline control system to faithfully duplicate the operation of the production control system complete with identical operator graphics, alarms and control strategies. Most all control system manufacturers today offer a soft controller or simulator that emulates the operator stations, engineering station, process controllers and other higher level system functions. These OEM products provide an environment where the control system can run in a manner identical to the actual plant, and updates to the production control system can be readily synchronized across the two platforms.

In turn, modeling of the transmitters, final control elements, and the process itself in a dedicated dynamic simulation environment allows the user to easily develop and maintain process models to the level of complexity or fidelity required by the task at hand. Further, software functionality for training logistics should reside in yet a third integrated domain (Figure 1) that allows supervisory control of both the control system and the process simulator.

**Figure 1.** For best performance and maintainability, a dynamic process simulator should be implemented separately from the offline control system with which it works.
Despite a paucity of on-record reports of cost savings due to the use of dynamic simulators, anecdotal figures in an ARC Advisory Group report from 2006 continue to impress: up to $500,000 per day; $1 million in savings per production run due to higher on-spec product; $100,000 per hour in operating cost savings due to more proficient operators; and $1 million in risk mitigation per incident through better identification and addressing “dormant errors” in automation systems.

For example, Ron Cisco, DCS training specialist at Salt River Project’s coal-fired Coronado Generating Station, reported at the 2013 ARC Advisory Group Industry Forum that the company was able to bundle an operator training simulator into a larger control system migration project because it represented a relatively small additional cost. Even so, the simulator was justified based on the demographic crunch of retiring operators that has only intensified in recent months. Indeed, in the two years since the project was completed half of the plant’s control room operators had retired and 100% turnover is expected within five years.

What surprised Cisco and the rest of company management even more was the 144 control logic issues that were discovered and resolved with the aid of the dynamic simulator before operation began and “before we even started operator training,” Cisco said. These were issues that were not seen during the factory acceptance test with simple, non-dynamic I/O tiebacks. It was only when the true process dynamics were simulated that these issues appeared. Management consensus was that the dynamic simulator “already paid for itself” before the new control systems even came on line.

And at Barrick Gold’s $3.8 billion Pueblo Viejo mine in the Dominican Republic, dynamic simulators on 10 major processes are helping operators to deal with ore variability, including hardness, mineral content and other characteristics that can help or hurt recovery, according to Paul Yaroshak, process systems engineer. “Our processes need robust logic to effectively respond to these changes, and simulations help us to better understand process interactions, remove bottlenecks, and provide insight for managing variability.”

“Likewise, our training simulations include using actual screens and graphics with realistic process dynamics and responses, which force operators to react in real-time to different alerts, alarms and process interlocks, and prepares them to handle many situations and failures,” says Yaroshak. “The old way would have been to wait until the plant was running to do this kind of training, so the simulations buy us a lot of time. We’re also using our simulations to develop testing of configuration and function logic within our DCS, so we can evaluate and fine tune interactions between different elements of the control system, and make sure they’re working together as designed and intended.”

Similar benefits of dynamic simulation are evident in reports from other plants using various automation and simulation systems:

• A leading pharmaceutical company undertaking a control system modernization project reported that dynamic simulation for testing and training “served to minimize surprises during commissioning and qualification.”

• A major operation extracting oil sand for processing into refinery feedstock reported training simulations led to greater safety, environmental compliance and efficiency, faster startups and reductions in downtime, energy costs, equipment damage, production loss and more.

• And a recent survey of 250 simulation users in Norway by World Oil Online attributed a 31% increase in operator effectiveness to the use of dynamic simulators for operator training.

In the end, an investment in dynamic simulation is much like an insurance policy. It represents a known upfront cost that can pay for itself many times over when a hidden automation system error is exposed or when an operator in unfamiliar territory finds he knows what to do because of the training and preparation he’s received on the plant’s dynamic simulator.
This *Essentials* guide on Dynamic Simulation was made possible by MYNAH Technologies, a leading provider of a life-cycle dynamic simulator that is used for a variety of purposes from automation system acceptance testing to operator training, and industrial Ethernet solutions. MYNAH’s Mimic simulation software is used in more than 1,300 sites in 68 countries worldwide ranging from hydrocarbon production and refining to chemical, pharmaceutical and biotech industries.

Learn more about MYNAH Technologies’ dynamic simulation offering.