The Benefits of using Dynamic Simulation and Training Systems for expanding Operator Knowledge and Understanding

What’s Inside:
1. Abstract
2. Introduction – Simulator Objectives
3. Operator Training
4. Control System Checkout
5. Controls Analysis, Configuration, and Tuning Test Bed
6. Engineering and Operational Analysis Test Bed
7. The Solutions
8. What is Virtual Simulation?
9. Project Methodology
10. Improved Operator Knowledge and Understanding—the HSE
11. Expert Tutor Systems
12. Conclusion
1. Abstract

Dynamic Simulation and Operator Training Systems (OTS) have been available in the marketplace for a long time. However, over the last five years the improvements in technology — the computers, the software and the market understanding — have meant that the use of OTS has become a reality for many processes. No longer are Training Simulators primarily the realm of airline pilots, nuclear systems and astronauts, but now they are available for processes such as FPSOs, LNG terminals, GTL plants, refineries, etc. In the last few years, Invensys has become the new “Tier 1” OTS supplier to the Process and Power Industries, leading the market with the new software - DYNSIM® in the SIM4ME™ Environment. Invensys OTS’ have been used worldwide on large-scale projects for not only thoroughly checking the control system configurations in integrated systems before they are applied to the actual plant, but also for training the operators, instructors and plant management in how to best operate their facilities. Plant management has found that a relatively small investment in an Invensys OTS can save hundreds of thousand of dollars with paybacks measured in weeks or months. OTS’ have been used to uncover any control system configuration, graphic or logic errors that might lead to unit trips, equipment damage, or other events that would result in an extension of the planned outage window associated with the upgrade effort. This paper describes the project justifications, model development process, and the Control System team integration processes that have been used on Invensys OTS Projects.

2. Introduction – Simulator Objectives

Invensys has developed over 80 Operator Training Simulators (OTS) in the Chemical, Oil, Gas, and Power industries. These OTS’ have been used primarily for the training of operational staff prior to and following the start-up of the main facilities, with the aim of training the operational staff in:

- Procedures for plant start-up and shutdown situations
- Handling of utility system and process unit trips, turndown and other upsets
- Fault diagnosis, alarm handling and corrective actions in case of process equipment malfunction during normal operation
- Steady state operations
- Reduced start-up and shutdown times
- Increased safety
- Reduction in environmental concerns
- Increased unit up-time
- Increased operator awareness, skills and readiness
- Assess operator competence

Additional uses of the OTS have been:

- Testing and validation of operating procedures
- Testing and validation of control strategies and logic
- De-bottlenecking
- Investigation of engineering solutions
- Sharing of incident and operating scenarios across shift teams
The Invensys approach allows the following plant life cycle objectives to be met:

### High Fidelity Plant Simulators

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Process equipment design</td>
<td>• Control and graphic design verification</td>
<td>• User interface familiarization</td>
<td>• Control and process design testing</td>
</tr>
<tr>
<td>• Relief system design</td>
<td>• Graphic display improvement</td>
<td>• Startup training</td>
<td>• Alarm management</td>
</tr>
<tr>
<td>• Control strategy validation</td>
<td>• Controller pre-tuning</td>
<td>• Emergency response training</td>
<td>• APC pre-tuning</td>
</tr>
<tr>
<td>• Process operability analysis</td>
<td></td>
<td>• I&amp;C diagnostic training</td>
<td>• Operation procedure optimization</td>
</tr>
</tbody>
</table>

#### Figure 2. Uses for Dynamic Process Simulation and the SIM4ME Dynamic Simulation Suite

### 3. Operator Training

The primary objective is to provide plant specific high-fidelity Simulators for initial training and retraining of control room operators, operating supervisors, and other plant equipment operators.

Based on the specific training plan developed by the instructor, the Simulator can:

- Improve understanding of general plant theory and concepts
- Increase knowledge of plant systems and their function and interaction with other systems
- Enhance understanding of plant control theory and operation
- Gain operating experience, confidence, and accuracy in normal and abnormal plant operations
- Provide practice following specific operating procedures
- Demonstrate recovery from various upsets and malfunctions

### 4. Control System Checkout

A further objective is to provide a tool that can be used to check the new controls for the plant before the actual initial start-up of the plant.

Control system checkout allows the Simulator to be used to:

- Pre-tune control loops
- Test motor start/stop logic
- Validate permissive logic
- Evaluate controls stability
- Check graphics displays
- Implement checkout controls on the plant
- Test shutdown systems and logic sequences
Control modifications that are required for start-up and proper plant operation can be validated on the Simulator and then implemented on the plant. Invensys clients who have taken advantage of this type of testing and pre-start-up training opportunity have experienced nearly flawless first-time start-ups.

The elimination of extra start-up days through control system checkout using a fully rigorous dynamic model is often, in itself, a common justification for the Simulator purchase.

5. Controls Analysis, Configuration, and Tuning Test Bed

In addition, another objective is the ability to carry out further personnel training, such as Instrumentation Technicians and I&C Engineers. Simulator controls will be an exact duplicate of the actual plant controls.

This approach allows staff to:
• Develop and conduct control system analysis
• Troubleshoot problems that occur on the actual plant controls on the Simulator
• Test control design changes before implementing them on the actual plant
• Pre-tune new control loops
• Tune emergency control loops without risking plant operation

6. Engineering and Operational Analysis Test Bed

Finally, a rigorous Simulator based on first principle heat and material balances, hydraulics, equipment design, and controls is provided.

The Simulator will have comparable steady state accuracy to that of steady state simulation such as Invensys SimSci-Esscor’s™ PRO/II® software.

However, the training Simulator will extend the solution to also include constraints that are not always included in steady state simulations such as hydraulics, control valve sizes, pump and compressor curves, column flooding, and heat exchanger surface areas and fouling.

Once the model is tuned to match the actual plant performance, the engineering staff to can use the Simulator to:
• Evaluate equipment line-up changes
• Perform de-bottlenecking studies by eliminating key constraints
• Evaluate alternative operating procedures
• Perform “what if” studies

7. The Solutions

(OTS) are created within the SIM4ME environment to recreate accurately, within the defined scope of the customer, the working environment of a process operator.

The OTS will provide a sufficient level of fidelity that allows efficient, repeatable training exercises using Process and Control Simulations.

DCS
• Foxboro® I/A Series® FSIM Plus™ (virtual simulation)
• ABB/Bailey Infi90/ControlIT (full simulation & full emulation)
• Emerson SimulatePro DeltaV (full simulation)
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- Yokogawa Centum CS300 (full simulation & full emulation)
- Honeywell TDC3000 & Experion (full emulation)
- Siemens Teleperm XP (full emulation)
- GE Mark VI (full simulation)
- Westinghouse Ovation WDPF (full simulation)

PLC
- Triconex® Tricon™/Trident™ TRISIM Plus™ (virtual simulation)
- ABB Procontrol/Turbtrol (full emulation)
- GE Mark IV/V (full emulation)
- GE PLC-6 (full simulation)
- ModiconPLC-984/Quantum (full emulation)
- Woodward Governor (full emulation)
- Allen-Bradley PLC-5 (full emulation)
- CCC Series 5 (virtual simulation) Process Models
- Multiple Engines & Libraries, such as OLGA2000 interface
- 3rd Party Simulation Packages, such as Hysys.Dynamics, INDISS, etc.
- Plus many more

8. What is Virtual Simulation?

Virtual simulation permits the development of a Simulator with virtual controller hardware instead of actual controller hardware, which is accomplished by executing the controller software on a simulation workstation.

In a virtual simulation-based Simulator, the control configuration and graphics will be identical to the actual DCS as it is configured from the same files as the actual DCS and uses actual operator console hardware.

The result is that a virtual simulation-based OTS dramatically reduces the commissioning and the start-up of the control system and allows accurate analysis and troubleshooting of the system performance and response. Moreover, a virtual simulation-based OTS provides the ability to generate a wide range of simulation models for testing, validation and training purpose.

All these benefits are achieved in a completely non-destructive environment.
9. Project Methodology

Invensys has significant experience in delivering complex OTS solutions on time and on budget for both the Process and Power Industries. In order to do so, a precise, detailed approach is required, tailor made for each Project but based on our comprehensive experiences over the past 15 years.

Each Invensys OTS Project, irrespective of its destination client or type of Project (Process, Power, Nuclear, Pulp and Paper, Mining, etc.), incorporates a detailed execution plan for the Simulator.

Typically, a unit-specific, high fidelity dynamic process model is built to match a client’s requirements and against a delivered steady state Simulator or heat and mass balance. The subsequent process model simulation is then connected to the various control systems required for the OTS.

Once these connections are made and tested internally on the Project and then externally with the client both at Invensys location and site (Factory Acceptance Test (FAT) or Site Acceptance Test (SAT)). After these testing periods are completed to the client’s satisfaction, the Simulator is then used actively throughout the Project lifecycle, typically over a period of 20 years or more.

Invensys’ experience in the marketplace today is that many OTS’ are not used for more than a few years. There are a number of reasons for such occurrences, such as:

- Cost of ownership
- Cost of maintenance
- Ease of maintenance
- Flexibility of solution for upgrades

However, Invensys’ OTS solutions address these problems comprehensively by:

- Reducing costs of ownership and maintenance
- Improved ease of maintenance
- Easier upgrades capability

Invensys’ solutions also provide these “Rolls Royce” benefits at comparable costs to other Simulator vendors.

10. Improved Operator Knowledge and Understanding – The HSE

While proposed by the U.K. Health and Safety Executive (UKHSE), there are no internationally accepted benchmarks for OTS. The UKHSE has recently stated that they, “...recommend a recognizable, measurable and detailed form of Operator Training Certification for all process operatives working in the petrochemical, oil and gas industries.”

In its 2001/2002 UKHSE safety report, the figures show that the number of incidences of major and fatal injuries for the UK oil industry increased despite increased preventative measures. During 2001/2002, in onshore and offshore operations in the U.K. sector, there were:

- 4 deaths
- 63 major injuries
- 195 minor injuries

The petrochemical, oil and gas industries were seen as having higher severe accident and fatality occurrences than most other industries. While there was a reduction in dangerous occurrences of hydrocarbon releases and fire and explosions by 15-20%, these factors remained the two major causes of severe injury and operator error could be attributed to many of these dangerous events.

As a result, many of the oil majors, especially those active in offshore and onshore, are investigating making the use of OTS as standard operating procedure.
11. Expert Tutor Systems

Invensys’ Expert Tutor System (ETS) is an add-on available to DYNSIM™ that allows a completely open multimedia student interface.

In this case, the ETS will provide an automated program to the trainee operators via a “real time” interface. The ETS exercise takes control of a plant simulation just like an instructor would (load, IC reset, run, malfunctions, etc.), but provides appropriate “hints” or “alerts” based on plant parameter values or exercise state.

Hints or alerts can be multimedia (including synthesized voice) or training documentation.

Students interact with the exercise by giving voice commands or mouse clicks on a GUI. Speech recognition capabilities include “run,” “pause,” “acknowledge,” “help,” etc. The ETS exercises are built graphically using a simple drag and drop interface.

There are three exercise modes: mentor, monitor, test; which offer decreasing levels of assistance to the student. ETS also features an integrated report generator that produces student scores based on plant parameter values.

12. Conclusions

Invensys’ virtual simulation OTS solutions combined with the power of its SIM4ME OTS environment and the DYNSIM process simulation software, provide one of the most up-to-date OTS’ for the market today. Even as the control system software is still being developed and tested, virtual simulation solutions allow for a rapid OTS schedule as well as a fixed Simulator “ready-for-training” delivery date.

The Simulator provides the control system project with its final touch – putting it through what can be thought of as a “dynamic” FAT, testing the control system just as the operator would use it.

In addition to dynamic tuning, this testing also uncovers hidden “logic errors” that only reveal themselves when certain operational sequences are performed and all of the control system pieces are integrated with real world timing.

Finally, strong Project Management is needed from all team participants to balance their own purely commercial interests against the main goal of the project: a highly successful OTS Project with rapid return on investment.

In conclusion, Invensys Simulators are more than just training tools, but the benefits they provide do not happen overnight.

The right combination of foresight, distributed simulation processing, control system simulation design (Virtual Simulation) and a capable, motivated team are required to realize these inherent benefits.