The Benefits of Using Dynamic Simulation & Training Systems for Expanding Operator Knowledge and Understanding

Dr. Paul W. Seccombe – Invensys Systems UK Ltd.

Abstract

Dynamic Simulation and Operator Training Systems (OTS) has been available in the marketplace for a long time. However, over the last five years, improvements in technology (computers, software, and market understanding) have meant that the use of Dynamic Simulation and Operator Training Systems (OTS) has become a reality for many processes. No longer are Training Simulators the realm for 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 'Tier1' OTS supplier to the Process and Power Industries, leading the market with new software, such as SimSci-Esscor's 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 managers on 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.

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 operations staff in:

- Procedures for plant start-up and shut-down situations
- Handling of utility system and process unit trips, turn-down 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 shut-down times
- Increased safety
- Reduction in environmental concerns
- Increased unit up-time
- Increased operator awareness, skills, and readiness
- Assess Operator Competence

Figure 1. The Shell EA FPSO Offshore Nigeria

Additional uses of the OTS have been:

- Testing and validation of operating procedures
- Testing and validation of control strategies and logic
- Debottlenecking
- Investigation of engineering solutions
- Sharing of incident and operating scenarios across shift teams

The Invensys approach allows the following plant lifecycle objectives to be met:

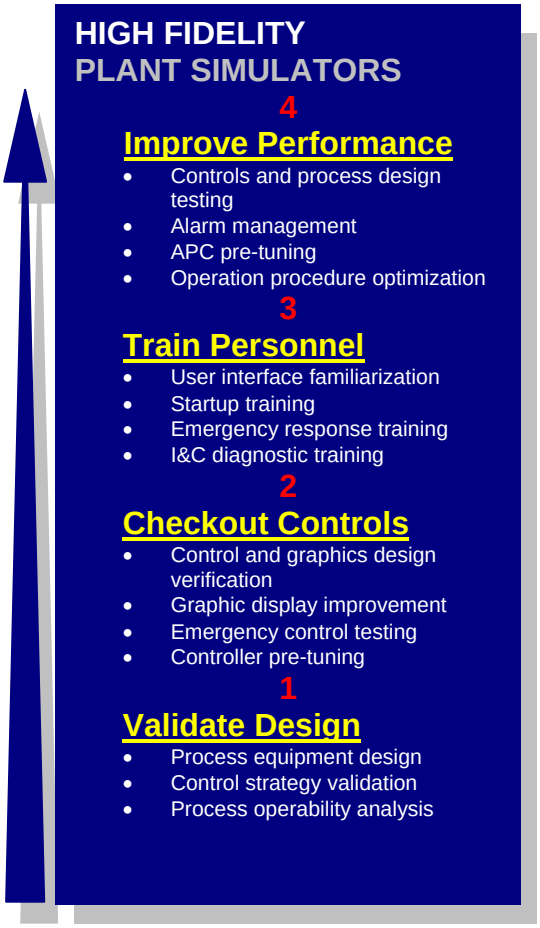

Figure 2. Uses for Dynamic Process Simulation and the SIM4ME Dynamic Simulation Suite

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.

Control System Check-out

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 check-out 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 check-out controls on the plant
- Test shut-down systems and logic sequences

Control modifications that are required for start-up and proper plant operation can be validated by 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 check-out using a fully rigorous dynamic model is often, in itself, a common justification for the simulator purchase.

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.

The simulator will use the same controls configuration and graphics such that the simulator controls will be an exact duplicate of the actual plant controls.

This approach allows staff to:

- Develop and conduct control system analyses
- 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 controls loops
- Tune emergency control loops without risking plant operation

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 found in 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.

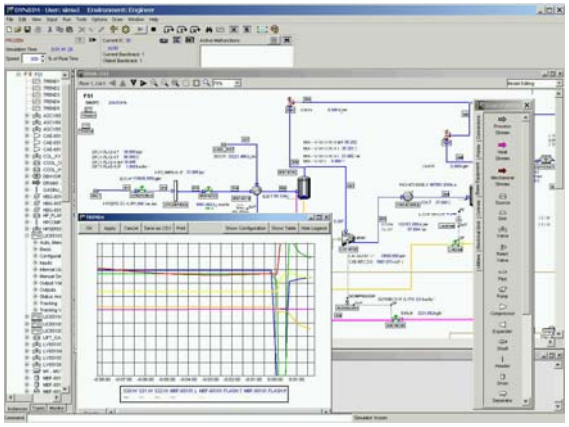

Figure 3. A Process Model in DYNSIM

The Solutions

Invensys Operator Training Simulators (OTS) are created within the SIM4ME environment to recreate accurately, within the defined scope of the customer and 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.

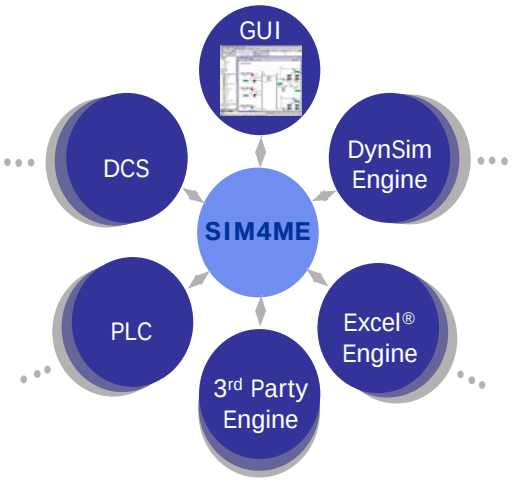

Figure 4. The SIM4ME Solution

DCS

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

PLC

- Triconex Tricon/Trident **TRISIM Plus™** (virtual stimulation)
- ABB Procontrol/Turbtrol (full emulation)
- GE Mark IV/V (full emulation)
- GE PLC-6 (full stimulation)
- ModiconPLC-984/Quantum (full emulation)
- Woodward Governor (full emulation)
- Allen-Bradley PLC-5 (full emulation)
- CCC Series 5 (virtual stimulation)

Process Models
Multiple engines and libraries, such as

- OLGA2000 interface
- Third-party simulation packages like INDISS, etc.
- Plus many, many more….

What is Virtual Stimulation?

Virtual stimulation 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 stimulation 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 stimulation 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 stimulation based OTS gives the possibility 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.

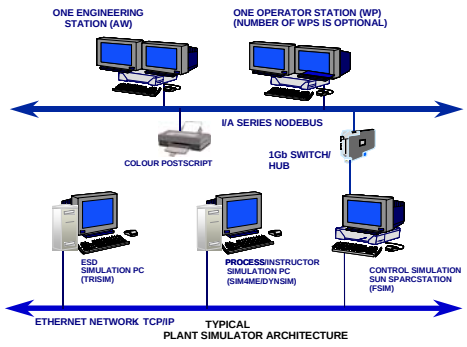

Figure 5. Typical Simulator Architecture

Project Methodology

Invensys have 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 last 15 years.

Each Invensys OTS Project, irrespective of its destination client or type of project (process, power, 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 the Invensys location and site, they are Factory Acceptance Test (FAT) or Site Acceptance Test (SAT).

After the testing periods are completed and to the client's satisfaction, the simulator can then be used actively throughout the project lifecycle, typically over a period of 20+ years

Invensys' experience in the marketplace today, proves that some OTS' are not used for more than a few years. There are varying 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.

Improved Operator Knowledge and Understanding – The HSE

Whilst 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 recognisable, measurable and detailed form of Operator Training certification for all process operatives working in the petrochemical and Oil & Gas industries."

In its 2001-02 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 and oil and gas industries were seen as one of the industries where highest severe accident or fatalities occurred.

Whilst there was a reduction in dangerous occurrences of hydrocarbon releases, 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 use of OTS as standard.

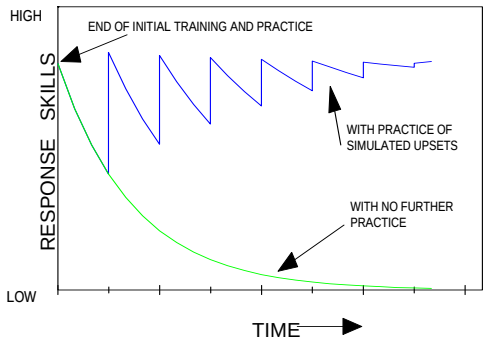

Figure 6. Operator Response With and Without Appropriate Training

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 a 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.

Student interacts with the exercise by giving voice commands or mouse clicks on a GUI. Speech recognition capabilities for "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 help to the student. ETS also features an integrated report generator produces student scores based on plant parameter values.

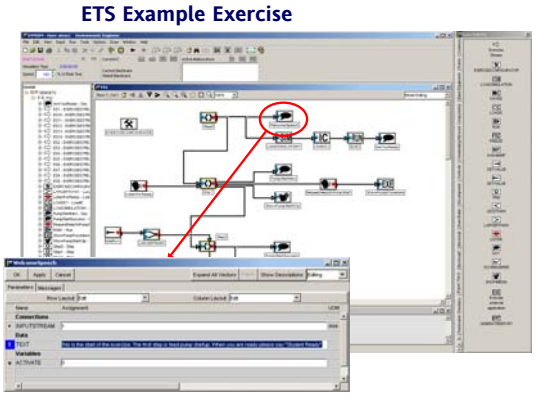

Figure 7. An Expert Tutor System in Dynsim

Conclusions

Invensys' virtual stimulation OTS solutions combined with the power of the SIM4ME environment and DYNSIM process simulation software provides one of the most up-to-date OTS' for the market today. Even as control system software is still being developed and tested, virtual stimulation solutions allow for a rapid OTS schedule; 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 stimulation) and a capable motivated team are required to realize these inherent benefits.

Figure 7. The Shell Bonga FPSO OTS being staged at Invensys Crawley, UK.

Figure 8. 'Shell Bonga FPSO – By Night'