SIMULATING SUPERIOR *Performance*

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An operator training system (OTS) is one of the best methods to train staff in operations before a producing plant starts up. Carrying out this training before plant commissioning ensures a fast learning curve of the new process and control and instrumentation systems. Moreover, the operators can be exposed to emergency situations or process upsets that are not part of the daily operation. This will facilitate the operator response to normal and abnormal process conditions.

On top of that, the OTS accumulates expertise that can be reused in order to improve human efficiency and therefore, it facilitates the knowledge dissemination between experienced and more junior operators. This knowledge is not stored as a pile of books that just need to be read by the operator, the key advantage is that the OTS allows conducting interactive training exercises under a carefully supervised environment on how to drive a plant in a more efficient way, increasing safety and reliability, while minimising risks on equipment failure or damage, on operator errors or on process interruption.

The operator expertise is not built by 'reading' or 'listening' to a large amount of rules or facts. Genuine knowledge is truly acquired through experience (real or simulated). The functionality of the process automation system can thus be learned without the stress of running the real plant. Therefore, there is no risk for personnel, the environment or the plant equipment while being trained on normal operation or on plant upsets.

The benefits of such a tool do not have to finish or begin with the training of the operators. In fact, they can start long

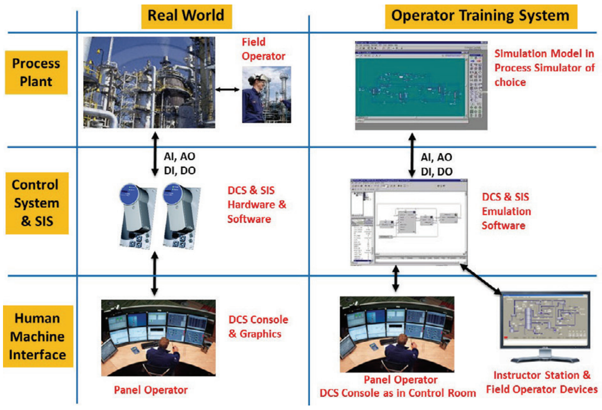

Figure 1. Elements of an operator training system and its equivalent in the real world.

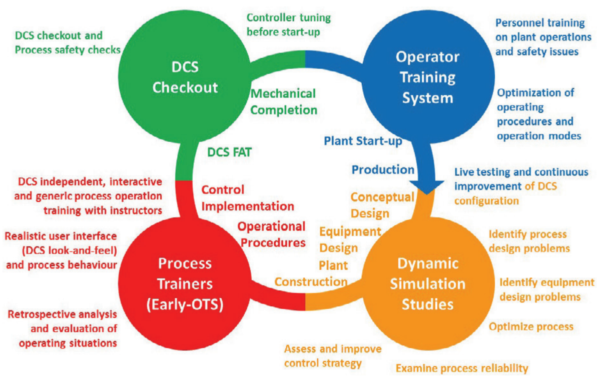

Figure 2. Inprocess' lifecycle approach.

before initial training and continue all along a plant's lifecycle. Unfortunately, many plants do not consider several uses of simulation technology that can greatly improve the overall safety and process reliability, while reducing capital and operating costs and environmental impact.[1]

Technically speaking, an OTS is a computer based training system that uses a dynamic simulation of an industrial process, usually integrated with an emulator of the distributed control system (DCS). The OTS uses the dynamic simulation of the process in order to generate the appropriate data to feed the emulation of the plant control and safety system. The fidelity of training simulators is relatively high, compared to simulations used for testing process automation systems. In addition, the response must accurately replicate the response of the real process to reinforce positive training behaviour.[2]

As shown in Figure 1, the hardware and software elements of a typical OTS, compared with what exist in real operating plants, are:

- Dynamic simulation software.
- Process model.
- DCS emulation software.
- Replica of the operator station.
- Instructor station.
- Control system integration software.

The use of the dynamic simulator all along a plant's lifecycle can help clients in leveraging their investment in an OTS by expanding its use in four clear stages. Figure 2 tries to exemplify graphically what type of studies and processes in a plant lifecycle can benefit from dynamic simulation and when they have to be applied:

- Dynamic simulation studies during plant preconstruction stage.
- Early delivery of an emulated OTS for process training.
- Checkout and auditing of the DCS database being built by the DCS vendor.
- Training tool for control room and field operators.

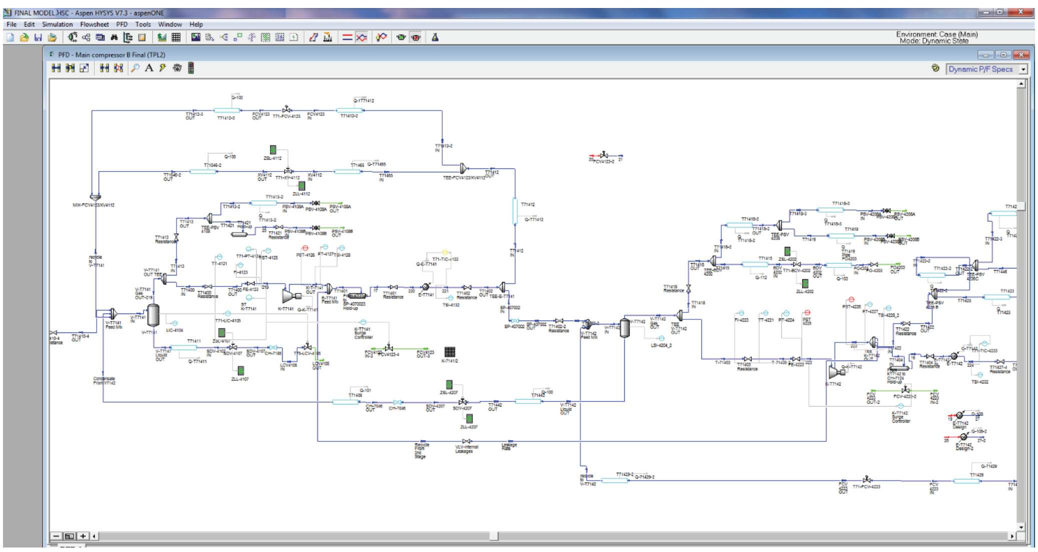

Figure 3. Example of a dynamic process flow diagram for a two stage compressor of a compression system with eight compressors.

Before plant construction

Approximately 60% of the capital investments for a new producing plant are decided during its early design phases. By using a dynamic model at these stages to carry out some of the engineering studies, project costs could be driven down while sustaining project schedules and managing risks. The engineering dynamic simulation studies are carried out with a complete process model, including all relevant pieces of equipment with detailed design characteristics such as geometry of vessels, characteristic curves for valves, performance maps for compressors and pumps, sizing and parameters for columns, vessels and heat exchangers, controllers structure, insulation data for heat loss, elevations, reactions, thermodynamics, etc.

The process model is based on first principles with full thermodynamic properties. It is engineered to reflect the overall plant operation in such a way that differences between the simulation model and the actual plant are minimal. In fact, the dynamic model typically uses the same simulation software that was used in the design of the plant from where the steady state heat and material balances are produced, but the dynamic model incorporates more equipment details (valves, columns, compressors) and takes into account some hydraulics effects (static head, elevations, nozzles, pressure flow equations) which produce a more accurate representation of the actual plant. Figure 3 shows an example of a process flow diagram of a simulation model developed with one of the commercial simulators.

Development of control philosophy

The configuration of the control systems can be better assessed by using a dynamic plant model (that creates realistic operating scenarios) than by the traditional static checkout method. The dynamic plant model allows control engineers to evaluate whether:

- Regulatory controls sustain reliable operation conditions.
- Approach to risky scenarios is avoided by safety systems.
- Manual or automatic operating procedures for normal start up, normal shutdown, load change, product transitions, emergency shutdown, etc. work as expected.
- The configuration of the operator stations shows an operable environment of the process.
- The system alarms effectively warn the operators about process upsets.

Engineering verification

Engineering studies carried out preceding capital investment and initial operations allow engineers to optimise equipment design, ensure that reliability and safety are considered, and confirm operational readiness. When in a lifecycle project these studies are combined with the training of the operators, these studies can help identify any deficiencies with the DCS or safety system (interlocks and emergency shutdown systems) configuration.

It is best to use dynamic simulation to review plant startup or emergency procedures because errors there can significantly impact production. This review might take a few weeks, with additional time likely required to enhance the system. Improving the behaviour of complex systems may require some iterations. However, it is certainly better to invest time during earlier project phases rather than during initial operations.

For example, many plants rely on large expensive compressor systems whose damage can quickly cost tens of millions of dollars in equipment and loss of profits during downtime. In addition, if a large compressor is severely damaged, a replacement may require a two to three year lead time. It is therefore critical that compressor protection systems are properly designed and correctly operating. By dynamically modelling these systems, engineers can study potential trip events and identify any defects, or ensure the systems are designed right and fully protected.[3] Figure 4 shows how a dynamic process simulator can mimic the behaviour of a centrifugal compressor and its head curves.

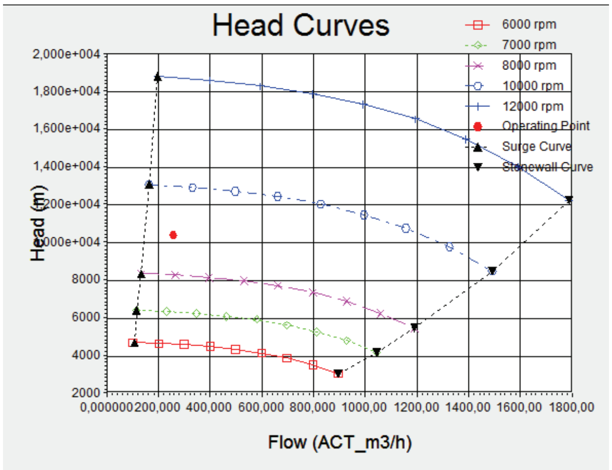

Figure 4. Example of a compressor map.

Another valuable use of simulation is for checking whether an existing flare system will be sufficient for a plant expansion. Detailed studies of unit depressurising, including dynamic models of the flare system, can determine the existing relief system's ability to handle new loads. In many cases such studies have shown the current relief system is adequate, thereby obviating expansion of the relief and flare system and thus providing savings that can amount to tens of millions of dollars.

Developing optimal strategies

Creation and validation of layouts, procedures and control strategies with the help of dynamic simulators is highly efficient thanks to its ability to predict how the plant will behave during start up. Errors can be identified and solutions can be found prior to capital investment, during engineering design, and not onsite with the associated costs, project risks and delays. Ideally, design, control and process engineers should be involved in this step.

Pressure swing adsorption (PSA) units in refineries perform differently depending on the mode of operation of each of its beds. Dynamic simulation enables refinery engineers to rectify bad performances by testing the transitions from one operating mode to any of the possible alternative ones and by deciding what the best possible transition procedures are.

DCS checkout

Once a dynamic simulation model of the processing plant exists and it has been validated against plant or design data, the checkout of the DCS is carried out against the signals generated by the dynamic model instead of against simple tie backs or manual stimulation. In this way, the full control and safety logic is truly verified by realistic simulated signals of all instruments.

Through control systems test studies, improvements can be made to the sequence logic giving smooth and trouble free performance during plant start up. The test studies also detect configuration errors, speeding up the project during critical and costly commissioning phases.

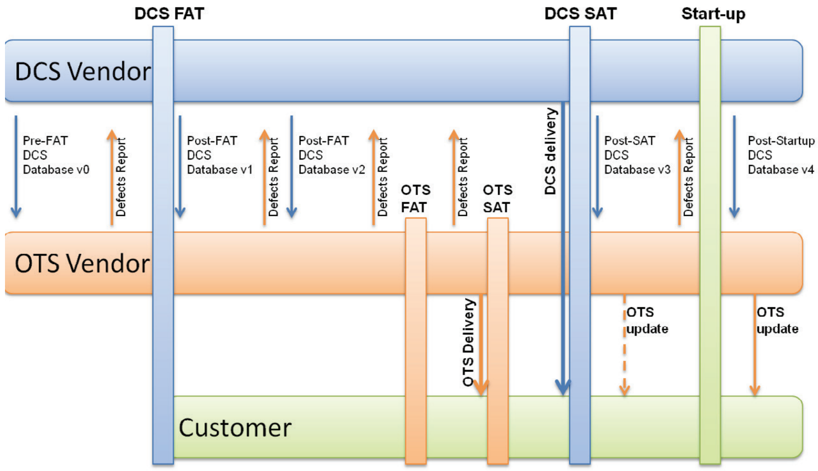

Figure 5. Revision cycles during an OTS implementation project.

Figure 5 below shows the multiple revision cycles of the DCS code during the development of an OTS, where OTS vendor is acting as an independent auditor of the DCS code.

Some of the typical verification tests are for:

- Alarm and trend systems.
- Control and shutdown logic.
- Startup sequences.
- Controller tuning.
- Plant operations robustness.

Achievements

Several have been the OTS projects where the checkout of the DCS database has shown quantifiable benefits for the client.

A selection of achievements follows:

- In an OTS project for a gas oil separation plant (GOSP) in Bolivia the checkout of the DCS database prior to plant commissioning detected several problems with the operators screens, with the tuning of the controllers, with alarms in controllers and indicators (wrong limits trips spurious alarms together with signal noise that could trips ESD); configuration of modules (control modules configurations generated wrong signals affecting other modules that generate range deviations and could trip ESD).[4]
- In an OTS project for a phenol/cumene plant in China allowed to detect a series of errors related to the implementation of the control narrative in the DCS database, specifically to the plant feed system. Some instrumentation ranges were not rightly implemented, some controllers were not in the database, some controller modes were wrong and some control logic was not working as expected.
- The auditing process of the DCS in an OTS project for a new aldehyde plant in Sweden, detected several problems with the operator's screens functionality, where some objects in screens were badly linked and the associated variables were not in the database control modules. Additionally, some cascaded controls were missing in the database and several controllers were setup with the wrong action.

Training activities

Qualified personnel are the key to keeping a plant running safely and efficiently. Process trainers and OTS' are tools that allow operators to practice on virtual plants. The core of this tool will be the dynamic model (either the one developed for preconstruction studies, if following the lifecycle approach; or a built on purpose model for the OTS), which will be connected to custom made interfaces for operators and instructors. A process trainer (or early OTS) fits into the gap between a full featured OTS system (dynamic model connected to an emulated DCS) and a standalone dynamic model. A process trainer can be developed as soon as the dynamic simulation model is ready and once it has been enhanced with the control strategy. It has a self made DCS 'look and feel' instead of an emulated DCS. This intermediate option can even sound attractive for small new investments and smaller existing plants and, in comparison with an OTS can have lower costs.

An OTS itself does not guarantee that the operator becomes competent. It needs to go together with an suitable training program which follows the MakeMeThink (MMT) educating methodology.

For every training scenario the operators are divided in groups of two people and follow the MMT four basic steps:

- STUDY: Explain scenario, predict behaviour, forecast actions.
- EXECUTE: Conduct scenario in the OTS (each group).
- COLLECT: Compile the actual vs predicted behaviours, actions taken and reported key performance indicators (KPIs) of each group.
- LEARN: Discuss the results with the group, suggest improvements, report lesson learnt.

Continuous training

An OTS is a suitable platform to practice for operators because it provides an environment to perform unfamiliar process and control tasks in a safe environment. Any mistake, any error will be converted in to a lesson learnt without any real life consequence. It is key to maintain the practice of the procedures as a regular task for operators and provide refresher training at regular intervals and whenever a modification in the plant or in the control or safety system is implemented. Activities with the OTS should include operations such as start up and shutdown ahead of time, and work through the response to infrequent abnormal situations, based on best practice procedures. Training on best practices allow operators to run through the routines on a regular basis, so it is advisable not to allow too much time to elapse between refresher training.

Unfortunately, most of the licensed OTS' are never used again after initial operators training. However, ongoing training programs can provide significant benefits. It is widely recognised that approximately 90% of plant incidents can be prevented.[1] Moreover, the majority result from the actions or inactions of people. Plant personnel will always play a role in operations decision making; therefore, there will always be opportunities for human errors to contribute to unexpected situations. Modern process automation systems have allowed operators to assume responsibility for a larger scope of a plant's operation. However, as systems become broader, they create the potential to place the operator in a weak position. This situation arises because as systems become more complex they become more difficult to operate. One solution is to add more automation, but this increases complexity. Moreover, automation obstructs operators' ability to maintain their expertise. The skills lost are precisely the ones most needed when automated systems cannot handle a problem and the operator must intervene. That is why it is important to use OTS for training throughout the life of the process, not just at the initial startup phase.

Conclusion

For the plant owner, production manager or operator, dynamic simulation studies, DCS checkout and operator training systems contribute to higher efficiency, lower production costs, and improved plant safety.[5] This is achieved through:

- Increased process knowledge.
- Better trained and more confident personnel.
- Faster start ups with fewer problems.
- Risk free and repeatable exercises of rare and potentially dangerous situations (abnormal situation management).
- Risk free engineering and continuous improvement of control system configuration; safety system and controller tuning before and after start up.
- Better utilisation of existing plant capacity.
- DCS checkout before start up (OTS), process safety checks.
- Optimisation of operating procedures and operation modes.

Many of the above benefits have been recently measured in a survey among Norwegian oil and gas companies.[6] The authors summarised their findings outlining that all the participating group, operators, instructors, engineers and management, attributed remarkable benefits related to operator training. For the operators, the benefits come from repeated team training on rare events, process upsets and new procedures, which, in turn, increases confidence, enhances effectiveness and decreases work related stress. For the plant and company, the benefits come from accelerated time to production start up, reduced operational risk, enhanced facility integrity and increased production performance.

The improvement in operator effectiveness was estimated by the participants to be 31%. on average They also estimated that commissioning and start up required on average 18 days less for new facilities and two days less for existing plants (after major revamping). An average estimation of three unplanned shutdowns per year could be avoided by the use of the OTS'. And total savings were estimated to be approximately US$15 million/plant, with under 14 months of payback. Moreover, the operator training simulators are used for various purposes other than training, thus increasing the value of the simulator investment. HE

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