SIMULATION APPLICATIONS FOR ALUMINA REFINING

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Abstract

Strong demand and environmental considerations are increasing the pressure for alumina producers to operate safely, reliably and efficiently. Traditional operational methodologies are being tested and compared to best practices in other industries for improvement opportunities. Operator training simulation is one technology, used extensively for many years throughout the hydrocarbon processing industries, which is now being deployed successfully within alumina refining, especially for greenfield and brownfield expansions..

Operator training simulators utilise dynamic simulation to provide a high fidelity model of the process dynamics associated with an alumina refinery. This has been proven to provide benefits through increasing availability (operators better able to handle upsets), safety and operator competency certification. Additionally it enables process and control design validation minimising design shortfalls that would negatively impact throughput, quality and commissioning times.

This paper provides an overview of this technology and the benefits with reference to an alumina refining case study – the Gove double digester simulation project.

1. Introduction

The traditional view that minerals processing operations are all about shovels and conveyors is changing. There is an increasing awareness of the complexity and demanding requirements for the efficient operation and maintenance of mineral processing plants. Coupling this with occupational health and safety places a heavy onus of training on owners. As a result extensive use of dynamic process simulators is becoming the norm for greenfield facilities in metals and mining, including alumina refineries. Many leading companies are benefiting from the use of dynamic simulation for greenfield projects and control upgrades because the inherent risk in new process plant design and the complexity of controls in the Bayer cycle. Interactive and accurate simulation provides the mechanism for enhanced operator training, and for validating and improving new process and control designs.

A correctly built dynamic simulation is a tool that can be used throughout an operations lifecycle, from process and control engineering through operator training to operational debottlenecking. In order to fully realise the benefits it is necessary that a full high fidelity model of the process be built. This must be based on engineering first principles with full energy and mass balance capabilities. Considerable work is required to configure such a simulator making full use of kinetic, thermodynamic and phase equilibrium data, however the paybacks can be enormous. A high fidelity process simulation model will provide realistic hands-on experience without risk of damaging the plant. That is the simulator has the look (displays) and feel (operations) as the real plant.

For a project, the major uses of dynamic simulation can be categorised as:

Process engineering
Control engineering
Operations training

Each of these areas will provide for significant benefits, however in order to avoid three separate simulators to cover all of these the simulator chosen should provide for all these functions.

2. Simulator Applications

2.1 Training Process Operators

2.1.1 Using Custom Models

A custom simulation model of the process, control and logic systems can be delivered which would include malfunctions, process disturbances, training performance assessment, event recording, third party applications and training exercises. This simulation model can then be used during start-up and shut down, during normal operations and when new technologies either control or process are trialed. It can be specifically used to:

- Train operators, maintenance and engineering personnel how to run the plant;
- Train new operators or replacement personnel;
- Certify operators to meet specific standards;
- Maintain and upgrade operator skills on an on-going basis;
- Develop operating, maintenance and emergency procedures;
- Develop and test training and operations documentation;
- Develop optimum operating strategies.

2.1.2 Using Standard Models

Some vendors offer standard models which are "off-the-shelf" examples of typical processes which meet industry standards and specifications. Although generic in nature, standard models are realistic in how they operate and respond to changes. They include process specific malfunctions and disturbances, selected user functions, and training exercises. They may utilise a Distributed Control System (DCS) operator console (which requires an interface program), or the colour monitor of the simulation computer.

The standard models are a useful alternative when:

- Only general process knowledge is required;
- The simulation budget is limited;
- The engineering data will not be available in time to develop custom models;
- Short delivery time is required.

2.2 Process Engineering

A custom dynamic simulation model can be used during the engineering design phase of the process and control systems to vet designs and uncover potential start-up problems. It can also be used to assist in evaluating modifications to existing plants.

It can be specifically used to:

- Test design philosophy;
- Locate design flaws;
- Identify constraints in existing or proposed equipment;
- Test alternate designs;
- Develop start-up and operations plans and procedures;
- Conduct HAZOP studies.

2.3 Control Engineering

Some dynamic simulators offer full emulation of control algorithms for DCS systems. This allows for the validation of control strategies off-line. As well, the simulation model can be connected to the operator console and the control devices to completely check out the implementation of the DCS control database, safety systems, graphics and alarming systems.

The simulation model can be specifically used to:

- Test the DCS configuration;
- Test the regulatory control strategies;
- Test the Emergency Shutdown System (ESD) and other logic systems;
- Test and tune advanced control and optimization programs;
- Develop and optimise the control strategies.

3. Simulator Requirements

There are four main requirements for any simulator:

Realism

The system must closely represent the control room environment. It achieves this by connecting directly to an actual DCS operator console similar to those used in the plant control room, and by utilising the actual plant DCS control and display configurations. The operator therefore becomes fully familiar with the keyboard, screens, process displays, tag names, alarms, logic, and control schemes before using the DCS in the plant.

Fidelity

The system must closely represent the actual performance of a process, unit operation, area or plant. The software must enable building of a high fidelity model of the process which simulates its operation and the actions of the associated regulatory, sequential and supervisory control algorithms. The software must have an extensive physical properties database, and perform mathematical calculations to accurately represent the dynamic behaviour of the process or control system. The model must be based on actual process and control information, and include malfunctions and process disturbances. The operator must be able to start up the model, run it in real time, shut it down, change production grades, and experience emergencies and alarm conditions.

Maintenance

The system must be easily maintained. This is aided if the software used to build the simulation model is modular. The nature of the software must allow the model to be changed as the process changes. It should contain modules that represent the various components of process equipment, such as heat exchangers, distillation columns, compressors, turbines, pumps, valves, etc. A graphical model building program will speed up the configuration process and make the system easy to use. The system should be an open system that can be updated on an on-going basis and easily maintained.

Functionality

The system must be flexible such that it spans a wide range of applications, accessed through the graphical user interfaces. Each interface representing a potential user of such as engineers, instructors, and trainees. These interfaces must be able to run the simulator, set specific exercises, trigger malfunctions and upsets, monitor the simulator and document operator performance. Ideally they would also be used to build, tune and update the simulation model, perform diagnostic actions, and control access to the simulator. The result is a simulator that is effective for training, testing and operations applications.

4. Benefits

There are many benefits from dynamic simulation including:

- Improved plant start up times;
- Reduced off-specification product during start up;
- Competent trained operators;
- Design check and verification;
- Fault finding of control code;
- Controller tuning prior to start up;
- Operating procedure validation;
- Testing and implementation of control schemes, logic and graphics;
- Control System Optimisation.

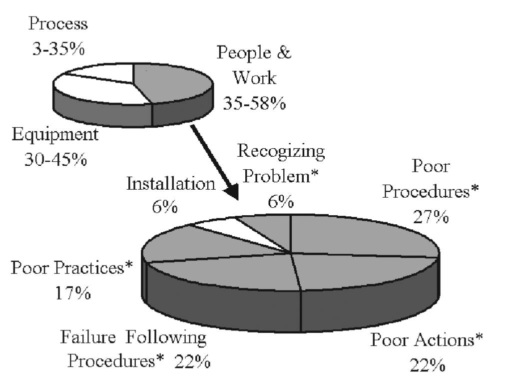
One of the major benefits is for improving operator effectiveness. In most operating alumina refineries, the equipment is operated continuously and many operators are not well practiced in running under startup, shut down, or emergency conditions. Similarly, in new installations, operators may have even less skills in managing the process and the knowledge of the equipment limits, even under normal operating conditions. Fundamentally, the essential mechanism in learning is comprehension and repetition. Dynamic simulation provides these essential learning mechanisms through allowing operators to practice their operational skills without the possibility of damaging the plant.

The need for better operator training to reduce incidents is further exemplified by the Chemical Manufactures Association's study of six sites regarding the causes of incidents and found that:

Causes of Incidents:

People and work context	35 – 58%
Equipment	30 – 40%
Process	3 – 35%

The people and work context can be further broken down as illustrated (Figure 1).



*Impacted by dynamic simulation when used for training and developing procedures.

Figure 1. Causes of Incidents

The benefits of dynamic simulations include improved safety and reduce environmental incidents. Tangible financial benefits include better response to upsets that regain quality or production, identify malfunctions or design errors that minimize downtime and production losses. Reductions in commissioning time by as much as 25% have been reported.

5. Case Study – Gove Digestion

The Rio Tinto Alcan Gove bauxite mine and alumina refinery is located at Nhulunbuy on the Gove Peninsula in the east Arnhem Land region of Australia's Northern Territory. Rio Tinto Alcan Gove is 100% owned by Rio Tinto a global leader in aluminium and packaging and one of the world's largest alumina producers.

The Rio Tinto Alcan Gove alumina refinery has just completed a (US) $3 billion expansion (formerly known as the G3 Expansion Project) which when fully commissioned will increase alumina production from 2 million to 3.8 million tonnes per annum. The expansion represents a significant investment, delivering long term security and economic benefits to the Gove region, and allowing the refinery to operate independently of its local bauxite reserves.

One of the major benefits from this expansion is predicted to be a 10% improvement in recovery of alumina from bauxite and a 25% reduction in residue per tonne of alumina produced through improved digestion technology. This technology, known as double digestion, uses both low temperature digestion for removal of trihydrate alumina followed by high temperature digestion for the monohydrate alumina. Gove had not previously used this technology which therefore represented significant operational risk. In order to mitigate this risk it was decided to develop an operator training simulator of the digestion process using the Honeywell UniSim Operations Suite software package.

The simulator was justified on the basis that it could save approximately 1 month from commissioning, from two main areas

1. Operator Training; Rio Tinto Alcan Gove recognised that there was no previous experience of running the double digestion process. Hence without a simulator, it would be difficult to effectively train operations personnel without adversely affecting plant operations.
2. Control System Commissioning; The control system architecture involved interfacing between multiple DCS platforms which had to be managed to minimise the impact due to mismatch of data. Additionally the control system code was developed off site (due to labour constraints and EHS considerations). The simulator allowed for comprehensive code testing before transfer to site.

In addition there would be significant benefits from:

- Improved Environmental, health and safety;
- Ongoing competency based training;
- Control scheme validation and tuning;
- Operating procedure development;
- Plant control optimisation.

5.1 Simulator Description

The UniSim Operations system is a direct connect, full replica, dynamic process simulator. It is an integrated collection of computer and control system hardware and software which allows a high fidelity model of the process to run in real time and appear from the DCS console as though a real plant is being controlled. In addition other features are provided which facilitate the use of the system as a training and instruction tool.

The operator trainee sits at the DCS console with the actual process control schematics and can proceed through the various steps to start up, run or shut down the plant. The operator learns how to react to alarms, emergency shutdowns and other lesser crises. The operator can also be taught how to optimise the process and make best use of the control facilities available to them.

A separate console is used by the trainee for operation of those field operated devices (FODs) which are not available through the DCS operator console, but require manipulation to allow effective operation of the plant. Those activities are normally taken by a field operator in concert with the DCS operator. The combination of an FOD station and the DCS console allows the trainee to fully operate the simulated process without outside help.

Instructors can control the simulation through the instructor console, which is also the FOD console in this case, and conduct training exercises, examine and change values in the simulation and create new exercises. They may execute such capabilities as malfunctions, freeze/unfreeze, backtrack, record/replay, slow down, speed up, trainee performance monitoring, etc. Trainees can also access the system and perform training sessions without instructors if desired.

5.2 The process model

The UniSim software contains a library of modules which mathematically represent the behaviour of process equipment, logic and control components under dynamic conditions. The modules include heat and material balances, operating equations, thermodynamics and physical property calculations. These modules are used as building blocks to create a realistic representation of a specific process, area or plant.

The digestion process model includes 135 tank modules, 85 pumps, 1037 control valves and approximately 158 other pieces of unit process equipment such as heat exchangers. There are 386 field operated devices, mainly manually operated valves, and 7370 control points are simulated. Training features include 1242 malfunctions. The process model takes about 0.2 cpu second to run on a personal computer and the model runs every 2 seconds, which is more than sufficient to realistically simulate the process dynamics.

5.3 Implementation

The project had a very aggressive schedule meaning that a standard project delivery method would not have been successful. Hence the project was set-up as a partnership between all the stakeholders (design, operations, control and simulation) as an integrated team. This enabled transparent information exchange which was managed through a closed loop change management process.

This project required considerable engineering hours and inorder to meet the tight delivery schedule up to 12 simulation personnel were resourced from Brisbane, Perth and Pune. These teams developed sub-models, according to predetermined dynamic simulation standards, which were merged to form the final models. Once process models were completed DCS integration and testing for the training process models was done before factory acceptance testing. All of this was coordinated by the Brisbane simulation personnel who worked in the Rio Tinto Alcan Engineering offices throughout the project. This maximised communication with Rio Tinto Alcan process engineering, Rio Tinto Alcan management and the control system engineers.

The project was delivered in 2 phases to coincide with plant commissioning. Each phase had simulation factory acceptance testing with the control system in Rio Tinto Alcan's Brisbane office before commissioning on site at Gove. The low temperature digestion section was delivered for site training 3 months before commissioning. Finally the complete digestion simulator, including high temperature digestion, was delivered 6 months before high temperature digestion commissioning.

5.4 Benefits

The simulator project was delivered to enable many months of operator training prior to plant start up. This resulted in the operators being knowledgeable on the process and the control system, but perhaps more importantly on how to control the process. Thus the operators became a valuable part of the commissioning team and were able to retain the lessons learnt from commissioning.

In order to enable operator training several months in advance of plant commissioning the control system had to be developed 6 months earlier than would have been necessary without the simulator. Whilst this placed an additional burden on the control system engineers, the result was that the control system was able to be tested and commissioned on the simulator well in advance of plant commissioning. This resulted in over 240 improvement suggestions ranging from nice to have to critical, examples being:

- Feed should trip on LTD trip;
- Numerous controllers tuned;
- Numerous control system graphic fixes;
- Trip setting improvements;
- Highlighted need for major high rate decanter control system changes before the commissioning. These improvements were made just in time;
- Enabled changes to allow use of high rate decanter flocculant control system before commissioning.

In effect this meant that the control system was fully commissioned prior to actual plant commissioning, allowing the commissioning engineers to just focus on the process and equipment.

6. Conclusions

Rio Tinto Alcan Gove are in the final stages of commissioning their upgrade project aimed at doubling the plant capacity. This is making use of a Rio Tinto Alcan technology, double digestion which uses both high and low temperature digestion to maximise alumina extraction. This was a new technology for Gove and a Honeywell UniSim simulator was constructed connected to the distributed control system to mitigate the risk by training the operators and testing out the control system configuration prior to plant commissioning.

The dynamic simulation, based on engineering first principles with full heat and mass balancing, was used throughout the project lifecycle providing benefits in:

- Health and safety – reducing the need for people on site;
- Operator training – training on a facility with the same look and feel as the real plant under numerous operating conditions;
- Control System Design – Effectively pre-commissioning before site delivery.

The Gove simulator proved to be very successful resulting in a large number of control system improvements prior to start up and justified the prediction of a month improvement in achieving full production.

In order to operate safely, reliably and efficiently it is necessary to have well trained competent operators. It is very difficult, especially for a new operation, to obtain this without a direct connect high fidelity simulation that replicates plant conditions and problems. This has been recognised for many years throughout the aerospace industries and within the high risk process industries such as for oil platforms. There is now recognition within the alumina refining industry that this technology can significantly improve commissioning times and incident avoidance.

References

1. Don K. Lorenzo, "A Managers Guide to Reducing Human Error"; (American Chemistry Council, Washington, DC, 1990, p. 11).