AUTOMATION SOLUTIONS FOR THE ALUMINA INDUSTRY

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ABSTRACT

The production of alumina is a highly intensive process involving the interactions of numerous processes. The ability to make this process economically viable relies on good process design together with an understanding of the process dynamics. Automation (encompassing instrumentation, control, advanced control, information systems and dynamic training simulation) is one of the technologies that ties this together. Widely used throughout the oil refining and petrochemical industries it is being recognised as an enabling technology to safely and effectively improve the performance of alumina refineries throughout their lifecycle from construction through operations.

Automation systems only represent a small percentage of the overall cost of an alumina refinery and are often perceived to be costly and complex. With careful consideration to design and architecture these systems can have a significant impact on operations and profitability, particularly in the areas of advanced process control, and dynamic simulation.

This paper reviews automation technologies and the relationship to benefits. Case studies are presented for the areas of dynamic simulation and advanced process control highlighting the benefits.

1. INTRODUCTION

It has been estimated that in the USA alone over $20 billion are lost each year in the process industries through abnormal situations. Generally it is perceived that production is only lost when there is an alarm, however Figure 1 illustrates that this is merely the tip of the iceberg.

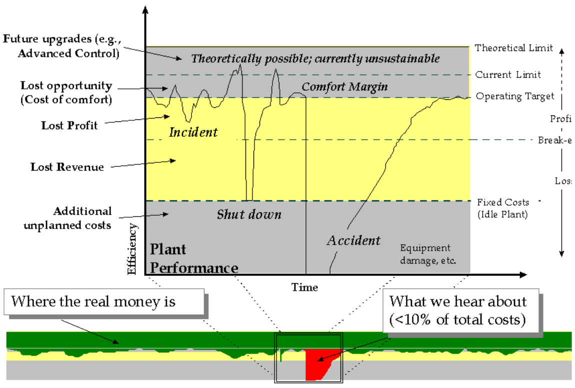

Figure 1. Theoretical Production Capacity

It can be seen that there is a huge potential for increased profitability through adequate control of plant operations. However, the production of alumina is a highly intensive process involving the interactions of numerous processes with varying degrees of dynamics. It is the ability of the operations personnel to perceive, understand and control these dynamics that provides for better or worse plant control. Automation plays a major role in enabling operations to control the plant dynamics.

Automation should be considered in its broadest term covering everything from measurement through control to information management. Whilst the automation systems represent a small percentage of the overall cost of an alumina refinery they can have a significant impact on operations and profitability. However, these systems can be complex and in order to maintain these careful consideration should be given to the design and architecture.

2. ISA95 STANDARD

ANSI/ISA-95 (IEC 62264) is an international standard for developing an interface between control systems and enterprise systems for manufacturing operations. ISA-95 provides a consistent terminology for clarifying application functionality as well as a number of information and operations models that give a foundation for defining how information should be used and exchanged between functions. The functional hierarchy model defined in ISA-95 depicts levels which provide different functions and operate in different time scales. The levels are described in Table 1.

Table 1. ISA95 Automation Levels

Level	Functions	Time Frames	Examples
4	Business-related activities needed to manage a manufacturing organisation	Months, weeks, days	ERP, Plant Production Schedules, Shipping & Inventory Levels
3	Managing the works flows to produce the desired end-products	Days, shifts, hours, minutes, seconds	Data Historians, Laboratory Information Systems (LIMS), Plant Performance Management Systems
2	Monitoring and control of the physical process.	Hours, minutes, seconds, sub-seconds	Real-time Controllers, DCS, HMI, SCADA software
1	Sensing and manipulating the physical process.	Seconds and faster	Sensors, analysers, actuators
0	Actual physical process		

The ISA-95 models help define the boundary between the Enterprise systems (Level 4) and Control systems (Level 2 and below). An activity should be included as a Level 1, 2 or 3 function if it is directly involved in operations, includes information about personnel, equipment or material and is critical to plant safety, plant reliability, plant efficiency, product quality or maintaining regulatory compliance.

It is important to understand where a particular plant activity fits within the ISA-95 models so that the appropriate application or technology is used to implement the required function. Applications at different levels will have different requirements in terms of redundancy, availability and accessibility. If the models are used then a system can be designed so that information is transferred between systems in a timely, accurate and secure manner reducing data duplication and manual entry of data in multiple systems.

In addition to the functions above, there may be non-operational activities that occur at Level 3, for example; security, personnel safety and asset management. These activities are not covered by ISA-95 but are still important to the operation of the facility. So, one interpretation of this, relating to the automation of an alumina refinery, is as illustrated in Figure 2.

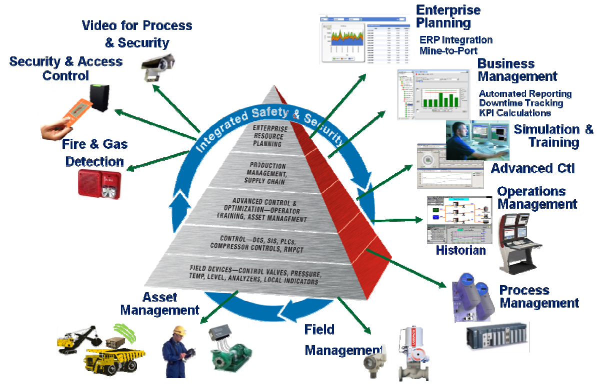

Figure 2. Requirements for Automation Levels

There can be significant benefits to be gained from all areas of automation, although some of the most visible benefits can be realised in the ‘Simulation and Training’ and ‘Advanced Control Areas’.

3. Simulation and Training

The major asset that any organisation has is its people. It is the people and the way that they operate the plant that is key to the profitability of the organisation. In order to fully utilise the operations personnel it is vital that they be adequately trained. The training requirements are really three fold:

Control System
Operations personnel need to be totally familiar with the control system and how to use it. This should be considered a vital tool in the execution of their duties which successfully deployed can alleviate considerable effort.

Process
An understanding of the process and chemistry will enable the operators to make correct decisions relating to the optimal operation of the plant.

Controlling the process
To correctly operate it is necessary to combine the knowledge of the process with knowledge of the control system and to understand the dynamics of the operation. This will enable the avoidance of possible abnormal situations as well as provide an ability to optimise the operation under varying conditions.

The only effective means of training in all three aspects is through the use of a direct connect dynamic simulation which replicates the environment in which the operator works. This simulation must provide a view of the

changing state of a process in operation by calculating future states of a process as it reacts to changing conditions. As these changes occur throughout the system, they can be observed and tracked, providing the "look and feel" of real-world operations. This can only be achieved through first principal models, based on rigorous chemical and thermodynamic principles, integrated with the process control system to provide the same look and feel as experienced by the operator controlling the real plant. This being analogous to the flight simulators which are an integral part of pilot training.

Throughout the lifecycle of a project, design, construction and ongoing operations, simulation can provide significant benefits, although most training simulation projects are effected during the design and construction phase and then used throughout the ongoing operations. This simulation model can be used during start-up, shut-down, normal operations and when new technologies either control or process are trialled.

A number of the recent new alumina plants and major expansions (Toro et al; Freeman et al; Honeywell) have made use of simulation technology to:

- Train operators, maintenance and engineering personnel on how to run the plant
- Certify operators to meet specific standards
- Maintain and upgrade operator skills on an ongoing basis
- Develop operating, maintenance and emergency procedures
- Develop and test operations documentation
- Develop optimum operating strategies and procedures
- Tune the control loops
- Process design verification

One of these projects (Freeman et al) had a model that included 135 tank modules, 85 pumps, 1037 control valves and approximately 158 other pieces of unit process equipment such as heat exchangers. There were 386 field operated devices, mainly manually operated valves, and 7370 control points are simulated. Training features include 1242 malfunctions. The process model took about 0.2 cpu seconds to run on a personal computer and runs every 2 seconds, which is more than sufficient to realistically simulate the process dynamics and enable running at up to 10 times real time.

The simulator project was delivered to enable many months of operator training prior to plant start up and 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.

One other simulation project reported an improvement in start-up time of 25% with a resultant reduction in off specification of 50%. This translated to many millions of dollars in revenue improvement providing a payback in months.

4. ADVANCED PROCESS CONTROL

The challenge to any alumina refinery is to minimise the cost of production per tonne of alumina consistent with safety and environmental considerations. This translates to maximising the production of alumina (plant flow and yield) and minimising the energy costs per tonne of alumina. For the liquor circuit this equates to maximising the liquor flow whilst maintaining liquor concentration. In addition liquor inventories and surge volume must be maintained within high and low limits. Similarly mud washer dilution must be carefully controlled to maximise caustic recovery whilst minimising the dilution.

The Bayer circuit poses unique problems for control. Recovery of energy and caustic are what makes the Bayer Process economically viable. This causes the unit processes to be highly interactive. Combined with long dead times this causes problems for conventional control. Advanced control techniques in the form of multivariable predictive control can solve these problems.

This type of control considers an entire process at a time, such as digestion or heat exchange. In this way the control objectives become those of the process. The process is kept within operational limits by the manipulation of variables that are not at their limits. Similarly the process is optimised by

pushing the process to the operational constraints.

The controller incorporates a model of the process dynamics that it uses to predict future behaviour of the process and to determine how to adjust the controller's outputs in order to bring all process variables to setpoints or within limits. If there are any degrees of freedom remaining, the controller adjusts the process to optimise operations, for example by maximising total product value.

Jonas, 2004, cites a number of areas within an alumina refinery that are well suited to the application of advanced process control, as illustrated in Figure 3. Typical benefits can easily equate to over $5 per tonne profit improvement.

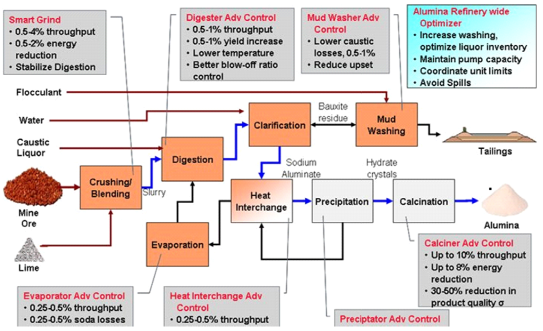

Figure 3. Alumina APC Benefits

The digestion unit is one area where significant benefits have been reported for advanced control (Lawrence, Jonas. 2005; Lopes et al, 2009; Oliviera et al, 2008). Typical control objectives for a digester unit are:

- Control of digestion blow off ratio
- Maximise productivity (bauxite and liquor flows) whilst maintaining process constraints
- Provide safe and stable operations
- Protect the unit from defined, measurable constraints such as hydraulic, mechanical or environmental constraints.

The dynamic response model within a Multivariable Predictive Controller provides for predictions of the process response to future changes whilst examining all interactions between the process variables. In essence a matrix is compiled of the relationship between variables that can be manipulated and those that need to be controlled. Modern systems, such as Honeywell's ProfitController, provide automated means of compiling and implementing these models.

Lawrence and Jonas (2005) report that for an alumina refinery in Jamaica there were significant improvements in flow rates, as shown in Figure 4.

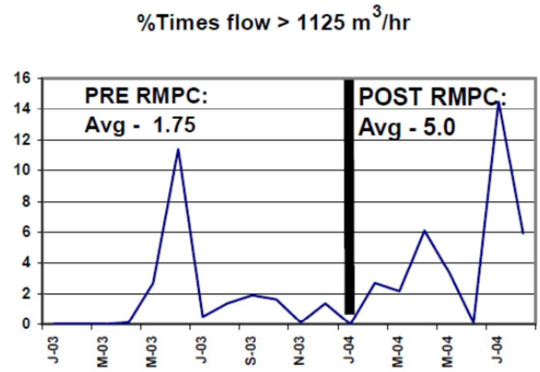

Figure 4. Digestion Flow Improvements (from Lawrence, Jonas)

Additionally Oliviera et al, at Alunorte, reported improvements in blow off ratio control, Figure 5 and productivity, Figure 6.

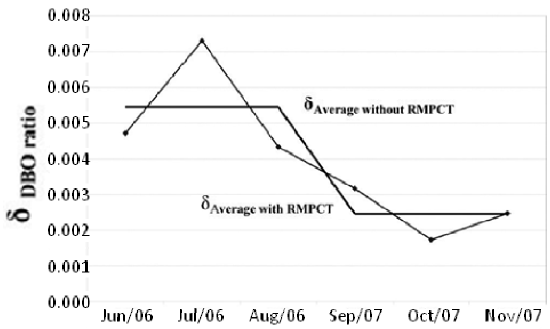

Figure 5. Blow Off Ratio Improvements (from Oliviera et al)

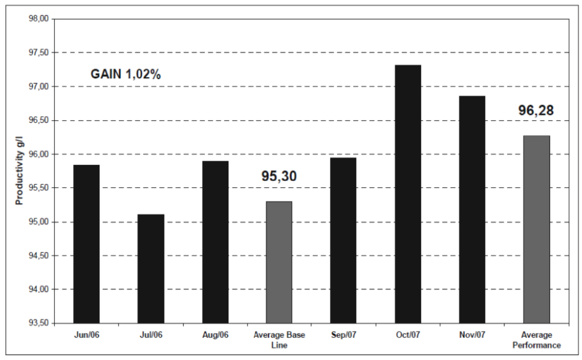

Figure 9. Behaviour of productivity in digestion system with and without RMPCT operation.

Figure 6. APC Productivity Improvements (from Oliviera et al)

In both of these examples not only were there production improvements reported (the impact of which can be clearly measured) but there were also significant reductions in operator actions and manipulation of the process variables. The business benefits of the latter are hard to quantify however will result in maintenance reductions and better process response (as a result of freeing up of operators time). The ultimate test of success

is operator acceptance and with controller uptimes of over 93% it is clear that the operations personnel see value in this type of control.

The cost associated with advanced control is very effective when compared to capital equipment costs. For instance a new 1 million tonne per annum refinery might cost of the order of a billion dollars. This equates to 10 million dollars per percent of production. Advanced control techniques can generally achieve this same increase for a fraction of the cost making it an attractive investment.

5. CONCLUSION

This paper has described the case for automation in particular the losses associated with process upsets. In many cases these can be mitigated through correct application of automation technologies as illustrated through the ISA95 model. Significant benefits and operational improvement can be obtained through effective operator training through the use of operator training simulation as illustrated through a number of case studies. This type of system enables operators to become more effective, further advanced process control can provide a mechanism to stabilise and optimise the highly interactive control of an alumina refinery.

6. REFERENCES

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