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PROCESS CONTROL IN ALUMINA REFINING, REVIEW AND PROSPECTS

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Abstract

This paper will review the evolution of process control in the alumina industry. The comparison with others such as Oil and Gas will be useful to measure where we are now and what other steps, particularly in advanced control, we can envisage to bring value to our business. We will look at what this might (and will) imply both in terms of equipment infrastructure and development of the organization.

The need to control its own environment is probably built into the human nature. It starts with the control of bodily functions (body temperature, blood composition - sugar, metals, etc.). People want to know what to expect: the temperature of their shower, the pressure of the water tap. It is noteworthy that the need is latent in men's nature but the extent and the complexity of control has long depended on the techniques or technologies which were available at a particular moment in history.

A brief review of control technologies and architecture

As soon as refining of alumina became a continuous process, the process and control engineers attempted to reproduce the most favorable and consistent conditions for the process and, within the limits of the then existing technology, stabilize the operating conditions.

From local panels to area control rooms

In alumina refining, most variables that are continuously measured are simple physical parameters such as pressures and temperatures. In the early days and for a long time, flowmeters used a diaphragm to convert flow into a differential pressure. If pressure indications could travel relatively far from their point of measurement, early temperature signals would be carried by capillary tubes and hence would not travel more than a few dozen feet. This is certainly one of the main reasons why early instrument and control panels were located in the field, very close to the equipment they served. Alumina refineries built in the early 40's would be typical of this generation. The Alcan Canadian refinery in northern Quebec, in 1970, had more than 18 control panels spread out across the plant.

Chemical characteristics were analyzed in the laboratory from samples taken at regular intervals in various positions in the Bayer cycle.

After the second world war, the oil industry embraced pneumatic transmitters and control technology. This was particularly well suited for the oil and gas industry as it provided an intrinsically safe environment, free of sparks and other ignition sources. Alumina refining went that route also, and today there are a number of plants that still have vestiges of that age.

The operational amplifier was born in the early 60's. This triggered the development of the analog transmission of signal and control. The 4-20 mA standard for analog transmission of data became ubiquitous. This enabled the transmission of measurement and control signals over longer distances but still not much beyond a few hundred yards. In the 70's, control engineers designed area control rooms with a dual objectives of providing the proper environment for the instruments and the consolidation of the control operator's tasks. Scattered control panels were replaced by fewer control rooms and, in the same plant as mentioned previously, the number of control rooms decreased to 8 or 9. The concept of area control rooms was introduced in the design of plants that were conceived and built in that period. It is worth noting also that the organization of the work teams followed a similar evolution. The self-directed teams of the 80's are modeled on the process areas that are delineated by each control room.

The world goes digital

In the mid 70's, although initially little noticed by the industry, the first digital controllers appeared on the market. At first, the designers of control architecture reproduced the same area control room concept. In the Alcan designed Aughinish Alumina plant, there were 7 area control rooms equipped with an early version of digital controllers. Control manufacturers also, for a while, copied architectural concepts from the world of single analog loops. Taylor, in its Mod 3 early DCS, had one controller card per loop, stressing the perceived need to have "Single loop integrity".

Today's control systems are moving very fast towards Digital Distributed Control (DCS) which is widely accepted even in places where management considers it needs a robust, maintenance-free and operator-proof control system.

Present Digital Distributed Control Systems known as DCS's are hybrid where analog measurements are still generally transmitted by 4-20 mA signals to concentrating rooms often called Satellite Instrument Houses. This architecture is likely to be replaced by digital transmission of the signal from the instruments themselves to the control systems via a digital field highway. The Fieldbus standard is slow to emerge mainly because of the competitive efforts by vendors to impose their own standard. It is however only a question of time before the entire signal transmission is carried in a digital form.

Central versus area control: Where does the organization fit?

As the technology enabled it, control architects started to promote the perceived merits of central control rooms:

- better global coordination between sections and thus less chance of production losses by improper management of each section individual capability.
- possibility of consolidation of tasks hence improved man-power efficiencies.

But, as the organizational model is still very much influenced by the self-managing teams, there is a large gap between what the technology can bring and what the organization can adapt to.

Where does Advanced Control fit?

The key element of an "advanced control" is the ability for the control strategy to do more than a basic single input, single output (SISO) control scheme. This can take several forms:

- the ability to take several variables into account to perform an elaborate feed-forward algorithm
- the ability to perform non-linear control on a SISO loop i.e. variable gain, adaptive controllers of various kind to acknowledge varying dynamics.
- the ability to continuously track the dynamics of a very non-stationary process.
- the ability to infer (either through first physical principles or by artificial intelligence) process variables that are not directly measurable with an instrument. This technique is sometimes called the establishment of "virtual instruments".
- The ability to design and implement multivariable control to uncouple control loops that would otherwise interact with one another.
- The ability to incorporate complex logic as in the case of rule based expert systems

It has been Alcan's experience that basic frontline regulatory control (the kind that is put in place at first when installing a new DCS) will bring 3 to 5% improvement in raw materials efficiencies and 7 to 15% of capacity increase. In some cases such as in Aughinish Alumina, Ireland, the capacity increase has been more spectacular. But the cost to reach that position has been typically of the order of 15 to 20 US$ Mi. accounting for significant improvement needed in the area of field instruments.

Smart machines now accomplish most of this, i.e. by software operating in some sort of computer. This has been made possible by the sharp decrease in the cost of computing equipment and by its increase in performance (figure 1).

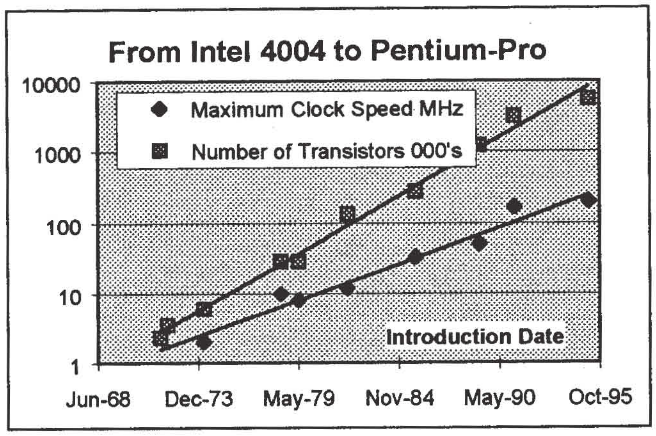

Figure 1 - Performance of microprocessors
(source : www/intel/museum/25anniv)

The Oil and Gas industry pioneered many of the advanced controls. The economic optimization of refining processes is worth million of dollars to that industry.

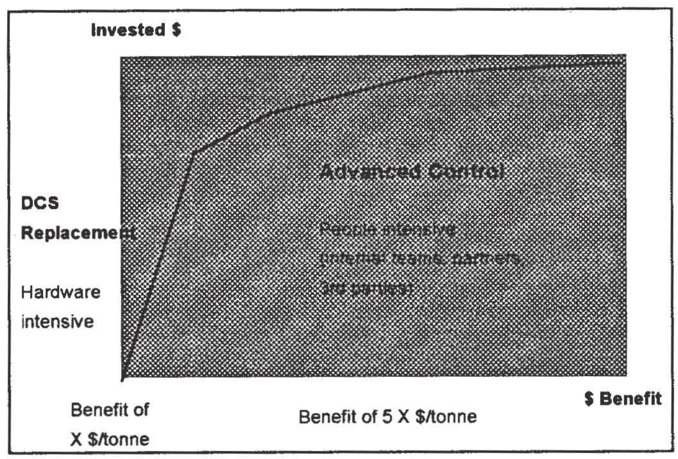

Figure 2 - Benefits and requirements of Advanced Control

Advanced control is everything that exceeds or goes beyond the PID controls or the simple cascade, simple feedforward and ratio controls (that can be implemented, albeit with some headaches, on analog instrumentation). It includes:

- multivariable feedforward and model reference control (grinding control, digester charging ratio).
- Non-linear single loop control (management of surge tanks).
- Expert systems (Rule based, fuzzy logic) (Calcination control, load management…).
- Neural networks (modeling complex problems) .

What can Advanced Control do for alumina plants?

It has been a long debate between traditional process engineers and the proponents of "soft technology". The former advocate that good operation (that is close follow up of process performance, good knowledge and understanding of basic principles) will bring "excellence" in operation. Soft technologies are sometime perceived as impediments and obstacles to shopfloor supervision as they take too much engineers' time "playing with computers".

Computer oriented process engineers reply that reliable information and automation of control tasks free operators and technicians from menial tasks and leave them time to analyze the process or simply improve staff efficiency.

No one can provide clear cut answers in this debate as modern process control is in essence the search for continuous excellence in operation. Process control engineer need to be as close to operations as one can think and allow. In these conditions, advanced process control can do what it has demonstratively done for the Oil and Gas industry:

- It can stabilize process variables, so as to operate at better efficiencies (caustic, energy, bauxite recovery.)
- It can reduce the load on operators and reduce the number and the importance of operator generated upsets. This contributes to the reduction of incidents, improving safety of operations and achieving full production potential.
- It contributes to improvements in man-power efficiency and reduction in man-power costs.

Many process control consultancies claim that the financial returns will be several times those flowing from basic front line regulatory control (figure 2). We have not yet demonstrated this in any of our refinery. However, indications are that savings will be at least as important than the ones brought by the DCS itself. The investment, though is a lot less important in dollar terms if not in people.

What are the pre-requisites?

To be able to implement the above controls, plants need to have their integrated (to be able to access variables on a peer to peer basis) digital (to be able to calculate easily) control system. At this moment in the evolution of the control technology, this is best implemented in a DCS. However, the architecture of commercially available DCS is changing rapidly towards a more open, industry standard architecture based on the PC. Key DCS manufacturers are working on this and offering products in this direction.

The development of virtual instruments generally needs a large amount of historical data. This is best archived and retrieved in "Mill-wide" plant information systems. Complex and lengthy calculations are best performed on specialized application computers that communicate with the historian through Local Area Networks. The control architecture now merges with the traditional Information Technology sometimes still called MIS.

But above all, smart applications are developed and implemented by people. Solutions do not come in a box. No one should expect benefits flowing from the installation of hardware alone. Savings in efficiencies and increase in capacity come from control applications that are tailored to the specific conditions and the specific need of one particular plant. At this moment, there are very few applications that are pre-developed for the alumina industry. In that sense our industry is isolated compared to cement or petrochemical because of the market size it represents. Applications are still custom built using application software platforms such as G2, neural networks and data historians. These
are commercially available packages but at this moment, they are only application platforms and their use necessitate intelligent, motivated and trained people.

It appears to be essential to organize the development of control applications through process control teams that:

- are close to the process and operations.
- integrate instrumentation, control systems (DCS or process control computers) and IT (information technology).
- are accountable to plant management either through operations or technical departments.

Where will this lead us?

Judging from the current trends, we should expect more of smarter (and smaller, and object oriented) entities (distributed devices) connected to networks. The distribution of the computing power and its orderly integration in networks starts to resemble to "intelligence".

This will require (in addition to smart people to put all of it together) a greater connectivity between devices and applications. To achieve this, we will need standards for the definition and the handling of objects (an object broker for process control ? ActiveX? OLE for process control?)

In the field, smart instruments and transmitters will require a unified communication standard. Fieldbus is needed but is slow to come to the market because of the commercial interest of competing corporations.

But we should remember that benefits will accrue from the applications and that these applications will need people to understand and implement them. Installing a modern control system is not sufficient to capitalize on the benefits. A team of control applications engineers of at least two or three persons per plant is key in obtaining what is often claimed in the Request for Funding.