STEP-WISE IMPLEMENTATION OF ADVANCED PROCESS CONTROL IN MINERAL PROCESSING

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ABSTRACT

The advantages of an Advanced Process Control (APC) solution such as expert systems and the use of process models are well documented within the mineral processing industry. At this time, the cost of entry for these systems may prevent some plants from capitalising on the technology. This paper details how APC can be implemented in a stepwise fashion, where each step demonstrates a return and builds towards the overall achievable benefit. Initial efforts focus upon areas that demonstrate the highest potential for quick payback. By attacking small, contained scope, the APC solution is manageable from both a commercial and technical perspective. While this approach results in a slower implementation with correspondingly delayed payback, it provides tangible benefit and addressees the fiscal reality of many operations.

INTRODUCTION

WHY ADVANCED PROCESS CONTROL?

There has been a profound change in the way we operate plants in the metal and mining industry. Through significant advances in measurement and management technologies, plants around the world are operating at unprecedented levels of efficiency. The progress has been steady. First was the introduction of instrumentation that provided accurate, real time, direct measurement of key process parameters. Once assured that the measurements were reliable, the opportunity for real time "management" or control was possible. Through the PLC and DCS paradigm operators are able to demand a certain level of performance for the process parameters and be assured that they will receive what they ask for. An operator today can request a "pull rate" on a flotation cell. Through the implementation of camera technology tied to a control system that manipulates the tails valve to control the level in the cell, the operator can be confident that the pull rate will be maintained. This confidence changed the operator's role. Rather than focusing on maintaining a certain "value" (whether that was density, tonnage or "pull" rate) the operator could now focus on what that value should be to achieve the optimal performance. This transition from a "tactical" to a "strategic" position resulted in a step change in plant performance. The challenge now focuses on how this "strategic" approach could be consistently applied without the natural variation that results from operators of different skill and experience levels operating the plant. Advanced Process Control and in particular Expert Systems, addressed this need. Using a heuristic model that simulates an operation, the Expert System is able to evaluate the state of a process and suggest the change that will drive the operation towards an optimum defined by a "goal".

Over the last 10 years acceptance of expert system technology has grown exponentially as it has been demonstrated to be a robust and maintainable, high return, low risk technology. Many plants designed today include an expert system at start up.

Although sound regulatory control remains the cornerstone of process control in the plant today, true process optimization relies upon judicious process setpoint selection. While a skilled operator can fulfil this need for satisfactory circuit control most of the time, they cannot be expected to be the best controller at all times. Often, the operator is faced with large amounts of plant information, safety and communications to operating personnel, as well as the entry of shift operating data into information systems. Moment to moment vigilance of the operation is not humanly practical for entire shifts.

That is for a skilled operator – in today's operating environment these people are becoming increasingly difficult to find. 2005 represents one of the most difficult employment environments in the history of the industry. Experience is at a premium and operations are having trouble filling critical roles with capable people.

This environment, however, is quite suited to expert systems that can interface with the plant SCADA and control the process via a networked desktop computer. The significant returns that have been realized from advanced control are well documented[1, 2]. Throughput increases of 5+% are typical. This represents millions of dollars in terms of increased revenue.

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While expert system pricing has reduced substantially over the last few years and the return on investment of these projects greatly exceeds even the most conservative economic hurdle – many operations still find it difficult to secure the funding to proceed with a project. Cash flow and strategic decisions are often the culprit with harsh economic reality contradicting fundamental business rationale. This paper addresses these issues by changing the rules of engagement and searching for a means to introduce the technology in a controlled stepwise manner.

THE APPROACH

Given the significant returns obtainable from advanced control, why is there hesitation to undertake these projects?

In the early stages of the technologies development the hesitation was understandable due to perceived and real technical risk. At this point the technology is robust and proven – the hesitation now relates to the commercial reality that many operations find themselves in. A reality in which CAPEX is increasingly scarce and balance sheets full. In this environment operations struggle to find money even for the most profitable projects. Different techniques are employed. Some operations lease solutions in order to transfer the cost to a more flexible OPEX budget. Others are creative in the way they reallocate budget so that they can reap the benefits of the system designed not to increase capital on site but to make better use of the substantial capital investment already there.

For smaller operations this creative approach is more difficult as both OPEX and CAPEX budgets are stretched to the limit. For these situations a radical change is required. One which will result in slower realisation of the full benefits of the technology but gets the technology on site nonetheless and allows the operation to proceed with global optimization at a sustainable and affordable pace. Larger operations benefit from the economies of scale resulting from the expeditious implementation of the system resulting in lower up front costs and fast paybacks.

However, advanced controls have progressed such that smaller operations can now benefit from them. A "bottom-up" approach is adopted (see Figure 1) – vertically integrating the system within a particular unit operation. The advanced control solution is implemented in a controlled manner. Eventually providing fully stable and optimized control. Proven capabilities are deployed to impart an increasing level of stability and performance as the implementation matures.

The first step addresses gross errors and severe process instability. As increased performance is sought circuits are pushed the their limits. These limits are known, but pressure to perform, especially when a circuit is a bottleneck, erodes the operational zone that allows for operators to appropriately return the process to stability when they are overstepped. The initial stage in the implementation is a system that monitors the process and determines, at the earliest possible moment, when an operational limit has been compromised and through an automated procedure the system recovers control and safely and optimally returns the process to normality. Utilizing reasoning capabilities, these procedure are more than just a "trimming" approach… the state of the process is constantly monitored leveraging "trend based" reasoning and models to understand when the system has slipped from a controlled to a chaotic state.

A typical example would be an overload of a primary mill. In serious cases, a primary mill overload results in a stoppage either through a control interlock or through the actions of the operator, and it may not be possible to start the mill again due to excessive load. The overloaded mill may also have pushed the feed chute out, and spilled material upon the floor forcing a mill stoppage. The only recourse is a lengthy mill shutdown to dig out the ore within the mill, sometimes by hand and shovel. The loss of production due to the downtime alone, even once per year, would pay for an advanced control project. A project that detects the onset of the overload condition and corrects for it – ensuring that the mill will not overload – has a sufficiently reduced scope that the implementation would represent only 40% of the cost of a complete comminution advanced control solution. Advanced process control (APC) now has a footprint on site. At the conclusion of this stage of implementation the benefits realised are through the avoidance of a serious condition as opposed to the optimization of the process.

EXPERT SYSTEM IMPLEMENTATION

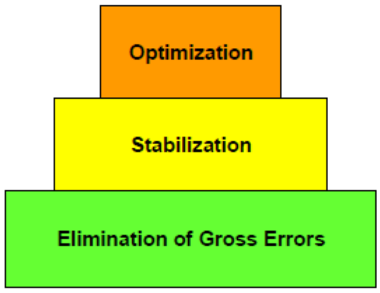

Figure 1:the "Bottom-Up" Approach to Expert System Implementation

The next project to tackle is circuit stability – the addressing of typical disturbances such that a more uniform product is produced at a higher average rate. This is the second level of improved performance. With the circuit operating limits set and with logic in place to avoid gross losses in performance, the stage is now set to increase returns from the stabilization of the circuit. Operating know how is captured[3] in a set of logic rules that manipulate setpoints of key operating variables within the circuit. The sources of variability are monitored and stability is automatically maintained. The current capabilities can be quickly deployed and offer robust algorithms to quickly tune this layer of logic for optimum results.

Examples can be selected throughout the operation - improved throughput or flotation recovery[4] are achieved by ensuring that the circuit is behaving as it should in a consistent manner not oscillating through various states. The result is a more consistent product which benefits downstream processes facilitating their control and optimization as well as improved "average" performance of the controlled process as it operates around a tight mean as opposed to hitting the highs and lows of normal operation.

Some examples of process stabilization routines follow:

ROUGHER OR BULK FLOTATION

Within many rougher flotation circuits individual cells oscillate between a hard pull and no pull at all. This fluctuation in performance impacts the recovery of the circuit as well as the recovery of downstream circuits (such as cleaners) and the performance of regrind circuits. It can also present a challenge for certain components within the circuit that are not designed for the highs and lows but rather for typical flows – concentrate launders are an example. Through the implementation of camera technology to measure the pull rate on the rougher cells coupled with the MET expert system, designed to ensure a consistent rate of production, Escondida achieved an increase in rougher recovery of 1.66% while significantly reducing overflows of the concentrate launder and providing a more consistent and better product to the cleaners.

COMMINUTION

Improved stability for a SAG mill can lead to internal as well as downstream benefits. In order to maximise production, most mills operate on the edge of their capabilities - in a state of flux between a semi-overloaded condition and under loaded state. They are dynamic, always loading or unloading. The result is a varied product – either too coarse or too fine – with a corresponding fluctuation in nominal throughput. The averages may be on target but the highs and lows significantly challenge the flotation and dewatering circuits resulting in an average or poor quality product. The mill itself suffers from the strain of extreme operation. An under filled mill is not a good state as steel on steel collisions occur and often result in damaged grinding media and ultimately damaged grates and lifters. The result – in the best case – is sub-optimum mill performance – in the worst case – unscheduled downtime to fix the problem. Ultimately the result is damage not only of the mill but also associated equipment such as pumps and cyclones as steel enters the circuit. Additionally, the fluctuations result in the circuit being controlled to the lowest common denominator. As oscillations are expected, the mill must be run so that the peaks do not go to far and result in a full overload. The result is an average that does not quite reach its potential. Work completed at Ok Tedi demonstrated that stabilizing an oscillating mill results in additional tonnage – without increasing the maximum tonnes achieved at any particular point. Ok Tedi benefited by 2% through this process.

The stabilisation layer typically represents 40% of the value of a complete expert system.

Once the gross errors are avoided and the circuit has been stabilised – such that operations has confidence that the process will react as expected when a change is made – the opportunity exists for true optimization. A model is developed for the process. It can be heuristic, stochastic, phenomenological or fundamental. Once an objective function is in place with the appropriate boundary conditions defined the system can be solved to determine the conditions required to meet the target. An example of this approach would be the maximization of tonnage with particle size as the "constraint" or the optimization of grind within a tonnage range. Within the flotation circuit the balance between grade and recovery is always a challenge. In this case economics can be incorporated to determine the maximum value being produced at any given time.

There is a midway point between the stabilised and fully optimised systems. If confidence in the model is not sufficient it can still be used to "test" or simulate responses prior to implementing them. In this way errors are avoided and lead to "more" optimised behaviour. This approach has been documented.

The optimization layer typically represents 55% of the value of a complete expert system. The comparison to a full expert system value is a guideline; each step can be justified in and of itself. Each plant is different and it is important to realize that this approach is customizable so that in some cases only one of these steps may be selected.

CONCLUSIONS

The benefits of APC within the mineral processing are well documented. However, this technology is not readily available to some smaller operations due to the financial outlay required. This can be addressed through a step-wise implementation or mini projects, where benefits realized first through gross error elimination, then stabilization, and finally optimization can be achieved while managing cash flow and often funding the project through savings at each stage.

At the conclusion of the three-step implementation site has a fully functioning expert system – it has cost in the order of 135% of the price for a turnkey solution.

From a time value of money perspective this approach is highly sub-optimum. The solution will typically take 3-4 times the amount of time to implement at a price premium. With paybacks on the order of 5% increased throughput the lost opportunity costs can be substantial but this must be balanced with the fact that sites using this method of implementation would often have had to go without a system all together in the past and therefore would have missed out on the optimization and automation opportunity altogether. With plants becoming increasingly sophisticated and personnel becoming increasingly scarcer, expert system technology will continue to move from the realm of luxury to a necessity. The approach outlined in this paper will make it a reality in the near term, allowing smaller and often more marginal plants that need this assistance towards efficiency to benefit.

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