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An NPV Justification to Implement Advanced Process Control (APC) for Ore Comminution

Background

Ore comminution is reduction of solid materials to a target particle size through crushing, grinding and screening. This is an energy-intensive process that plays a central role for production at a mining facility. Not only must traditional Operator objectives be met such as maximizing production and/or product quality, but factors have now been introduced to the modern-day Operator. For instance, decisions around control set point changes now take into consideration minimizing energy consumption, minimizing water consumption, minimizing other consumables (reagents, grinding media, etc.), minimizing environmental impact and others. And all the while, attempting to maximize the plant profitability. Advanced Process Control is a general term used to describe process control software that can simultaneously controls multiple setpoints of the entire ore comminution process. This paper suggests using the Net Present Value (NPV) as an ideal method to justify the installation and maintenance of Advanced Process Control software at an ore processing facility.

Reported APC Successes in Mining and Metals (M&M)

For the Mining and Metals industry, APC's have been successfully implemented with documented benefits of guaranteed production improvement. Depending on the project size and complexity, installed costs of APC projects range between $200k – $500k with returns on investment of 1 year or less. In the M&M industry these kinds of ROI's exist for applications such as:

- SAG and ball mill grinding
- Washing and finishing circuits
- Flotation circuits
- Roasters and other pyrometallurgical processes
- High-Pressure leach and other hydrometallurgical processes
- Cement processing and lime kilns

Typical APC projects can take between 6 – 10 months to complete and commission. APC and optimization can improve operating profit margins in 4 ways:

i. Higher production rates with documented improvements typically from 3% to 5% – by pushing against constraints.
ii. Lower raw material, energy usage per unit of product and emissions with documented improvements typically from 3% to 5% – by pushing against constraints.
iii. Lower product losses & rework – by reducing quality variability with documented improvements typically from 10% to 20%.
iv. Improved production stability and continuity by reducing production variability
v. Improved maintenance costs such as reduced refractory consumption with documented improvements typically from 10% to 25%.

How an APC Technology Project can be Justified

A technology project has no value unless it can drive profits for the Mining and Metals operation. Advanced Process Control (APC) is a software technology that can play a dominant role in driving the company bottom line. A previous article in the 2017 Fall ISA newsletter discussed "Applications and Benefits of Advanced Process Control in M&M". Refer to that article to get a good background on what APC is all about. In this article, we will explore APC justification further. The technology has increasingly become more "mainstream" not only because of the recognized and fully-established benefits, but because costs have decreased due to improved control system OPC connectivity, lower APC software licensing costs and easier "off-the-shelf" implementations that have been witnessed and experienced throughout the industry.

Approach in Justifying an APC Project

Justifying APC is done by establishing process variability of key process variables (CV's) for the Manipulated Variables (MV's). And then an estimate is made on the reduction in key CV variability APC would achieve – it's typically a reduction in one-half to one standard deviation. Establishment of Disturbance Variables (DV's) or feedforward variables, along with Process Constraint variables (AV's), will determine the limits on what would be the potential change in the new setpoint.

Justification is developed by predicting the potential process variability reduction and then the corresponding potential change in setpoint based on the constraint limits. This is shown in Figure 1:

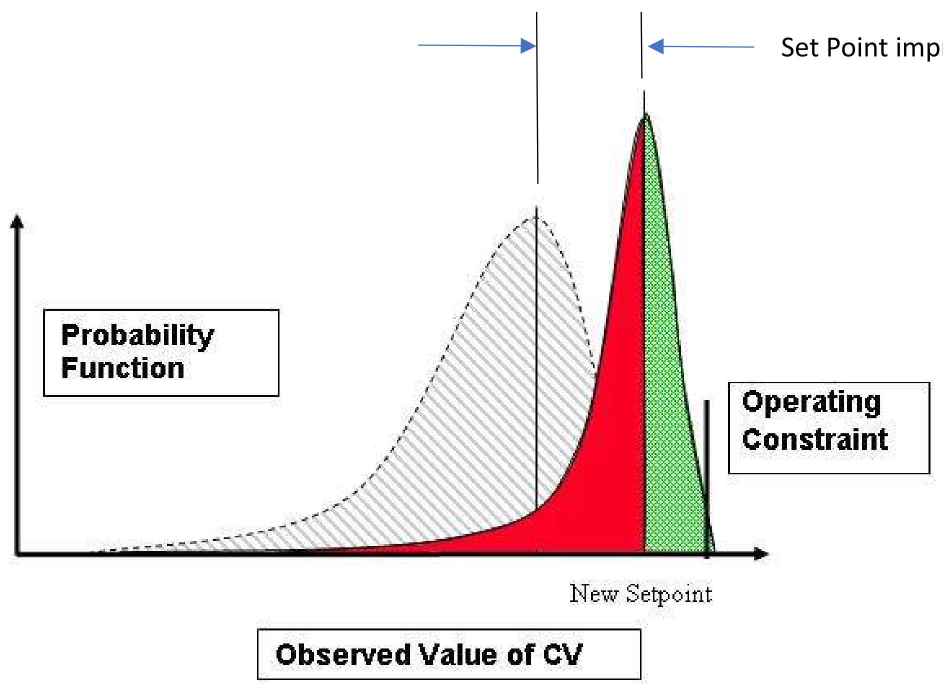

Figure 1 Improvement in Set-Point due to reduction in CV variability

This figure shows that:

- Random influences create a normal CV variation
- Advanced control can reduce the standard deviation of a performance variable typically by up to half a standard deviation
- This then allows to move the set point an amount equal to the reduction in initial standard deviation or to the constraint limit and will yield economic benefits with no degradation of product quality
- Based on a newly established Set-Point, an economic justification can be made to project expected benefits.

Establishing economic benefits for the improved Set-Point typically is associated with improved production by operating closer to the constraint limits. Or with APC implementations, closer to optimum values through additional constraints and optimization. as per traditional APC or closer to overall value when adding new constraints. The reduction in variability also improves specific energy consumption along with product quality improvements. Most justification ignores quality improvements because it is a difficult value to establish objectively. But production improvements and specific energy reduction are well-established and justification is then done with either a Return On Investment (ROI) calculation or a payback calculation. This is the most common approach for justifying an APC project.

Having either a hard (ie; software implemented with control software) or soft (operator advisement) avoidance of running into a constraint limit, improves equipment Mean Time Between Failure (MTBF). There is a direct impact on MTBF when key equipment is operated and not exceeded over its design constraints. But improvements to MTBF typically takes over a year or longer to be achieved. Also to measure the payback takes often time beyond 6-12 months. What does an increase in MTBF have for an impact on profitability? How can an improvement in MTBF be captured over a multi-year time horizon when justifying a project?

MTBF improvements allow for an increase in Available Time for production during the course of a given time period. This translates directly to an increase in Overall Equipment Effectiveness (OEE) and have a substantial impact on profitability. One approach to evaluation justification in OEE improvements is by using the Net Present Value (NPV) approach and can nicely take into account multi-year time horizons. This approach is reviewed with an example related to an APC investment for a SAG Mill.

Increasing the MTBF of a SAG Mill

Semi-autonomous Grinding Mill's (SAG Mills) are the largest capital-cost machine at a mine, the largest energy consumer and most typically is the production facility bottleneck. If the SAG Mill is running poorly or is down, plant production is directly affected. APC installations for a typical SAG Mill have the following documented improvements:

- Increased throughput 2 - 5%
- Reduced electricity consumption 2 - 5%
- Reduced quality variability 10 - 20%
- Reduced liner consumption 10 - 25%

Throughput and specific energy improvements are well documented for APC justification on SAG Mills. Improved quality has also been claimed, though that proves harder to use for justification purposes. But an improvement in liner consumption directly affects the MTBF – or when a SAG mill needs to be shut down for a liner replacement. Industrial equipment like a SAG Mill will always have a longer runtime when it's not operating over design constraint limits. Typical APC constraints (AV's) to improve SAG Mill MTBF include:

- Maximum feed rate
- Recycle tonnage rate
- Cyclone feed density (maximum % solids)
- Ball Mill loading (minimum amps)
- SAG Mill motor protection (maximum amps)
- SAG Mill load or bearing pressures (Feed and Discharge) i.e. prevent classic overload
- Product Grind Size/Liberation maximum (microns)
- Hydro-cyclone feed pressure, flow rate, motor current

The problem with establishing the impact of reduced liner consumption is that this improvement from an APC install may not be realized in the first year. Nor the second. If it's a 25% liner lifetime improvement, that could potentially not be recognized until the 5th year of an APC installation if the existing liner replacement frequency is 12 months. How important of an issue is MTBF to establish the economic justification? Let's look at a financial model of a mill to see and use an NPV anlysis:

Financial Model of a Mill

A simplified financial model of a mine mill was created with the following assumptions:

Parameter	Units	Base Case	APC Install Yr. 1
Operating days		344	344
Throughput rate	t/h	1500	1530
Power cost	$/kWh	0.1	0.1
Grinding media cost ($ per tonne of media)	$/t	1200	1200
SAG mill liner replacement per year	$ M	5	5
Grinding media consumption SAG mill	kg/t	0.4	0.38
Grinding media consumption ball mill	kg/t	0.5	0.5
Total media consumption	kg/t	0.9	0.88
SAG mill liner cost	$/t	0.39	0.39
Power	$/t	1.39	1.3622
Grinding media	$/t	1.08	1.0584

The further assumption that there is an improvement to the APC of the following:

Production improvement	2%
Energy efficiency improvement	2%

SAG media cost saving improvement	2%

And with the following business scenario (required for this simple mill financial model, plus the NPV analysis):

Power as percentage of total cost of manufacturing (assumed)	35%
Mill Profit margin	15%
Return on investment	20%
Year 5 realization of extended liner replacement	$1,500,000

NPV Analysis

Net present value (NPV) is determined by calculating the costs (negative cash flows) and benefits (positive cash flows) for each period of an investment. NPV can be an useful analysis approach in the mining industry because of a known mine lifetime, which defines the period N. Or the period of time N one wants to look at the investment.

$$\boldsymbol{NPV\,(i,\,N) = -C_o + \sum_{i=1}^{N} \frac{C_i}{(1+r)^i}}$$

r = discount rate – can be where you can better put your money, *or risk of your investment*

C_i = Cash inflow, for a given time *i*

C_o = Cash outflow at the onset

The cash flows in net present value analysis are discounted for two main reasons, (1) to adjust for the risk of an investment opportunity, and (2) to account for the time value of money. One of the nice features of an NPV analysis, is that if the investment risk is high (like a development project), one can increase the discount rate *r* to further discount the expected cash flow.

NPV analysis can also capture investment opportunities related to OEE improvements, particularly projects that are multi-year. The following values were used in the financial model for this APC project example:

- Specific energy decrease of 2%
- Production increase of 2%
- Media cost savings of 2%
- Improved MTBF liner replacement of 25% (because of operating within constraints)
- Improved quality is not considered for simplification, but does exist
- Capital project of $500,000
- Liner replacement cost of $1,500,000

Results of the NPV Analysis

Even if there is a heavily-discounted project (maybe because it's considered "high risk") where in this example the discount rate was considered to be at 20%, we can still see how big of an impact on MTBF has with the graphical results shown in Figure 2 below:

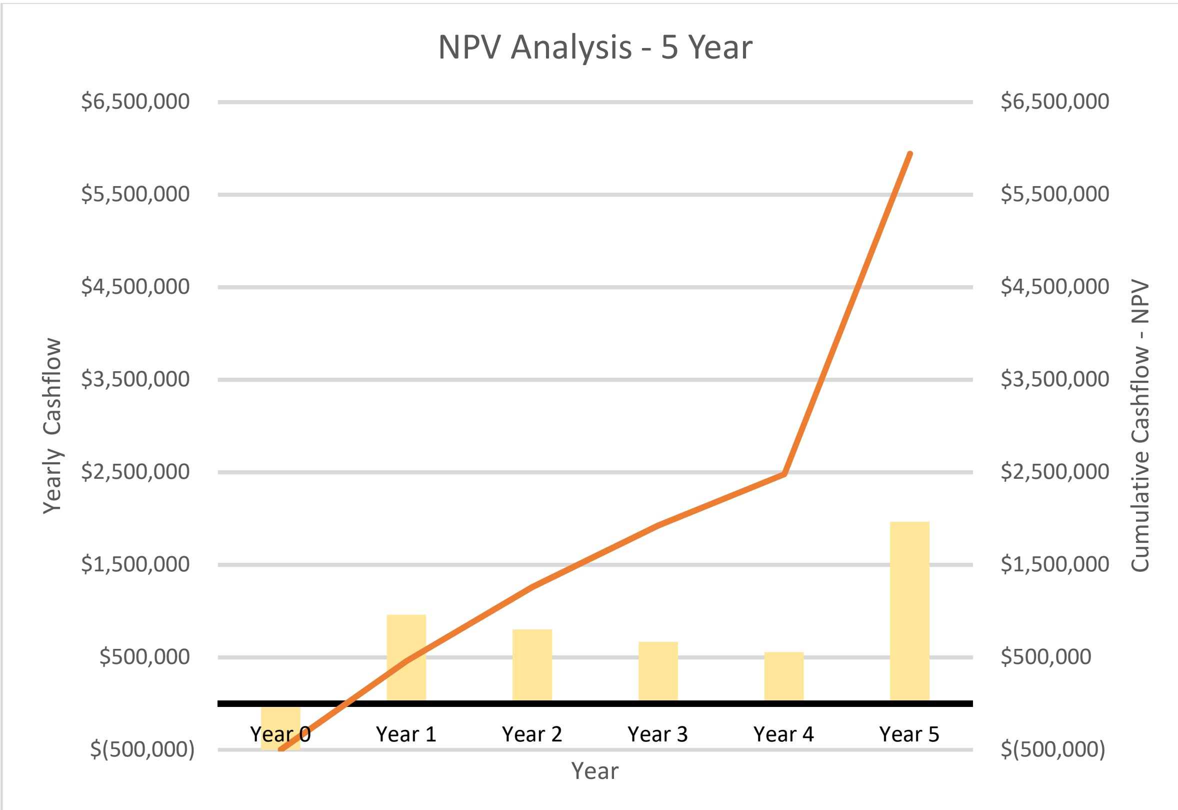

Figure 2 NPV Analysis over 5 years

The orange line is the cumulative benefits and the bars are the cash flow for each year of the project. Where the orange line crosses over the horizontal axis speaks to a payback of something like half a year. So an NPV analysis also establishes the expected payback for a project. But what this analysis also shows is the benefit of an APC project where an increased MTBF ***can potentially far outweigh any cash flow benefits*** of improved production or specific energy consumption! Even if this improvement in MTBF is a benefit not fully realized for 5 years!

APC's are a great opportunity for the M&M Industry

In summary, APC's are becoming increasingly common-place with the Mining and Metals industry. This is due to lower capital costs for these types of projects, availability of capital, relatively fast installation times of less than six months (and without plant interruption), along with recognized and proven increase to overall plant profitability. Most the major automation companies have proven APC solutions, and most are built on similar technology platforms. APC applications are no longer development projects and now can be characterized as using well-established control engineering methodology. In summary

- APC for comminution is becoming an increasingly mainstream technology
- NPV model analysis shown in this example demonstrates a significant cash inflow at ~ Year 5 because of the 25% improvement in MTBF starting in Year 1 (each year there's a 3 month improvement over the base-case of a 12-month MTBF in liner wear)
- A simple payback or ROI model doesn't properly capture economic benefits of technologies that improves MTBF – especially for multi-year projects

This simple example on a SAG Mill liner is directly applicable to other M&M opportunities for APC, high-value regulatory loops, process improvement projects or flow improvement effects on production downstream. All these have not been considered in this conservative business case. It has been shown for instance that furnace refractory life has been increased with APC installations due to not running the furnace above temperature design constraints.

This simple NPV analysis demonstrates that perhaps one of the biggest project justifications can be often be overlooked. Namely, the improvement in MTBF where a plant can run longer between scheduled shutdowns. And the use of APC's is a perfectly viable approach to increase MTBF's and significantly improve overall profitability.

Further references

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