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PROCESS AND ASSET MONITORING AT A PGM CONCENTRATOR FOR UG2 CONCENTRATE

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Abstract

Advanced process and equipment analytics have been around for a while. However, with accessible IT infrastructure and site maturity, it is possible to analyse, monitor, and control processing plants and equipment easily. These various disparate systems provide different reports requiring the involvement of various personnel and attention to different reporting platforms. For efficient harnessing of the systems' capabilities, as well as effective improvement and monitoring of process and equipment, a single point of entry is required.

A process and equipment optimization solution was required at a concentrator in South Africa, focussing on the product stream of platinum group metal (PGM) concentrate from the UG2 Reef. The investigation of data to identify strategies for optimization was required to allow visibility into plant operations to guide operators, an easier method to identify process loop problems, identification of imminent equipment failures, and advanced process control to optimize throughput and stability.

A collaborative effort between the client and General Electric Intelligent Platforms (GEIP) investigated data-driven solutions to each of the problems. With the focus on process optimization and asset monitoring, as well as equipment monitoring, a combination of approaches was utilized to address the various problem areas that were identified. Each was implemented separately in the control layer of the plant IT infrastructure. The integration was done in a centralized web-based reporting tool that integrated the detailed results from the various solutions.

On the process control side, monitoring of control loops was included by calculating performance statistics that were reported daily to identify sub-optimally performing control loops and indicating potential problems. The advanced process control solution for this site includes a surge tank controller, stabilizing flow through the flotation banks, and preventing the surge tank from overflowing or running empty.

Equipment monitoring was investigated, for preventative maintenance, by making use of statistical data models to indicate imminent equipment failure. These predicted alarm events included the cause for failure, drilling down, and allowing focus on a specific variable for preventative action.

The results included a more stable flow through the mill, with fewer stoppages due to surge tank overflows or running empty. The causes for process drift could be identified and operators could react early. Alarms warning of equipment failure 2½ and 4 months in advance were identified in an offline analysis.

Site background and operations

The basic structure of the platinum value chain is depicted in Figure 1. The focus of this study is on the concentrator and utilities. The concentrator studied processes ore from the UG2 platinum reef only – ore from the Merensky and UG2 reefs differ significantly in terms of mineralogy, therefore the focus is on UG2. UG2 ore has a higher chromite content, resulting in processing challenges, but can also contain higher concentrations of platinum group metals (PGMs). The UG2 ore is fed to the concentrator where it is crushed and separated by means of flotation cells. The pumps, motors, and compressors are controlled through proportional-integral-derivative (PID) control loops, expanding the focus from only processing units to include utilities as well.

The scope for concentrator and utilities solutions are briefly defined in this section, as set out in Figure 1. Detailed methodology and implementation is discussed in the following sections.]

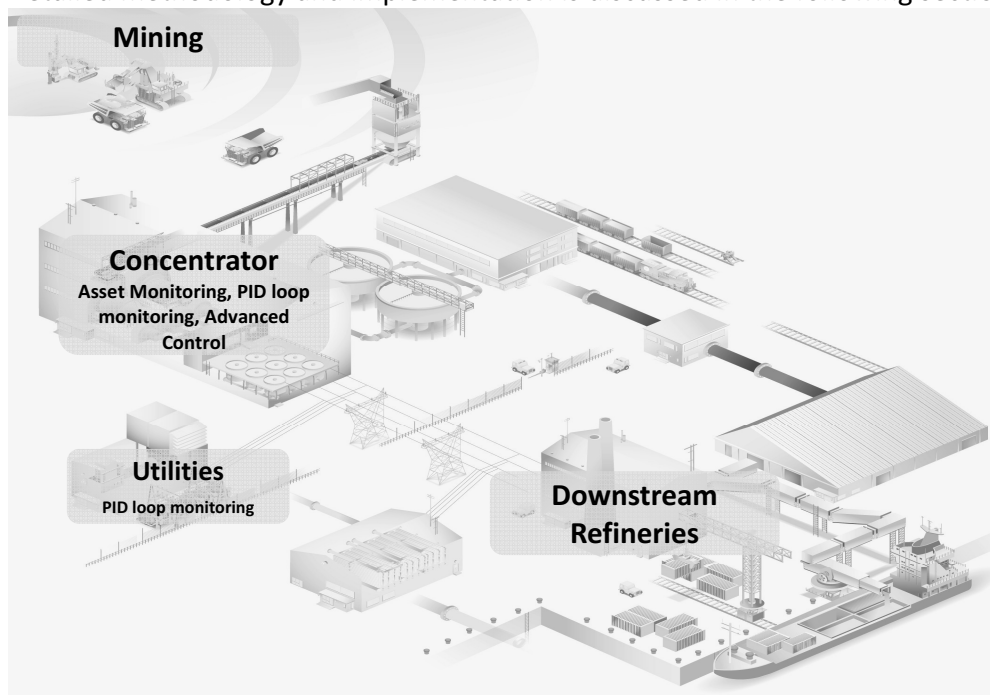


Figure 1-The PGM value chain. The concentrator is the focus of this paper

Loop monitoring focus areas

Control loops for the concentrator are monitored for the whole site, and total 112 control loops. The reporting on loop performance is done per loop, per section. The per section split, as set out in Table I, allows reporting spits, as well as visibility into which area requires the most attention from automation personnel. It is clear that the rougher-, cleaner- and reagent sections are the most automated and might require the most attention. Loop monitoring will assist in differentiating priorities of which loop requires attention.

Table I-Number of loops per concentrator section

Sections	# of loops
Final Concentration	2
Final Tailings	2
Primary Classification	1
Primary Cleaners	12
Primary Mill	8
Primary Roughers	24
Reagents	16
Secondary Cleaners	14
Secondary Mill	5
Secondary Roughers	22
Services	5
Tailings Thickener	1

Asset monitoring focus areas

Asset monitoring monitors items of equipment with the goal of pre-empting failure. The equipment may be fixed, such as pumps, motors, plant processing equipment, or moving, such as trucks. For the concentrator the focus is on the primary and secondary pumps on the primary mill tails, the primary rougher pump train, and the mill motor and gearbox assembly.

Advanced process control focus areas

Advanced process control (APC) is a wide concept focused primarily on supervisory control. An APC approach may include any number of variables or types of algorithm or predictive models, and may even be very application-specific. On the concentrator studies, the APC controls the pump action for the UG2 plant primary surge tank, secondary surge tank, and the primary rougher tails tank.

Loop performance monitoring

Method and on-site implementation

Loop monitoring makes use of the values for:

- current manipulated variable (MV),
- current control variable (CV),
- current set-point (SP),
- range limits around the set point

- mode of control – manual, auto, cascade, shut down

This data is read from the site object linking and embedding database (OLEDB) for process control (OPC) server in real time, and various analyses are carried out and the results written to a structured query language (SQL) server, from where reporting is done.

Analysis criteria and site visibility

The overall performance of the plant will be evaluated based on the time the control loops spent out of the control limits, the time spent in the various control modes, and the time that the controller output was outside of the optimal control range.

The analysis engine identifies the amount of time a loop was over the upper and below the lower limits, given the changing set-point. The result is stored granularly at the execution rate of the analysis, typically 1 minute intervals, and then reported on at lower frequencies. The performance and effectiveness of a control loop can be assessed by the percentage of time that the process variable (PV) spends outside the specified upper (UL) and lower control limit (LL) while the loop is operating in automatic or cascade mode. This gives an indication of the control loop's ability to keep the process within its acceptable operating region during normal operation.

The second analysis approach points out time spent in an operational mode. Ideally, PID control loops should be robust enough so that the plant can be operated in automatic/cascade mode most of the time. The percentage of time that the control loops spend in automatic/cascade mode thus serves as an indication of the efficiency and robustness of the control loops.

This analysis compares the percentage of time that is spent in automatic mode, cascade mode, manual mode, and shutdown mode respectively. The percentage of time spent in shutdown mode can serve as an indication of whether the plant was experiencing problems, whether it be due to maintenance, feed resources, utilities, etc.

The third criterion analysed is the region of frequent operation, i.e. whether the control element's MV is in the lower or upper range of control. The average controller output gives an indication of whether the final control element, such as a valve, is designed according to specification. It is considered healthy if the control element output is on average between 30 per cent and 70 per cent. Average operation below 30 per cent may indicate that the control element is over-designed, while average operation above 70 per cent may signify control element size restrictions.

These results are aggregated per month for this evaluation, which is the same time period reported on for monthly site figures.

Asset monitoring

Method and on-site implementation

Measurements from the assets allow monitoring of performance. The principle of basic threshold rules is normally the first level of monitoring, whereafter more advanced techniques are required. A statistical technique, similarity-based modelling, allows monitoring of the separate measured variables compared to the expected operating range. This range is based on the location of the other measured variables, thus creating a dynamic envelope of operation.

The measured variables of an asset are analysed to establish if enough measurements are available to create a model of operation. The data for these variables is then used to create a statistical representation of the dynamics per variable, given the operating points of the other variables. This model is then deployed in real time with an OPC connection, analysing the real-time data. Resulting alarms are triggered and displayed on a dashboard, with an associated level of severity. The aim is to pick up long-term trends and degradation in equipment prior to failure.

Analysis criteria and site visibility

The deviation from the expected envelope of operation triggers an alarm. These alarms are displayed on a time series view, together with the measured variable and provides a view on degradation. Analysis of these alarms over time provides a determinate view on the performance of the equipment. The alarms are not displayed at the operator level, but rather at the supervisory or advanced maintenance level. Ideally, a determined function should monitor this behaviour daily and report on it weekly, thus filtering the results as well as maintaining the models.

Advanced process control (APC)

Control philosophy

The main aim of the APCI on the surge tanks is to stabilize the flow out of the surge tank, while allowing fluctuation in the level of the surge tank. The surge tanks are situated upstream of the flotation banks, and a more stable flow out of the tank will result in more stable operation of the flotation cells, and ultimately higher recovery. The secondary aim is to prevent the surge tank from running empty or overflowing, which can result in product loss, process downtime, and equipment damage. Variable-speed drive pumps are used and manipulated to maintain a certain flow out of the surge tanks. A main and backup pump is in place after each surge tank, and both pumps can be controlled by means of APC.

The APC is implemented at three surge tanks on the circuit: before the primary rougher cells, before the secondary rougher cells, and before the primary rougher tails cells. The APC is integrated with the plant's base layer PID control in such a way that if APC experiences downtime, or communication is lost, the base layer control takes over automatically. Logic is also implemented that ensures bump-less transfer when switching between base layer PID control and APC.

Site implementation and visibility

The control is implemented in the Windows environment and communicates with the plant programmable logic controller (PLC) via OPC. The operator can switch the control on or off via the Supervisory Control and Data Acquisition (SCADA) system, and informative indicators are displayed to the operator via the SCADA interface screens, informing the operator of the communication and calculation health of the APC. No other visibility is supplied directly to the

operator. Automatic daily performance reports are communicated to the applicable plant personnel via e-mail, and reinforced by control experts auditing the performance monthly.

Monitoring visibility implementation

The key to this plant optimization approach is to provide visualization to a monitoring function that can follow medium-term trends – improvement and monitoring is not a primary plant function. This requirement is essential, as monitoring for improvement should be focused primarily on drift and long-term performance advances. Furthermore, the single access point approach to plant performance, using the analyses and systems mentioned earlier, is not effective and executable on site unless a view can be accessed from a single platform.

In this case a web interface is used, logging the most important data to be viewed. This includes major loop monitoring tags per loop, APC variables and calculated variables, asset monitoring alarms, as well as normal plant process variables in a single interface. Navigation of this interface is enabled via a plant breakdown delving down into the plant, operation, processing unit, and equipment, with tags logically organized in this structure, as seen in Figure 2.

Figure 2

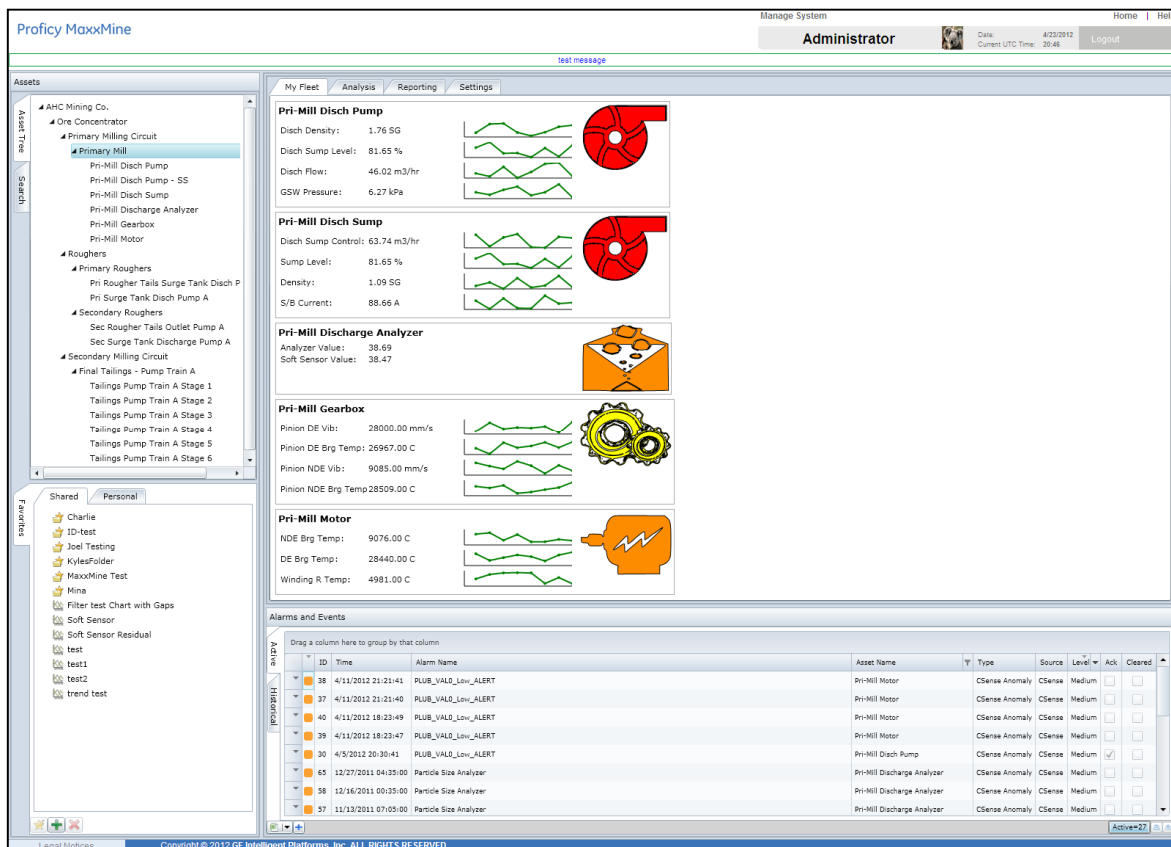


Figure 2-Plant layout with pumps, mill motor and gearbox defined. Main KPIs are portrayed in main view, with detailed trends available

The data is obtained from OPC, or calculated based on available data, and located in a plant historian. The calculated variables are based on statistics required per solution, such as controller-on time for a controller and percentage limits exceeded for the control loop monitoring. Alarms are generated and written to an alarms database. These variables and alarms are viewed on the web interface for report-back on plant performance. Figure 3 shows the data architecture required and various calculation and alarming steps for the implemented solution.

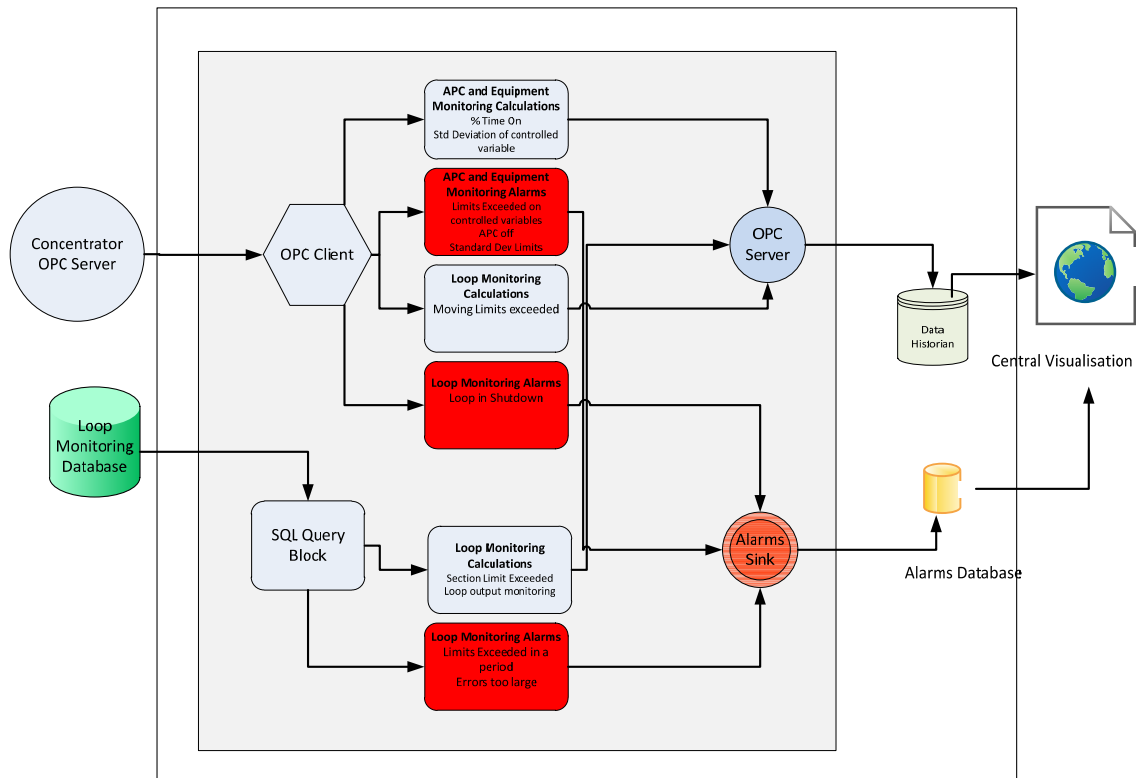


Figure 3-Data flow from OPC via the performance monitoring solutions, to the final performance visualization

This single access point shows results after analyses and control moves, allowing both the process as well as the solution be evaluated. In the case of loop monitoring, this results in loop tuning and thus process stability improvement. For asset monitoring this drives a better understanding and views on asset performance, as well as early failure detection, thus less underperformance and unplanned downtime. The APC monitoring allows alternative advances in control to be investigated, as well as tuning of the control. Overall, an increased involvement in the process and plant performance is cultivated.

Results

Control loop performance monitoring

A decrease in the percentage limits exceeded is noted over the period February to April 2012 as seen in Figure 4. **Error! Reference source not found.** From January to February there is a change in the loops being monitored, causing the change in percentage limits exceeded. During the period February to April, the limit values as well as some *ad hoc* loop tuning resulted in limits being exceeded. As of April, the plant loops have been refined and these limits are used as a benchmark for future comparison.



Figure 4-The limits exceeded across all loops on the concentrator show an increase in performance as the limits exceeded decrease

The analysis of loop performance identified the following:

- The average percentage limits exceeded for all control loops on the plant is less than 10 per cent, which is good performance
- Some sections have a high percentage of control loops exhibiting an average controller output of below 30 per cent or above 70 per cent. This might suggest that some control element resizing is needed, but this needs to be verified and monitored in following audit reports.

Asset monitoring

The two case studies presented here are for the mill motor and the sump pump.

For the mill motor it was found, during an analysis after breakdown, that the phase temperature stepped high positive residuals, with increasing frequency on shutdown. The motor bearing vibration showed positive residuals, increasing until shutdown.

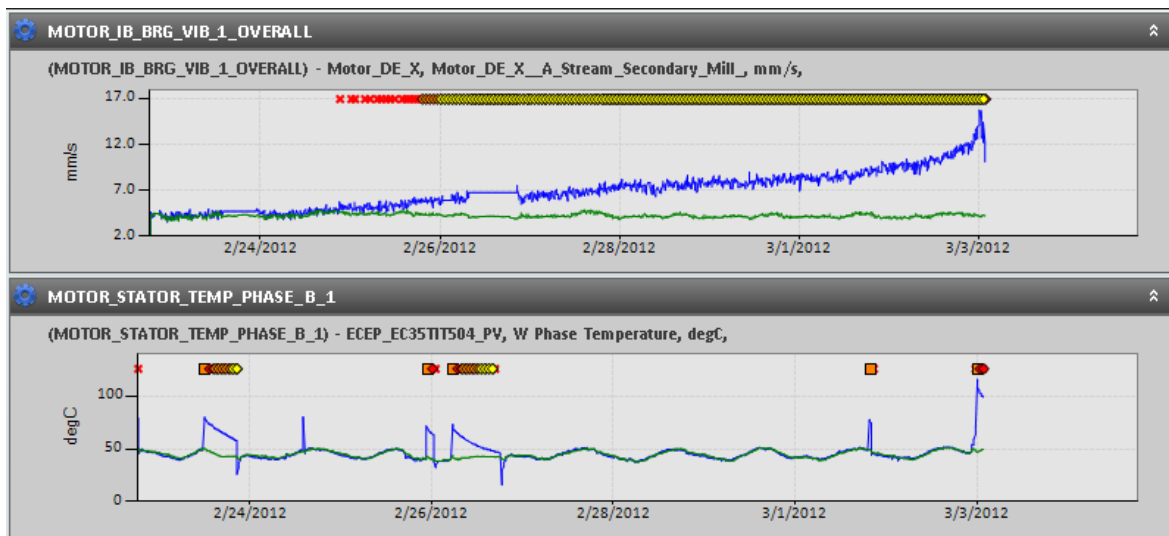


Figure 5-High steps in stator phase temperature identified. This is linked to the increase in vibration on the motor

The diagnosis is a possible bowed rotor causing a short during shutdown. The simulation of alarms and events of the online statistical analysis show the first meaningful alarm 2½ months prior to the breakdown; breakdown being 3 of March, on the far right of

Figure 5.

The second case study, for the sump pump, is also a historical analysis, showing the first sequence of meaningful alarms 4 months prior to failure. Based on the pump hydraulic efficiency and pump total power input (

Figure 6), it was diagnosed that internal erosion of the pump was leading to loss in hydraulic efficiency. A pump overhaul or impeller change was prescribed, with the recommendation to include pump changes before the motor shows increased signs of stress.

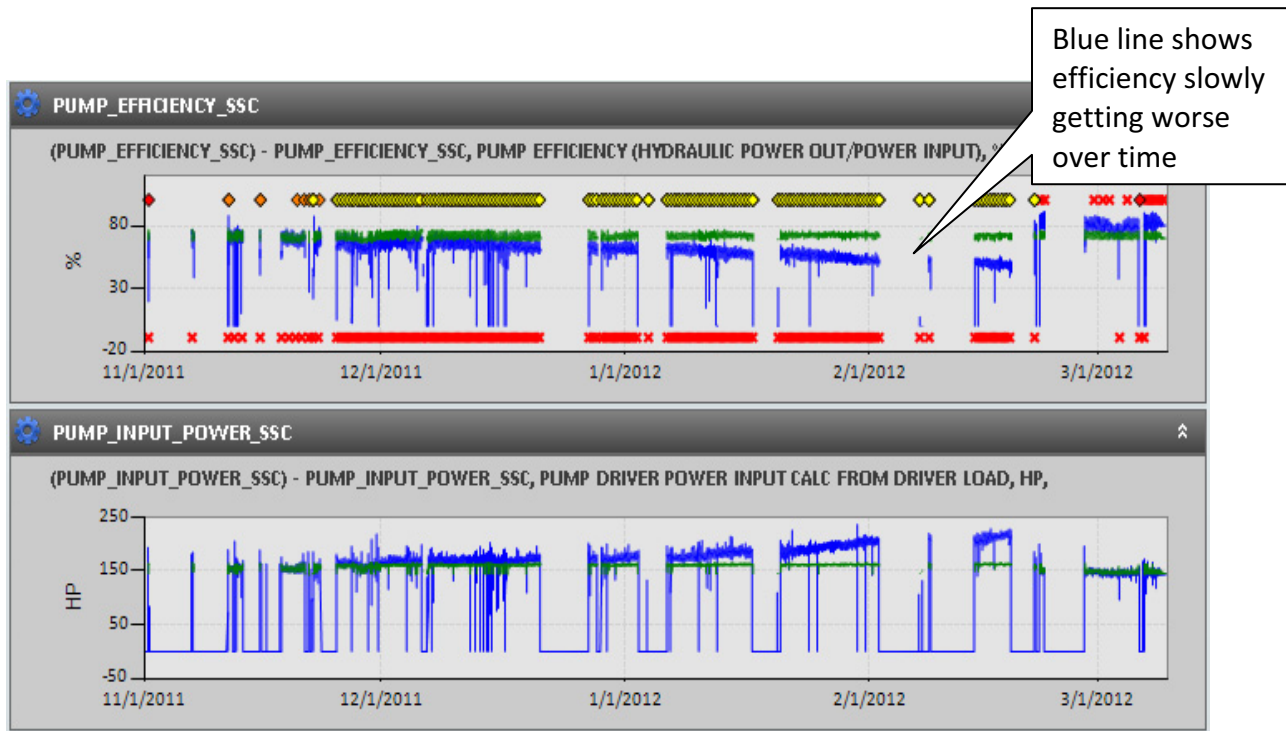


Figure 6-A decrease in pump efficiency, together with an increase in input power to the pump, shows clear signs of ageing

Flow control (APC)

The APC results are clear from the before and after analyses of the controllers shown in Figure 7 for the primary surge tank, Figure 8 for the secondary surge tank, and Figure 9 for the primary rougher tailings tank. In all three cases the level and flow standard deviations are lower in the last 2 months (red), than prior to the implementation of APC. The average flow rate is the same for the primary surge pump, and higher for the secondary surge pump and primary rougher pumps. The success of the controllers is illustrated by the amount of time the operators kept the controller on, which is 98 per cent and 99 per cent for the surge tanks and 99 per cent for the primary rougher tails tank.

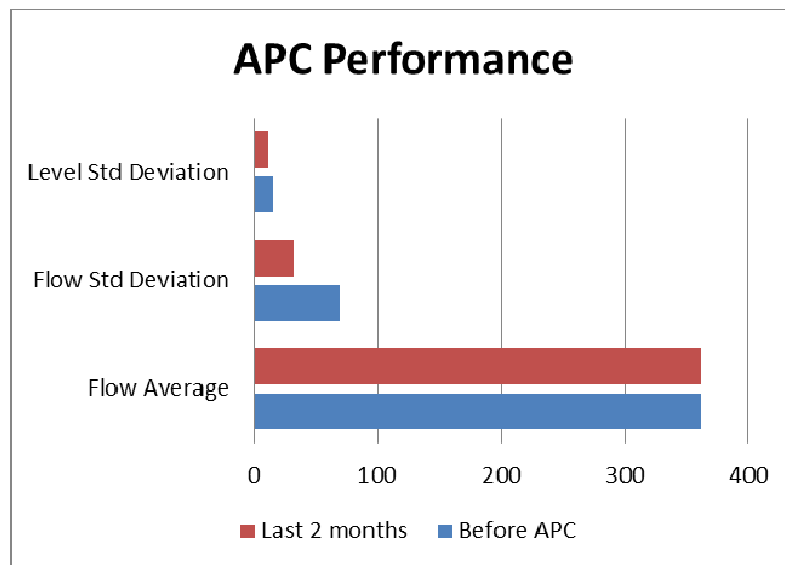


Figure 7-Primary surge tank APC performance indicates less variation in both tank level and flow

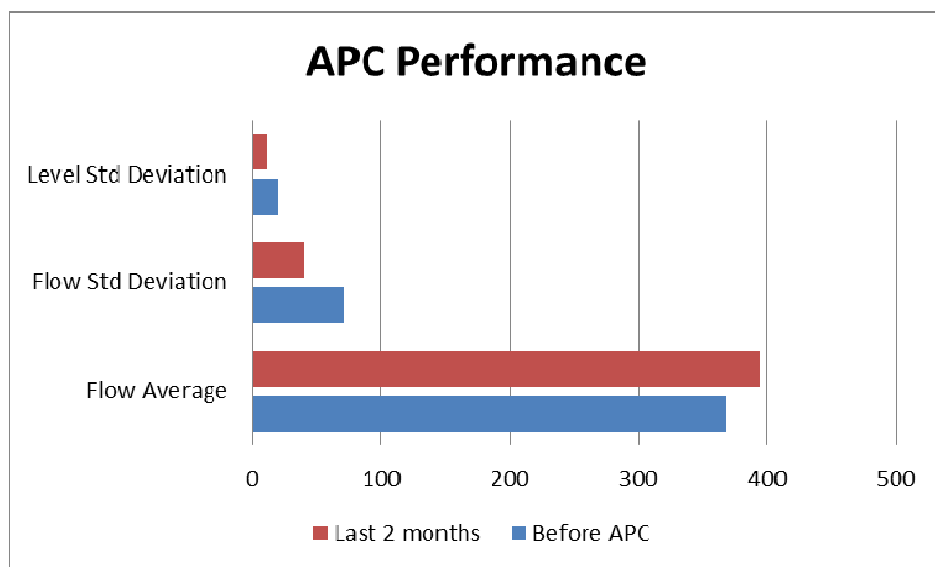


Figure 8-Secondary surge tank APC performance indicates less variation in both tank level and flow

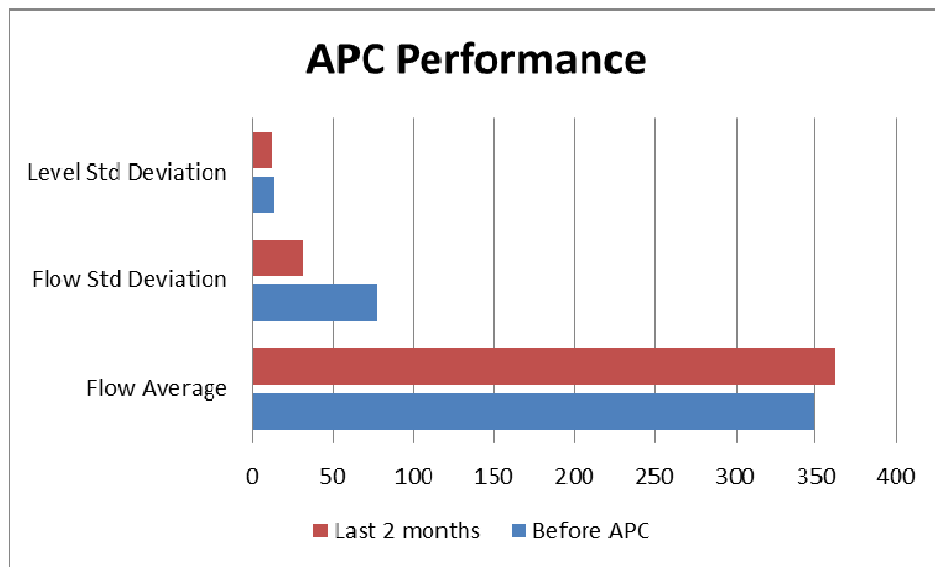


Figure 9-Primary rougher tailings APC indicates a decrease in flow variation

Conclusion

An overall plant performance monitoring and improvement solution was required for a platinum ore concentrator plant. This was delivered in four modules; namely process control loop monitoring, asset monitoring, advanced process control, and a single combined view and monitoring approach.

The single combined view was enabled on the plant site by an underlying data architecture consisting of real-time plant data, alarm- and calculation engines, and a data historian and alarms database. This combined view supplied a single point of entry for alarm investigation and data viewing on a single platform.

The advanced process control implemented on the two tanks decreased variation in flow and stabilized the tank level. The loop performance monitoring supplies a point of entry and persistent monitoring for continuous improvement of control loops and process monitoring. The results obtained in April 2012 will be used as benchmark for future loop performance.

Two case studies on asset monitoring indicated that the first meaningful alarms were identified 2½ months before failure for the mill motor, and 4 months prior to identifying the impeller wear on the surge pump. These analyses, combined with a dedicated monitoring function, showed value in that the possible causes could be narrowed down for physical investigation and decision-making.

The integrated approach focusing on optimization on the control and process layer through advanced process control, alarming based on control loop- and equipment monitoring solutions, and an integrated view for monitoring and analysis resulted in a platform for monitoring and optimization. The current results supply a base the plant can build on going forward.

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Started in Supply Chain consulting, then moved over to metal accounting and production reporting in the platinum industry. Proceeded with consulting on MES strategy and site maturity, but found that data can be used more effectively than only for reporting.

Commenced studies in data driven modelling and statistics, after which he joined General Electric Intelligent Platforms as Project Engineer, delivering data analyses on processes which proceed to control system or business process adjustments, mainly in the Platinum and Steel industries. Currently mainly involved with process monitoring, advanced process control and equipment monitoring systems in the platinum industry clients.