

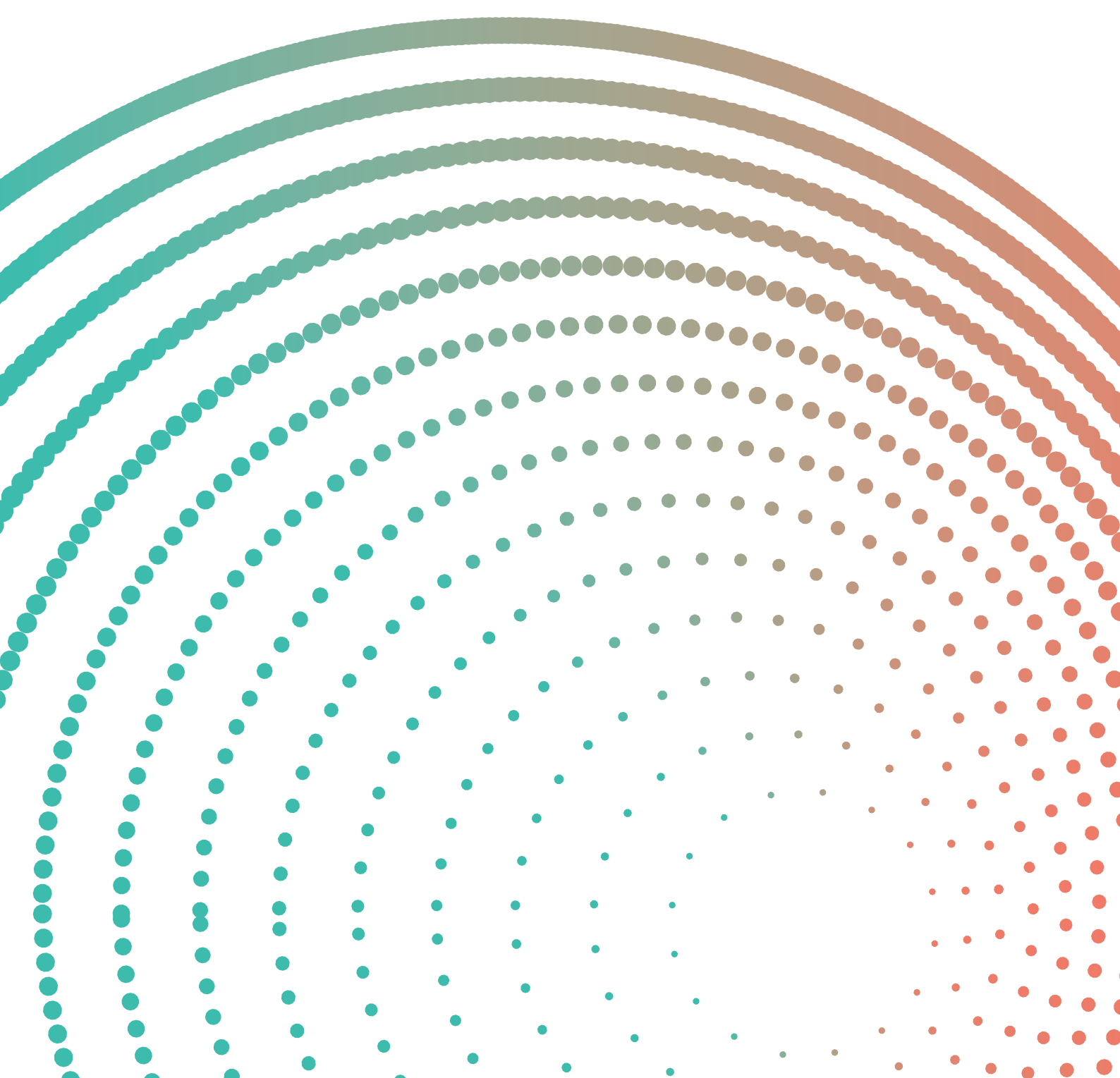
MillStar

Milling Control & Optimisation



Advanced Control

Process Optimisation



MillStar Overview

Due to the complex nature of milling circuits, it is often found that conventional control does not address many of the common problems experienced.

These include:

- long process response times
- multivariable interactions and disturbances
- non-linear systems with varying dynamics
- constraints on variables
- lack of reliable process measurements.

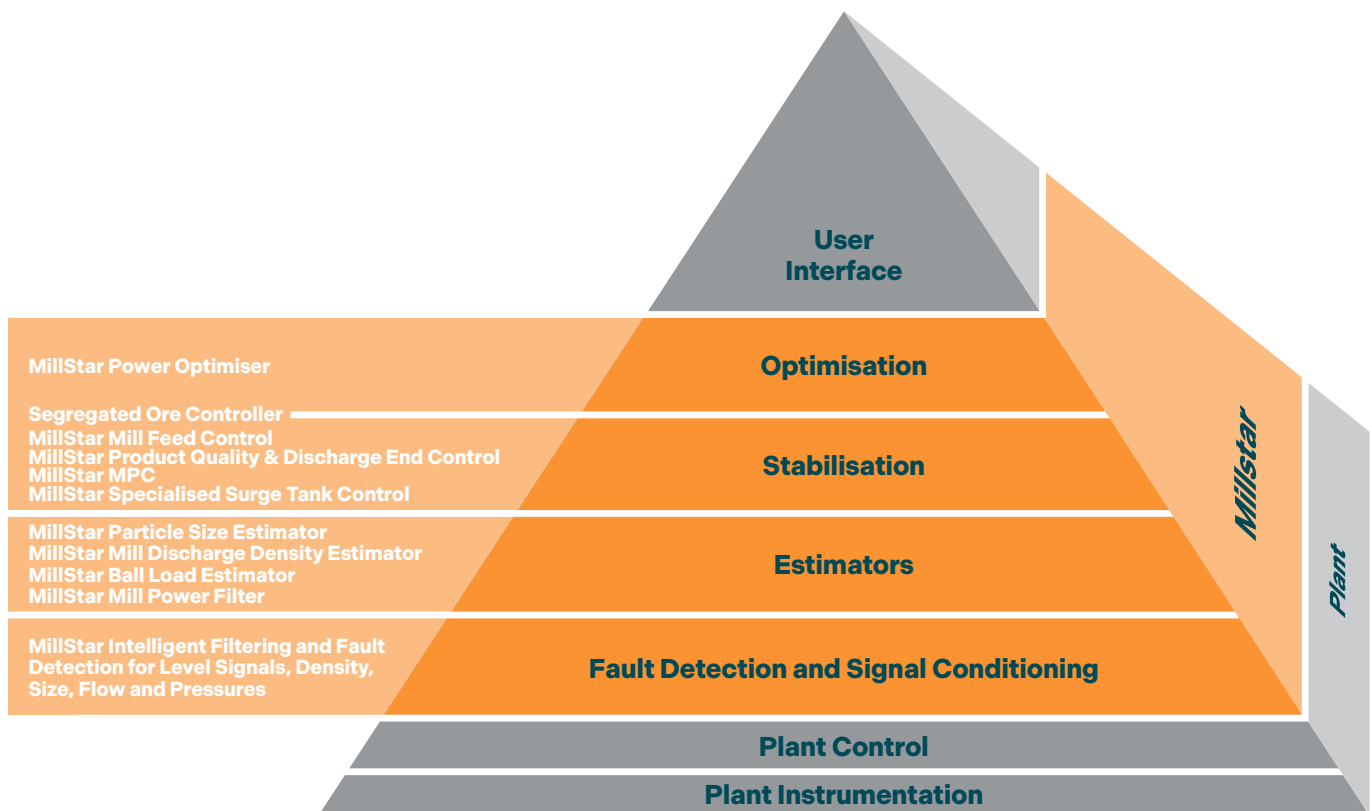
The MillStar Advanced Control System, a Mintek product distributed by Molycop, has a comprehensive suite of control strategies that can be applied to provide an innovative control solution for almost any milling circuit configuration.

The main goals are:

- stabilise the mill feed
- control product quality to the downstream processes
- optimise throughput and grinding efficiency
- provide a robust control solution.

Benefits

- Maximises throughput.
- More consistent feed to downstream processes, thereby increasing recovery.
- Optimal usage of mills.
- Individual customisation.
- Improved control of mill feed rate.
- Better management of fine and coarse material, thereby preventing mill overloads.
- Prevents violation of constraints, making daily operation easier.
- Robust control solutions for effectively handling instrumentation failures.
- MillStar boasts a typical payback period of just a few months.



Research

Mintek enjoys a proud history of research in the minerals processing industry and is continually striving to expand its knowledge in the field through:

- partnerships with Industry
- inter-divisional collaboration within Molycop (Minerals Processing, Mineralogy, etc.)
- university interaction.

Materials Handling

Mill Feed Control

Smooth operation of a milling circuit is difficult to achieve due to:

- the varying nature of the feed material (size, ore hardness, etc.)
- the unfavorable dynamics between feeders and the weightometer. These dynamics degrade the performance of PID controllers, making feed optimisation more challenging.

MillStar's Mill Feed Controller will:

- compensate for the feed dynamics by modeling feeder responses
- adapt for any model errors
- adjust the feeder speeds in a desired ratio.

The graph on the right (Figure 2) shows a comparison between PID control and MillStar's Feed Controller for the plant illustrated in Figure 1. It is clear that setpoint tracking is much tighter and faster under MillStar control.

Mintek control solutions from Molycop are extremely flexible and can easily be adapted for other applications. For instance, the mill feed controller has been used to stabilise and optimise the operation of a **Crushing Circuit** by overcoming the following challenges:

- Multiple feeder and weightometer system.
- Variable time delay in process responses.
- Frequent belt trips due to limits on power draw of belt feeders.

The Mill Feed Controller was combined with Mintek's safety controllers to achieve the following: (See Figure 3)

- Effectively stabilise the mass flow through the crushing circuit, which improved screen performance and thus increased throughput and reduced circulation load.
- The safety controllers prevented belt trips by selecting the correct operating conditions.
- Tighter control enabled the plant to be pushed closer to its limits.
- An increase in throughput of 4% was obtained.

	MillStar OFF	MillStar ON	% Improvement
Throughput mass flow average (t/h)	389	403	4%
Throughput mass flow standard deviation (t/h)	94	73	22%
Circulating mass flow average (t/h)	969	916	5%
Circulating mass flow standard deviation (t/h)	141	128	9%

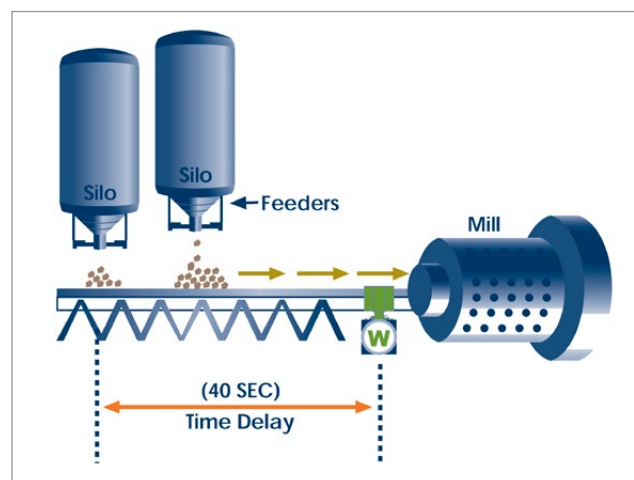


Figure 1: Example of typical Time Delay on Mill Feed.

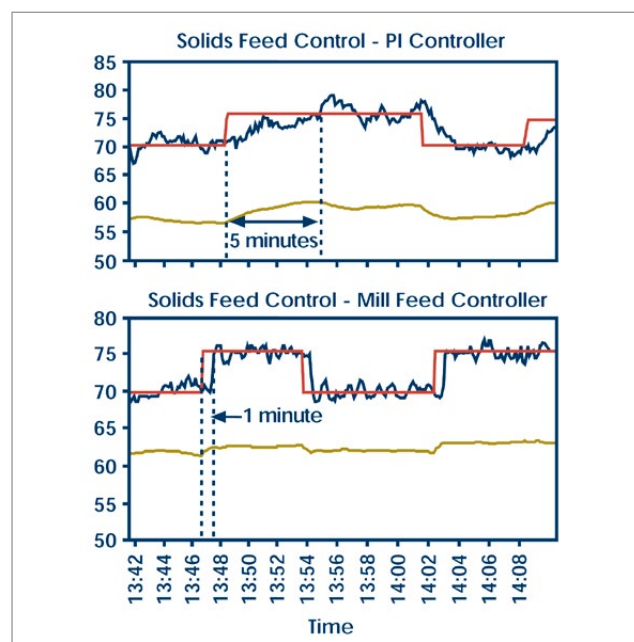


Figure 2: Comparison between PID control and MillStar's Feed Controller.

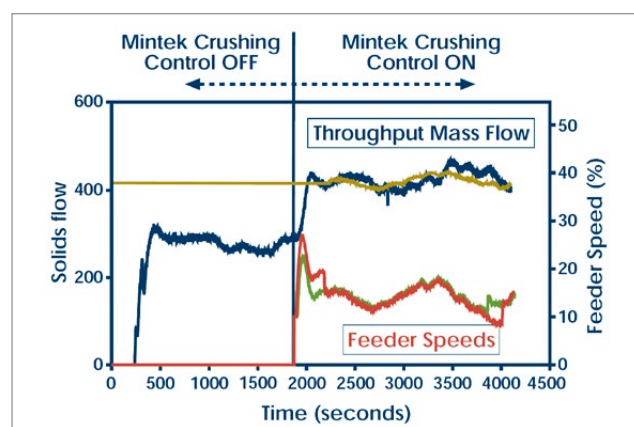


Figure 3: Mintek's Crushing Control.

Segregated Ore Feed Control (Feed Ratio Optimisation)

On milling plants fed by a segregated feed supply, such as a stockpile, the varying size and hardness of the mill feed material affects the residence time in the mill and the power drawn.

When the load becomes critically high, the feed needs to be cut in order to 'grind the mill out'. This dramatic change in mass flow and particle size is passed to the downstream processes, causing recovery to be compromised.

MillStar's Segregated Ore Feed Controller is designed to:

- prevent mill overloads
- adjust the coarse and fine feeder ratios to make optimum use of the ore supply and limit the need to grind the mill out
- interact with operators' rating of the coarseness of each feeder to determine the size distribution of feed material
- use advanced model-based techniques to reduce variation in the feed and thus enable increase in average throughput by operating closer to limits
- integrate with visual or other rock-classification systems.

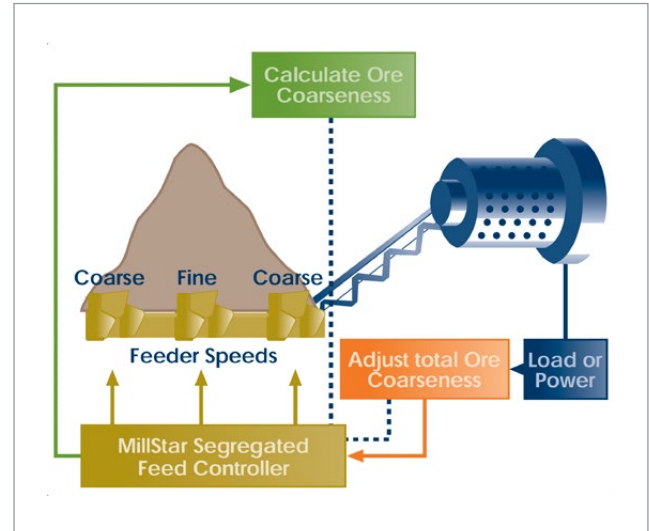


Figure 4: MillStar Segregated Feed Controller.

Throughput Optimisation

Power Optimisation

For the most productive milling operation it is often best to operate close to the maximum mill power draw. The power-load relationship is highly non-linear and shifts around as the ore and steel load/liner changes. Traditional control and modeling techniques can therefore not be used.

Mintek has developed a Power Optimiser that:

- continuously 'seeks' for the optimum mill operation by changing the solids feed or load setpoint
- uses the changes in the mill load and power to automatically detect whether the mill is overloaded or underloaded
- uses safety controllers to change the solids feed rate and feed water to prevent mill overloads
- estimates the power load curve and optimum load.

By optimising the mill power usage and preventing mill overloads, significantly increases in throughput from 6 to 16% have been achieved.

Recirculating Load Optimisation

By optimising the recirculating load it is possible to maximise the possible throughput of the milling circuit. The Recirculating Load Optimiser dynamically adjusts the recirculating load to ensure optimum efficiency of the circuit based on operator-specified constraints. This strategy is particularly beneficial for overflow mills.

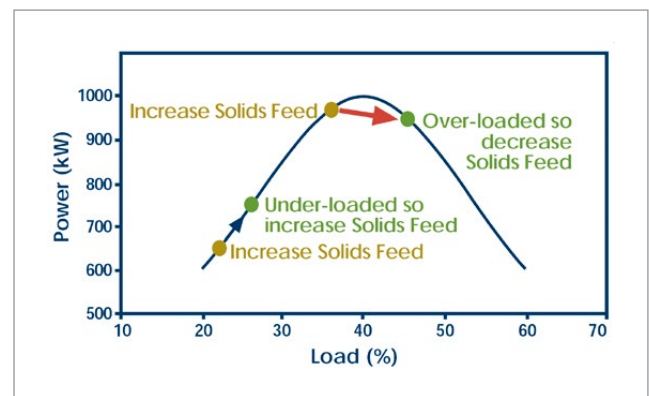


Figure 5: Typical Power/Load curve.

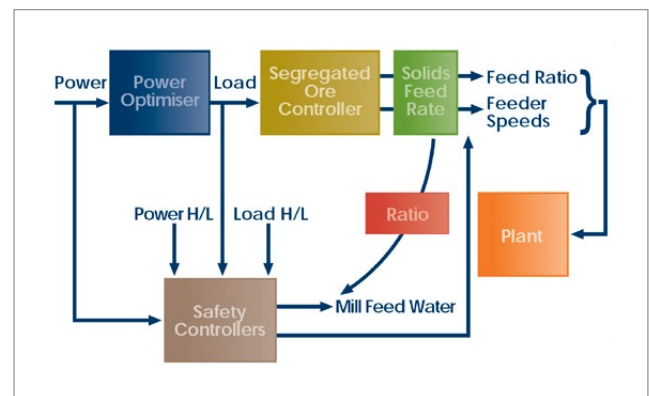


Figure 6: Mill Optimisation Control Strategy.

Mill Discharge Product Control

The MillStar sump/product stabilisation focuses on:

- taking into account multivariable interactions between input and output mill discharge variables
- controlling the sump level and cyclone overflow product size and/or density
- minimising flow variation to the downstream processes
- optimum usage or surge capacity of sumps, hoppers and conditioning tanks
- handling constraints of the sump level (to prevent pump surging and spillage) and cyclone density (to prevent pipeline chokes and pressure variations).

Mintek has developed a Model Predictive Controller (MPC) specifically for controlling milling circuits, with the following advanced features:

- Fully fledged multivariable controller that can efficiently eliminate interaction between variables.
- Explicitly handles limits on input and output variables to ensure all variables are kept within their allowed operating range.
- Very efficient in handling long time delays and slow-reacting processes.
- Special features to handle noise, integrators and model errors.

Case Study 3

Data collected from a platinum plant is shown on the right (Figures 7 to 9). The feed to flotation in terms of volume flow and density (mass flow) is much more stable in MillStar mode.

Stabilising the product quality from the milling circuit leads to improved recovery downstream. In the case of flotation processes, improvements of between 0.5 and 1.5% in recovery have been shown. On gold leaching circuits, MillStar will minimise grind size while still maintaining throughput targets. This leads to considerable reduction in residue grinds.

	Standard Deviation		
	MillStar OFF	MillStar ON	% Improvement
Flotation Feed Flow (m ³ /h)	15.77	2.77	82%
Flotation Feed (SG)	0.0107	0.0048	55%
Mass FLOW (t/h)	0.169	0.013	92%

Cyclone Switching Control

Clusters of cyclones are often used for mill discharge classification. By controlling the number of open cyclones the pressure within the cluster can be controlled. Stabilising the pressure improves the stability of the cyclone overflow particle size and density, which improves the consistency of the feed to the flotation. The module can also balance cyclone usage and, if required, estimate the cyclone's state (open/closed).

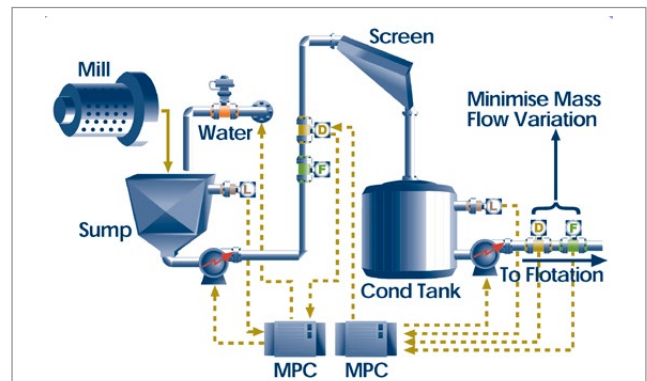


Figure 7: Example of Mill Discharge Circuit showing MPC Controller.

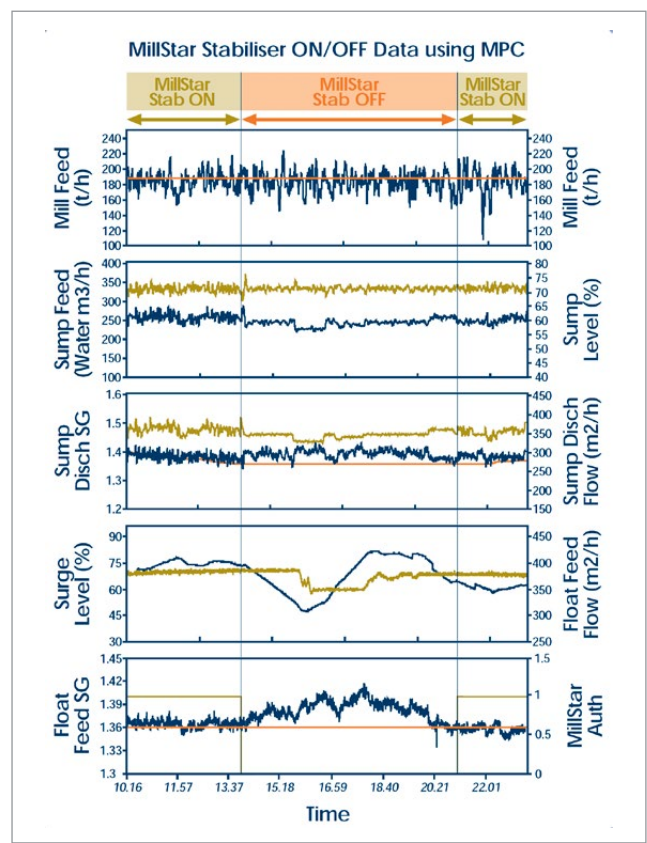


Figure 8: MPC results for Case Study 3.

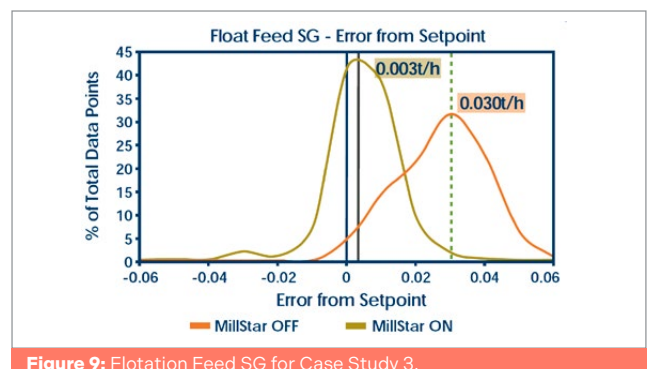


Figure 9: Flotation Feed SG for Case Study 3.

Mill Discharge Density Estimator (MDDE)

The MDDE estimates the mill discharge density and flow using dynamic volume and mass balances. An energy balance can optionally be performed to enhance the accuracy of the estimate. Grinding efficiency is highly dependent on the viscosity of the material within the mill, which correlates closely with the density. The calculated density can therefore be controlled by changing the amount of water added to the mill, to ensure optimum grinding.

Particle Size Estimator (Pse)

The PSE is a soft sensor capable of accurately predicting the particle size of the hydrocyclone overflow product. It has the following features and uses:

- The PSE uses an empirical model, identified from extensive plant testwork.
- It can be used as a back-up sensor for a physical size measurement device.
- It can provide a continuous estimate of the particle size in-between slow updating or multiplexed measurements.
- When a size measurement is available, this information is automatically used by the PSE to continuously adapt the model.
- The PSE can also serve as an intelligent filter that eliminates the delay associated with physical measurements by inferring the particle size from measurements that have much shorter delay times.

Mill Power Filter

An accurate mill power measurement is essential in ensuring reliable control of a milling circuit. It can also give useful information about the load in the mill. The power measurement is, however, cyclical in nature and quite noisy. While conventional filters fail to separate actual process variations and process noise effectively, the Mill Power Filter succeeds by using high-frequency data and a sophisticated filtering algorithm. The result (as shown in Fig. 12) is a smooth power signal suitable for control and immune to noise and cyclical variations.

Fault Detection

MillStar completes and complements its control suite with a range of fault detection and signal conditioning tools that can be used in conjunction with expert rules to timeously detect instrumentation failure and take necessary action to ensure smooth operation.

Steel Ball Addition Module

- Estimates the steel ball load in the mill.
- Reminds operators of steel ball additions at pre-defined intervals.
- Displays steel ball addition history.
- Suggests the amount of steel balls that should be added, based on ore characteristics and changes.
- Can be linked to an automated ball addition system to control ball addition.

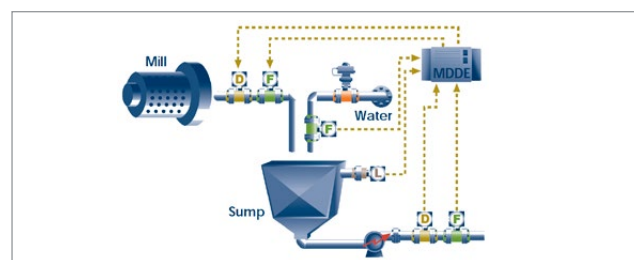


Figure 10: Mill Discharge Density Estimator.

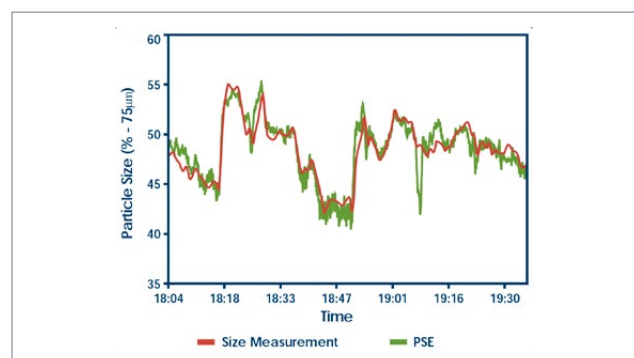


Figure 11: The graph above shows how well the PSE tracks the real particle size measurement. Note how it can be used to eliminate spikes and noise in the measurement.

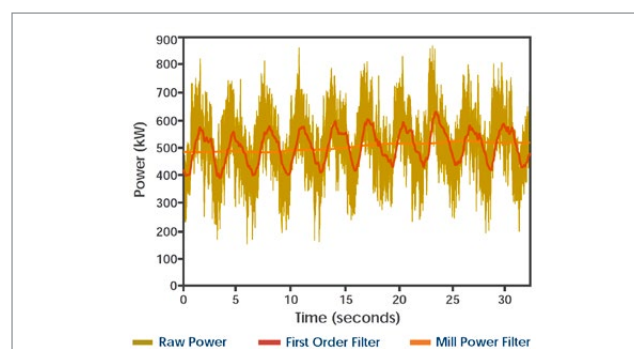


Figure 12: MillStar Power Filter result.



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