MILLSTAR

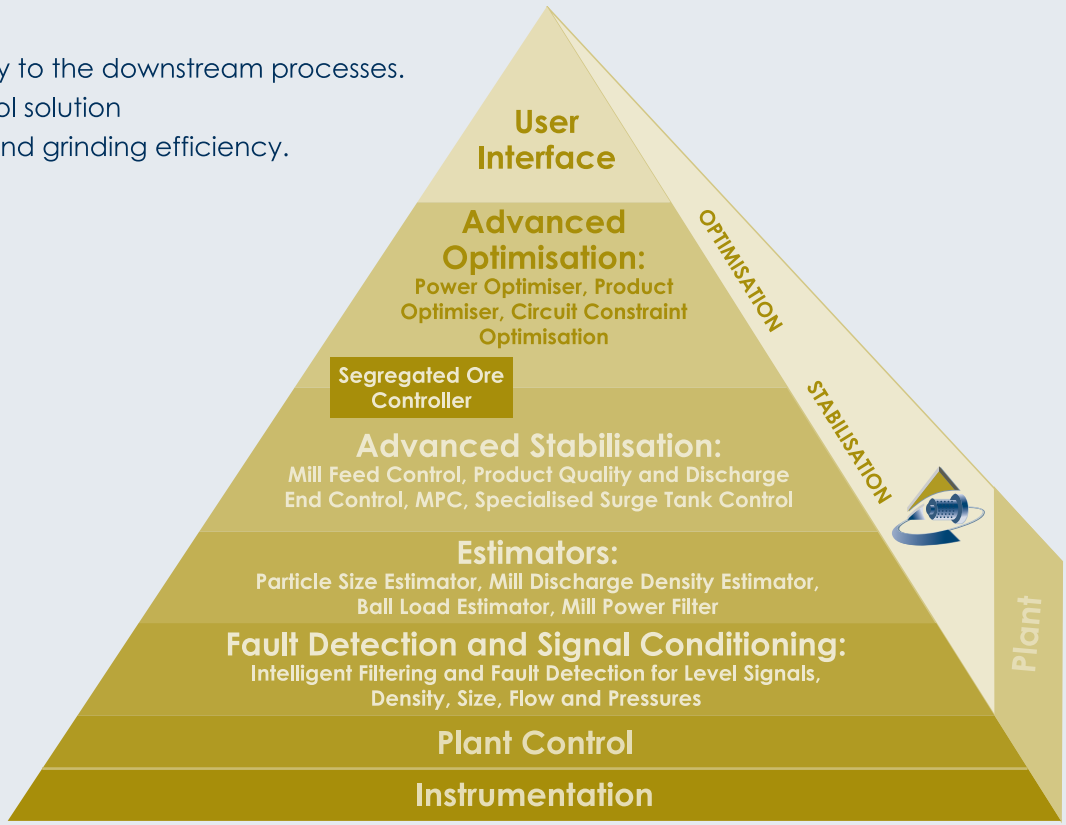
Milling Control

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

- 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 has a comprehensive suite of control strategies that can be rigorously applied to provide an innovative control solution for various milling circuit configurations. The main focus is to:

- Stabilise the mill feed.
- Control product quality to the downstream processes.
- Provide a robust control solution
- Optimise throughput and grinding efficiency.



Materials Handling

Mill Feed Controller (Feed Stabilisation)

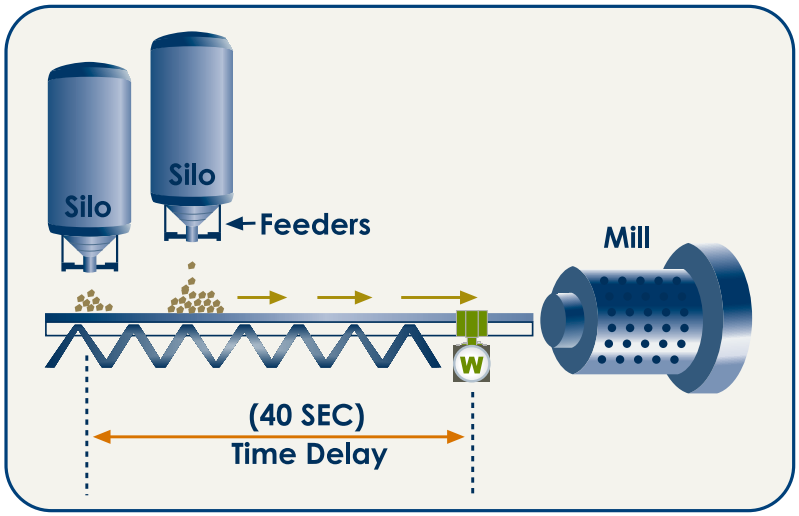
It is difficult to operate the milling circuit smoothly due to:

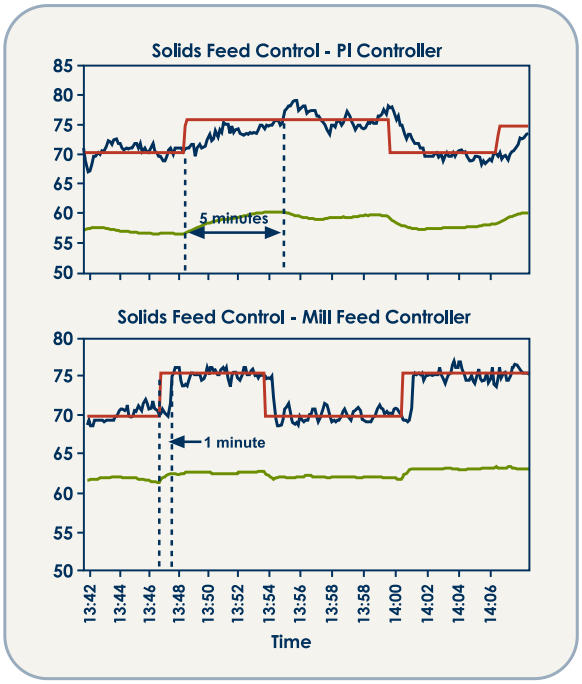
- The **varying nature of the feed** material (size, ore hardness, etc.)
- The **unfavorable dynamics** between feeders and the weightometer. These dynamics degrade the performance of PID controllers, making feed optimisation more challenging.

MillStar's Mill Feed Controller will:

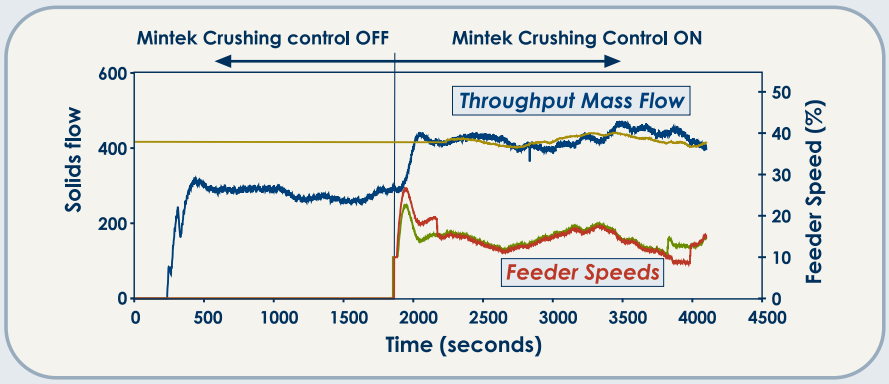
- Compensate for the feed dynamics by **modeling feeder responses.**
- Adapt for any **model errors.**
- Adjust the feeder speeds in a **desired ratio.**

The graphs on the right show a comparison between PID control and MillStar's Mill Feed Controller for the plant in the figure. It is clear that setpoint tracking is much tighter and faster under MillStar control.





Mintek's control solutions are extremely adaptable and can easily be applied to other applications. For instance, the mill feed controller has been applied to a **Crushing Circuit** to stabilise and optimise the operation of the 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:

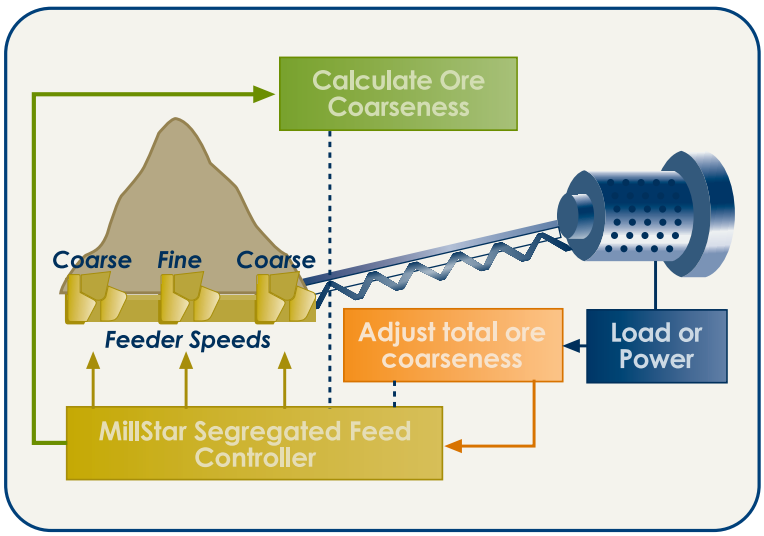
- Effectively stabilise the mass flow through the crushing circuit, which improved screen performance and thus increased throughput and reduced recirculating load.
- The safety controllers prevented belt trips by selecting the correct operating conditions.
- Tighter control enabled the plant to be pushed 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%

Segregated Ore Feed Controller (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. If the load or power drawn 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.



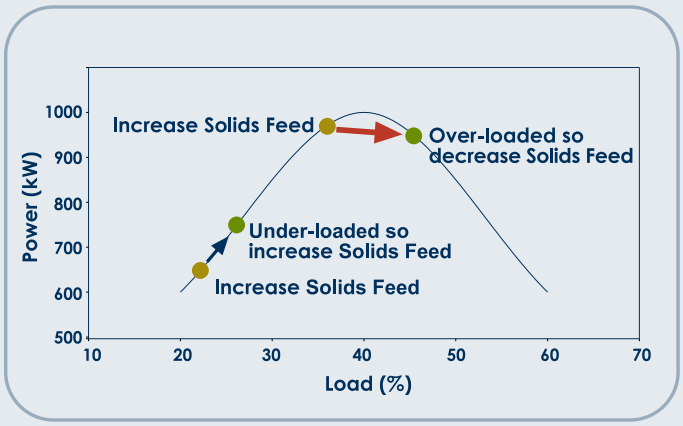
MillStar's Segregated Ore Feed Controller is designed to:

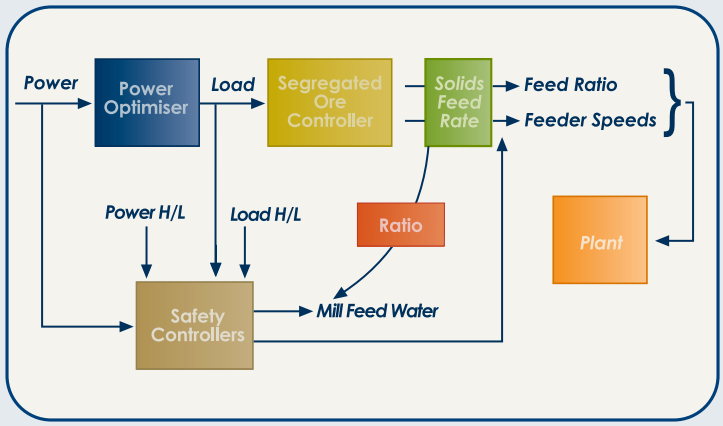
- **Adjust the coarse and fine feeder ratios** to make optimum use of the ore supply and limit the need to grind the mill out.
- Interact with operator's rating of the coarseness of each feeder to determine the **size distribution** of feed material.
- Prevent mill **overloads.**
- Use advanced model-based techniques to reduce variation in the feed and therefore enable increase in average throughput by operating closer to limits.

Power Optimiser

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 modelling 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.

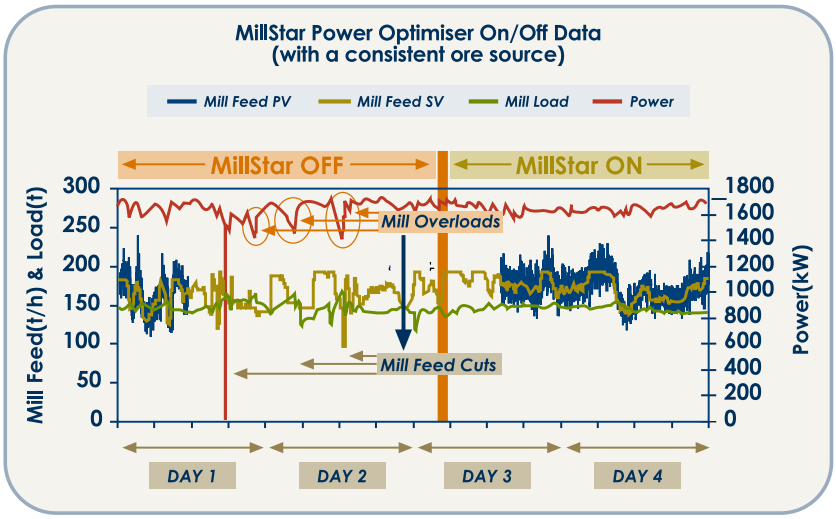




With optimising the mill power and preventing mill overloads significant increases in throughput of between 6 and 16 % have been achieved.

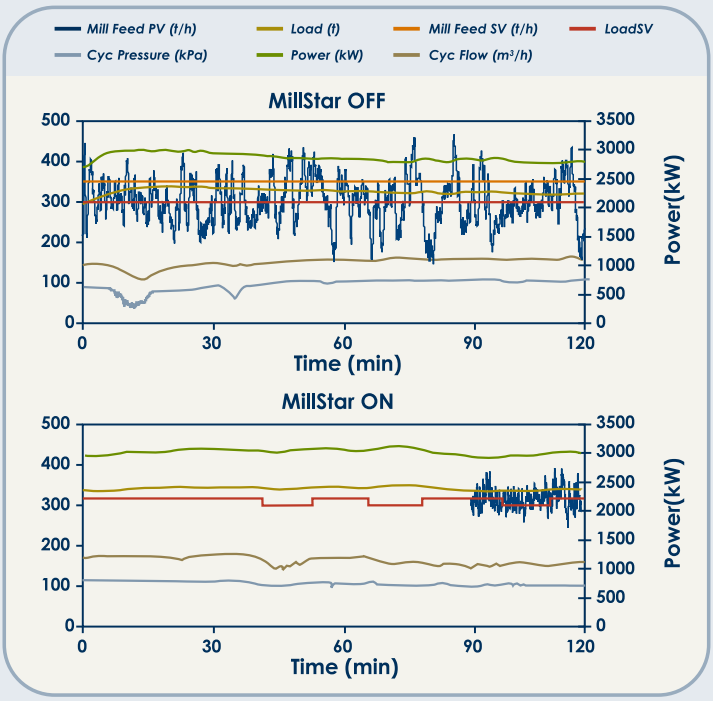
Case Study 1:

The figure right shows data collected from a platinum plant, where the ore treated was very difficult to mill. In the first 2 days, the mill experienced numerous power dips (overloads) and on at least 7 occasions the feed to the mill had to be completely stopped to "grind" the mill out. Also, the mill load varied in the range of 125 to 165 tons. These disturbances propagated throughout the milling circuit and even to the flotation circuit. The MillStar Power Optimiser offers the following benefits:



- Mill feed cuts were prevented, resulting in a stable mill loading.
- No huge power dips since any sign of the mill overloading was detected and rectified timeously.
- The standard deviation of the mill load, flotation feed flow and density was considerably less in MillStar mode, as can be seen in the table.
- A significant increase in tons milled of 15.5 t/h on average (about 10 % increase in (throughput).

		MillStar OFF	MillStar ON	% Improvement
Mill Throughput	Average t/h milled	160.42	175.95	10
	Std Dev	32.06	17.25	46
	Minimum	0	142	
	Maximum	185	185	
Mill Load	Std Dev	7.21	3.91	46
Mass Flow to Flotation (t/h)	Std Dev	0.627	0.363	42



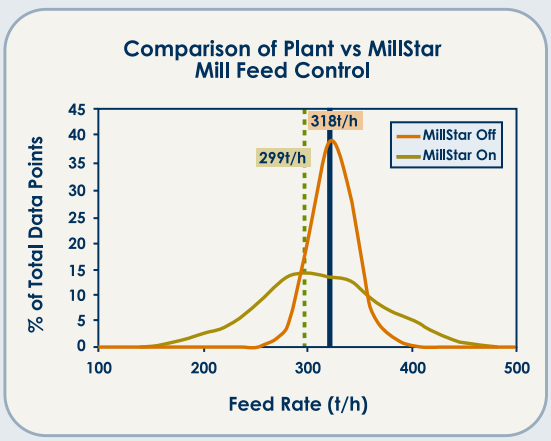
Case Study 2:

These figures below show results from a Gold Plant SAG Mill achieved with MillStar's Segregated Ore Feed Controller combined with the Power Optimiser:

- The standard deviation of the mill feed control is greatly reduced.
- The cyclone feed is more stable, allowing for consistent size separation and feed to downstream processes.

Due to the tighter control the feed setpoint can now be set closer to its maximum operating limits with confidence.

	Standard Deviation		
	MillStar OFF	MillStar ON	% Improvement
Feed Rate (t/h)	56.57	19.41	65.7
Cyclone Feed Pressure (kPa)	9.72	5.11	47.4
Cyclone Feed Flow (m³/h)	64.16	52.01	18.9
Cyclone Feed Density (SG)	0.09	0.01	84.3



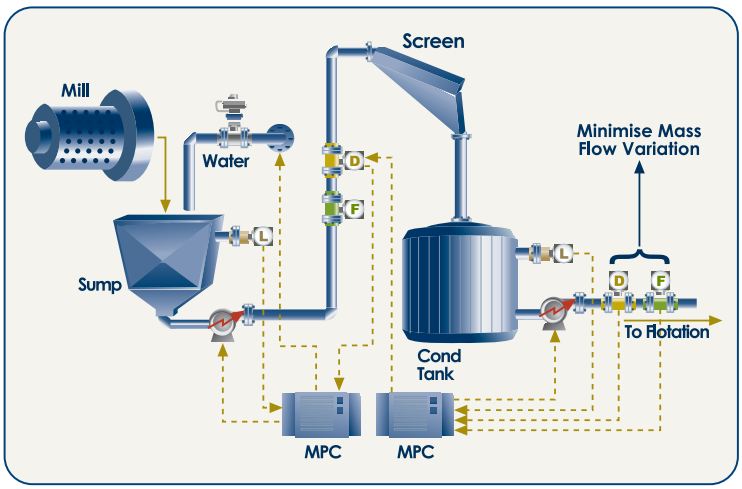
Product Quality and Mill Discharge-end Control

The MillStar Sump/Product Stabilising Controller focuses on:

- Minimising **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 of 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).

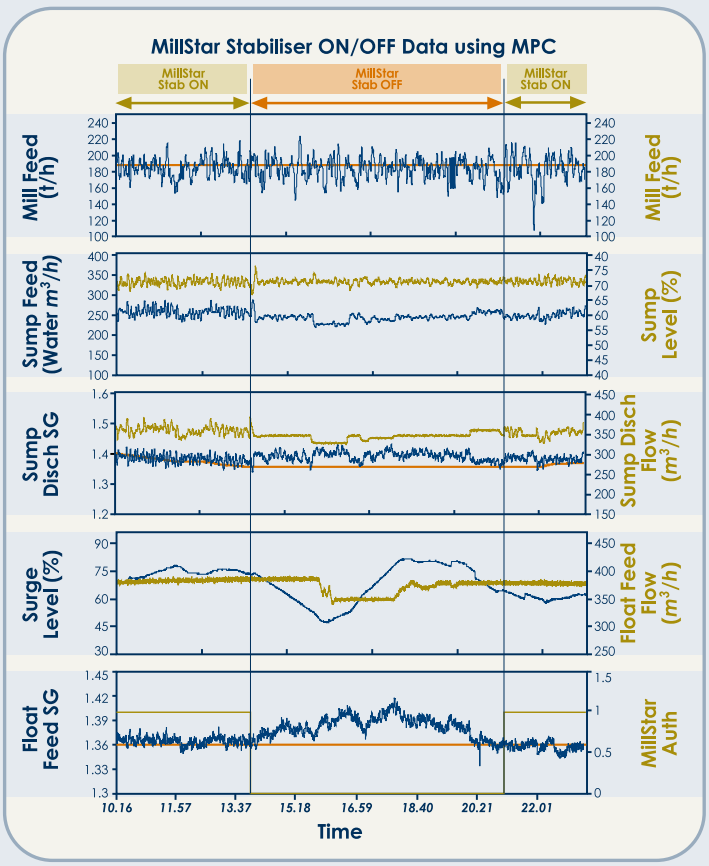
Mintek has developed a Model Predictive Controller (MPC) specifically for controlling milling circuits with the following advanced features:

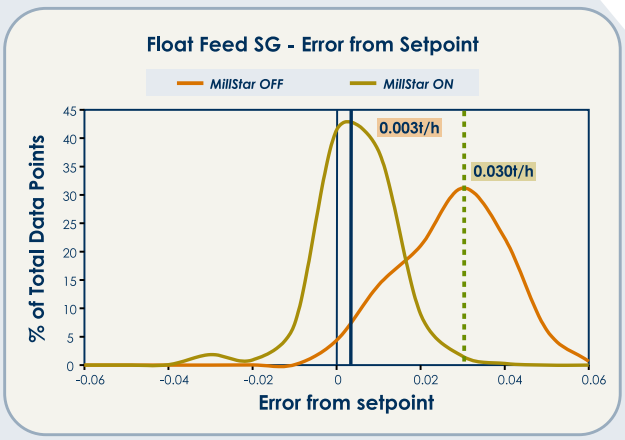
- Fully fledged multivariable controller that can efficiently eliminate interaction between variables.
- Explicitly handles limits on input and output variables to ensure all variables are kept within their allowed operating range.



- Very efficient in handling long time delays and slow-reacting processes.
- Special features to handle noise, integrators and model errors.

Data collected from a platinum plant is shown below. The feed to the flotation in terms of volume flow and density, i.e. mass flow is much more stable in MillStar mode. An added advantage is that this provides a consistent base line for adding reagents to downstream processes.





	Standard Deviation		
	MillStar OFF	MillStar ON	% Improvement
Flotation Feed Flow (m³/h)	15.77	2.77	82
Flotation Feed (SG)	0.0107	0.0048	55
Mass Flow (t/h)	0.169	0.013	92

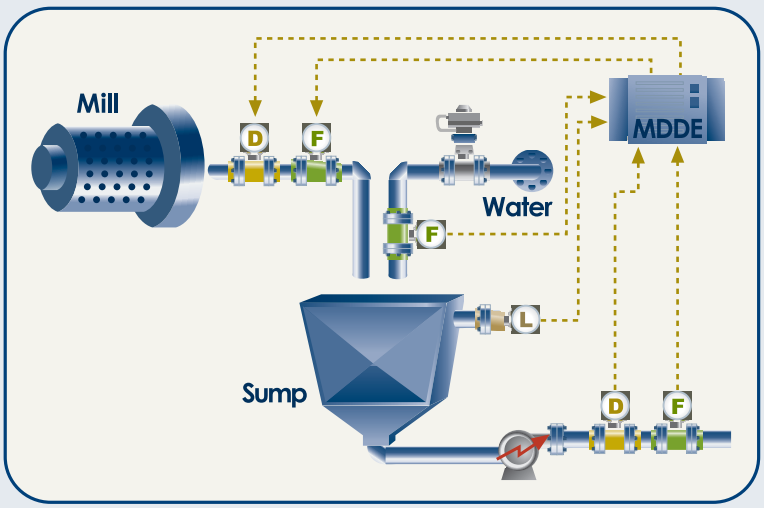
Stabilising the product quality from the milling circuit leads to improved recovery downstream. In the case of flotation processes, improvements of between 0.5 and 1.5 % in recovery have been shown.

On gold leaching circuits, MillStar will minimise grind size, while still maintaining throughput targets. This leads to considerable reduction in residue grinds.

MillStar Estimators

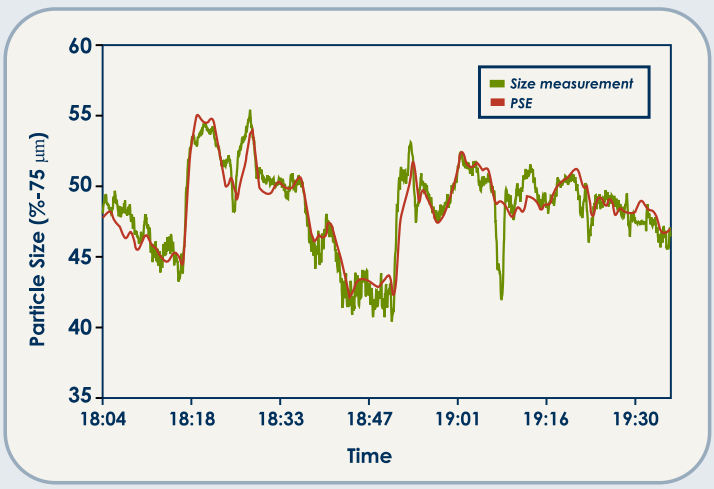
A problem often experienced in milling circuits is the fact that certain variables are difficult or impossible to measure. Due to the harsh conditions, measuring devices are also prone to fail or give false readings. Mintek has therefore developed the following estimators to calculate variables that cannot be measured or to supply backup readings when measurements fail or have long update intervals:

- Mill Discharge Density Estimator (MDDE)
- Particle Size Estimator (PSE)



The **Mill Discharge Density Estimator** 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.

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

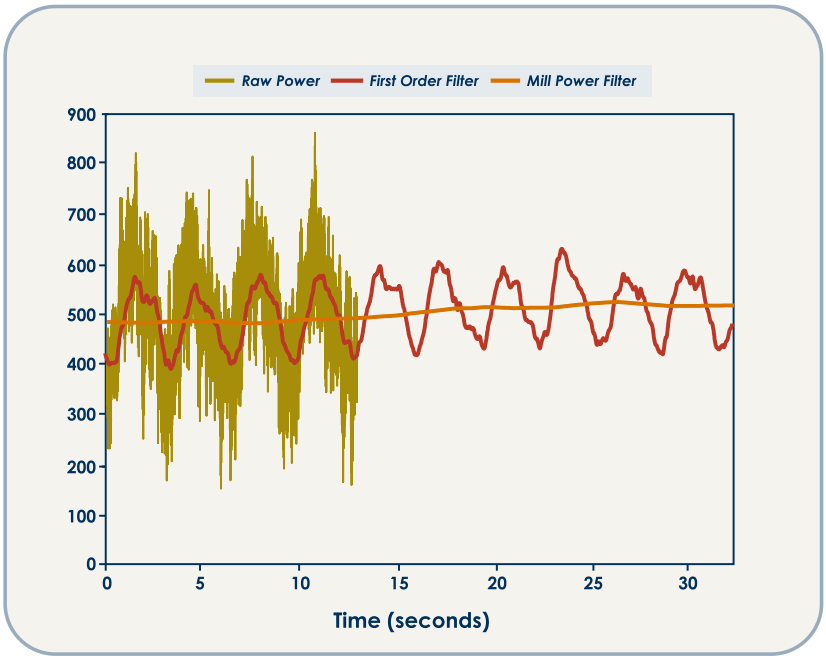


The graph above shows how well the PSE tracks the real particle size measurement. Note how it can be used to eliminate spikes and noise in the measurement.

- Being an entirely non-contact device, it is virtually maintenance free.
- The PSE uses an empirical model, identified from extensive plant test work.
- 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 the graph below) is a smooth power signal suitable for control and immune to noise and cyclical variations.



Fault Detection

MillStar completes and compliments 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

MillStar's Steel Ball Addition Module is a tool for:

- **Estimating** the steel ball load in the mill.
- **Reminding** operators of steel ball additions at pre-defined intervals.
- Displaying steel ball **addition history**.
- Suggesting 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.

Overall MillStar Benefits

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