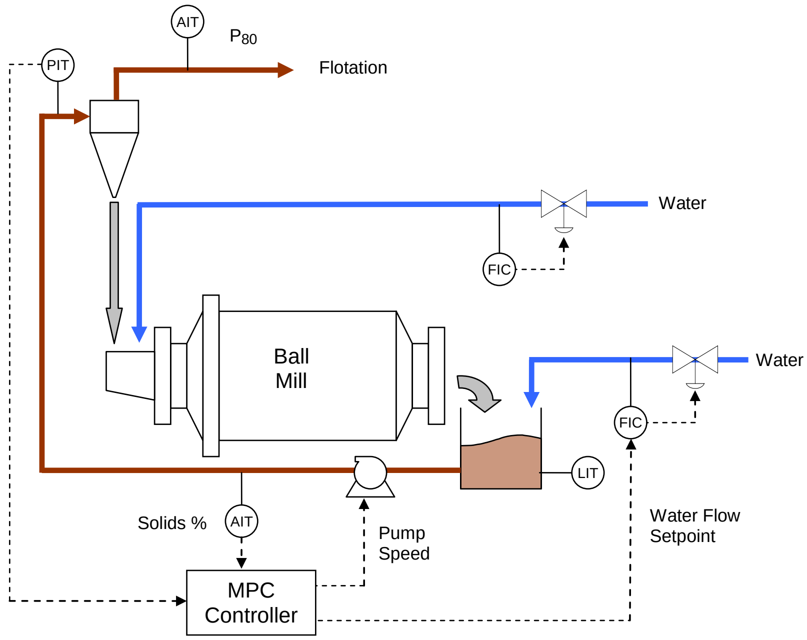

Figure 5: Ball Mill Control strategy Diagram

An MPC controller is used to control the cyclone feed pressure and cyclone feed density by adjusting sump pump speed and dilution water flow. A rule-based expert system is used together with the MPC to control the sump level by adjusting the number of cyclones in service. The expert system also adjusts the cyclone pressure set point over a small, specified range to assist with the sump level control for the purpose of minimizing the number of cyclone openings or closings. This strategy transfers disturbances caused by production rate variations to the sump level instead of disturbing the cyclone pressure. Cyclone pressure variations were 6 to 14 psi with the existing controls and were reduced to 9 to 11 psi with the new controls. The improved cyclone pressure control results in less fouling of the Flotation Cells due to transfer of oversize material from the cyclones and also reduces unnecessary recirculation of fine material to the Ball Mill.

PHASE 3: Pipeline Operator Training at Minera Los Pelambres

Minera Los Pelambres (MLP) is one of the lowest cost producers of copper in the world. They achieve results by adopting the right technology, and have a culture of training their operators to achieve results. The pipeline did have an existing leak detection system, but many false positives desensitized the operators, so when a real leak did occur they did not detect it in a timely manner. ANDRITZ AUTOMATION was contracted to design a training system that would enable pipeline operators to correctly detect when a leak occurred in future. ANDRITZ replicated the MLP control room in the ANDRITZ Santiago office and supervised the training of all operators to be able to detect and correct pipeline abnormal operations. To accurately simulate two tailings 50 km pipelines (28-inch and 36-inch) with five 370 hp pumps and one 8-inch 120 km concentrate pipeline with four displacement pumps, a combination of operations expertise, control understanding, and the ability to correctly model the transient behaviour of high density slurries in real time was required. The details of the modelling techniques were presented at the SME in Salt Lake City in February 2014 (Cristoffanini et al, 2014). Once the modelling of the pipelines was accomplished, the IDEAS virtual pipeline model was used to connect to an offline version of the Emerson control system and the leak detection system. Once the process model was connected to the offline control system, the IDEAS Instructor software was added to introduce process upsets and measure operator responses. Twenty operators were trained on normal, specific scenarios and traceability conditions (Figure 7). Training proceeded with pipeline operators until they were able to correctly identify specific fault conditions, and is repeated yearly to recertify. When a similar leak occurred a year after initial training certification, instead of taking multiple hours to respond, operators were able to detect and correct the error in a few minutes.

Figure 6: Santiago Remote Support and Training Centre

This result was achieved by having an accurate model of the pipeline, connected to the same graphics and logic used in the real plant, and a training system that was able to simulate a leak, and measure whether the operators could tell the difference in pressure response between normal and abnormal operation.

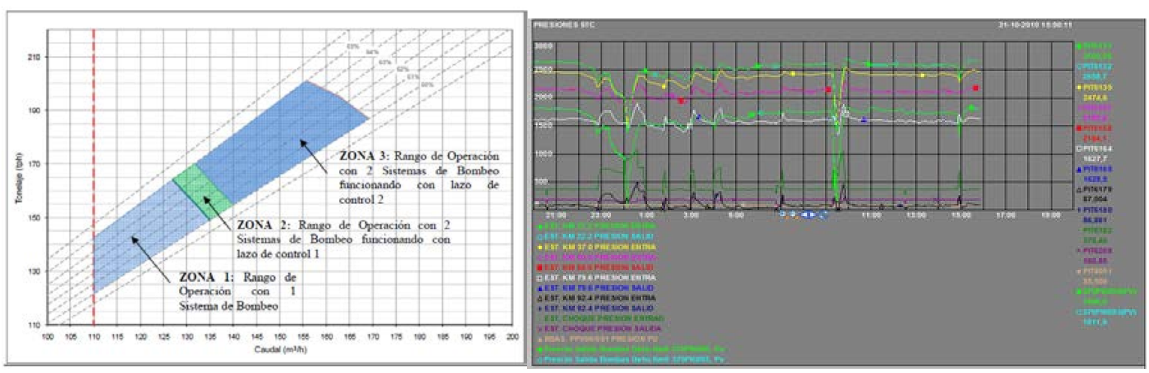

Figure 7: Operating Guidelines and Control System Pressure Trends

The success of this approach has led to several companies adopting the same methodology for complete copper concentrators and encapsulating the entire remote support and training facility inside an air-conditioned container that can be placed at site or anywhere the operating company decides. With the advent of remote access to virtual computers, all support can be done in Santiago, and the field training only requires a high-speed internet connection to achieve the same realism as if the computers were residing in the same location. This approach has saved cost, support time, and is a much more flexible and scalable training option (Figure 8).

Figure 8: Site Remote Support and Training Centre

Future Direction

A large copper concentrator under construction and commissioning in 2014 will utilize the Virtual Plant concept to test whether the circulating load and hardness of ore can be accommodated with the chosen equipment. If additional production is required after start-up, the simulator has pinpointed where to change the control and equipment to achieve it. Advanced process control will also be tested against the virtual plant prior to start-up. This means a more automated way to run the concentrator will be in place at start-up because the system has been tested against the virtual plant and operators are trained in both standard and Advanced Process Control from day one. In addition to Simulator Based Training (SBT), many mining companies are adopting Web Based Training (WBT). WBT includes, sound, graphics, P&IDs and a 3D interactive environment that provides a virtual walk-though that accelerates understanding.

Summary

The virtual plant concept unites the engineering disciplines and enables process and control designs to be tested prior to start-up. Model Predictive Control has been shown to provide additional production and improved operability. Operator training can utilize the virtual plant prior to or after start-up, and the advent of high-speed internet with virtual computers operating remotely has lowered the cost and increased the effectiveness of training. The combined result is a plant built with operations in mind, a workforce continuously trained, and an operation that is more optimal from the start of production and into the future.

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