PROCESS SIMULATION FOR IMPROVED PLANT DESIGN THROUGH P&ID VALIDATION

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Abstract - Advanced dynamic process simulation can help mining companies and engineering contractors improve plant design through P&ID Validation. This paper will discuss the P&ID Validation performed by ANDRITZ AUTOMATION for Newmont Mining Corporation's Conga copper and gold project in Peru. ANDRITZ AUTOMATION built a dynamic process model, or Virtual Process Plant, in the IDEAS Simulation Software for Conga. Then in conjunction with Newmont and the engineering contractor, ANDRITZ AUTOMATION performed P&ID Validation to identify process design problems/concerns, and assist in determination of solutions and/or design improvements. Investigations into the planned process plant behavior included analysis over a range of ore characteristics, ore feed rates, and operational settings and limitations. Investigations helped align Newmont and the engineering contractor by illuminating key process design assumptions and decisions. Finally, the Virtual Process Plant helped discover dynamic system behavior problems, including process control issues. As with the Conga project, P&ID Validation with advanced dynamic process simulation improves the engineering design for mining projects.

Introduction

Process simulation has played an important role in various industries, and has become increasingly common in the mineral processing industry. The use of simulation in metallurgical processing has been detailed in other papers, such as Anderson & Nikkhah (2001). For a general case of simulation for control system verification and operator training, see also Bogo et al (2002). Since those publications, ANDRITZ AUTOMATION has continued to expand its IDEAS Simulation Software for mineral processing. More recent developments of IDEAS, specifically for dynamic simulation in the mineral industry, have been discussed in Parthasarathi, Szaruga, & Szatkowski, (2009). That work also provides an excellent overview of the capabilities of IDEAS for both steady-state and dynamic modeling, and for a wide range of applications in each phase of a project's life cycle. Notably, IDEAS performs steady-state and/or dynamic simulation for the entire process, including performing mass and energy balances, tracking the flow and concentration of components, compounds, elements, and chemical species in multiple phases, and handling particle size distribution (PSD). Most recently, Nees & Gamarano (2011) describe the creation of a “Virtual Process Plant” – an accurate representation of the planned process plant in terms of metallurgy, material movement, engineering design, and process control. They describe the use of the “Virtual Process Plant” for P&ID validation for the Newmont Conga project, and also future use of the Virtual Process Plant for control system testing and operator training. The current paper provides further details on the work of this Conga P&ID validation project.

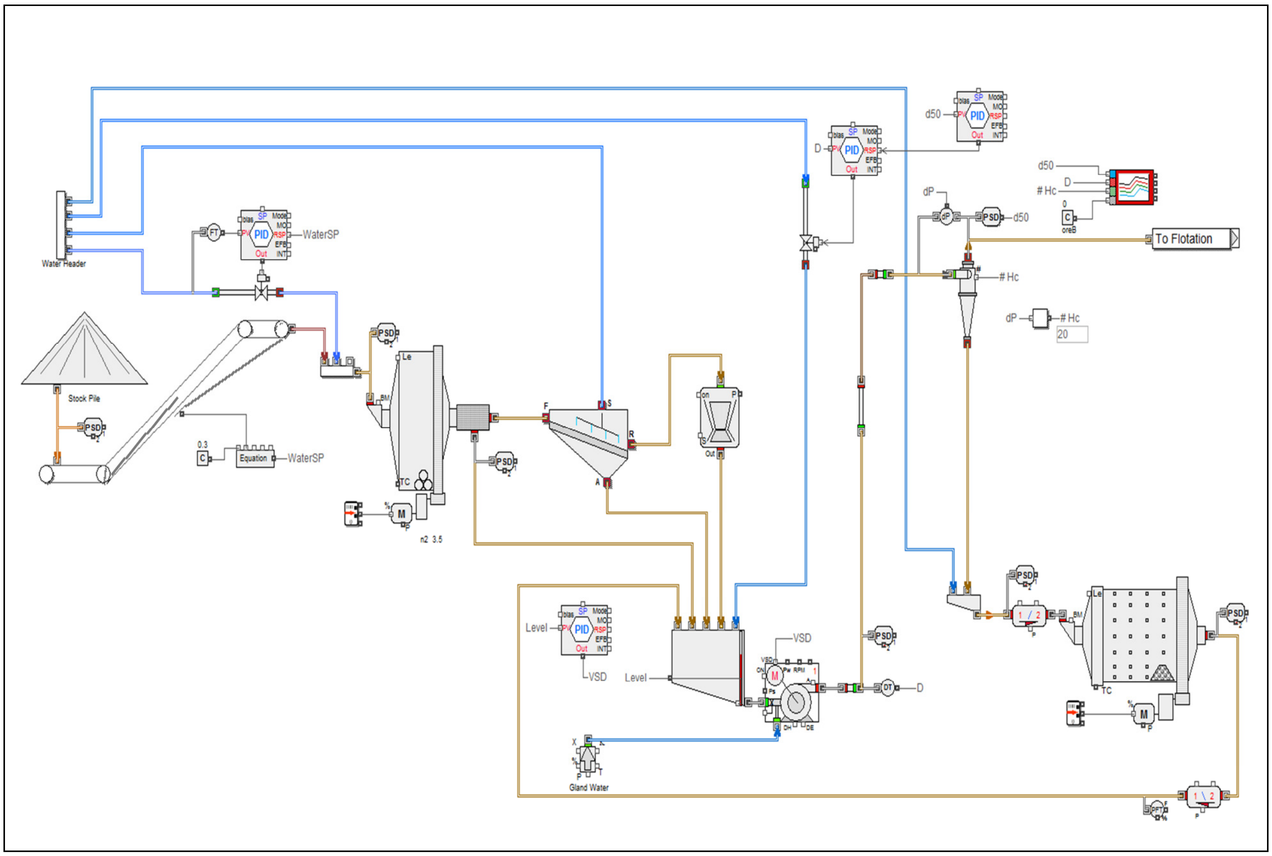

Figure 1. Overview Comminution Model in IDEAS.

Background Information

In October 2010, Newmont and ANDRITZ AUTOMATION began their P&ID validation project to construct a dynamic process model to assist in the engineering of the Conga copper-gold concentrator project. The planned work included implementation of certain Newmont-preferred technologies into the IDEAS Simulation Software, construction of the dynamic process model, and investigations with the model into the capabilities and characteristics of the as-designed process.

Newmont sought methods to improve the results of their engineering projects, and the subsequent plant start-ups. ANDRITZ AUTOMATION proposed a multi-phase project that would include P&ID validation, control system verification, and simulator-based operator training. Newmont chose to align this work with their engineering project phases. The overall goal of this work was improved operational readiness for the new facility, through improved engineering design, improved control system implementation, and more highly-trained operators. For the first phase of this work, the goal was improved engineering design through P&ID validation of the planned mineral processing facility.

Project Goals

Newmont's overall goal for the P&ID validation project was simply to improve the design of the planned processing plant. The individual tasks to achieve this overall goal included:

- Create a "Virtual Process Plant". Build the model of the planned plant to behave as the planned physical plant would behave. The finished model should accurately simulate the actual plant using state-of-the-art process models.
- Use Newmont-standard technologies. In some cases, Newmont requested that their preferred technologies be used for modeling, such as JKSimMet comminution models and proprietary flotation spreadsheets based on Aminpro technology.
- Investigate the engineering design. The Virtual Process Plant would be used to investigate the design and identify potential design issues and concerns. Run the simulator, just as a real plant can be run, through startup sequences, production rate changes, ore changes, etc. to determine how the plant will behave, dynamically, during such changes. The simulation allows discovery of design issues as early in the engineering process as possible, thereby reducing the impact of potential design changes, and improving the financial position of the project.
- Illuminate difficult design and control strategy decisions. In some cases, there simply is not a best choice answer for some engineering design and control questions. Identify such situations, and use the simulator to quickly consider the relative merits of different alternative solutions.
- Support further design decisions. Use the simulator to run various scenarios to support (or deny) further engineering decisions.
- Provide the Virtual Process Plant for future applications in
    - Control System Verification, and as an
    - Operator Training Simulator.

In addition to the overall goal of an improved engineering design, there were other positive side effects that were anticipated in a hopeful manner. The first was improved initial designs from the engineering contractor. Hopefully, knowing that the simulator would be used to test the design, the engineering contractor would operate with even greater diligence. The second hopeful side effect was an improved understanding of the process itself. With planned review and process investigation sessions, engineers from Newmont and its contractors would learn more about the process by seeing the Virtual Process Plant in operation.

Project Execution – Technology and Modeling

During the first few months of the project, two tasks were completed in parallel. The first task was the embedding of additional technologies into the IDEAS Simulation Software. Coordination between ANDRITZ AUTOMATION, Newmont, and the respective vendors (JKTech and Aminpro) produced all the necessary technical components and agreements for embedding of technical content from JKSimMet and Aminpro, respectively, into IDEAS. It should be noted that both of these external packages are intended for steady-state modeling only, not dynamic modeling. Later in the project, JKSimMet's steady-state nature would prove to be a technical challenge.

The second task was the off-site construction of the process model, or Virtual Process Plant, in IDEAS. A team of experienced simulation engineers from multiple continents built the process model, with data supplied by Newmont and the engineering contractor. The team built the model in three sections, essentially comminution, flotation, and 'filtration and other'. These separate models may be combined at a later date if desired. This model construction occurred in parallel with basic engineering work. Therefore, not all data was immediately available, and reasonable assumptions had to be made. The team recorded all such assumptions for future adjustment. The data required for such model building includes:

- Process flow diagrams (PFDs)
- Piping and instrumentation diagrams (P&IDs)
- Process design criteria
- Process description
- Process control philosophy
- Mechanical equipment list
- Mine plans and ore delivery schedules
- Ore characteristic data (JKSimMet parameters, flotation parameters, densities, etc.)
- Equipment elevations and layouts
- Pump and control valve data sheets, and other equipment specifications
- Piping line lengths and resistances (orthogonal drawings)

It should be noted that the initial work by ANDRITZ AUTOMATION for this project occurred at a point where limited steady-state modeling had already been performed using other technologies. However, for some projects, IDEAS modeling includes steady-state simulation for heat and mass balance creation during the feasibility study phase. IDEAS is created and used by ANDRITZ AUTOMATION, and is also available for use by external clients. A number of external engineering contractors use IDEAS to perform steady-state modeling of mineral processes.

In late February 2011, the "Simulation Team" of three simulation engineers from ANDRITZ AUTOMATION and two metallurgical engineers from Newmont proceeded to Santiago, Chile, to complete construction of the Virtual Process Plant onsite at the engineering location. Physical proximity to the Conga project team, including the engineering contractor, proved valuable in obtaining the latest and most accurate data for completion of the process models. Onsite cooperation also allowed quick reconciliation of apparent data errors between different sources. In some instances, the Simulation Team noticed different values from different sources for the same exact data. Usually, the difference was simply caused by one document being updated to the latest design before another document. The simulation work produced a reminder that the other documents would also need to have such data updated.

The ANDRITZ AUTOMATION team also performed onsite modification of some of the embedded technical content from Aminpro. After a face-to-face meeting with Aminpro, Newmont requested this modification for greater model detail. The IDEAS software structure is such that software modifications may be realized quickly, as occurred in this case. During the course of the project, the ANDRITZ AUTOMATION software development team supported the project through this and other additional, minor software enhancements.

During this final model construction phase, the Simulation Team worked alongside one another acquiring the latest data, entering data, reconciling data, and reviewing the models. Twice a week, the Simulation Team reviewed the Virtual Process Plant with a larger group of engineers from Newmont and the engineering consultant. These larger meetings allowed everyone to see the model progress and help clarify any outstanding questions that required input from multiple people. The models were already highly developed and were ‘run’ to simulate process operation in faster-than-real time. During these meetings, the larger team began the transition of thought from viewing the model as a software file, to viewing the model as the Virtual Process Plant. In this manner, the Virtual Process Plant came to life in these meetings.

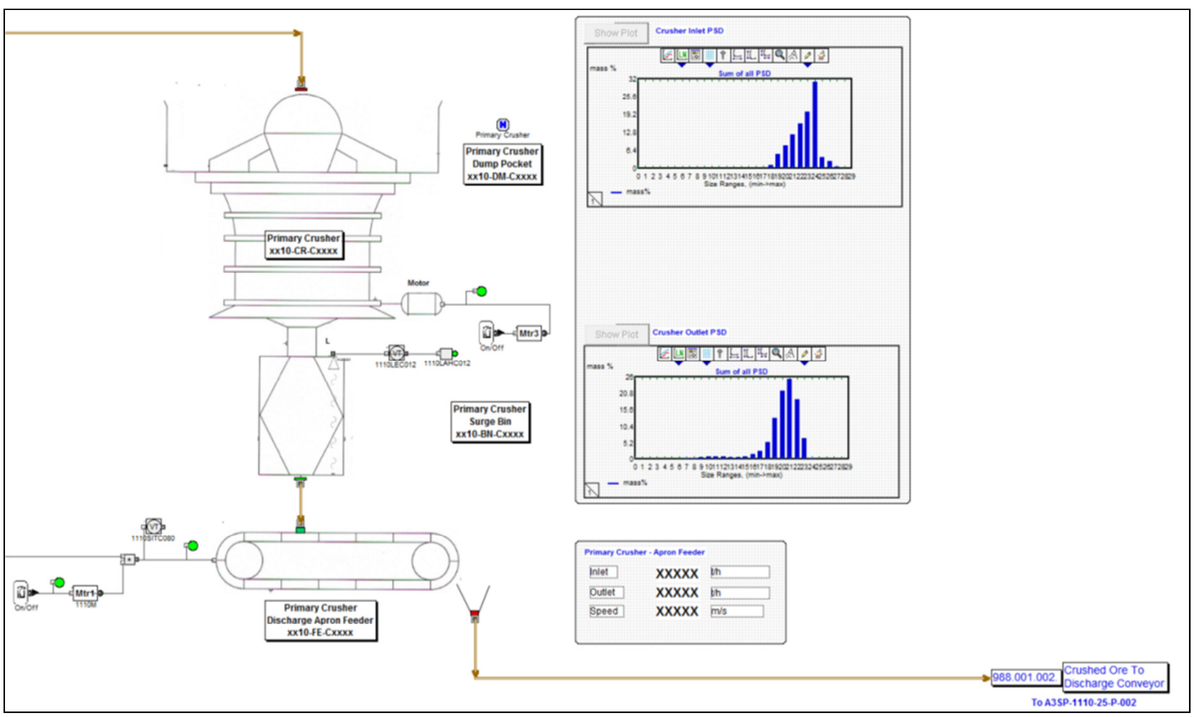

Figure 2. Dynamic Modeling in IDEAS with PSD before and after Primary Crusher.

Project Execution – P&ID Validation

In April, 2011, the process models included all the latest available engineering data, and assumed data, which had been mutually accepted, where no firm data existed. At this point, the model review meetings were replaced by Virtual Process Plant investigation meetings.

Each day, the ANDRITZ AUTOMATION simulation engineer would check the engineering design by running the model, or Virtual Process Plant, through a variety of operational scenarios. They would include analysis over a range of ore characteristics, ore feed rates, and operational settings and limitations. These scenarios would help identify any process design problems/concerns, such as bottlenecks, excessively high or low slurry velocities, overflowing or emptying tanks, and pump or valve cavitation. During this phase, the Simulation Team included two to three ANDRITZ AUTOMATION simulation engineers and one to two Newmont engineers. The Simulation Team conducted these daily investigations, continued to obtain engineering updates, and adjusted the models accordingly. When the simulation engineer discovered process problems in the Virtual Process Plant, he would confer with the Newmont engineer(s) to help investigate problem. In some case, they would also confer with other Newmont engineers or with the engineering contractor. Since the engineering work was ongoing, it was common to find that data had been updated very recently, and that the updated data would rectify the perceived problem. In other cases, a few questions asked to the right people would lead to the problem being solved in other ways. In one instance, a pump cavitation problem had already been identified by the engineering consultant, and the pump's feed tank elevation had been increased to provide sufficient suction head pressure, but the new elevation data had not been updated in all the proper engineering documents.

If the problem could not be resolved quickly, the Simulation Team would present the problem/concern at the next semi-weekly Virtual Process Plant investigation meetings. Some problems required group discussions to solve, and such discussions occurred at these meetings. For some problems, the solution would require a process design change. Occasionally, external resources, such as engineering consultants from other locations, or equipment vendors, would be required to help resolve problems. During these Virtual Process Plant investigation meetings, discovered problems would be investigated and resolved, and/or a path forward for resolution was determined. The engineering contractor maintained a punch list of perceived problems/concerns with details and responsible party names. The entire team reviewed the open items on list at each meeting, closed out solved items and added new items.

In addition to problem resolution, these investigation meetings provided further opportunities for the entire team to operate the Virtual Process Plant. The highly-experienced team members recognized additional issues in some these meetings. For example, one conveyor experienced non-continuous solids flow: At any point on the belt, there was less than a 50% chance that material would be present at any given time. For most belts, this situation might not have been a problem. But a critical cross sampler existed on this belt. This sampling point required continuous material on the belt for proper reporting. Due to the dynamic nature of this problem, only with a dynamic process model could such a discovery have been made. Newmont raised this problem to the attention of the engineering contractor's remote expert for engineering redesign.

Following these investigation meetings, the simulation engineer would conduct more detailed investigations into the behavior of the Virtual Process Plant. These investigations could take several hours to perform, and might include evaluation of new alternatives to the process design which had been proposed in the meeting. He would present his results at the next meeting. For larger investigations, to preserve investigation records, the ANDRITZ AUTOMATION team would produce a Technical Investigation Report. Nine such reports have been issued for the Conga project, across all major areas of the plant. Some Virtual Process Plant issues not already discussed earlier include undersized conveyors, excessive launder and pipe velocities, and possibly undersized flotation dart valves under some dynamic conditions.

Finally, with the variable nature mine plans and ore delivery schedules, there are instances in a designed plant where there may be no good engineering solutions. In one instance, the Virtual Process Plant revealed a pipe that could not possibly be sized properly to obey the project's design criteria for slurry velocity under all expected process conditions. The engineering contractor had correctly identified this issue. And the Virtual Process Plant assisted Newmont by illuminating this particular issue, and the decision that the engineering consultant made. Newmont will expect this pipe to be problematic in the future, rather than simply being surprised in the future when this pipe faces plugging and/or erosion problems.

Project Discoveries

As described above, the Simulation Team investigated the performance of the Virtual Process Plant, and identified potential design issues and concerns. Several significant issues were identified at this early point in the engineering process, thereby reducing the impact of potential design changes. The simulation also allowed comparison of alternative engineering design changes, as well as process control strategies.

The majority of discoveries made during the P&ID Validation phase were resolved quickly, prior to the next Virtual Process Plant investigation meetings. Some issues were resolved during these meetings. Those items not resolved quickly before or during the meetings were recorded for further handling on the punch list of perceived problems/concerns, as previously mentioned. More than 20 items appeared on this punch list, including several instances of mismatched values between process design criteria document, P&IDs, calculation sheets, and data sheets. For remaining issues within their area of responsibility, the Simulation Team conducted further investigation of the problems, with the help of others within Newmont and the engineering contractor. And where appropriate, the simulation engineer would create a Technical Investigation Report. As a sampling of the discoveries and investigations, the Technical Investigation Reports produced, and a brief description of each, are listed here:

- Investigation Report SAG Mill 20110414 – An investigation into the SAG Mill's peak on the power versus loading curve.
- Investigation Report Conveyor 20110428 – Discovery of highly under-designed pebble crusher discharge conveyor, and other conveyors and feeders under-designed when considering process design criteria surplus factors.
- Investigation Report Launder and Slurry Pipes 20110509 – Discovery of high launder slurry velocities under all conditions. Discovery of high pipe slurry velocities under design conditions. Discovery of some sanding conditions (slurry velocity < deposition velocity) at minimum flow conditions.
- Investigation Report Filtration Conveyor 20110511 – Presented discoveries regarding excess concentrate conveyor capacity, the need for a variable speed drive, and expected sampling difficulties related to discrete presence of concentrate on the conveyor.
- Investigation Report Filtration Conveyor 20110529 – Further investigations to the above report.

- Investigation Report Filtration Conveyor 20110530 – Further details added to the above report.
- Investigation Report Flotation Dart Valves 20110705 – Investigation into the dynamic behavior of the dart valves and their ability to maintain operation within the desired operating range of 40% to 70% open for both the Intermediate and Discharge Box dart valves.
- Investigation Report Ball Mill Limiting 20110929 – Illustrates the dynamic behavior of the Conga comminution circuit for different ore types and transitions. This report also produced comparison between alternate control strategies at the cyclone feed area. One plot of the dynamic behavior at the cyclone feed area is shown in Figure 3. Notice the changes when cyclone feed valves are opened or closed.
- Investigation Report Flotation Dynamics 20120104 – Illustrate the dynamic behavior of the flotation area following the sudden removal from service of one of the three rougher and rougher scavenger flotation cell trains.

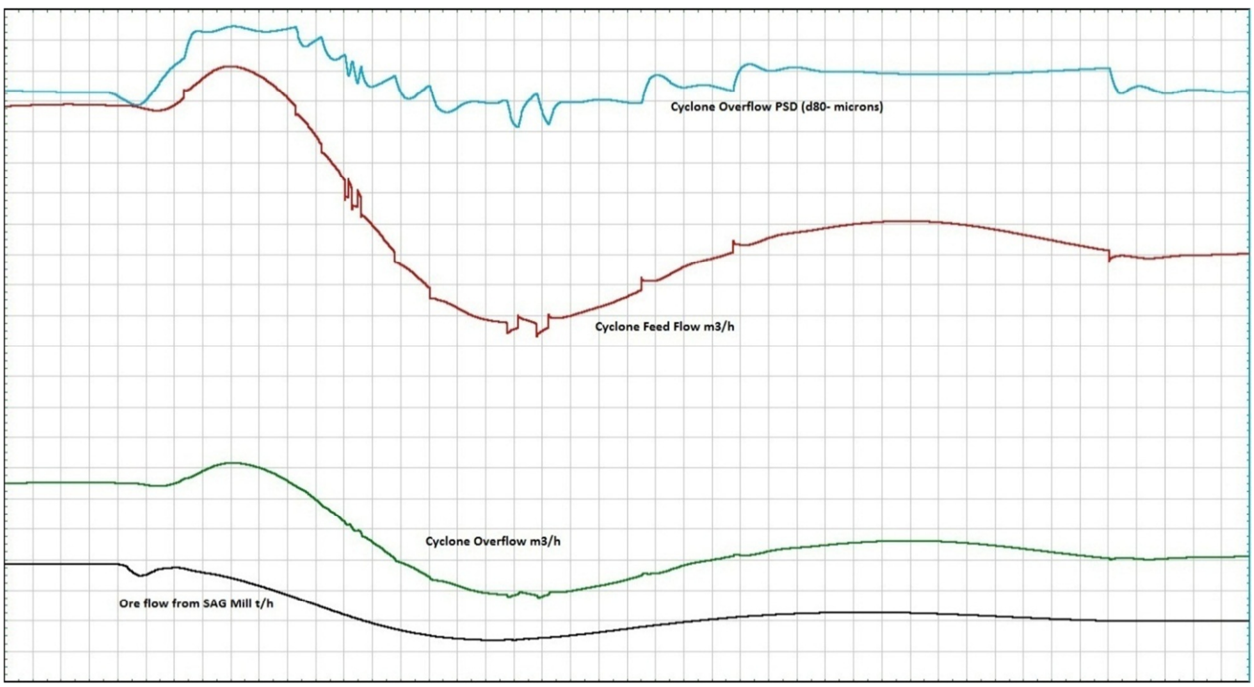

Figure 3. Dynamic Cyclone Area Behavior with Ore Change

The nine Technical Investigation Reports, the 20+ items on the punch list of problems/concerns, and the numerous other discovered issues represent significant discoveries of engineering design problems and areas for improvement. This project allowed Newmont to identify, understand, and remedy many engineering design issues at an early stage of the engineering process. By making these engineering design changes early in the engineering process, the impact of these changes is greatly reduced. Early problem detection and adjustment of engineering design provides improved financial position for the project over later detection, and obviously over non-detection.

Project Results

At the end of May, 2011, the Simulation Team concluded the P&ID Validation work in Santiago. During the project, the goals stated earlier in this paper have been met. The Virtual Process Plant was created in the IDEAS Simulation Software. Highly-experienced Newmont metallurgical engineers found the accuracy of the Virtual Process Plant to be realistic for planned future operator training purposes. The model uses Newmont-preferred technologies (JKSimMet comminution and Aminpro-based flotation spreadsheets). Through the Virtual Process Plant investigations, ANDRITZ AUTOMATION identified many process design problems/concerns early in the engineering process, and assisted in evaluation of their alternate solutions, and assisted in their resolution. The authors also believe other positive anticipated side effects were realized. As described in the Project Goals section, these side effects were: First, improved initial designs from the engineering contractor; and second, an improved understanding of the process itself.

Further collaboration between ANDRITZ AUTOMATION and Newmont is planned for control system verification and operator training using the Virtual Process Plant.

Conclusions

Advanced dynamic process simulation can help mining companies and engineering contractors improve plant design through P&ID Validation. Together, Newmont, the engineering contractor, and ANDRITZ AUTOMATION identified process design problems/concerns, and determined solutions early in the engineering process. The IDEAS Simulation Software allowed creation of the Virtual Process Plant, investigations into the plant behavior, and analysis over a range of ore characteristics, ore feed rates, and operational settings and limitations. Investigations illuminated key process design assumptions and decisions, and the dynamic system behavior. As with the Conga project, P&ID Validation with advanced dynamic process simulation improves the engineering design for mining projects.

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