Tonnage Control Under Maximum and Instantaneous Power Constraints

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Business Challenge

This paper presents a control solution to optimize ore transportation on a transfer conveyor belt fed by variable speed feeders. The purpose of this advanced regulatory control is to always operate at mechanical and electric constraints rather than at a sub-optimal average throughput.

In the mining industry, there are many applications for ore to be conveyed without posing a hazard to either personnel or equipment and without overflow or overload. In certain applications, there is a strong incentive to maximize conveyor throughput to minimize loading time, for example, to reduce hourly docking fees for boat loading.

A common installation is for multiple hopper-fed variable speed feeders to dump onto a long, fixedspeed transfer conveyor on which a belt scale measures throughput in tonnes per hour (t/h). The main constraint for high throughput is the power draw on all the conveyor motors.

The standard PID tonnage controller measures the belt scale weight and manipulates the feeder rates. The distance from the belt loading point to the scale, combined with belt speed (m/s), determines the transportation time lag. This lag is used to determine the difficulty of closed loop control; the longer the lag, the harder it will be to control tonnage, which means controller settings will have to be more conservative to minimize the risk of overloading the transfer conveyor belt. At startup, the time to reach the requested nominal tonnage will be directly proportional to the lag. For example, for a 700-metre distance between the belt loading point and the scale, at a speed of 3.5 m/s (at nominal tonnage), the estimated lag will be over three minutes. In closed loop control, it would take the tonnage PID controller approximately 30 minutes to stabilize, which would most likely result in a conveyor belt overflowing with ore and an overloaded motor.

Variable feeder operation combined with this lag-induced slow reaction time results in a lower average flow than the calculated nominal rate.

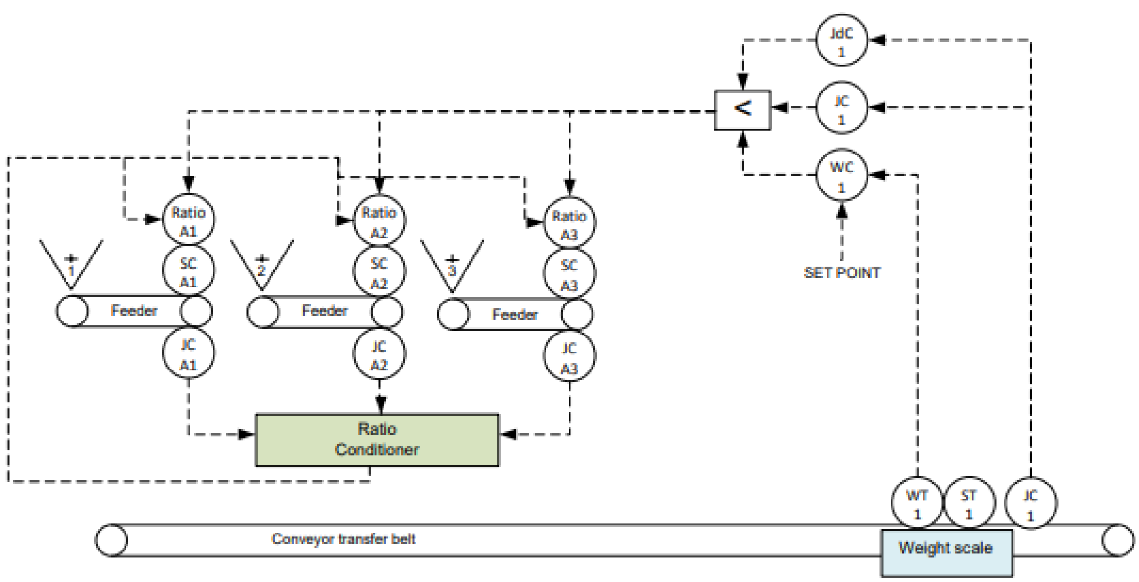
Solution Descriptions

To achieve optimal loading performance, it is best to use the conveyor power-to-weight ratio. This ratio is a reliable measurement of nominal and maximum conveyor capacity. The advantages of conveyor power control are a very short lag (in the order of 20 seconds) for power measurement and the ability to detect and act on a sudden power output surge before motor interlocks activate. Hence, controlling transfer conveyor belt power is a reliable way to maintain an average tonnage at nominal value.

Advanced Regulatory Control Solution

The advanced regulatory (PID) control solution can be broken down into two separate components:

- A tonnage controller (WC-1) limited by a maximum transfer conveyor motor power constraint (JC-1) and by a maximum power rate of change (JdC-1);
- The output of the active controller is sent to the feeder speed controllers; their relative contribution is managed by a ratio conditioner, based on the number of feeders used as well as their instantaneous power draw.



WC-1 - Tonnage Control

- The target tonnage is determined by the number and operation status of conveyors receiving ore from the transfer conveyor belt, as well as by the design nominal rate for the entire loading conveyor system. The operator can also impose a target flow that is less than the nominal target flow. This is the controller that should be active most of the time.

JC-1 - Maximum Power Constraint

- The target of this controller is the maximum power beyond which the transfer conveyor belt can no longer be restarted under load; if the conveyor is shut down unexpectedly (e.g. emergency lever, belt deviation, downstream interlock) at maximum load, it must be possible to restart it.

JdC-1 - Maximum Power Rate of Change Constraint

- This constraint is most useful when restarting an empty transfer conveyor belt. When the conveyor is restarted without any ore, because the measured tonnage (0 t/h) is lower than the target, the tonnage controller (WC-1) will ask the feeders to run at 100% speed. In short order, there will likely be excess material on the belt with a risk of overflow onto the ground and, ultimately, a power overload well before material reaches the belt scale. To manage this interim period at start-up, feeder speed will be limited for the time it takes to carry ore from the feeders to the scale (over three minutes).

- This constraint is also useful to avoid motor overload during continuous operation. The feeders take ore from a loading hopper filled by a loader operator. When a hopper empties, the tonnage control (WC-1) will ask for a higher loading speed to meet the target. When material is added to the hopper, the power required by the belt will surge. JdC-1 will detect the increase and will immediately reduce the requested feeder speed, thereby avoiding motor overload.

Total feeder capacity is often greater than the nominal transfer conveyor belt throughput. The tonnage controller's output, combined with each feeder's ratio, determines every feeder's speed. The ratios are mainly based the operation statuses of feeder and conveyor equipment across the loading system. When a feeder hopper runs out, its impact will only be measured at the scale over three minutes later. However, the power draw on its feeder motor will drop almost immediately. Knowing this, the ratio conditioner will compensate for the drop in this feeder's tonnage contribution by increasing the other feeders' speed.

JC-Ax (x=0 to n) - Minimum Feeder Power Measurement

JC-Ax controls the minimum feeder power required for ore to be transferred to the conveyor belt. This controller (JC-Ax) will be used to determine the ratios of each feeder's contribution. The choice of ratios will ensure delivery of a maximum of ore from the feeders in all situations.

Back-Up Control Solution

Power Control under a Rate of Change Constraint

- If the scale malfunctions, the process can still be operated with the power controller JC-1, using a target power as a percentage of maximum power. The operator can input the desired target tonnage by using a tonnes per hour to power percentage characterization obtained at start-up.

Conclusion

Adding power value and rate of change constraints to the classic tonnage controller allows the conveyor to always operate at motor load constraints. Likewise, dynamically managed feeder ratios lead to a quick reaction to hopper outages. This results in an increased average tonnage throughput and eliminates overflow and overloads. It takes special expertise in process control and controller configuration to implement this advanced control configuration; PID functions must interconnect to ensure a seamless transition from one controller to another.

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Serge Naud, Process Control Engineer, has more than 30 years of experience as a consultant. He has worked in numerous industrial plants as an automation engineer and process control engineer. As a process control expert, he acquired vast experience in process control optimization, start-up, troubleshooting and development of new advanced control strategies for industries such as mining processes, pulp mills, power and boiler plants, petrochemical and pharmaceutical plants, chemical processes and refineries.

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