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ABITIBI-CONSOLIDATED MILL REACHES FOR SHEET PERFECTION

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Riceboro, Ga., linerboard mill streamlines its process operations and improves end product quality by replacing its panelboard single-loop controllers with modern digital controls

Interstate Paper Upgrades to Digital Automation For Better Process from Chip Yard to Paper Reel

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Built in 1968 and running one 170-in., 2,250-fpm paper machine, Interstate Paper's Riceboro, Ga., mill focuses on next-day, just-in-time delivery of linerboard to box and sheet plants along the eastern seaboard. Supporting the paper machine are five batch digesters, two high-density (HD) towers, and seven refiners. Purchased chips and old corrugated containers provide the raw material.

Mill controls were originally pneumatic, replaced in 1990 by a batch supervisory distributed control system over panelboard, single-loop controllers in the digester house and by panelboard single-loop controllers alone in stock preparation and on the paper machine. In recent years, these controls had become unreliable, and many had fallen into disuse in favor of manual control. Much of the knowledge regarding how to best operate the mill is in the heads of senior operators, many of whom are nearing retirement.

To increase plant output, assure the highest product quality, and capture operator best practices, Interstate added a new top former and calender and replaced the panelboard controls with a PlantWeb digital automation system from Emerson Process Management. The project provided a fully engineered system utilizing open, off-the-shelf hardware and software modules right-sized for the digester house, stock preparation, and paper machine but easily scalable to include the entire mill site.

Automation features of particular interest to Interstate included:

- Windows graphical configuration of pre-engineered, paper industry-oriented control modules, algorithms, and graphics,
- Compact, field-mountable controllers assembled from plug-in central processing unit, power supply, input/output (I/O), and communications modules,
- Low-cost PCs as operator, engineering, and application workstations,
- A global database across all controllers and workstations,
- Networking between workstations and controllers via popular Ethernet, and
- Engineering, services, and startup support.

Dual-monitor operator stations, such as the ones used in Interstate Paper's digester house control room, allow operators to have more onscreen information for monitoring.

DIGITAL PLATFORM INTEGRATES CONTROLS. More than 1,100 I/O points are now serviced by five redundant sets of DeltaV controllers covering stock preparation and the paper machine, plus one set of redundant controllers for the digesters. There are no programmable logic controllers (PLCs); all discretes are handled in the new controllers.

The only non-DeltaV system is a four-year-old gauging system that provides remote setpoints to the DeltaV system for basis weight and moisture control. This is accomplished through directly wiring outputs from the gauging system to DeltaV I/O inputs. DeltaV executes all control to the final control elements. The mill does not have technology for a drive control system, but uses a line shaft instead.

As for operator stations, the automation features one dual-monitor PC for the paper machine, two dual-monitor PCs for the digesters, another dual-monitor PC in stock preparation, a fourth dual-monitor unit for the dryers, and a single-monitor PC for the refiners. Selection of dual monitors allows operators to have an enormous amount of data "up" at one time. Rounding out the PCs are engineering, application, and miscellaneous workstations. All computers and controllers reside on a single redundant set of IEEE 802.3 Ethernet networks provided as part of the DeltaV system architecture.

Engineering, procurement, programming, simulation, training, contractor interfacing, commissioning, and startup were joint efforts of Interstate, Emerson's Atlanta Solutions Center specializing in pulp and paper industry applications (formerly Orion-CEM Inc.), and Control Southern, Emerson's Atlanta representative.

BATCH AS CONTINUOUS. Through flexible, supervisory process strategies loaded into the single controller set, the five batch digesters have been integrated into a pulp supply system that provides consistently high-quality pulp. Steam and chemical valves, pressure and temperature transmitters, and field wiring were replaced to assure that field device precision and reliability were a match for the strategies.

Algorithms are driven by a schedule that blows one digester every 28 minutes, even if an operator has interrupted the process for a short time or an upset occurs. Any delays (or time gains) in charging, bring-up, or cooking are automatically compensated for within the algorithms. When the scheduled time for a blow arrives, the pulp is at optimum quality—not under or overcooked.

The ability of the configuration to perform variable reaction-rate integral calculations from data gathered across three phases and five digesters is believed unique. The automation also schedules steaming permission for the digesters to stabilize powerhouse operations and minimize variations in steam demand.

MAINTAINING CONSISTENCY. Should an instrument fail, the algorithms either disregard its output or compensate for it. If the instrument has to be replaced, this work can be done with minimal impact on the quality of the product because the batch can be held as last instructed or manually advanced. Once the replacement instrument is on line, the automation will compensate for the delay by formulating a revised time/temperature profile to complete the batch on time.

Operator workstations at Interstate feature a standard graphic layout segmented by functional areas for clean and easy access. Supervisory and static information is in one area, process information in another, alarms in a third, and changes in a fourth.

Because each Interstate digester has its own operating characteristics, the algorithms were customized to take these differences into account. As a result, finished pulp is highly consistent from digester to digester and batch to batch—less than 3% coefficient of variation. The control system's modified H-factor can also be simply raised or lowered across the entire digester house to accommodate variations among seasons, types of wood, and wood moisture content.

During charging, the proportions of wood, white liquor, and black liquor are now more tightly controlled. The mill formerly tended to overcharge with wood; cutting back has made for better circulation, fewer shives, and less refining. In the past, the primary target value in cooking was pressure. The target has been switched to temperature to more accurately control both alkali penetration into the wood and on-time completion of the chemical reaction.

Other improvements include extending the top and bottom thermocouples deeper into the digesters for greater accuracy, introducing steam purges closer to the continuous pressure taps to eliminate plugging and false readings, and bringing chip bin and conveyor limit switches and logic into the automation for faster troubleshooting compared with former hardwired interlocks.

Special maintenance tools are built into the digester algorithms. Among them

Variability Benchmarked and Remeasured for Results

To gain long-term variability reductions in machine-direction basis weight and moisture, paper mills should carefully study their processes, instruments, and control strategies. Many North American mills have been pushed to three times or more their original capacities without replacing stock chests, piping, and other equipment.

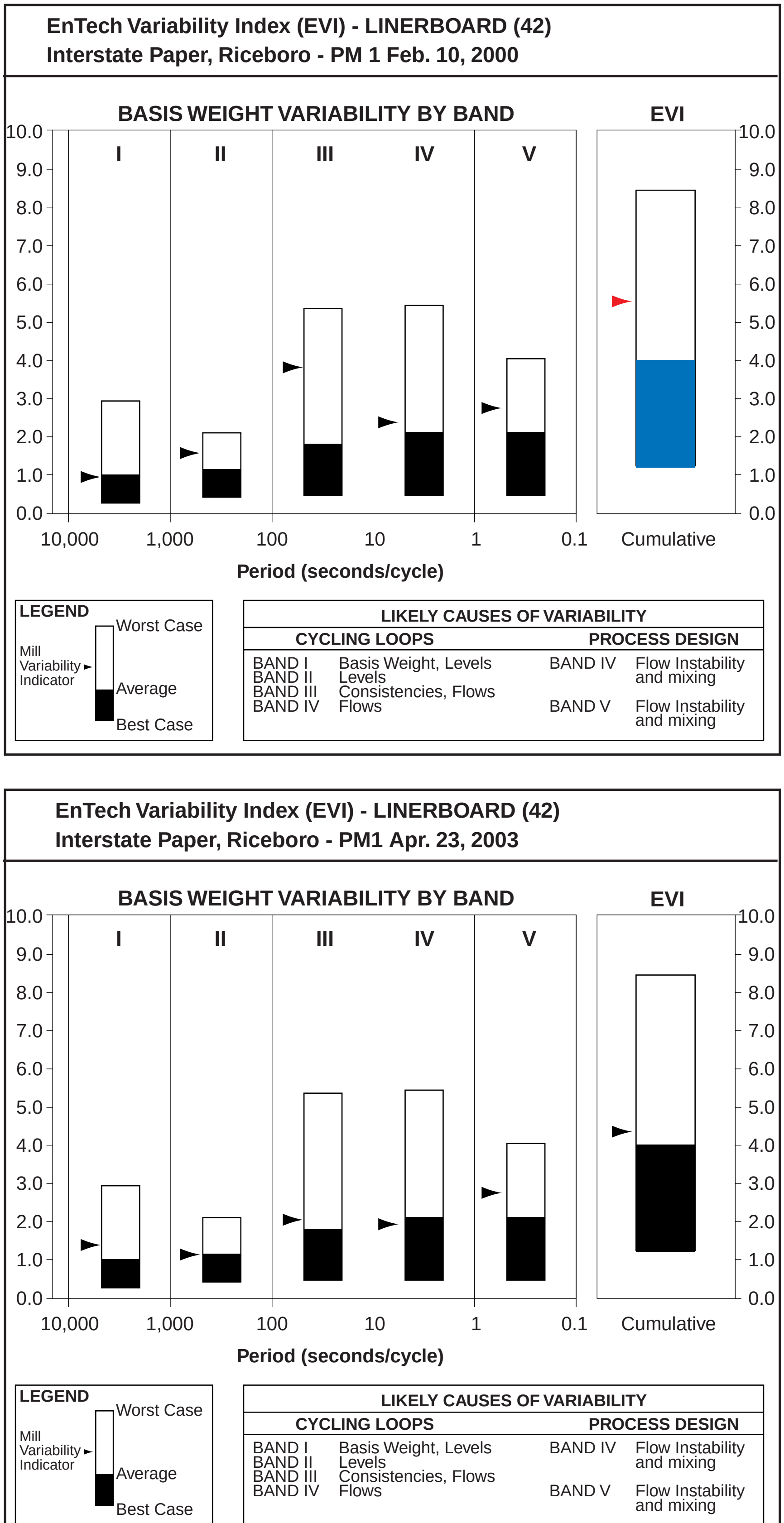
For such mills, it's absolutely critical that instrumentation and control elements be maintained in tip-top shape to hold process variations to a minimum. Control degradation from poorly performing devices and strategies cannot be tolerated when process equipment is overloaded. And don't think a well-tuned gauging system will help. Lousy loops, well tuned, won't hold up. Even more basic, gauging systems control with long deadtimes and cannot be tuned to get rid of variability at higher frequencies.

At Interstate Paper, the primary goal for the upgraded controls was to improve quality and output by reducing the very high-cost penalty imposed by excessive process variability. Success was achieved by implementing superior instrumentation and applying advanced control strategies standard within DeltaV automation. This was achieved without implementing any supervisory control algorithms for machine-direction or cross-direction control enhancement.

The before and after Entech Variability Index graphs in Figure 2 (see next page, provided by Emerson Performance Solutions in Atlanta) illustrate the improvements gained. The top figure details process variability in February 2000 before the automation project was begun. The bottom figure displays the reduced variability evident in April 2003.

The average variability index for linerboard in the experience of Emerson's Entech group is 2.96. Interstate had a 5.5 when measured in February 2000. But after the project was implemented, the cumulative EVI dropped to 4.36. In Band III, there was a significant reduction of 1.8, which could be attributed to the flow and consistency control changes. All measurements are 2 sigma, percent of mean values.

FIGURE 2. *The before and after variability graphs show the improvements gained by reducing process variability through the automation upgrade.*



are those that permit maintenance personnel to find, isolate, and replace a malfunctioning instrument without shutting down the digester. Interstate has found these tools especially helpful on the night shift, allowing the mill's single E&I night technician to become something of an expert in keeping the digesters—and the paper machine—running well. Previously, it was difficult for him/her to become an expert in any one area.

LESS STEAM, LOWER KAPPA. During the bring-up and cooking phases, the new control system does a superior job of steam control to assure that steam is maintained at saturation at the desired temperature just below the relief valve pressure setting. Steam use per cook has been reduced by about 10% because of more efficient consumption and less over-pressure venting. Further, fewer dirty blows occur. The DeltaV process automation system will shortly be extended to the powerhouse to improve operations there.

The completed pulp's target kappa used to be 108, relatively high because of process variations. Because the coefficient of variation in kappa has been reduced to below 3% using automation, the target kappa could be reduced to 103 and still safely assure 10% residual alkali in the black liquor after the blow. The lower average residual alkali is sufficient to slow scaling in the evaporators.

The lower and more consistent kappa, which has made for higher-quality paper, has not lengthened cooking time because of the control system's ability to automatically adjust process profiles. Further, the new kappa level has been achieved without increasing alkali consumption.

FUZZY LOGIC SMOOTHES CONSISTENCY. Interstate dilutes the pulp's 13 to 14% consistency in the HD towers to 4% at the outlet. Typical of most kraft mills, dilution in each tower is accomplished by a combination of a minor-dilution trim valve at the outlet pump and a major-dilution valve (mid-range valve) adding water to the bottom of the tower. The mid-range valve's job is to keep the trim valve operating within its normal range. At Interstate, a downstream pulp consistency meter and split-range PID controllers regulate the two valves.

Also typical of most kraft mills, variations in supply water header pressure played havoc with the dilution loops' tuning. For example, a drop in header pressure reduced the flow of dilution water and caused pulp consistency to rise. In reaction, the consistency controller opened the trim dilution valve, followed by the mid-range controller opening the mid-range valve to restore the trim valve to its normal range. When the supply water header upset went away, the process reversed itself. Several quick upsets in header pressure could cause the system to oscillate.

By adding two additional flow meters, one each on the trim and mid-range dilution lines (Figure 1), pulp consistency changes due to upsets in header pressure were corrected. The flow loops quickly compensate for variations in header pressure before the consistency can change.

The consistency controller now regulates pulp consistency by providing a remote setpoint to the trim dilution flow controller. In turn, this controller provides a remote setpoint to the mid-range controller. As a further control improvement, the mid-range controller was converted to fuzzy logic to minimize overshoots when correcting the trim valve's position. The flow-compensated consistency control scheme actually works well when using integral-only control for the mid-range control, but performance improves even more when incorporating the DeltaV fuzzy logic controller into the scheme.

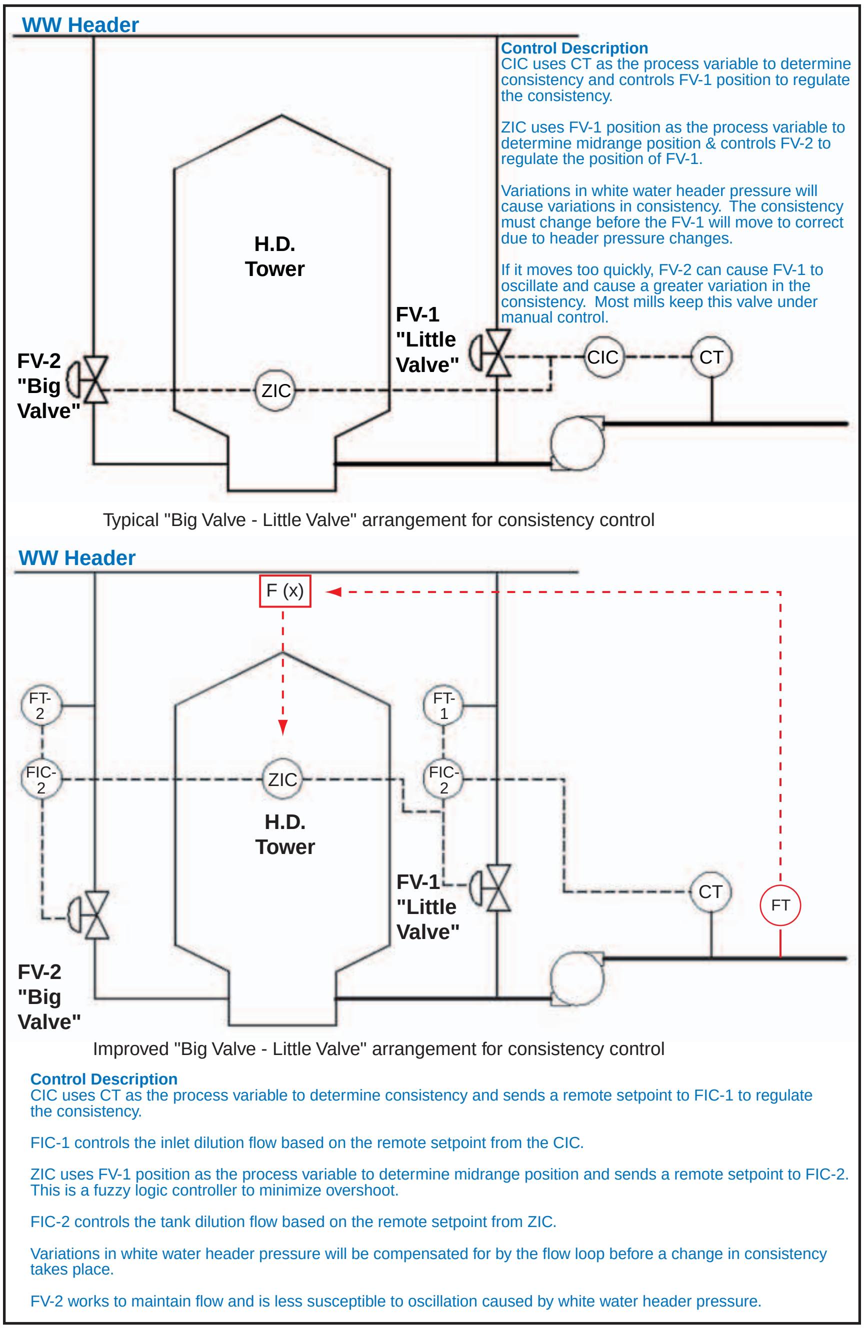
The paper machine's gauging system remains unchanged. Supervisory programs within gauging systems cannot properly react to short-term variations in basis weight. Further, at Interstate the gauge doesn't communicate with zone dilution control. Upgrading the gauging system could not have eliminated the cause of the variations seen in basis weight and moisture.

REFINER LOADING AUTOMATED. The Interstate mill's original design capacity was 400 tpd. Through the years, production had been raised to 760 tpd. This meant the couch pit had become undersized. During startup before the new automation, the sheet could not be threaded until the refiners were loaded and provided sufficient strength in the sheet. Until that point, all of the pulp ran off the fourdrinier into the couch pit. It did not take long to overflow the storage tank if the machine did not thread well.

The solution was to reduce the time to load the refiners through a stock preparation one-button start and fully automatic refiner loading. Loading had previously been performed two refiners at a time, with an operator watching ammeters while manually advancing the plates. Plate and motor damage was a constant hazard, and getting refiners loaded was a slow process. Today, the startup process—including loading six 1,200 hp refiners—takes just seven min, down from 30 min previously. Further, plate crashes have been eliminated.

One key to making automated refiner loading possible was measuring kW rather than amps. The problem with an ammeter is that readings change too little between a motor's unloaded and loaded states. It is difficult for an opera-

FIGURE 1. *Before and after schematics of pulp consistency control at Interstate. FIC-2 (left in the lower schematic detailing the improved control with flow control loops) uses fuzzy logic to prevent the mid-range valve ("Big Valve") from overshooting and adding too much dilution water to the tower. Also note the special production rate flow compensation (in red) that adds to the effectiveness of the new control scheme.*



tor (or a sensor) to detect that loading has sharply increased, which is the signal for the operator (or automation) to slow plate positioning. An ammeter reads total current, which includes both in-phase (power current) and reactive (useless current) components. This shortcoming makes it difficult to know the actual work being performed on the pulp because only in-phase current relates to energy delivered. In-phase current is the only current read by a kW meter in calculating power. Therefore, sharp variations in loading can be readily detected by operator or sensor.

The new refiner loading system also relies on a pulse-positioning algorithm in a custom function block to ramp the plates in and out without contact and minutely vary plate positions to maintain maximum power input. Another custom function block provides refiner area interlocks, a job formerly performed by a PLC.

There was some trepidation in the mill about automating plate movement. Before being placed in service, the refiner control configuration's inputs and unconnected outputs were watched through numerous cycles as an operator pushed buttons and flipped switches during manual starts. No problems were indicated during these simulations, and no problems occurred later during cutover or have arisen since.

MODEL PREDICTIVE CONTROL FOR pH. Controlling pH in the secondary blend chest had never worked well at Interstate using a conventional PID loop between a pH sensor at the outlet and a valve adding acid at the top of the chest. The loop's 6-min dead time and 15-min first-order time constant were just too great. It was easier for operators to simply put the acid valve in manual, eyeball pH every 10 minutes or so, and adjust acid flow to compensate for the amount of pulp being sent to the paper machine.

The solution to regaining automatic closed-loop control was to fortify the PID loop with DeltaV Predict, a model predictive control (MPC) software layer excellent for helping PID loops regulate under long deadtimes. MPC looks at a range of data to determine what a process will do in the future and formulates a response. Very basic MPC was used in this application: one control variable, one manipulated variable, and no disturbance variables or constraints.

After setting limits on the percent swing of the acid valve, only four hours of auto-tuned training of the model were necessary before the loop could be switched to closed-loop control. Online since startup, the advanced control has proven robust in compensating for variations in pulp flow, acid concentration, and the pH of incoming water. To operators, the MPC functionality is transparent—they view the pH loop today just like any other PID loop.

Some thought was initially given to using a modified Smith predictor on the original loop to compensate for deadtime. This was abandoned after it was determined that deadtime in the Interstate application varied too much. A Smith predictor also attempts to control ahead of time using past deadtime. Model predictive control is superior at looking into the future.

DRYER TEMPERATURE CONTROL TIGHTENED. Cascaded steam temperature, pressure, and flow PID loops have tightened control of the dryer section of the machine by automatically venting excess steam during a sheet break and thereby maintaining a constant steam flow from the powerhouse. In the past, one or two sets of paper were sometimes thrown away waiting for the dryers to regain temperature. Although venting is common in the industry, the complexity of the Interstate algorithms is believed uniquely effective.

Variations in sheet moisture were also experienced in the past because the main header had to operate too close to its pressure relief setting—130 psi versus 133 psi. An algorithm was therefore implemented that minimized overshoot so the relief valve didn't lift. Not unlike the dilution application detailed earlier, each steam section had a large valve and a small valve supplying steam to the header.

The two valves were previously controlled using a split-range algorithm. This method was changed to a mid-ranging application, where the small valve adjusts for small changes and the big valve moves slowly and keeps the small valve in the middle of its operating range.

Part of the dryer temperature control problem also derived from an unsettled steam supply affected by digester and other loads on the mill's older boilers. This weakness will be attacked shortly through the addition of DeltaV automated boiler controls that can better anticipate and react to load changes.

GRAPHICS OPTIMIZED. In addition to capturing operator best practices through engineering and automation, the DeltaV workstations feature a standard graphic layout segmented by functional areas for clean and easy access. For example, supervisory and static information is in one area on all screens, process information in another, alarms in a third, and changes in a fourth. A Navigation/Information bar separates the areas from one another.

Graphics are further divided into mill areas so operators need not skip from page to page. Because many easy-to-forget routines must be followed during startups, prompts and checklists precede the added one-button starts. Additionally, hyperlinks are included with many device icons so operators can pull up PDF-formatted descriptions of interlocks affecting those devices.

Maintenance screens are similar, allowing technicians to pull up related loop sheets and motor elementaries. Because operators and technicians have access to each other's screens, they now work better together in solving problems. Lastly, trend graphs and a historian indicate what happened in previous shifts. ■

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