Smart Enterprise™ – putting pulp & paper mills in *'Autopilot' mode*

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Paper mill managers and machine operators have long dreamt of an 'Autopilot' mode for operating the entire pulp and papermaking process. Push a button and the computerized system takes care of the whole mill's operation until the button is pushed again for manual control. So far this has remained a dream. ABB's Smart Enterprise™ system is the first step towards making it a reality.

Smart Enterprise capability extends from simple control – such as maintaining constant flows or consistencies – to ensuring maximum production capacity, highest quality and best economics, automatically and all the time. When bottlenecks occur, Smart Enterprise minimizes them on-line, for a single process as well as for the entire plant – ie, the fiberline, secondary fiberline, pulping, paper machines, power and recovery. Local optimization and high-level control is accomplished for various parts of a mill by sending setpoints to a distributed control system. This is done hierarchically, with single PID loops or model-based process control executing strategies. To make advanced optimization possible, extensive signal and process diagnostics are also implemented.

Optimization, diagnostics and high-level control software reside in a platform-independent environment. Communication is possible from this platform to ABB purpose-built control systems or to other control and information systems.

Functions

Until now, optimization and high-level control have been accomplished mostly locally, with very little integration of the different parts of the mill. Large amounts of information are gathered in the control and information systems. Smart Enterprise uses this information to optimize the whole plant.

Smart Enterprise starts by running an on-line simulation of the entire plant, using advanced mathematical models combined with adaptive empirical models and different diagnostic tools. The actual status of valves, pumps, levels, flows, pressures, temperatures, power consumption, consistencies, etc, is received from the distributed control

1 ***ABB's Smart Pulp Platform with different quality sensors provides the information required for better and faster control.***

system. Flows, pressures, levels, consistencies, and so on, are calculated and compared with actual measurements. Differences between calculated and actual control system readings are stored and analyzed to monitor sensor, equipment and process performance. When differences exceed certain levels, Smart Enterprise takes whatever action is necessary to diagnose the root cause, sending the results of the analysis plus alarms to the operator.

There can be several reasons for the distributed control system indicating that a flow is unexpectedly decreasing: a valve that is partially clogged; a pump not working at full capacity; or perhaps drift in the flow meter. The system will respond by changing the valve opening setpoints, after which the resulting pump energy consumption and change in flow meter reading are measured and analyzed. This provides knowledge about the most probable cause of the deviation. Advice is given to operators and maintenance people on how to fix the problem, or the system addresses the problem automatically if in automatic mode.

By monitoring process and sensor performance, disturbances can be detected at an early stage, enabling adjustments to be made before the situation develops into a bigger problem. It will also be possible to determine the root cause of a problem after a breakdown by analyzing the data and logging the experience into the system, thus avoiding the same problem later. This complements diagnostic tools for sensors and equipment.

If the analysis shows a sensor (eg, a consistency meter) reading to be wrong, a calculated value for the consistency is used for control until the sensor is fixed. The conventional strategy in such cases is to run operations manually when a sensor reading cannot be trusted. However, manual running is not likely to improve the process without actual knowledge of the process status.

Inputs for diagnostic analysis are received from field instrumentation and drives, as well as special sensors and scanners such as ABB's Smart Pulp Platform 1, Cooking Liquor Analyzer, Smart Sensors and Platforms and Smart Advisor System.

System structure

The Smart Enterprise system is outlined in 2. Control data is collected from the process and sent to a database, where it is stored. Snapshots – ie, all data from one single point in time – are sent to the calculation area. Here, there is a mathematical model of the whole plant, including the equipment, pressure flow networks and sensors, etc. The equipment models are built in a modular fashion and the mill model is built with objects, all the functionality of each separate piece of equipment being included. These are represented graphically by icons on the screen, and the process model is built using drag-and-drop techniques. Advanced or simplified models as well as connections are configured. Connections are configured graphically directly on the screen.

The actual programming code is written so that it can be run on any operating system, such as Microsoft Windows NT, Linux and others. The code, running primarily on a personal computer, communicates with the database or directly with the distributed control system through communications standards such as OPC, OMF or TCP/IP. This makes it compatible with older as well as future control systems.

New, advanced control functions for different plant areas

Advanced digester control has traditionally concentrated on measuring kappa numbers with tools such as ABB's Smart Pulp Platform, and minimizing kappa number variation by controlling the H-factor (the time integral of the cooking temperature). This has been accomplished with ABB AutoCook software for both continuous and batch digesters in many installations worldwide.

With Smart Enterprise, the cooking liquor is analyzed on-line by ABB's Cooking Liquor Analyzer. This makes it possible to adjust the actual cook with a model that predicts the outgoing kappa number. The model is created by measuring the actual kappa number via the Smart Pulp Platform.

More important is the possibility it offers to fine-tune the cook by analyzing not only the kappa number, but also the dry solids, dissolved lignin and residual alkali in-feed, re-circulation and extraction liquors. With these measurements, it is possible to optimize cooking, achieve optimal strength and obtain a high yield. Chemical and energy consumption can then be minimized, with obvious economic benefits. This new software package is called Smart AutoCook.

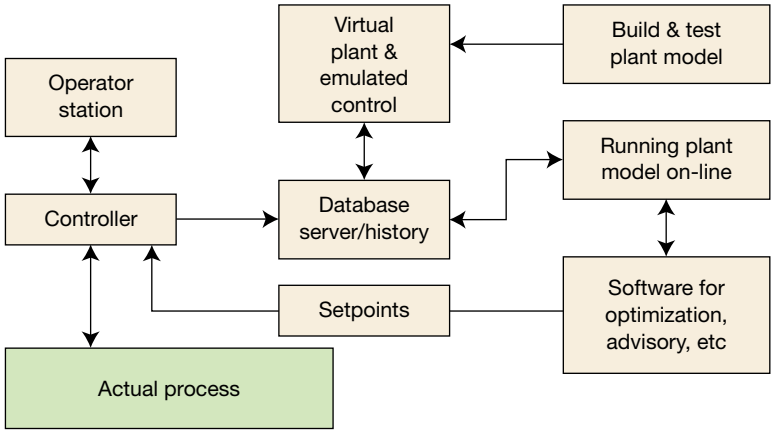
These measurements, together with pressure, temperature and flow inputs, are used in the diagnostic system to monitor the performance of the digester and related systems.

With ABB's Fiber Tracking System, fibers are tracked through the fiber line and down to the paper machine, making it possible to relate cooking conditions to paper properties. This data can be combined with other paper machine measurements to provide the operator with comprehensive process information and allow optimization of the entire process.

In the bleach plant, the focus has traditionally been on feedforward control for the incoming kappa number and mass flow rate, and fine-tuning feedback using the final brightness. With Smart Enterprise, this extends to variations in the bleachability of the incoming fibers, which is correlated with near-infrared spectra and the kappa number measured with the Smart Pulp Platform. The result is a significant saving in bleaching chemical, as well as minimized environmental impact and maximized fiber strength.

In the stock preparation area and wet end area of the paper machine, ABB traditionally controls the refiners to keep freeness variation low. With Smart Enterprise, freeness and energy consumption are measured in the refiner area, while the Smart Pulp Platform is used to measure the fiber size distribution and near-infrared spectra. The results are combined with the paper strength data measured on-line with Pulpexpert and with lab samples from the reel.

Fiber samples are taken with the Smart Pulp platform before and after the refiners, and with Pulpexpert before the headbox. Other important measurements include the fiber orientation, which is measured with ABB's new innovative, laser-based Smart Fiber Orientation Sensor, vacuum pressure, backwater flows, and retention in the formation/wire section. Many other measurements in the stock preparation and paper machine areas, such as wire speed, feedstock consistency and paper weight, are also included in the analysis.



2 ***Smart Enterprise™ system structure***

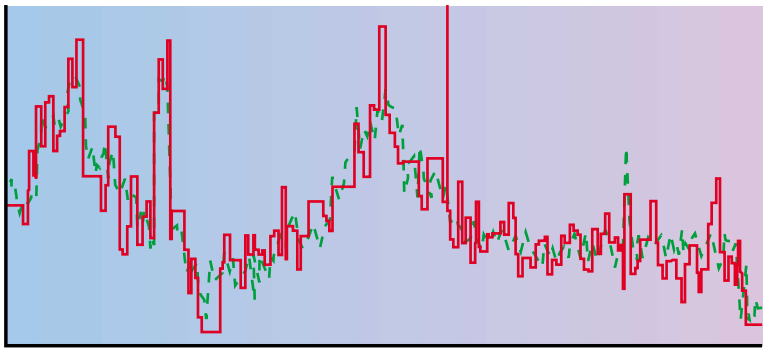
On-line paper strength measurement, as well as laboratory measurement of strength, brightness, surface smoothness and other properties, are correlated with stock measurements using multivariable data analysis. A polynomial is generated that predicts paper properties on the basis of the measurements and provides operating setpoints for the approach flow and paper machine.

Refiner setpoint adjustment, retention aid addition and vacuum pressure/flow control in the boxes are accomplished. Control is dependent on long-term variations, such as the refiner disc status and wire permeability, as well as on short-term variations, ie different stock mixes and fiber quality variations. Variations in chip quality and fiber tracking are especially important. Fiber history from the digester area through the mechanical pulp refiners (or waste fiber pulpers) is collected and used to predict properties for the stock preparation area.

Control is accomplished with ABB's new Multivariable Process Control using proprietary, interactive algorithms that optimize all the major variables. Dry end control is integrated with information from the fiber lines, stock preparation and wet end, and optimized accordingly.

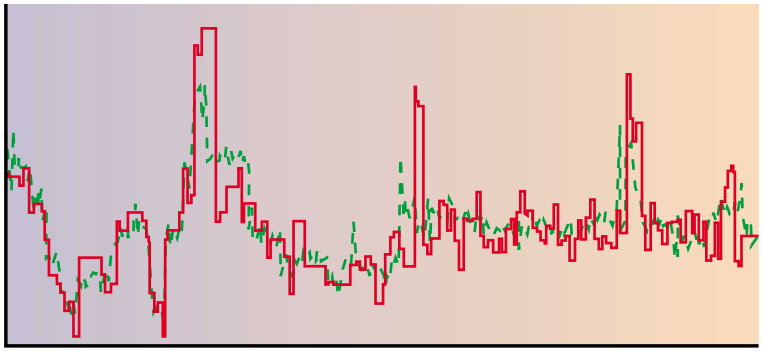
In the recovery area, new functions have been implemented for the recovery boilers, power boilers, limekiln and causticization. ABB's new Multivariable Process Control is used here as well. ABB also uses fuzzy logic, taking into account different setpoints for varying operating conditions. All in all, ABB's Smart Enterprise allows new, more sophisticated operation of the entire mill.

As mentioned earlier, the advanced control outlined above is not possible in the long term without good monitoring of sensor performance and status. Correlating different sensor measurements with the on-line simulation model achieves this. Mathematical models are built to model the basic behavior of certain equipment, but absolute correlation with the real process is accom-



3 *Results of a tear index test with Smart Enterprise. Laboratory measurements (red curve) versus predicted values (green curve) for a four-month period*

4 *Tensile index test comparing laboratory measurements (red curve) with predicted values (green curve) for a four-month period*



plished with an offset adjustment. This can be updated automatically using the collected data and performing what is called 'parameter estimation'. This is especially interesting if the process is rebuilt, as it enables the models to be automatically re-tuned without extensive manual work.

Overall optimization

Long-term production planning provides the input for overall optimization. This takes the form of: 'What qualities have to be produced by a certain date?' From this information, Smart Enterprise optimizes equipment settings to maximize production. If a pump fails or equipment performs badly, Smart Enterprise minimizes the negative impact. This takes into account the effect of running with a higher load, which may reduce production later. Thus, optimization is not just for the time being, but for the future as well. Optimization includes making the best use of all storage volumes by providing ramp-up setpoints for different parts of the mill, eg for handling grade changes, production changes, etc.

To optimize the plant as a whole, setpoints are sent to different parts of the mill, where specific ABB control software and systems carry out local optimization. Best use is therefore made of all available capacity in the plant. A bottleneck in one part of the mill will affect other parts at some point, which then also become bottlenecks. ABB Smart Enterprise helps to eliminate this problem.

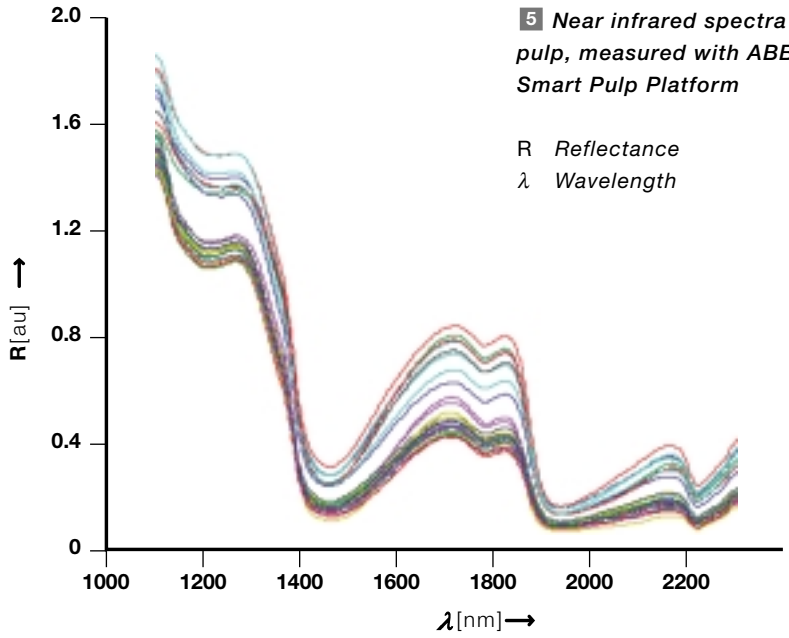
Strategies for overall mill optimization are tested and refined with the 'virtual plant' before being implemented in the real plant. This virtual plant is used later for on-line optimization with actual input from the control systems. Different types of potential faults can be entered to see if the system can detect them and compensate for them.

Experience

Smart Enterprise is being implemented in 2001 in a fully integrated Australian greenfield project: Visy Paper's Tumut mill. The mill has both a low-solids continuous digester fiber line and a waste fiber line. The recovery area has a recovery boiler and limekiln, as well as a bubbling bed bark boiler from Kvaerner. The Voith paper machine will produce two-layer paperboard. Total production will be 240,000 tons per year. Visy has visionary management, and they have joined with ABB in this project to build the most automated mill in the world.

For the mill, ABB will provide all the electrification, air handling and energy management equipment, field instrumentation, special instruments, drives, distributed and quality control systems, as well as the Smart Enterprise system featuring advanced control, on-line simulation, optimization and the Smart Advisor diagnostic/action system.

ABB has tested many elements of Smart Enterprise in different installations since 1996. They include the dynamic process simulators, advanced controls and soft sensors measuring near-infrared spectra and fiber size distribution with the Smart Pulp Platform, before and after the refiners. Sack paper strength predictions were made for a four-month period in one mill. Different grades were



5 *Near infrared spectra of pulp, measured with ABB's Smart Pulp Platform*

R *Reflectance*
λ *Wavelength*

run, as well as controlled variations during operation, to study the correlation between the predictions and measured values **3**, **4**.

The near infrared spectra for pulp shown in **5** have a number of absorption peaks representing different chemical compounds (cellulose, hemicellulose, lignin, water, etc) and, to some extent, the fiber size distribution. This is why combining near infrared spectra with fiber size distribution and other process measurements is able to provide such good correlation with different paper properties, such as strength.

In the same mill, advanced signal diagnostics were used to detect different sensor problems and to diagnose control loop performance.

At other mills, ABB's new Multivariable Process Control has been implemented for bark boilers and power plants, and will soon be started up with advanced bleach plant control. Here, both the kappa number and near-infrared spectra are measured with the Smart Pulp Platform, and ClO_2 demand is diagnosed not only on the basis of the kappa number, but also the bleachability. This is a totally new concept providing significant economic and quality advantages as kappa number and fiber variations are minimized.

Benefits

Advantages of using the new Smart Enterprise System include increased production, better quality and reduced chemical and energy consumption. This is due to the combination of Smart Advisor diagnostic/action system, optimization, advanced control and special instrumentation. The saving can vary as it is dependent on the actual processes and products. Figures can be in the order of 10-50 US$/ton.

Summary

ABB is implementing a totally new 'Smart Enterprise' concept, using complete mathematical models of all major processes along with actual measurement inputs, to achieve total plant optimization. By bringing together the most comprehensive control and information system offerings for the pulp and paper industry and its own extensive pulp & paper process experience, ABB is uniquely qualified to implement this total optimization concept.

ABB is taking up the challenge: combining ABB systems, software and services into an integrated overall system is a major step towards making the 'Autopilot' dream come true for pulp and paper makers. ■

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