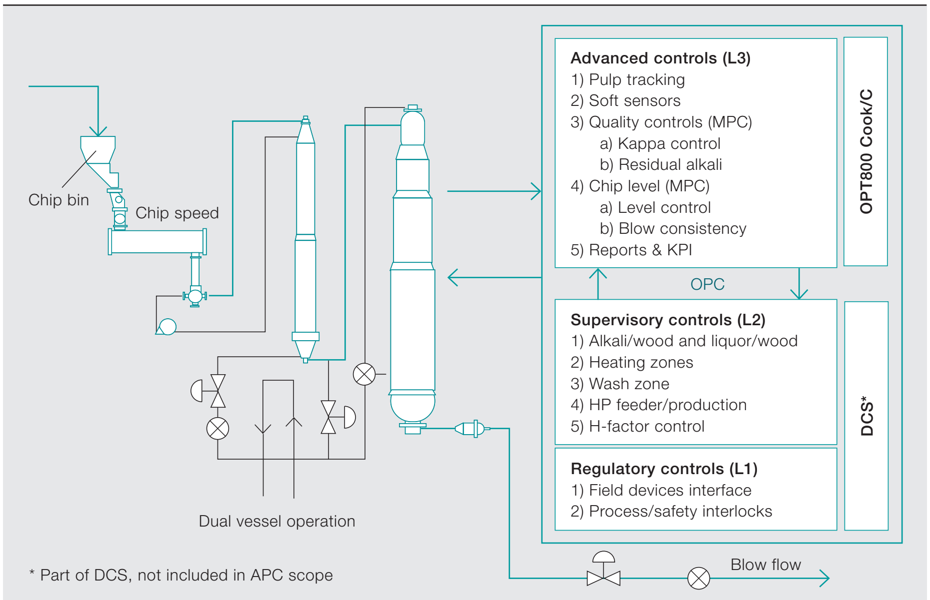
Pulp mill optimization no longer pulp fiction

Producing high-quality pulp consistently with advanced process control

ABHIJIT BADWE, RAMESH SATINI – When Mondi – the global paper and cardboard producer – decided to modernize their largest pulp mill in Poland, they chose ABB as partners to help improve and optimize the mill's two pulp production lines. For this undertaking, ABB developed an advanced process control solution based on model predictive control and soft sensors. The modernization resulted in an improvement of 56 percent in pulp quality as well as standardized solutions that can now be offered to other pulp mills.

1 Digester APC



In 2011, Mondi embarked on a project to look for ways to improve pulp quality and chemical usage, enhance production and reduce cost for its two pulp production lines in the Mondi Swiecie pulp mill. A number of factors played a role in this search. One was the company's policy of reducing the environmental impact of its operations – and in pulp mills this means cutting the use of heat energy and chemicals. A second factor was the requirement to improve the quality of the product. Mondi Swiecie mostly makes containerboard, corrugated packaging and industrial bags, which are surprisingly high-tech products. Thirdly, there were the universal goals of all industrial processes: increasing production volumes and decreasing production costs.

In 2011, Mondi Swiecie awarded ABB a contract to improve the quality and efficiency of its pulp mill. To better understand the challenge involved in this task, it pays to take a closer look at how the pulp process works.

Separating cellulose

The raw material for cardboard and paper is wood. The purpose of the pulping process is to separate the valuable cellulose fibers in wood from the lignin and hemicellulose polymers that bind them. Traditionally, this was done by physically beating the wood, but nowadays chemical methods are used – not least because they better preserve the integrity of the cellulose.

The process begins by stripping the wood of its bark, turning it into chips, screening the chips to achieve a roughly similar size, impregnating them with chemicals and feeding them into a pressure cooker (the digester).

In the sulfate process used at Swiecie, the chips are mixed with a solution of sodium hydroxide and sodium sulfide (known as white liquor), pressurized and heated to a temperature of about 160 °C with steam from coal-fired boilers. After a few hours, the material takes on the consistency and color of porridge and the amount of alkali in the sodium hydroxide decreases as it is turned into sulfates and carbonates as a result of reacting with the lignin in the wood.

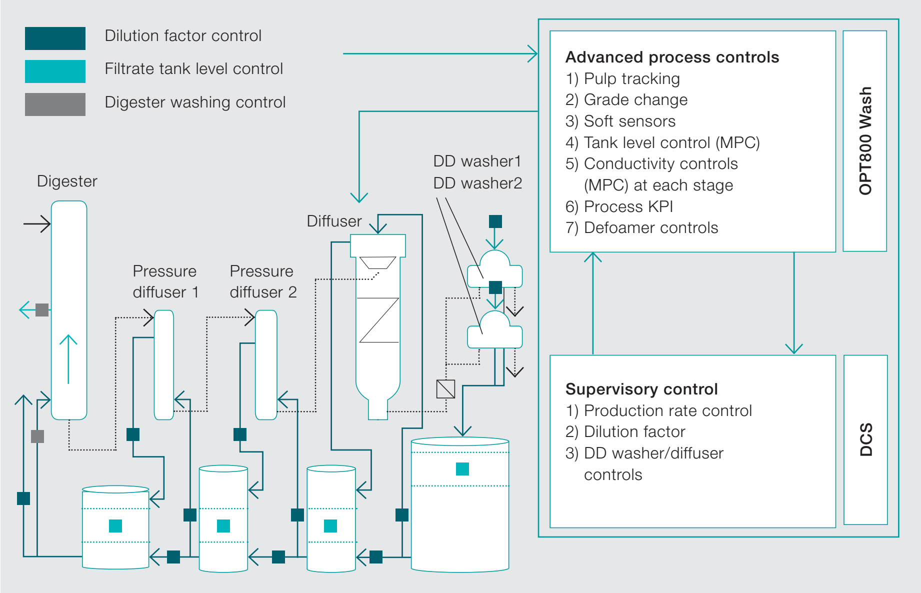
At the end of the process, the pulp is squeezed out of the digester through an airlock called the blow line. The sudden depressurization results in the rapid expansion of the cellulose fibers, which helps to separate them. They are then suspended in a liquid that is known to pulp workers as brown stock.

The next stage of the process is to "wash" the brown stock to remove the cooking chemicals (now referred to as black liquor) together with the degraded lignin and hemicellulose. After progressing through a number of tanks, the extracted liquid is reduced and its sodium and sulfur compounds recovered to make more white liquor. Meanwhile, the clean cellulose pulp is bleached, if necessary, and then pressed and heated to remove water, after which it is ready to be cut and rolled or bailed for further processing.

> One of the first things that the newly formed Mondi Swiecie did was look for ways to improve the pulp mill's production process.

Title picture
Advanced process control at the largest pulp mill in Poland has increased productivity – and stabilized the processes in the cooking and pulp washing lines in a way that conventional methods of DCS control could not.

2 Control overview – washing APC



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How to improve the process

The challenge was to make the process work more efficiently and to higher tolerances without replacing anything except the control system that operated the existing equipment. The key to this was to optimize the operation of the two lines' digester and brown stock washing stages. The first step was to audit and analyze the control loops, then develop an advanced process control (APC) action plan based on model predictive control (MPC) and soft sensors.

The cooking process

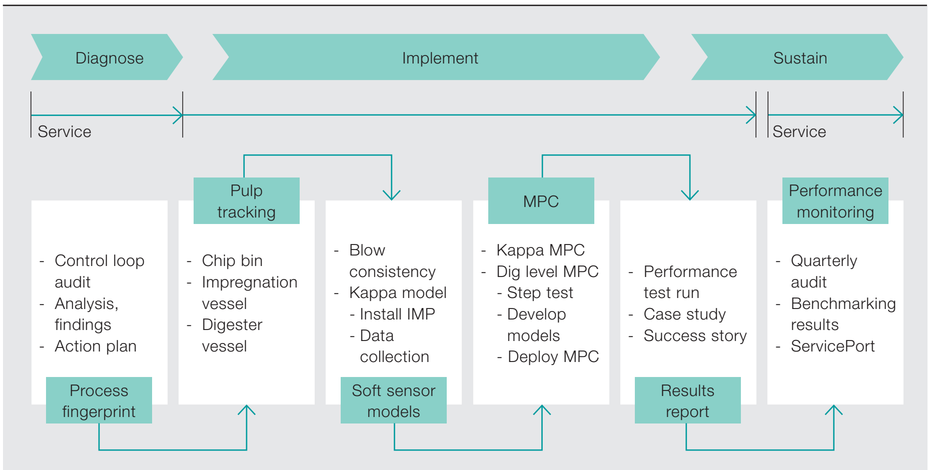
For the digester, the key variable for product quality is the Kappa number – this measures the lignin level in the pulp and thereby indicates how well the chips have been cooked. This number is difficult to control for two reasons. Firstly, because all the chips that are fed in have different moisture content and physical characteristics. Secondly, the Kappa number cannot be physically measured in the digester, but only after the chips have passed through it and entered the blow line. This is a problem because it is essential to know what the Kappa number is before this point. Like anything else that goes into an oven, the pulp has to stay there for just the right amount of time – long enough to yield as much cellulose as possible, but not so long as to break down its physical structure.

Therefore, to maintain a steady process with minimal variations in the quality of pulp, the Kappa number has to be arrived at by taking continuous measurements of the various process variables before the chips enter the digester and feeding these numbers into a mathematical model (or soft sensor) that considers the multiple nonlinear process effects.

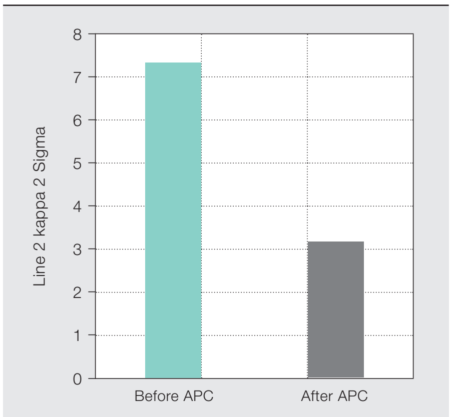
This is what ABB's solution does → 1. The advanced process control scheme employs a soft sensor – based on ABB's Inferential Modeling Platform – that yields soft measurements of the Kappa number from a series of process variable measurements. These measurements are tracked using a tracking function that creates a virtual model of the chips on their journey through the digester. Along the way, measurements are derived from the chip's characteris-

ABB's APC solution maintains the chip level by optimally manipulating the digester bottom scraper speed and the pulp flow out of the digester.

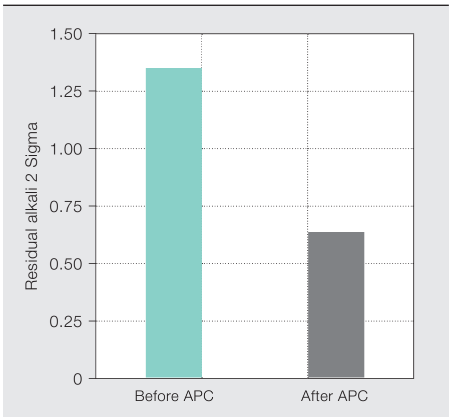
3 APC implementation approach



4 Reduction in Kappa Variation (2 Sigma)



5 Reduction in residual alkali variation (2 Sigma)

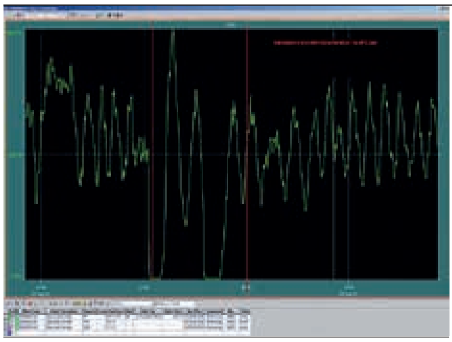


tics and these are fed into the model to predict the Kappa number in every zone of the digester. The soft sensor is deployed online and yields real-time virtual measurements of quality variables (such as the Kappa number) that are then used by a model predictive controller to optimize the cooking process, to decide the length of time the chips are exposed to a given concentration of effective alkali and to keep the concentration of alkali the same throughout the digester vessel. The APC is also able to maintain a consistent production rate of pulp. Finally, a log of the data that has been collected is packaged into concise reports, complete with measurements of key performance indicators.

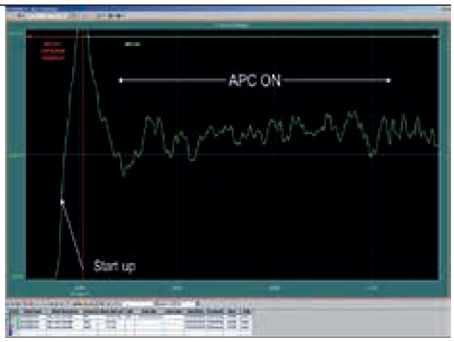
Another important variable in the continuous cooking process is the level of chips inside the digester. Variations in this chip level leads to nonuniform cooking, disturbances in the overall liquor balance of the process and nonuniform pulp flow at the digester outlet. ABB's APC solution maintains the chip level by optimally manipulating the digester bottom scraper speed and the pulp flow (or blow flow) out of the digester.

The first step was to audit and analyze the control loops, then develop an advanced process control action plan based on model predictive control and soft sensors.

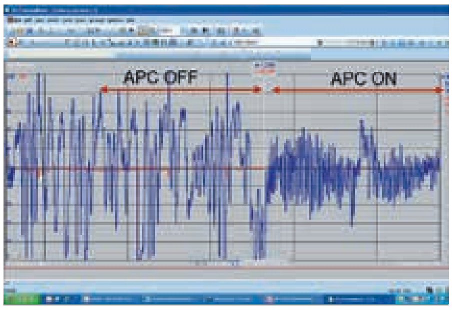
6 APC stabilizes chip level



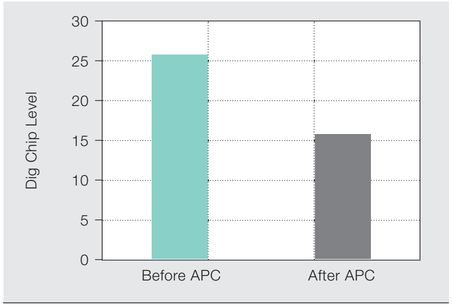
6a Chip level with no APC



6b Chip level with APC



6c Process stability is greater when APC is on.



6d APC leads to reduced digester chip levels.

The approach followed to achieve Mondi's objectives was based on ABB's Advanced Services philosophy – diagnose, implement and sustain.

While the APC is handling these complex measurements, making real-time predictions about the process and implementing optimal control actions, the ABB Extended Automation System 800xA distributed control system (DCS) handles the basic controls such as liquor and chip flows, temperature, pressure, etc. It also performs the vital job of controlling the H-factor – that is, the rate at which the lignin is being dissolved. As this is largely a function of temperature, the amount of heat applied to the digester has to be closely controlled. A variance from the optimal of just a couple of degrees can make a big difference to the quality of the pulp.

The obvious advantage of the APC and the DCS is that the outcome meets all of the customer's requirements for this step of the pulping process. The fact that just the right amount of steam has been added and just the right volume of white liquor or alkali injected means that as much waste as possible has been squeezed out of the process. And as the maximum amount of highest quality cellulose has been produced, the quality and quantity criteria have been met as well.

The brown stock washing process

The second key area where optimization has been achieved through an APC system is the brown stock washing. As with the digester, the data is gathered on a continuous basis so that soft sensors can give predictive readings of what is taking place.

The aim in this stage of the process is to control the levels in the numerous filtrate tanks so that just the right amounts of fresh water are added for each ton of brown stock to be washed (this is known as the dilution factor). If an optimal value for this variable can be continuously solved for, then the maximum quantity of the cooking chemicals can be recovered and the minimum amount of energy used in the evaporators. The alkali losses will also be reduced. This is achieved by the brown stock washing APC → 2, which computes the optimal dilution factor at each washing stage based on pulp conductivity measurements at various locations in the process; at the same time, it ensures that the levels in the filtrate tanks are within their specified ranges. As with the digester, the information gathered throughout the operation is presented to the control room in the form of key performance indicators.

The implementation methodology

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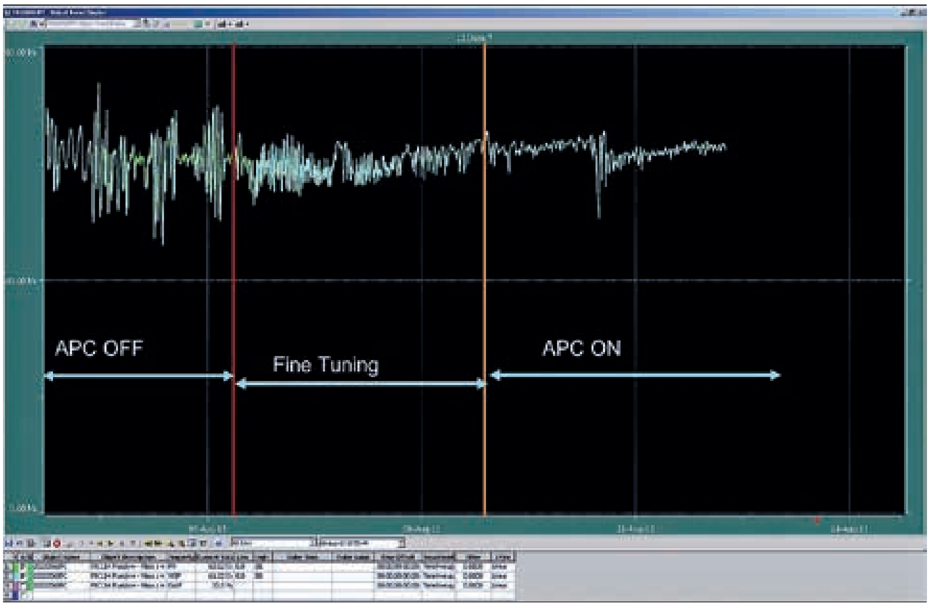
7 APC stabilizes blow flow



The diagnose phase involved performing a detailed audit of the process and control loops at Mondi Swiecie, which led to the development of a specific action plan for implementing the APC system.

The implementation phase involved the deployment of the pulp tracking function in the DCS followed by the development of online soft sensors to model the Kappa number. Subsequently, step tests were carried out on the process to develop mathematical models for use in the model predictive controller, which was then commissioned, tuned and handed over to the mill operators.

The APCs are currently in the sustain phase, in which ABB helps Mondi maintain the optimal performance of the APCs by performing quarterly audits, remote monitoring and online retuning.

A similar approach was followed for the implementation of the APC in the washing area.

The result

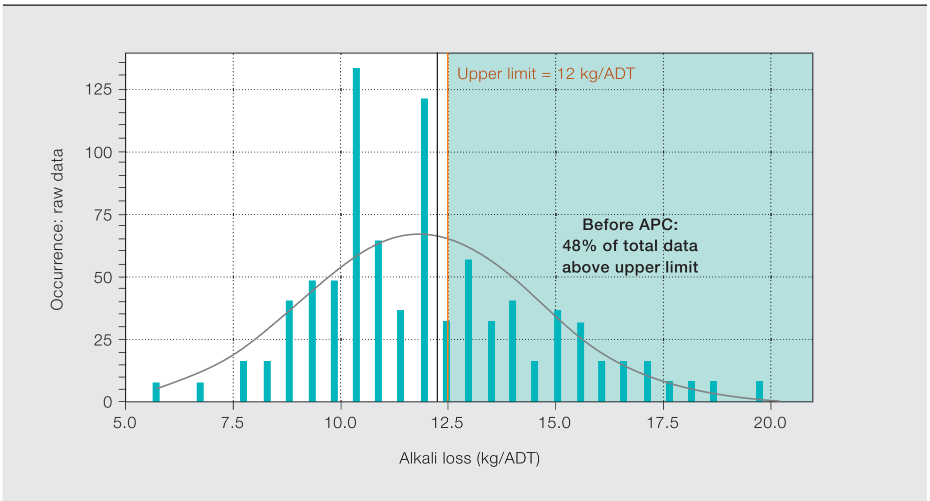
This work was carried out in phases between August 2011 and December 2013, by which time the system was completely installed and tested. During this process, the pulp mill's engineers were kept fully engaged to make sure they were confident in using the APC and were able to adapt their working and training practices to make best use of it.

Once the entire system was up and running, it was possible to arrive at some quantitative measures as to how well the objective had been fulfilled:

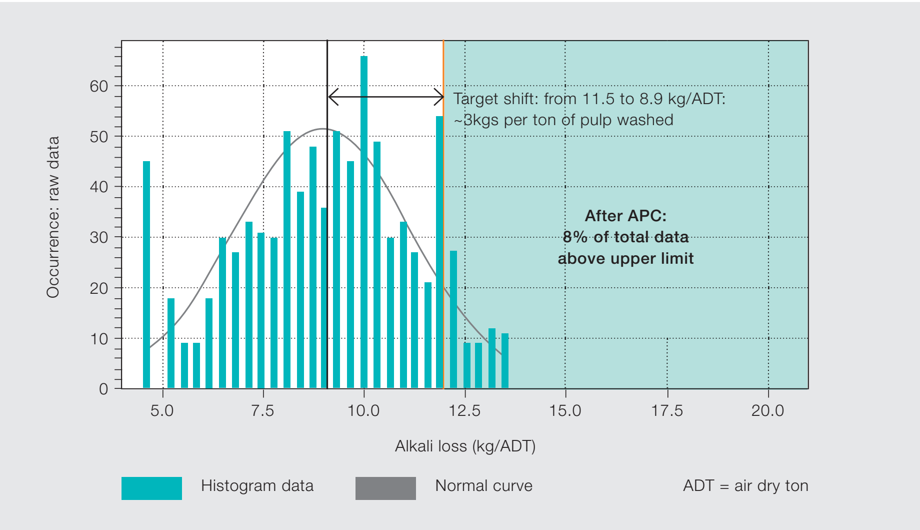
– Variations in the Kappa number in the digester were reduced by 56 percent, meaning that the APC has helped produce pulp of a consistently high quality → 4.
– Variations in residual alkali fell by 48 percent, implying a better utilization of white liquor in the cooking process → 5.
– Variations in the digester chip level were cut by 40 percent → 6, resulting in reduced variations in the blow flow → 7. This has led to much more stability in the pulping and washing processes.
– A 30 percent reduction in alkali losses in the washing proces was achieved → 8.

The obvious advantage of the APC and the DCS is that the outcome meets all of the customer's requirements for this step of the pulping.

8 APC reduces alkali losses in brown stock washing



8a Before APC



8b After APC

- The volume of fresh water used in the washing area and consequently steam consumption by the evaporators were both reduced.
- Washing filtrate and blow tank levels were stabilized, resulting in a reduced carbon dioxide and effluent load.

The whole process of solving the optimization problem and having that solution validated by the mill itself has made it possible for ABB to offer standardized solutions to other pulp mills – these solutions are now called OPT800 Cook/C for continuous digesters and OPT800 Wash for brown stock washing.

Finally, the APC solution has proved to be a door opener not only for other APC opportunities but also for System 800xA DCSs as well. One recent example is a DCS order for the world's largest pulp and paper mill, which is being set up in Indonesia. One of the key customer considerations was to have a proven APC solution on top of the DCS – the Mondi Swiecie project provided this.

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