Proactively control retention and reduce ash variability with ABB's Wet End Control (WEC)

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A paper machine is a highly complex industrial system, including a plethora of highly interrelating processes. A typical system includes a stock preparation area where pulp from different sources are individually refined to produce fibres of consistent properties and to optimise the freeness. The refined pulps are then blended in an appropriate ratio. Then, in the short circulation system, chemical additives and various fillers are added to the pulp to ensure that paper quality and strength parameters are within specifications. Whitening or colouring agents are also added, as required. In the wire section, the treated fibres are uniformly distributed onto a forming wire where water is drained by gravity as well as suction. Next, in the press section, further dewatering is achieved by passing the sheet through a series of rolls that press against each other by utilising water absorbent felts that support the sheet as it passes through the rolls. In the final, dryer section, steam heated cylinders are used to evaporate any remaining moisture and to form a sheet with uniform thickness and smoothness.

As described, forming of a paper roll involves a series of highly complex processes and a misstep in any of these areas will lead to a defect in the sheet forming or weakening of the paper web, eventually leading to a sheet break or rejection due to poor quality. For this reason, advanced process control to help monitor and analyse the wet-end processes can significantly reduce downtime, the usage of chemical additives and production costs while at the same time increase production.

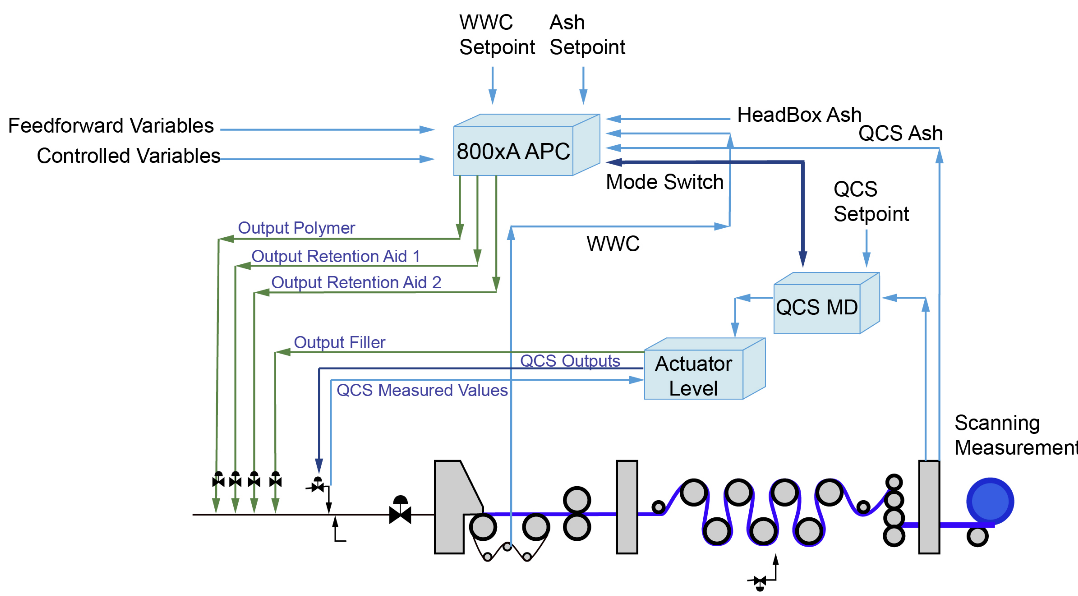

Figure 1. *ABB's Retention Management control architecture. The paper machine wet-end included the addition of two different retention aids, a polymer and clay. An MPC strategy was formulated to control the paper ash and white water consistency by manipulating the 4 different chemicals. All models were estimated using step test data obtained from the paper machine. The model matrix is shown in Figure 2, along with the step responses.*

CASE STUDY

This was the case at an Indonesian mill, at one of the world's largest paper manufacturing groups, known for using cutting edge technology to produce a wide range of high quality paper products.

In order to achieve the customer's objectives, namely improved wet-end stability, lower product variability, lower chemical usage, and improved machine runnability, an MPC (Model Predictive Control) strategy was implemented (see Figure 1). There is a wide scope for proactive control by implementation of advanced control strategies like MPC. The biggest benefit of proactive control is improved process stability at a lower operational cost. Although, most industrial applications are still limited to reactive control schemes that offers mainly single-input single-output control.

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For the Indonesian mill, savings of 10% in filler consumption, 20% in

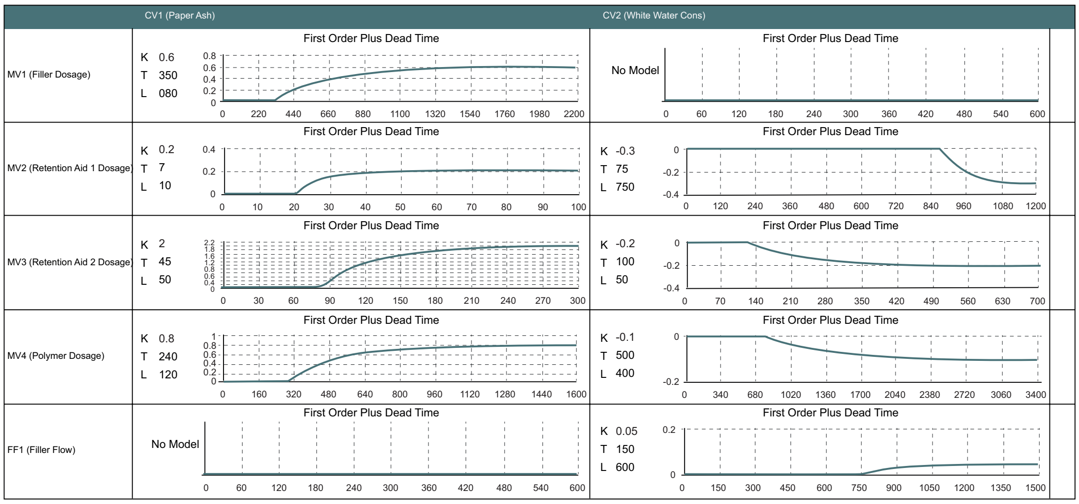

Figure 2. *APC Model Matrix*

retention aid consumption, 15% in polymer consumption, 10% production increase, 10% in sheet break reduction, and a decrease in production cost of $2.50/ton were achieved by effective control of the paper properties with 800xA APC Retention Management. Additionally, optimising the usage of chemicals and utilities, significantly reduced downtime and hence production costs.

ACTIVE RETENTION CONTROL

A variety of retention chemicals and fillers are added to the pulp to ensure that paper quality and strength parameters are within specifications. In addition, from the economic viewpoint, it is important to achieve this with minimum consumption of the various chemicals. Moreover, disturbances such as change in pulp properties, machine speed and product grade add to the complexity of the problem. Because of the nature and dynamics of the wet-end process, even small disturbances can destabilise the process and lead to significant downtime. A poor wet-end stability can have a comprehensive effect on the paper quality and lead to a substantial increase in product rejects.

The fundamental to achieving wet-end stability is maintaining optimal retention, for a given paper grade.

By active retention control, we aim to stabilise the basic short circulation chemistry and reduce the ash variability. This stability is paramount to ensure both paper machine runnability and the quality of produced paper. Fluctuations and variations in the short circulation system have a direct impact on the paper quality in both machine- and cross-direction. Ash variability in the wet-end affects paper quality parameters such as porosity, optical properties as well as strength. This variability will cause problems downstream in the coating and printing sections of the paper machine. The runnability of the paper machine is largely determined by the cohesiveness of the wet web, which enables the web to form along the wires and fabrics. The retention aids and coagulants added to the system ensure optimal cohesiveness and make sure the web doesn't break during the forming process. In Figure 3 typical factors affecting ash and retention are schematically shown.

FACT BOX

Through the application of the developed strategy across different paper machines, typical advantages of this control strategy are:

- Reduced filler consumption (10–20%)
- Reduced retention aid consumption (10–30%)
- Increased production (5–15%)
- Reduced production cost ($2–$4 per ton)
- Reduced downtime due to sheet breaks
- Improved wet-end stability
- Reduced rejects due to quality variations
- Smoother transitions and faster grade changes

The fundamental to achieving wet-end stability is maintaining optimal retention, for a given paper grade. In paper machines, retention is defined as the proportion of fibres that remain on the wire to form the sheet after being forced out of the pressurised head box. The fibres not retained on the wire, will flow into the wire pit, i.e. the white water, which usually contains a greater proportion of short fibres than does the fresh feed. The stability of the wet-end is mostly affected by the introduction of broke into the system after a web break. The broke has a significant effect as it affects the proportion of long fibres to short fibres and also brings in a different amount of ash as compared to fresh stock. Also, the broke has been treated with retention aids, and hence the dosages are unsettled, affecting the cohesiveness of the paper web, and

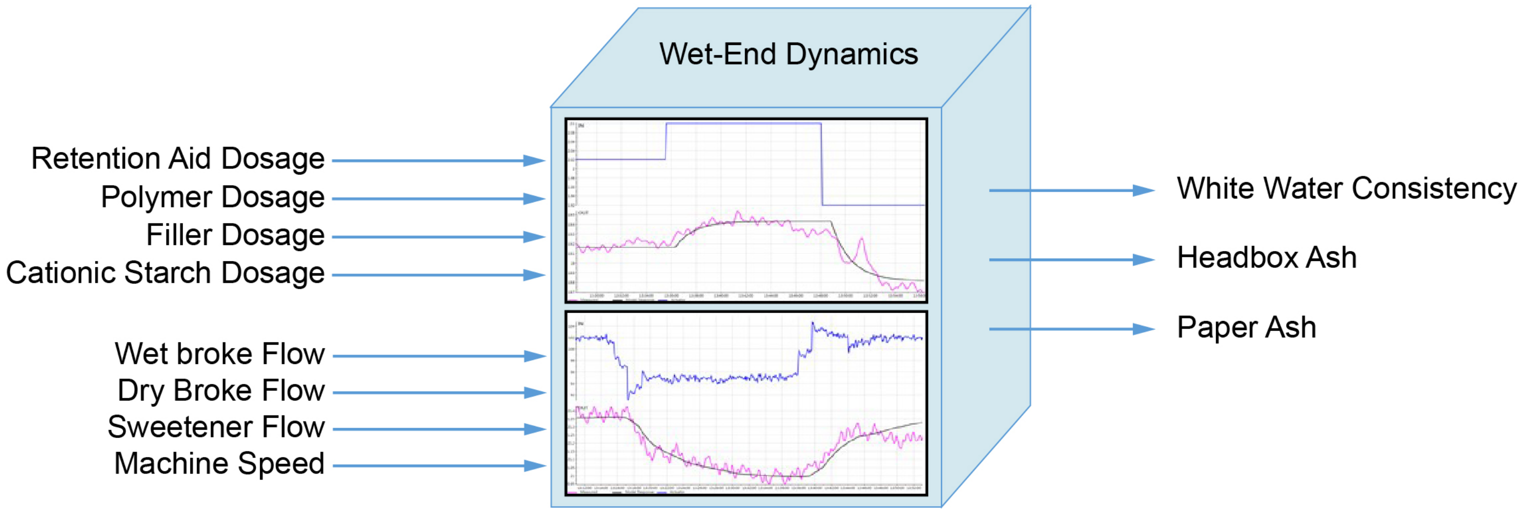

Figure 3. *Typical Wet-End Process Variables*

this is why compensation is required to bring the system back to parity.

There has been significant research and advancements in the area of wet-end control of paper machines in the last decade. The advent of online instrumentation that can accurately monitor the process in real-time as well as the availability of newer additive chemicals that improve the wet-end chemistry offers great opportunities for papermakers to measure and control both the retention and the ash properties of paper. On-line measurement of key wet-end parameters by model predicting enables proactive retention control, which optimally regulates the dosing of retention chemicals and fillers, and stabilises the wet-end.

CONTROL BY MODEL PREDICTION

Model Predictive Control (MPC) is a fairly general class of algorithms for feedback and feedforward control, based on the receding horizon philosophy; in other words, a sequence of future optimal control actions is chosen according to a prediction of the (short-to-medium term) evolution of the system, during the interval **[t, t+p]**, where **t** is the current time and **p** is a system-dependent prediction of the horizon length. The MPC technique utilises a model of the process/system,

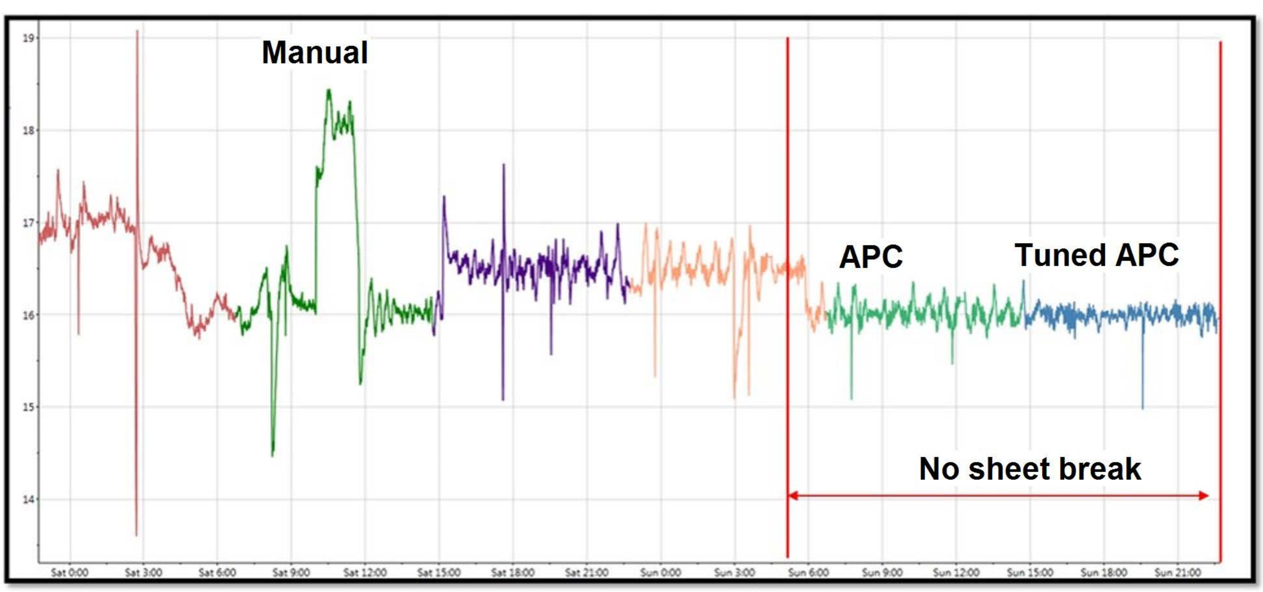

Figure 4. *Performance comparison of paper ash (%) before and after 800xA APC Implementation*

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subject for control, to predict the effect in various process variables, due to actual as well as future changes, in the manipulated outputs and feedforward variables. The sequence of moves for the manipulated variables are optimised in a multivariable fashion where the first term of the sequence is then applied to the plant. When measurements (or new information) becomes available, a new sequence – one which replaces the previous one – is determined. Each sequence is computed by means of an optimisation procedure, with particular regard to two objectives: optimise the performance and protect the system from constraint violations.

MPC is often used for the control and optimisation of industrial processes, and it is one of the building blocks of today's state-of-the-art process industry. The use of these techniques for real plants includes the development of (nonlinear) mathematical models describing the process, and the selection/design of a suitable cost functional, which takes into account the goals to achieve. For instance, the functional might penalise deviations from given desired operating points, or represent operating costs. The optimal inputs to the system are calculated via minimisation of this functional, subjected to the constraints defined by the mathematical model. Clearly, to be successful, the minimisation algorithms must exploit the structure of the problem, as given by the model type and the optimisation functional characteristics.

The dynamic model, which describes the real world process relates to how manipulated outputs (from either the operator or a controller) affects the actual and future process variables. The objective of the predictive control model could be defined as finding a sequence of current and future increments for manipulated outputs that minimises a weighted sum of future squared control errors and a weighted sum of increments in the sequence of manipulated outputs, while limits for manipulated outputs and limits for predicted process variables are considered.

At every iteration the MPC controller needs a good estimation of the plant conditions. Mathematically, it means having a good set of values to initialise each and every state in the model. Moreover, it is often the case that the model contains states that are not directly measurable, but likewise actual measurements are often corrupted by noise and biases. To deal with this problem, observers or state estimators are constructed, by being given

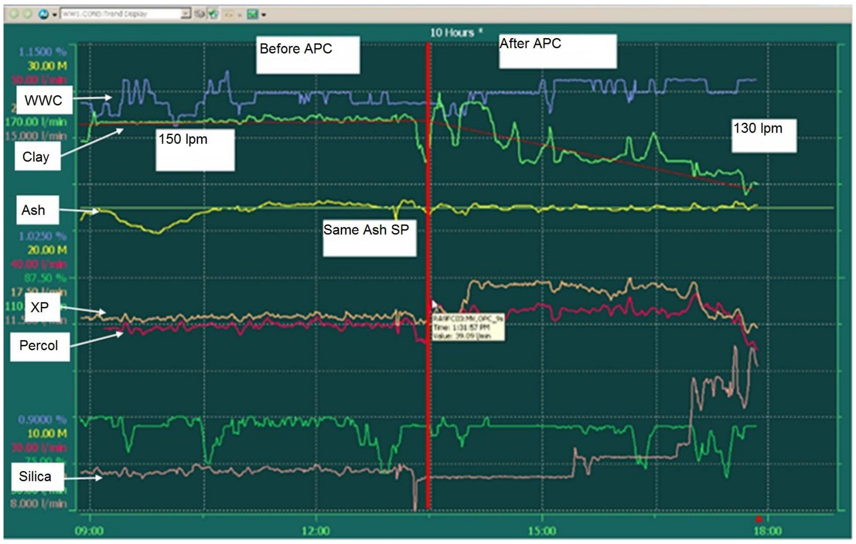

Figure 5. *Performance comparison of paper ash (%) before and after 800xA APC Implementation*

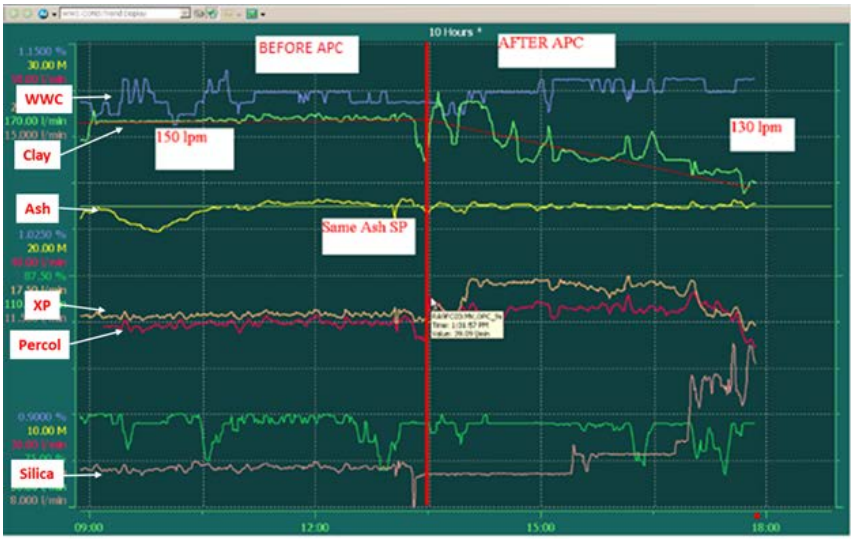

Figure 6. *Chemical Savings after 800xA APC Implementation*

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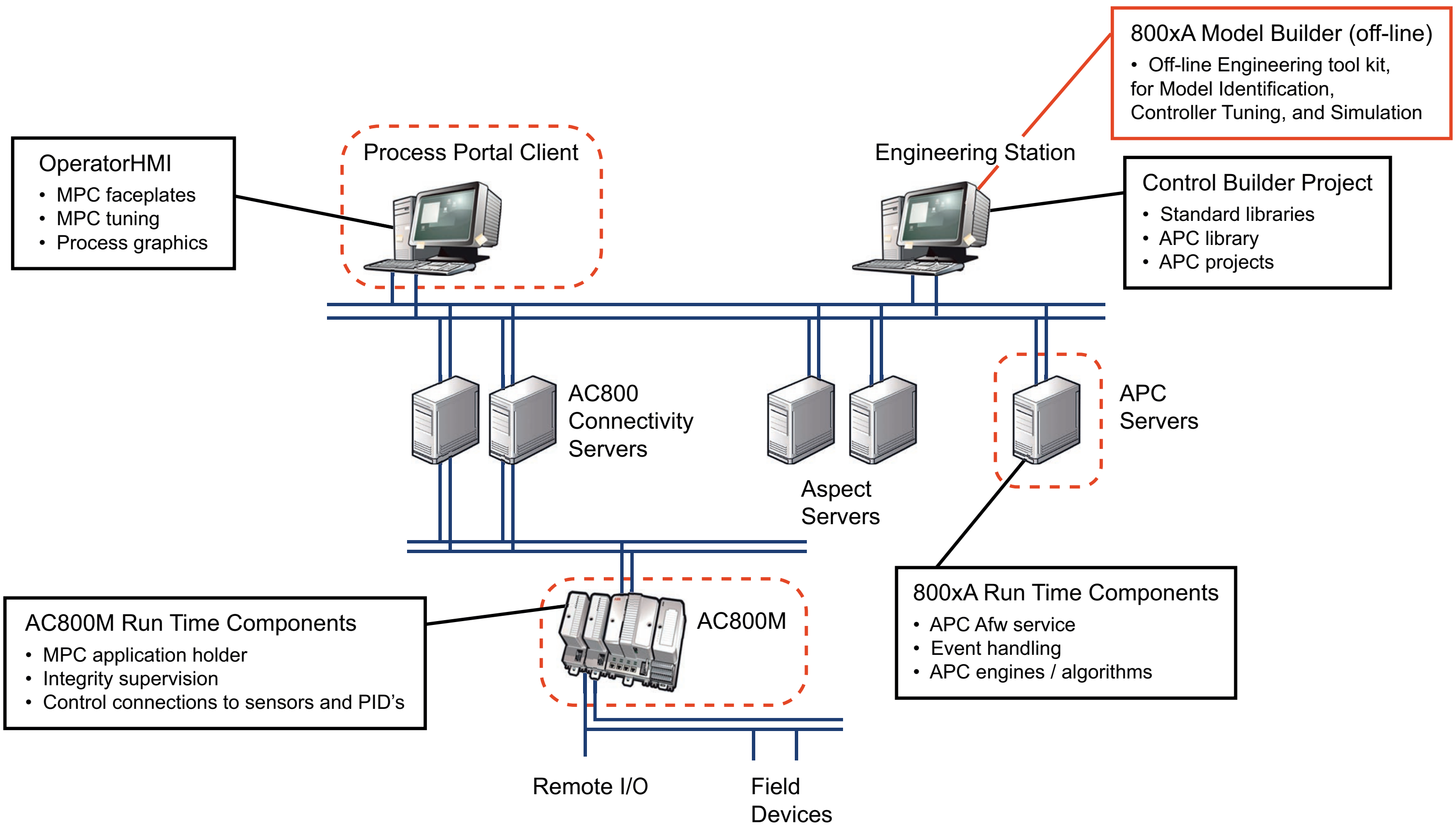

Figure 8. *ABB's 800xA APC System Architecture*

1. The history of actuators' moves and measurements
2. The plant model, including the constraints

The system calculates the trajectory of states that explains the given history and the model.

The performance improvement after the implementation of a well-tuned APC is shown in Figures 4, 5 and 6. There is a marked reduction in process variability after the MPC is switched on. The reduction in variability in paper ash and white water consistency enable operators to improve the set-points and increase/decrease targets as desired, to provide ideal paper quality. Also, there is an immediate reduction in the primary chemicals for the same ash targets. The overall performance improvements are shown in Figure 7.

Criteria	Achieved Improvement
Reduction in Filler Consumption	10%
Reduction in Retention Aid Consumption	20%
Reduction in Polymer Consumption	15%
Production Increase	10%
Sheet Break Reduction	10%
Decrease in Production Cost	$2.50/ton

Figure 7. *Achieved Process Improvements*

ABB's 800xA ADVANCED PROCESS CONTROL SYSTEM

ABB's state-of-the-art advanced process control system 800xA APC, is a model predictive controller that is fully integrated in the 800xA distributed control system (as seen in Figure 8). The tight integration enables the tracking of a plethora of information including, but not limited to, measurements, modes, alarms and events. The enforced MPC application structure ensures minimal maintenance and optimal operational efficacy

CONCLUSION

ABB's Advanced Retention Management System is highly effective in controlling the paper properties as well as optimising the usage of chemicals and utilities, significantly reducing downtime and hence production costs.

The enforced MPC application structure ensures minimal maintenance and optimal operational efficacy.