Digital technologies provide the tools for pulp and paper process optimisation

Ramesh Satini and Abhay Anand describe how digital technology can help bridge the gap between information technology and operations technology

By **Ramesh Satini** and **Abhay Anand**, Research & Development, ABB Singapore

In an increasingly digital world, pulp and paper companies are finding new ways to innovate, automate and optimise their operations.

The pulp and paper industry represents a large and growing portion of the world's economy. Specifically, the pulp industry has maintained a strong tailwind for a few years now for several reasons. According to Pöyry's World Fibre Outlook, the steady growth of the global tissue paper market, together with the tightening supply of recovered paper, dramatic changes in China's papermaking fibre furnish and enforced recyclables ban, and the strong global economy have all contributed to the present state of the pulp market.

For now, the long-term fundamentals of the packaging, tissue, and pulp markets look reasonably solid, and market imbalances have not distorted the overall positive sentiment of the industry. Although the wave of digitalisation currently sweeping the globe may appear to threaten the pulp and paper industry, the sector continues to grow, albeit at a slower rate than in previous years. While graphic paper has been on the decline for several years, the growing demand in other sectors - such as packaging, tissue paper and pulp for hygiene products - is stepping up to fill the gap.

Despite this, the industry faces challenges - not least the pressure to make wise capital investments, meaning mills need to focus on extending asset lifecycle and improving operational efficiency by new means.

According to McKinsey's report 'Pulp, Paper and Packaging in the Next Decade', the industry is experiencing the most substantial transformation it has seen in many decades. The key challenge is cost optimisation and within the operations field, that is being addressed with its own digital transformation.

There are significant opportunities for the sector to benefit from digital technologies to bridge the gap that has traditionally existed between information technology (IT) and operations technology (OT). By applying data analytics, artificial intelligence and machine learning to the growing volume of production data that is available, producers can transform the resulting improved visibility into actionable business insights to improve operational efficiency all along the value chain. One such solution connecting IT and OT comes through the ABB Ability™ digital platform.

For now, the pulp and paper markets look reasonably solid, even with slower but continuous growth.

LOOKING AT ABB ABILITY™ COLLABORATIVE OPERATIONS FOR PULP AND PAPER

ABB Ability™ is ABB's unified, digital capability that extends from device to edge to cloud. It securely collects data from devices at mills, applies advanced analytics and generates actionable insights for customer operations at all levels of the enterprise. It provides powerful digital solutions that leverage today's operation and information technologies to increase production efficiency, improve product quality and minimise costs.

Collaborative Operations, an ABB Ability™ offering, is a suite of connected services that leverage the availability and transparency of data from the ABB Ability™ platform into a data ecosystem where ABB engineers and customers can collaborate remotely to avoid problems or to meet an objective.

ABB ABILITY™ ADVANCED PROCESS CONTROL FOR PULP MILLS

When it comes to gaining valuable business insights from data utilising connected digital solutions, ABB Ability™ offers many applications for pulp and paper, including advanced process control (APC). APC helps industries attain operational and financial targets by increasing throughput and reducing energy use.

Case study: APC for lime kiln optimisation

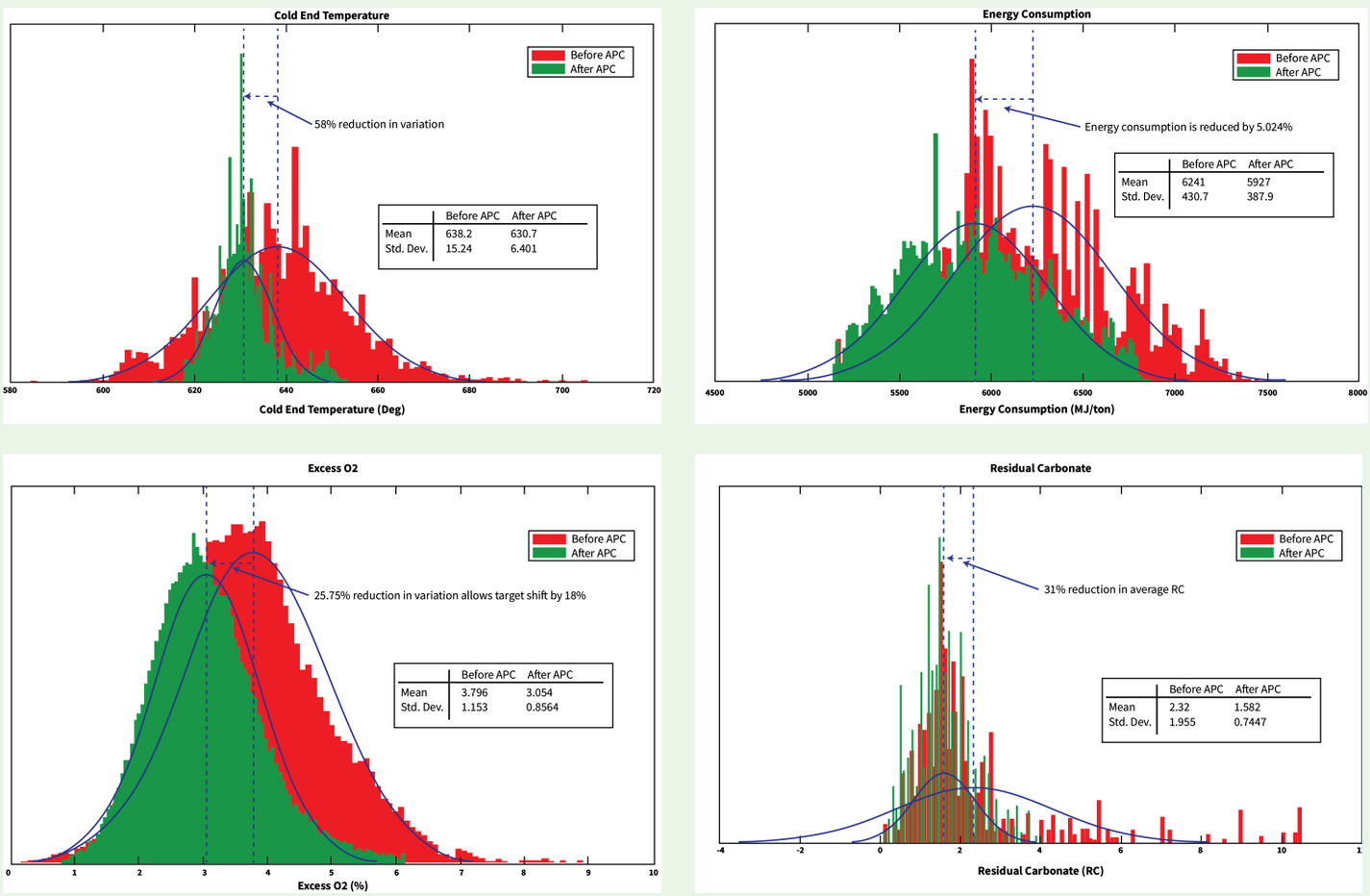

Figure 1. *Process optimisation through ABB Ability™ APC.*

ABB Ability™ Advanced Process Control (APC) was deployed in a lime kiln at a pulp mill in Europe, where the optimisation strategy is based on multivariable model predictive control (MPC). This has resulted in process optimisation (as seen in Figure 1) and improved lime quality, as seen in the 62% reduction in residual carbonate variation. Moreover, the customer saw a 5% reduction in fuel consumption, and a 58% reduction in temperature variability (as seen in Table 1). The ABB Ability™ Collaborative Operations approach has resulted in an overall improvement in the production efficiency and performance sustainability.

Criteria	Achieved Improvement
Reduction in Cold End Temperature variation	58%
Reduction in Oxygen variation	26%
Reduction in energy consumption	5.02%
Reduction in residual carbonate variation	62%

Table 1. *Lime kiln performance improvement results achieved through ABB Ability™ APC.*

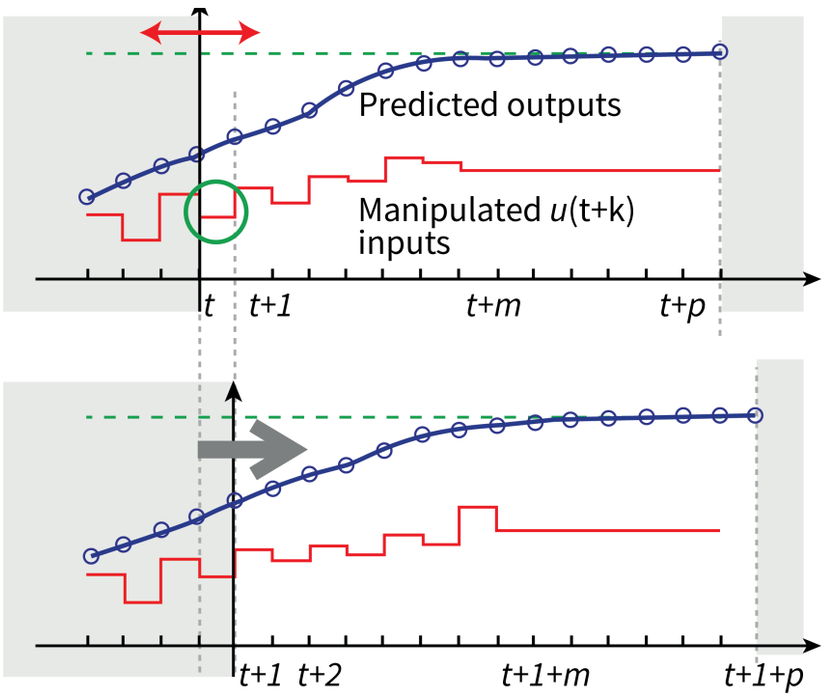

Figure 2. *Model Predictive Control enables performance optimisation by predicting outputs and calculating optimal input sequences.*

The benefits of APC solutions for pulp mills include the opportunity to stabilise, improve process operations, and minimise the variation of key variables while considering process constraints. These operational benefits translate into financial gains due to increased throughput and minimised energy and raw material use.

ABB Ability™ Advanced Process Control for pulp mills provides monitoring, predictive analytics and robust closed loop process control to optimise mill operations. The solution stabilises the process, reduces chemical usage and coordinates the numerous loops to incur optimum on-specification product quality at minimum variance. This technology is of particular value in the pulp and paper industry, where many processes are notoriously difficult to measure, and provides a better opportunity to model things that cannot directly be measured.

LEVERAGING MODEL PREDICTIVE CONTROL WITHIN APC

Traditional APC solutions rely on model predictive control (MPC) and state estimation strategies that use either a linear or non-linear mathematical model of the process and robust optimisation algorithms to estimate unmeasured states and control process variables.

MPC is often used for control and optimisation of industrial processes, and is extremely efficient given the highly interactive, non-linear, multivariable dynamics of these processes. The use of these techniques for pulp and paper mills includes the development of non-linear mathematical models describing the process, and the design of a suitable cost function, which considers the goals to achieve.

To understand how these techniques help, one must first understand how model predictive control works. MPC is a general class of algorithms for feedback and feedforward control based on the receding horizon philosophy. This means a sequence of future optimal control actions is chosen according to a prediction of the short to medium term evolution of the system. MPC utilises a model of the process 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 is optimised in a multivariable fashion (as seen in Figure 2). When measurements (or new information) become available, a new sequence to replace the previous one is determined. Each sequence is computed employing an optimisation procedure, achieving two objectives; to optimise performance and to protect the system from constraint violations.

In addition to MPC, the latest technologies - ranging from data access, analytics and visualisation to advanced modeling algorithms - are leveraged in ABB Ability™ APC to help customers optimise operations and drive their mill to its desired targets.

LIME KILN OPERATION

To understand how APC can optimise pulp mills, we are focusing on how it positively affected the lime kiln operations at one mill in Europe. The work on the pulp mill in Europe centred on the lime kiln. The lime kiln

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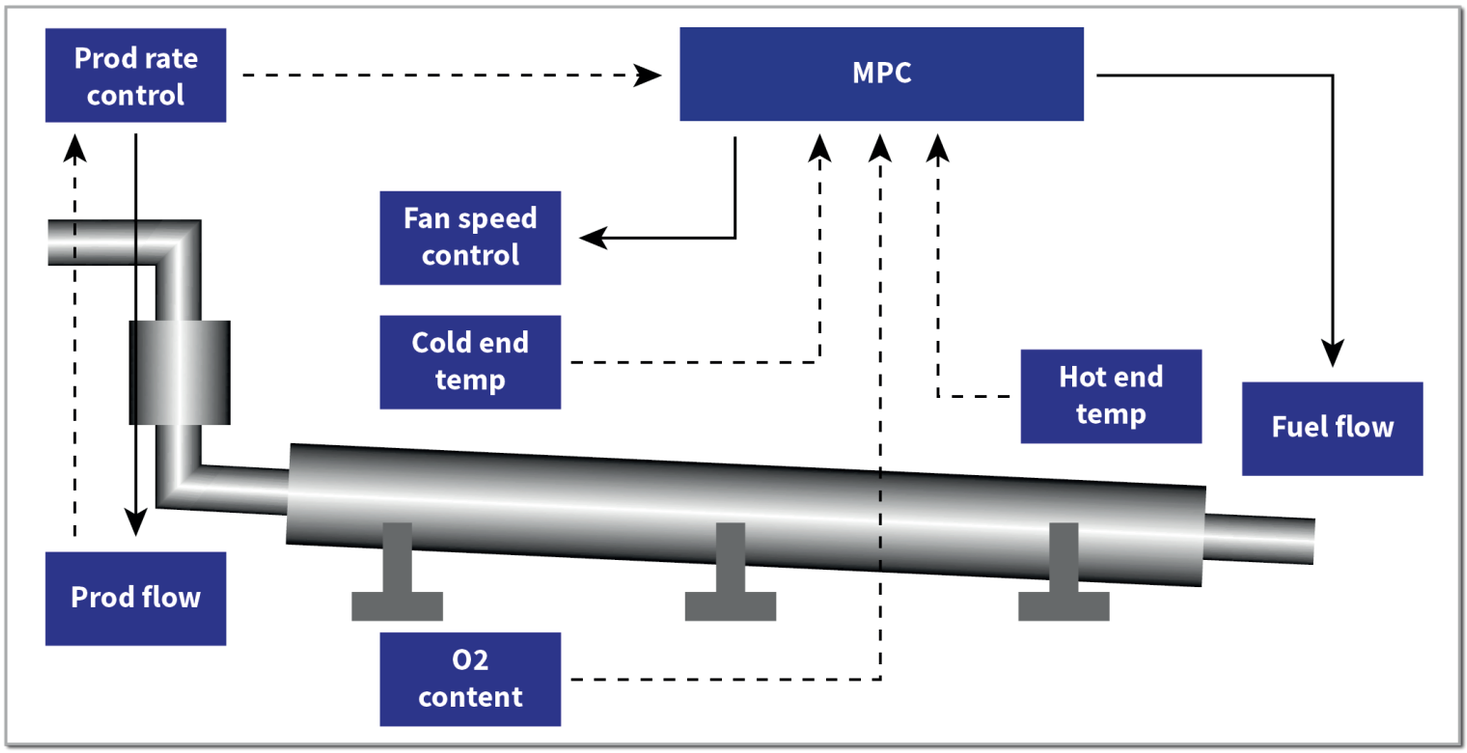

Figure 3. *Lime kiln system.*

system (as seen in Figure. 3) is an integral part of pulp mills where the lime mud is calcined into quick lime. It is then further processed into white liquor (to be used in the cooking section) by passing it through a series of slakers and causticisers. The process is endothermic, a great deal of energy is required in the calcination process and is one of the leading contributors to a pulp mill's energy costs.

CHALLENGE

Calcination is a highly interactive, multi-variable process, characterised by non-linear dynamics, subprocesses with time scale that vary from seconds to hours and a vastly varying feed that makes the optimisation and efficient control of a lime kiln a challenging problem. Furthermore, the complex operating conditions often result in multiple objectives (environmental, energy and efficiency) that are often conflicting in nature to be managed adequately.

The potential benefits that can be achieved through dynamic control are vast.

Because of the nature of the kiln where operating conditions exceed 1,000 degrees Celsius and significant quantities of dust are produced, most sensors are unreliable and frequently provide false signals that hamper real-time control. Other common disturbances in a lime kiln include varying density of the lime mud feed, varying production demands due to upsets in the cooking section and varying properties of the fuel, which makes designing robust control all the more difficult. Safety is of utmost concern, as poor control could lead to hazardous situations with the production of the dangerous carbon monoxide, and even lead to explosions.

OPPORTUNITY

Designing robust supervisory control and advanced control logic that coordinate the existing regulatory control system of a lime kiln is demanding yet essential. The potential benefits that can be achieved through dynamic control are vast. First and foremost is the significant increase in fuel savings or energy efficiency, which provides an immediate economic benefit. Stable lime quality will greatly improve the cooking process and result in less off-spec pulp production. The lifetime of the lime kiln will also increase, lowering the maintenance costs associated with refractory repairs, ring formation, and other effects of poor temperature regulation. Finally, the environmental costs of treating flue gas can also be reduced.

The lime kiln control architecture is typically built on a set of basic

instrumentation, on-line analysers, regulatory control logics (PID), and supervisory control logic. APC would further optimise the existing control system by coordinating their functioning by calculating optimal setpoints.

APPLICATION OF ADVANCED PROCESS CONTROL FOR LIME KILN OPERATIONS

Advanced Process Control application suite was implemented at a multi-fuel lime kiln in Europe. The aim was to control the cold end temperature at setpoint and the hot end temperature and oxygen within specified limits by manipulating the total fuel flow and the draft fan speed. The changes in production were accounted for by modeling the effect of the lime mud feed in the control system. The first step towards implementing a robust APC solution is modeling the process (as seen in Figure 4). Step tests were performed to develop data-based accurate process models.

The implementation of APC resulted in significant savings and is highly effective in optimising the lime kiln, reducing downtime, and improving lime quality. There was a significant reduction in the cold end temperature (58%) and oxygen (26%) variations. The reduction in these variations improved the lime kiln stability and overall efficiency, enabling the mill to reduce energy consumption by 5%. The improvement was achieved through optimal manipulation of the ID fan speed and fuel flow, which were previously controlled manually by operators. Further, the stable process also resulted in an improved lime quality, which helped achieved lower

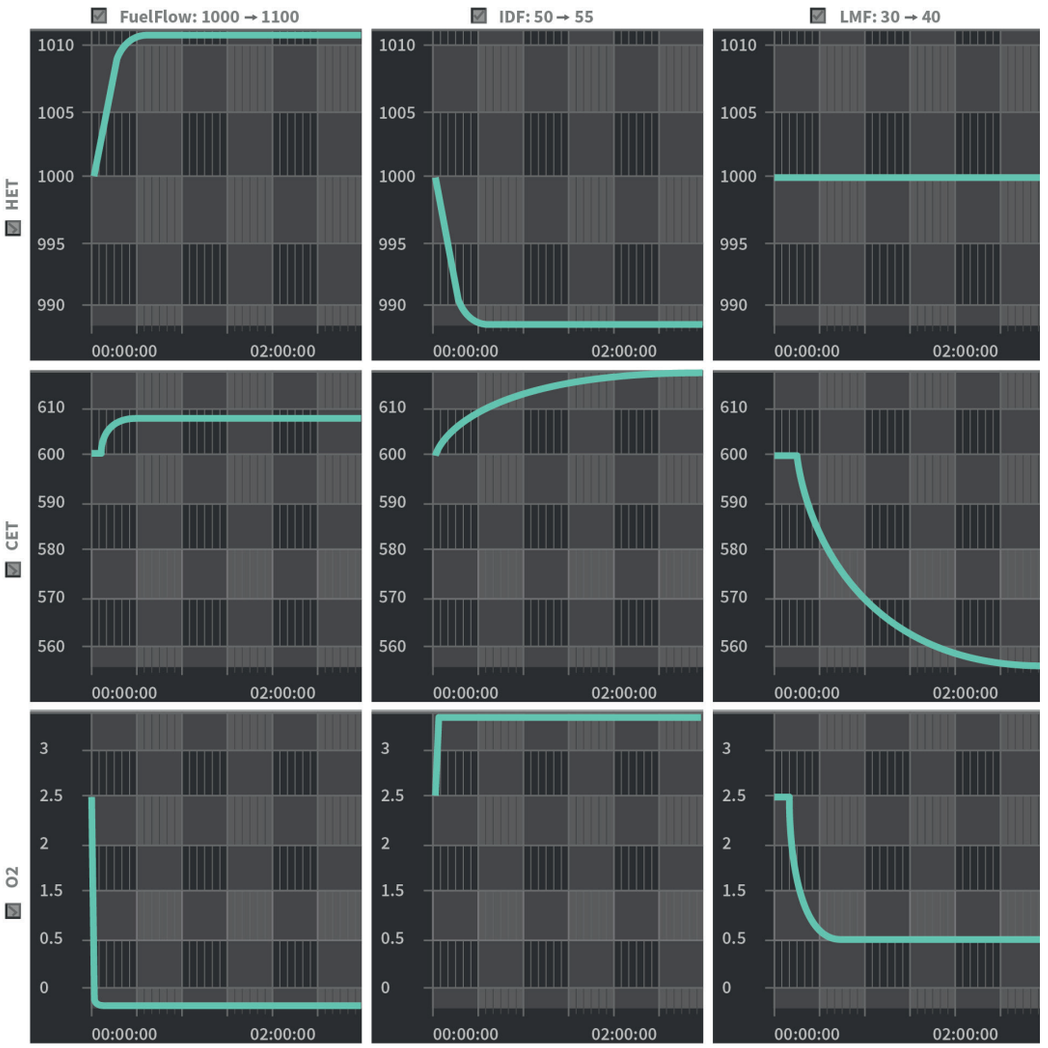

Figure 4. *Plant step tests were performed to identify data-driven process models.*

levels of residual carbonate due to reduced variability.

BENEFITING FROM COLLABORATIVE OPERATIONS

Another feature of the installation was the utilisation of ABB Ability™ Collaborative Operations. Utilising IOT infrastructure, Collaborative Operations provides a new breed of connected services that leverage the vast amount of information available today. Advanced data processing and analytical applications uncover trends, data patterns and relationships to improve operations, lower service costs and reduce downtime. Problems that once required experts to travel to the site can often be resolved remotely via collaboration operation centers. Condition monitoring, machine learning, and data analytics enable a small team of ABB experts to monitor and optimise a large installed base of equipment effectively.

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Collaborative Operations is a way of operating that allows both supplier and papermaker personnel to operate on the same information and

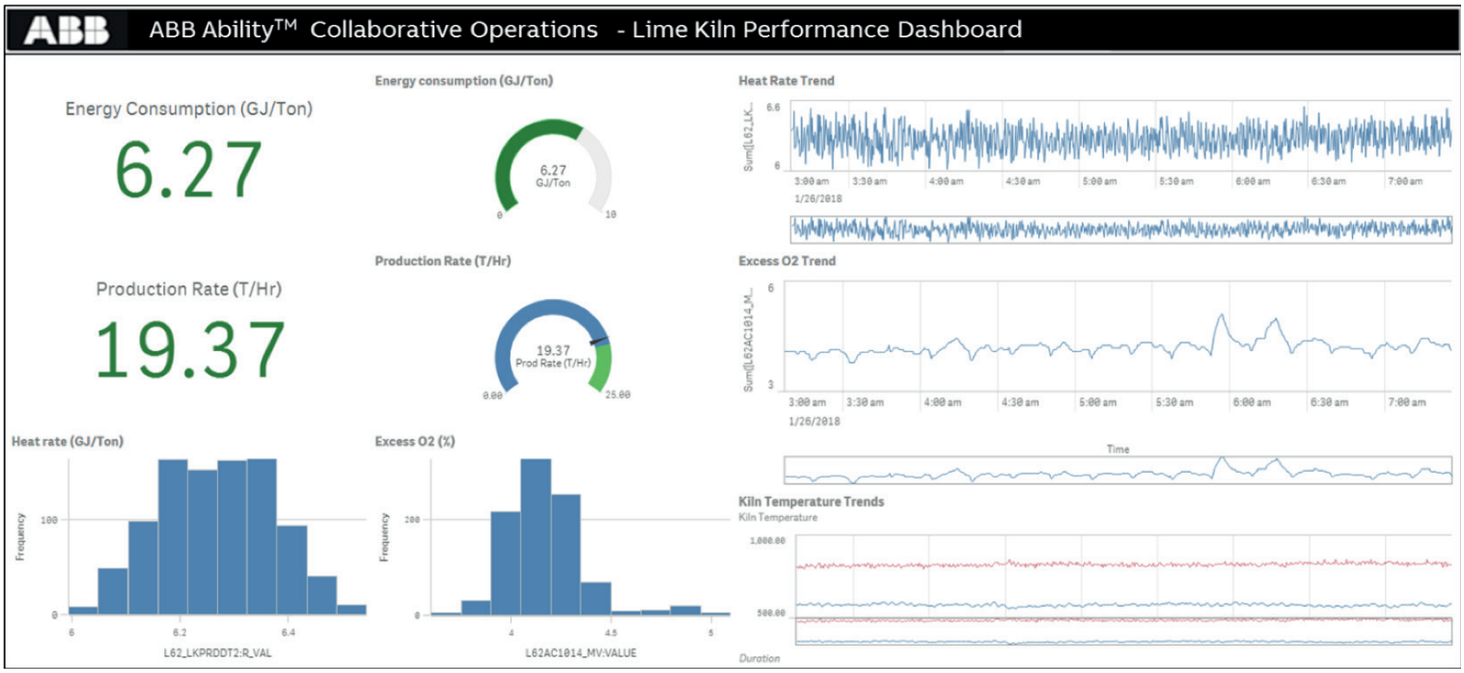

Figure 5. *Collaborative Operations Performance.*

communication backbone. This enables ABB and the customer experts to remotely monitor and optimise critical equipment and production processes, together, and improve overall plant performance.

Through the utility of ABB's Collaborative Operation Center, the performance of the lime kiln advanced process control strategy can be monitored continuously and help further optimise the system. The dashboard (see Figure 5) provides critical information that are specifically designed for the various stakeholders in the mill. For example, the process control engineer would have access to the data trends and correlations to troubleshoot problems and identify potential bottlenecks to be able to optimise the system further. The mill manager will have access to key performance indicators, environmental data and also be able to track the monetary benefits over time. ABB can monitor performance, alert on potential problems before they arise, and troubleshoot as required.

GAINING BENEFITS WITH DIGITALISATION

Through the application of ABB Ability™ APC and Collaborative Operations, significant improvements can be achieved. For the European lime kiln, the process was stabilised and optimised with APC, which resulted in significant cost savings while maintaining all process parameters within operational constraints. Furthermore, over time, benefits such as reduction in makeup lime requirements and reduction in maintenance downtime were also observed. The application of ABB Ability™ Collaborative Operations enabled continuous monitoring and sharing of key performance indicators with all stakeholders, through which the performance was sustained and further optimised over time.

Digitalisation through the ABB Ability™ platform... has found applications across the various processes in pulp and paper mills.

Digitalisation through the ABB Ability™ platform is not limited to lime kilns and has found applications across the various processes in pulp and paper mills. Improving the pulp quality in the cooking process, minimising water consumption in the washing process, minimising chemical consumption in the bleaching process, improving the runnability of paper machines are a few areas where the ABB digital solutions have been successfully implemented.

Pulp and paper companies should continue to explore opportunities for leveraging digital solutions to enable cost optimisation.