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Kuantum's Leap in Paper Industry: Boosting Productivity and Quality with AI

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Abstract:

The pulp and paper industry is witnessing a significant transformation to meet evolving market demands, sustainability objectives, and environmental challenges. Advanced technologies, particularly Artificial Intelligence (AI), are driving this change by enhancing operational efficiency, optimizing chemical usage, and improving product quality. AI enables real-time quality predictions, data analysis, and immediate corrective actions, leading to reduced defects and higher-quality outputs. Furthermore, AI applications in supply chain optimization and process efficiency are providing a competitive edge in the industry. This paper focuses on Kuantum's journey toward Industry 5.0, emphasizing the integration of AI-driven advanced process control (APC) in the bleaching process. By leveraging AI models, the company achieved a 1.49% increase in pulp brightness, reduced brightness variability by 70%, and significantly lowered chemical consumption (26% reduction in caustic, 24% in H2O2, and 10% in O2). The research highlights the challenges of implementing AI, such as data quality, availability, and process integration, while presenting a phased automation approach for overcoming these barriers.

Keywords: *Artificial Intelligence, Advanced Process Control, Data management system, Chemical Consumption, Model predictive control*

Introduction

By integrating AI tools like data management system, APC controls in bleaching and boiler processes, load management systems, energy management systems, and interactive dashboards, Kuantum has achieved significant improvements in operational efficiency and cost-effectiveness. These technologies enable precise root cause analysis, identify opportunities for improvement in plant equipment performance, and enhance decision-making accuracy. Furthermore, advanced maintenance practices have contributed to reducing downtime and ensuring consistent plant reliability.

AI Model Predictive Control

AI Model predictive control is a multivariable optimal control formulation that can handle constraints on manipulated and controlled variables. The controller uses a set of linear dynamic

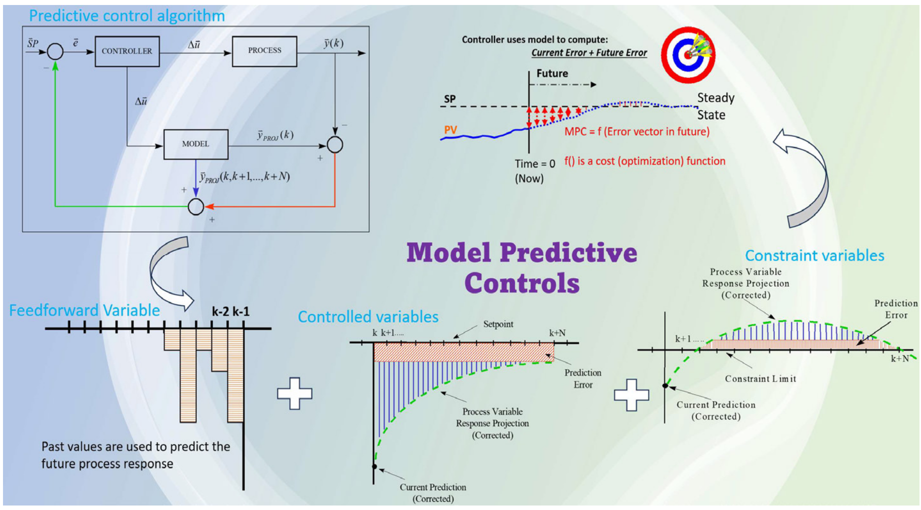

Fig1: Working of Model Predictive control

models representing the process to predict the effect of future control moves on the output variables (controlled and constraint). Hence predicting the output controls based on the real time data which further improve data driven decision making.

Implementation of AI Model Predictive Control

Kuantum implemented AI Model Predictive Control in the bleaching and boiler process to optimize chemical consumption and process efficiency, respectively. It collects real-time sensor data, applies predictive algorithms, and automates adjustments to reduce variations in pulp brightness while minimizing caustic consumption.

Key Features of AI Model Predictive Control

- Reduction in chemical consumption through real-time monitoring and optimized dosage control.
- Stabilization of process parameters like bleach load, pH, and brightness, leading to improved pulp quality and reduced off-spec brightness instances.
- Enhanced control of brightness fluctuations, ensuring consistency and higher efficiency.
- This model optimizes oxygen level and header pressure in Boiler Operations.

This paper focuses on Kuantum's structured approach to integrating AI-driven methodologies into their operations. It outlines how data integration and advanced control mechanisms have created a scalable framework for process optimization and improved decision-making across the mill. By leveraging these technologies, Kuantum continues to reduce operating costs, improve resource utilization, and align with global sustainability standards, setting a benchmark for innovation in the pulp and paper industry.

Materials and Methodology - Kuantum Paper Journey

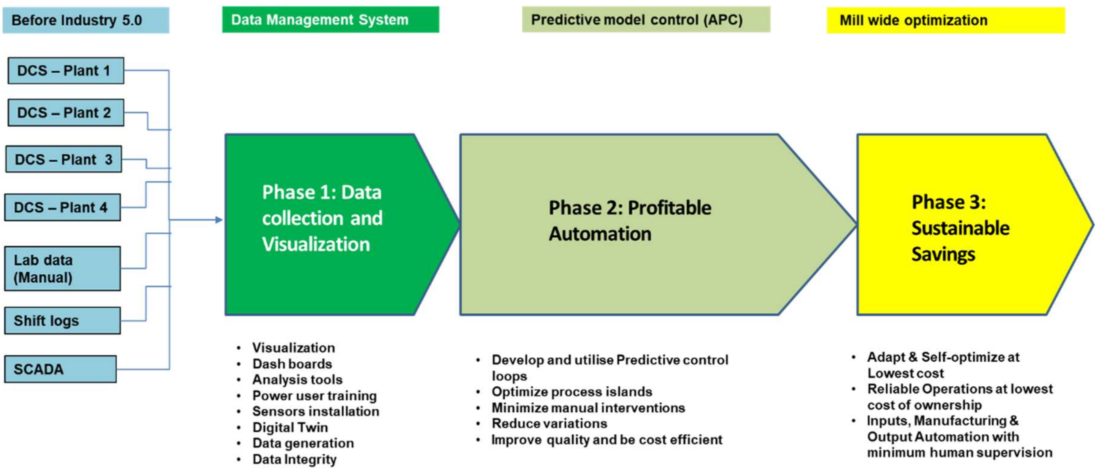

Fig 2: Kuantum's journey towards industry 5.0

Phase 1: Data management system

- **Data Integration:** Consolidated data from Distributed Control Systems (DCS), SAP systems, and manual entries using a unified platform – Manual Data Entry, data management system, to enable a single-source data framework.
- **Visualization Tools:** Implemented real-time dashboards, trend analysis, and KPI tracking for data-driven decision-making and improved process insights.
- **Soft Sensors and Digital Twins:** Developed predictive models and digital replicas of processes to simulate operational scenarios and improve data reliability.

Phase 2: Process Automation

- **Model Predictive Control (MPC):** Deployed AI-driven predictive control for critical processes such as bleaching and boiler systems, enhancing process stability.
- **Advanced Process Control (APC):** Introduced automation in key control loops, reducing manual interventions and achieving consistent quality and energy efficiency.
- **Optimization Algorithms:** Applied algorithms to minimize chemical consumption and stabilize production parameters, improving overall operational efficiency.

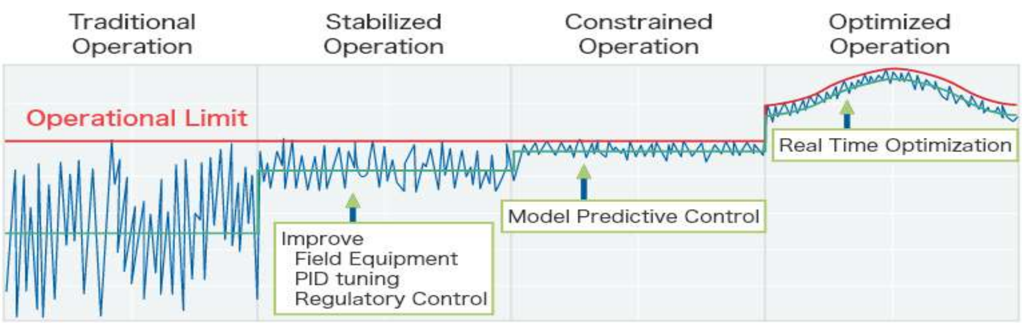

Fig 3: Traditional control vs APC control

Phase 3: Sustainable Optimization

- **Mill-Wide Integration:** Developed integrated models to monitor production, quality, and costs across all departments for improved collaboration and resource optimization.
- **Real-Time Monitoring:** Enabled AI-based adjustments to maintain operational consistency, reduce variability, and meet quality targets.
- **Sustainability Measures:** Focused on reducing chemical consumption, adopting biofuels, and optimizing energy use to meet environmental compliance.

Results and Discussions

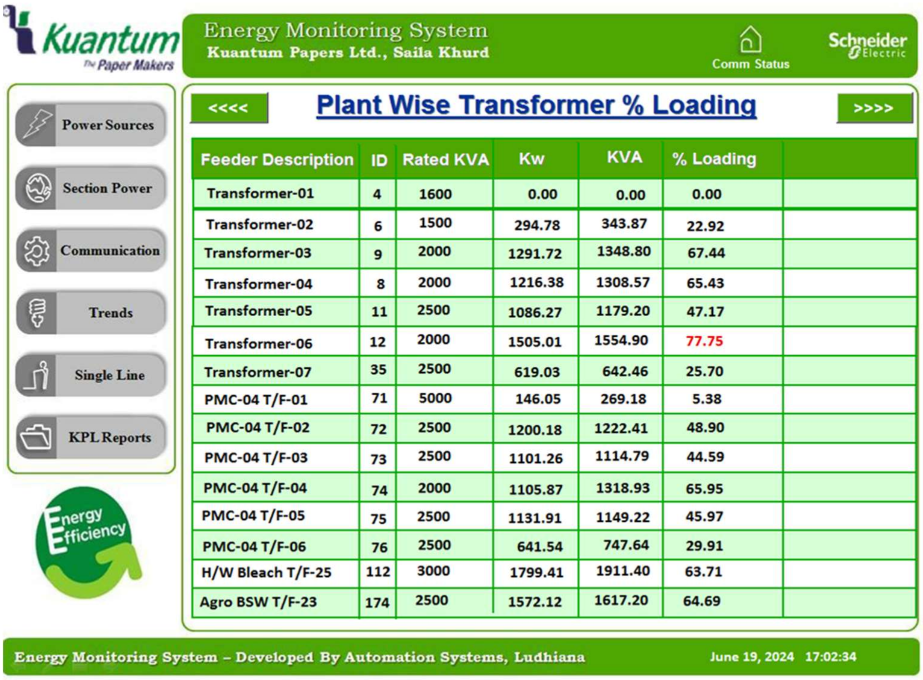

Fig 4: Transformer loading Dashboard with alarms

Data Management system (Phase 1):

Case Study -1: Power event analysis through data management system

With utilization of data management systems, we have developed energy monitoring dashboards with alarms and notifications for process improvement:

- The energy management system enabled us to visualize loading of transformers on a single screen.
- It generates an alarm when the loading of any transformer goes above 75 %.
- Necessary actions can be taken on time like load rise monitoring, winding and oil temperature monitoring etc.
- Energy management system enabled us to understand the root cause and impact of cascading and chronic power system events and use this information to reconstruct events, respond appropriately and determine cause to prevent potential issues in the future.
- Faster cause identification via analytics providing potential cause descriptions of various Power Quality events eliminating need to manually interpret electrical waveforms.
- By implementing an energy management system, we can identify energy-saving opportunities and optimize their energy usage, resulting in significant cost savings and reduced carbon emissions.

Table 1: Energy saving data after utilizing data visualization

Energy saving data								
S. No.	Equipment	Location	VFD or S/D Conv	Motor rated kW	Before (Kw)	After (Kw)	Saving (kW)	kWh/day
1	Chest 40 pump	PM3	VFD	15	14	6	8	192
2	Broke tower pump	PM3	VFD	11	8	2	6	144
3	PV blower	PM2	S/D CONV.	22	12	6	6	144
4	Chest 38 pump	PM3	VFD	15	12	4	8	192
5	Agro storage chest feed Pump	Pulp mill	VFD	55	35	22	13	312
6	Chest 14 agitator	PM2	S/D CONV.	15	8	3.5	4.5	108
				Total Saving			45.5	1092

Gains Achieved

- Achieved Zero Source tripping level in case of earth faults in system.
- Faults are limited to feeder level only.
- Saving in tripping of multiple plant feeders due to problem in one feeder.
- Savings in optimising the energy by 1092 KWh/day through data visualization.

Case Study -2: Incorporating Digital data display and analysis through data visualization tool

- We have created dynamic, highly-informative dashboards that give an at-a-glance overview of the condition of major process flows and KPIs at our plant.
- We have built dashboards with data from multiple physical sites or from various processes in a single display. Data from traditionally isolated data silos, such as lab quality data, or SAP inventory data, can be pulled in and presented side-by-side for analysis in a single display.

Dashboard for Data Visualisation

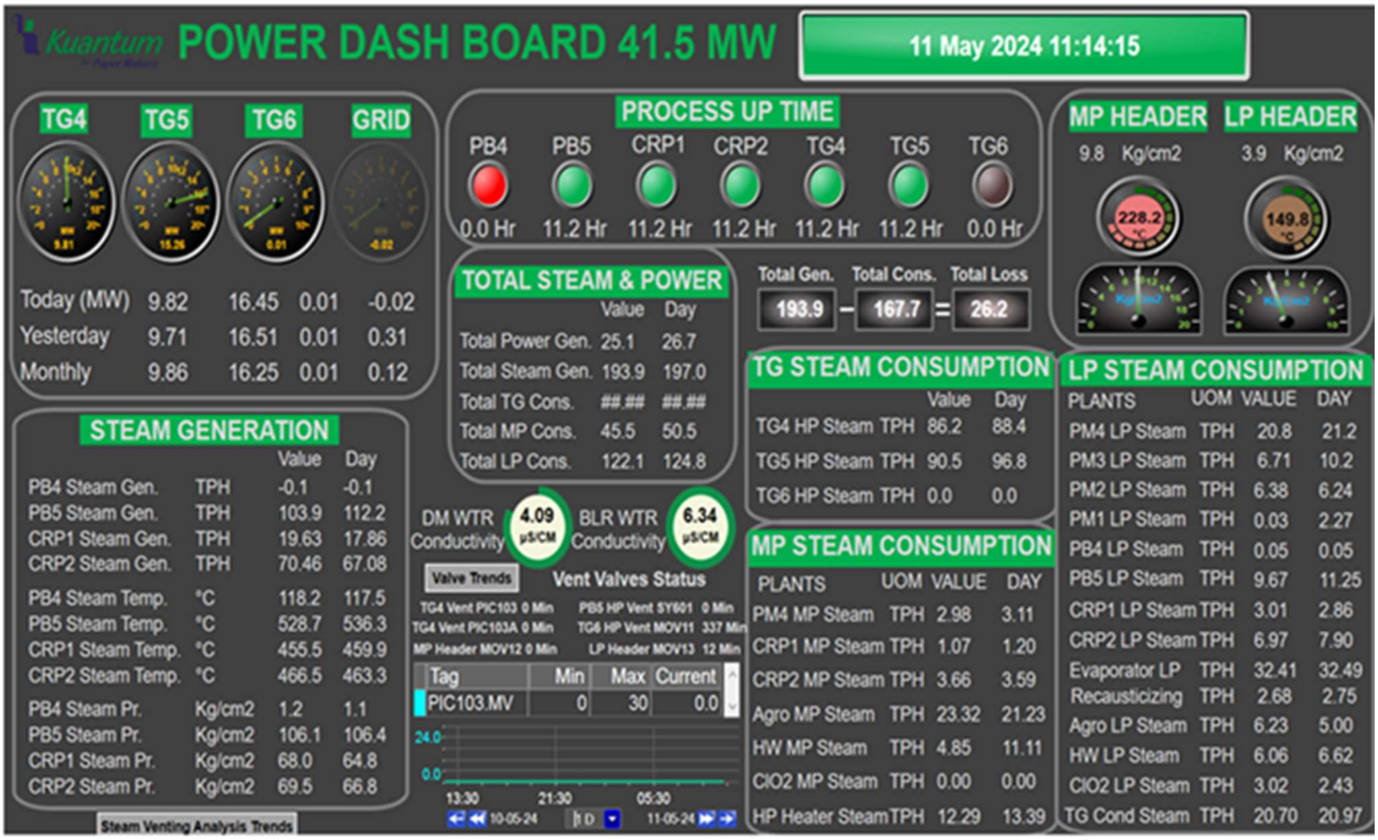

Fig 5(a): Real time KPI Dashboard

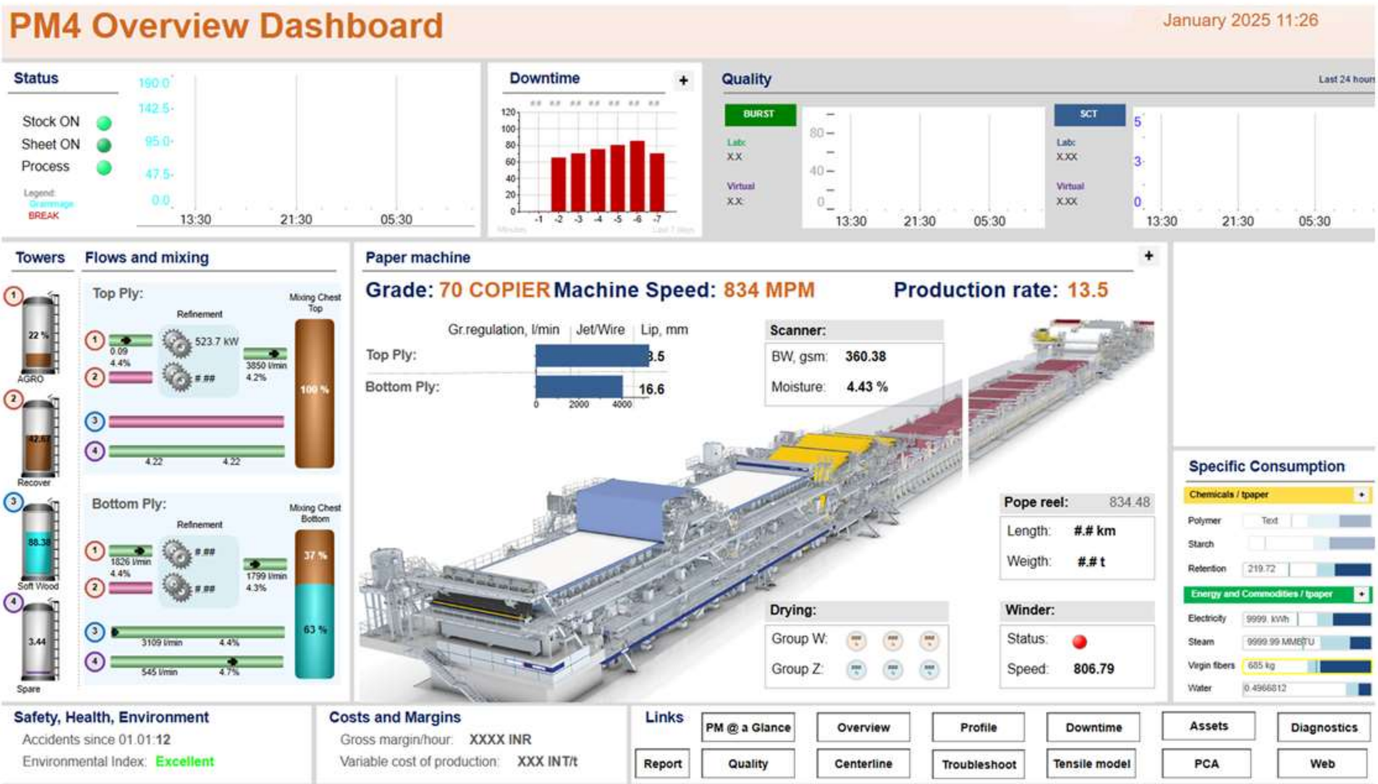

Fig 5(b): Real time KPI Dashboard

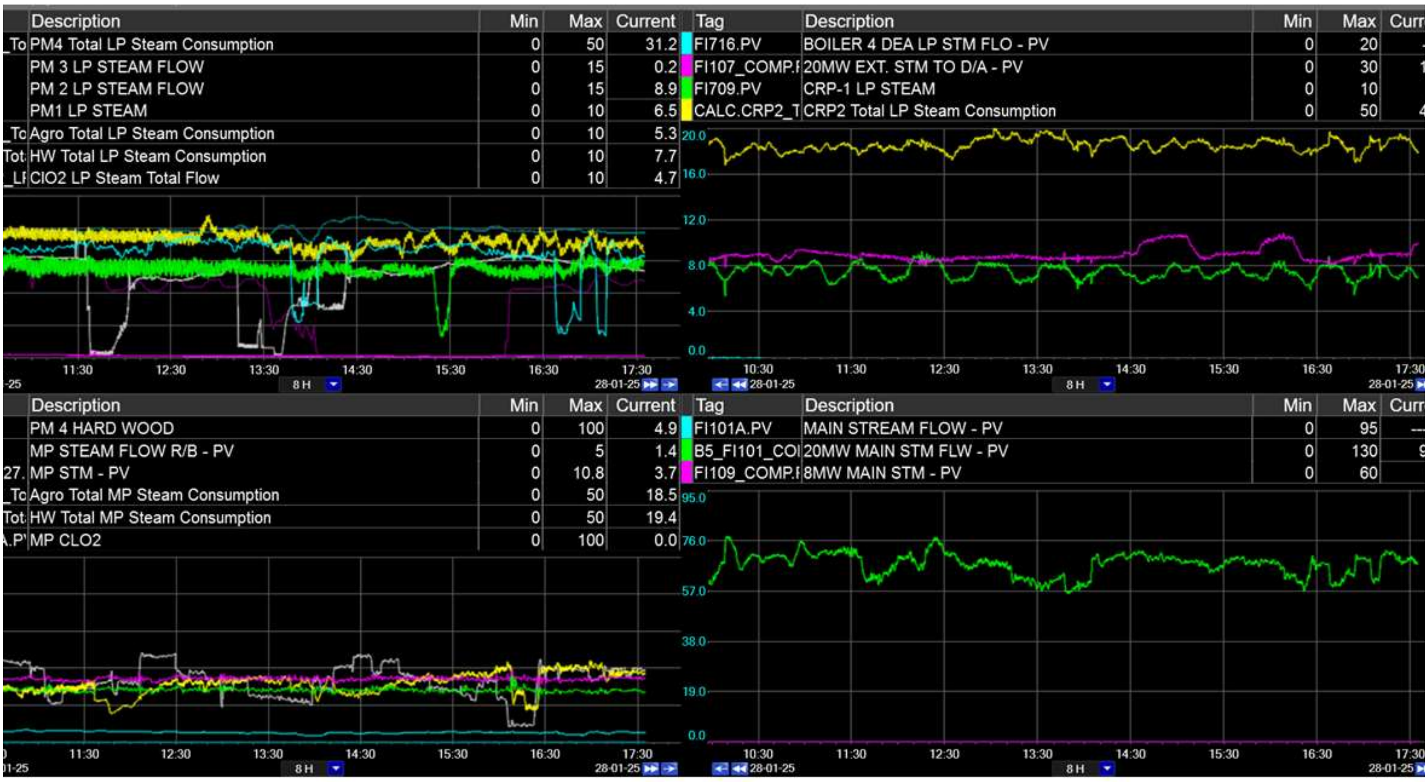

Fig 6: Real time trend analysis of different data sources

Gains achieved

- Improved our decision-making and troubleshooting capabilities. There are multiple analytical tools to do the analysis and resolve chronical issues in plant.
- Quickly transforming critical data into useful information for timely decision-making and root-cause analysis.

Advance process control (Phase 2)

Case study 3: Pulp brightness variation reduction and chemical optimization

- APC is used in pulp mill bleaching to reduce the variations and cost.
- This methodology uses both feed forward and feed backward controls between various measurements to achieve the desired results.
- Based on available data from the data management system, Predictive model controls were built. Further, subsequent bump tests were carried to test the models, followed by fine-tuning and going live.
- Moreover, this AI predictive models utilizes the sensors and lab data to keep the predictive controls model updated depending on the process parameters to minimize the process variations, hence maintaining quality.

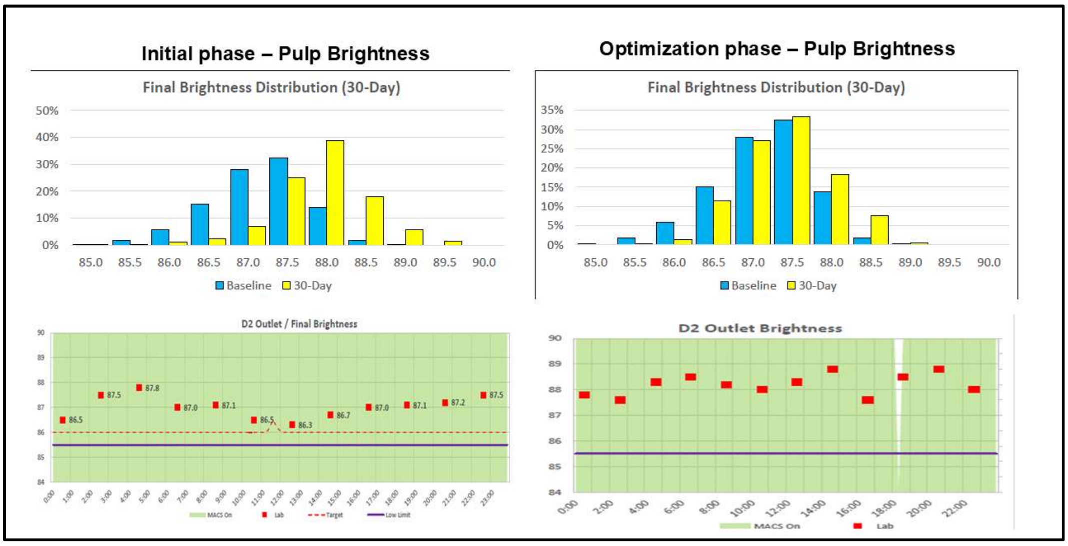

Fig 7 (a): Pulp Brightness (before and after APC)

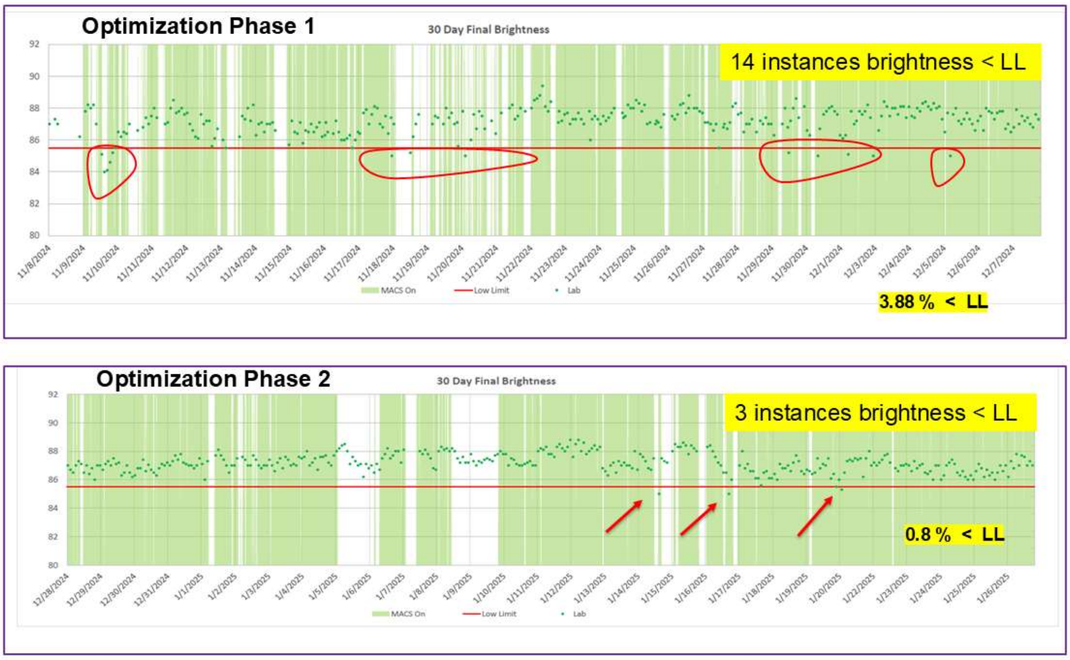

Fig 7 (b): Pulp Brightness (before and after APC)

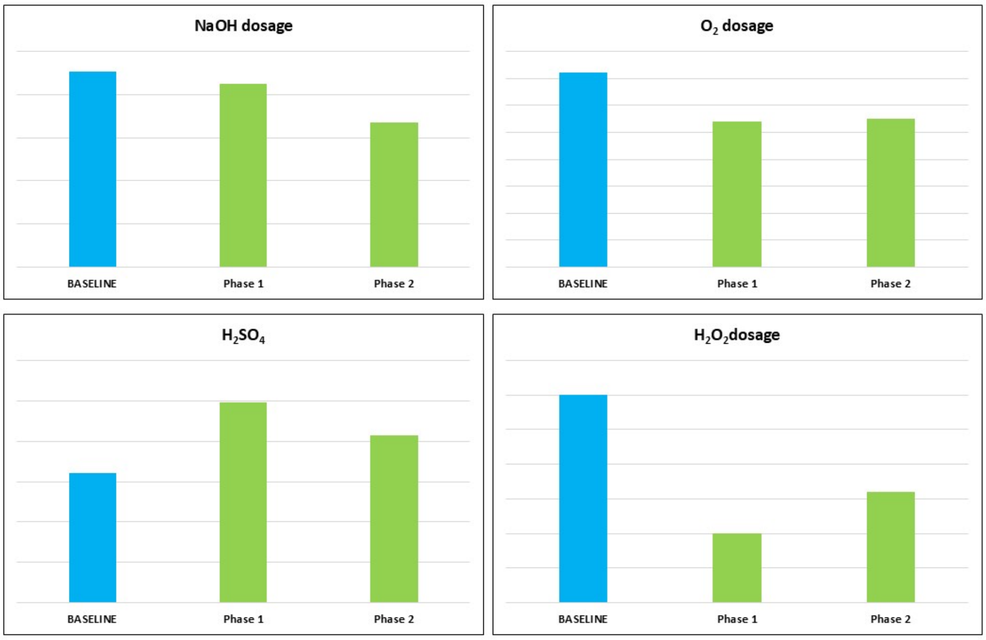

Fig 8: Pulp bleaching chemicals (before and after APC)

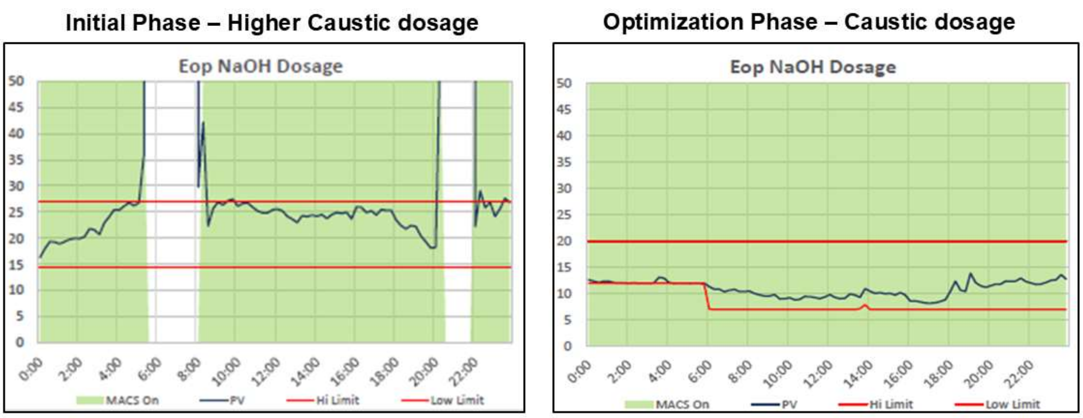

Fig 9: Caustic dosage (Before and after APC)

Gains achieved

- Adopting AI Model Predictive Control and data management system has resulted in:
  1. 1.49% increase in pulp brightness.
  2. 2.94% increase in whiteness.
- Brightness variability reduced by 70%.
- Reduced caustic consumption by 26%.
- Reduced O_2 dosage by 24%.
- Reduced H_2O_2 dose by 10%.
- Overall savings in chemical cost.
- Real-time monitoring and AI-driven adjustments ensures consistent quality improvements.

Case study 3: Boiler Efficiency Enhancements with APC (Phase 2)

- APC used for real-time monitoring.
- Coal feeders, primary fan and secondary fan predictive control mechanism adopted through APC to control the boiler KPI like header pressure, furnace temperature and bed temperature to optimise and control the operations.
- This model uses the exhaust gas parameters like, O_2% and CO concentration in stack emissions to improve the boiler efficiency.
- APC Boiler system optimizing oxygen level and header pressure.
- Faster control action; necessary for specific upset events in header pressure/air systems.

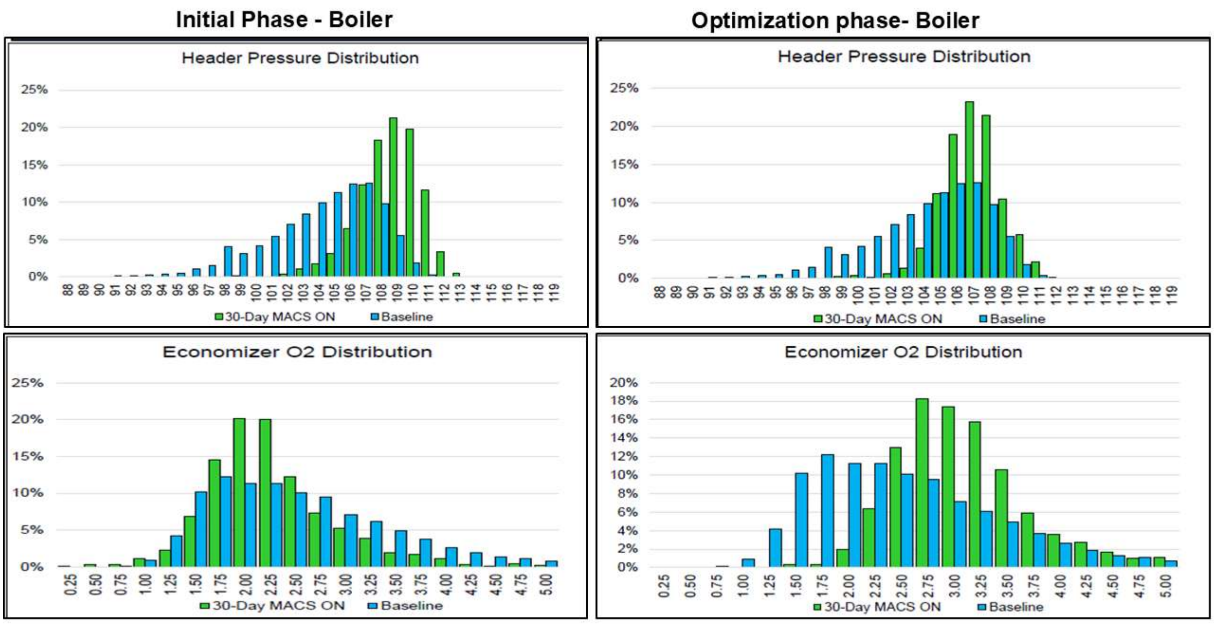

Fig 10: Boiler Parameters during optimization phase

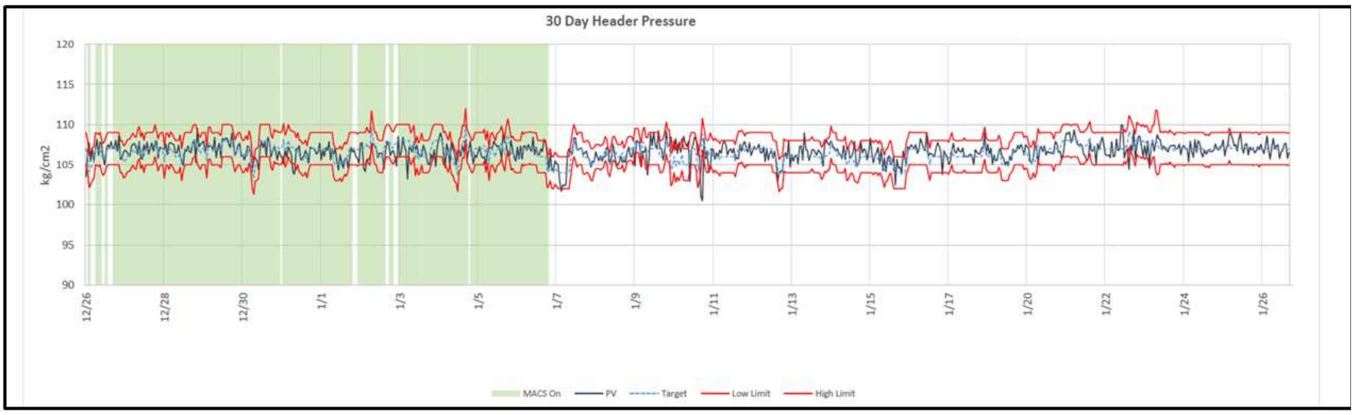

Fig 11: Boiler header pressure optimization

Gains achieved during optimization phase

- 0.25% efficiency improvement was observed during optimization phase of boiler, however further improvement is under progress.

Conclusion

Kuantum's journey into Industry 5.0 demonstrates the transformative impact of profitable digitalization on operational efficiency and sustainability. Key outcomes include creating a predictable, quality-focused operating environment through optimized processes, leading to cost reductions and increased yield. Environmental benefits are evident through reduced chemical and fuel usage, which lowers pollution load.

The initiative has elevated operators to process engineers by fostering a learning culture and empowering Big Data-driven decision-making. Meetings have been redefined into actionable work sessions by identifying the vital few from the data management system to drive the impactful outcomes.

A significant cultural transformation is underway, with the organization leveraging data to drive informed decision-making. This culture ensures that every team member, from operators to senior leaders, actively contributes to solutions and continuous improvement projects, driven by deliberate, data-supported strategies.

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