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Leveraging BIG-AI for Proactive Sheet Break Prediction in Pulp and Paper Industries

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Abstract:

In pulp and paper industry, sheet breaks used to be a nightmare for all production managers. In order to minimize sheet breaks, manual analysis and traditional methods were commonly used; however, this did not prevent the sheet breaks from recurring. Hence, sheet breaks led to significant production losses, more downtime, wastage of materials, and profit losses. This article discusses a new way to minimize sheet breaks using intelligent AI platform called BIG-AI that provides data-driven recommendations. BIG-AI's advanced algorithms capability not only predicts sheet breaks in real-time, but it also proactively identifies root causes before a 30-minute break occurs. Case studies from pilot implementations demonstrate the efficacy of BIG-AI in reducing downtime and improving operational efficiency, highlighting its transformative potential for the pulp and paper industry. BIG-AI is unique in equipping operators with insights on possible sheet breaks by highlighting variations in parameters like draw variation, HB cy variation, moisture variation, and vacuum variation. This empowers operators to quickly investigate and proactively prevent sheet breaks.

Keywords: *Sheet Break, BIG-AI, leverages, Machine Learning, Paper Machine*

Introduction

The pulp and paper industry is vital to the global manufacturing stage, as it produces essential products that range from packaging materials to daily consumer goods. This industry has integrated continuous production lines that are precision and efficiency-dependent to keep it profitable. However, sheet breaks are common and create bigger challenges in pulp & paper manufacturing process. These sheet breaks minimize production, leading to downtime and increased waste as well as operational costs. Furthermore, it often takes complex troubleshooting processes to deal with sheet breaks, leading to the disruption of production schedules and increased burden on resources (Brown. K, et al., 2020, Johnson. R et al., 2017 & Karlsson et al., 2021). In pulp and paper industry, sheet breaks used to happen due to either wet-end or dry-end. Dry-end breaks occur due to multiple reasons such as weak points, holes, insufficient stretchability, air-handling, fluttering issues and, sheet adhesion. All of these changes may arise within a very short duration, so it is very difficult to identify, but if wet breaks are analysed in real-time and their root causes identified, it helps minimize dry-end breaks. Hence, in this paper, we focused on wet-end breaks analysis and predicted various root causes.

Wet-End Breaks

Wet-end breaks occur due to various reasons related to mechanical properties such as web tensile strength and stretch. These properties are affected by moisture content variations. The rapid changes in the stretch of the wet web have made it very difficult to detect those large variations in real-time. The advancement of Industry 4.0 technologies such as artificial intelligence (AI) and machine learning (ML) has transformed the industries by enabling them to make data-driven decisions (Kumar et al., 2020, Lee et al., 2022 & Miller et al., 2021).

AI-driven platforms such as BIG-AI (turilytix.ai, 2023 & 2024) have shown an immense value in predictive maintenance, providing insights that were previously unattainable using conventional approaches. BIG-AI, an advanced AI-powered platform, is uniquely designed to address the sheet break prediction challenges in the pulp and paper industry. By leveraging new techniques like ensemble learning, deep feature analysis, or explainable AI, BIG-AI offers an end-to-end solution for sheet break prediction and decision support. Unlike traditional systems, BIG-AI can process multiple datasets including sensor data, operational logs, and environmental metrics, to proactively predict and mitigate sheet breaks. This paper explores the application of BIG-AI for proactive sheet break prediction, focusing on its ability to enhance operational resilience, reduce waste, and pave the way for smarter, more sustainable operations in the pulp and paper industry.

How BIG-AI is unique compared to other Platforms

BIG-AI is a transformative platform in the predictive analytics and AI-driven solution space. Unlike traditional AI systems, which often rely on isolated models and predefined workflows, BIG-AI takes a holistic, adaptive and business-centric approach to deliver actionable insights. BIG-AI excels in the analysis of several interconnected variables such as draw variation, HB cycle variation, moisture variation and vacuum variation. In contrast, many other platforms struggle to handle such complexities and fail to understand these intricate patterns. Additionally, BIG-AI applies sophisticated multivariate pattern recognition to identify subtle correlations and root causes that drive key outcomes. BIG-AI platform's uniqueness lies in the following core aspects shown in the Figure 1.1.

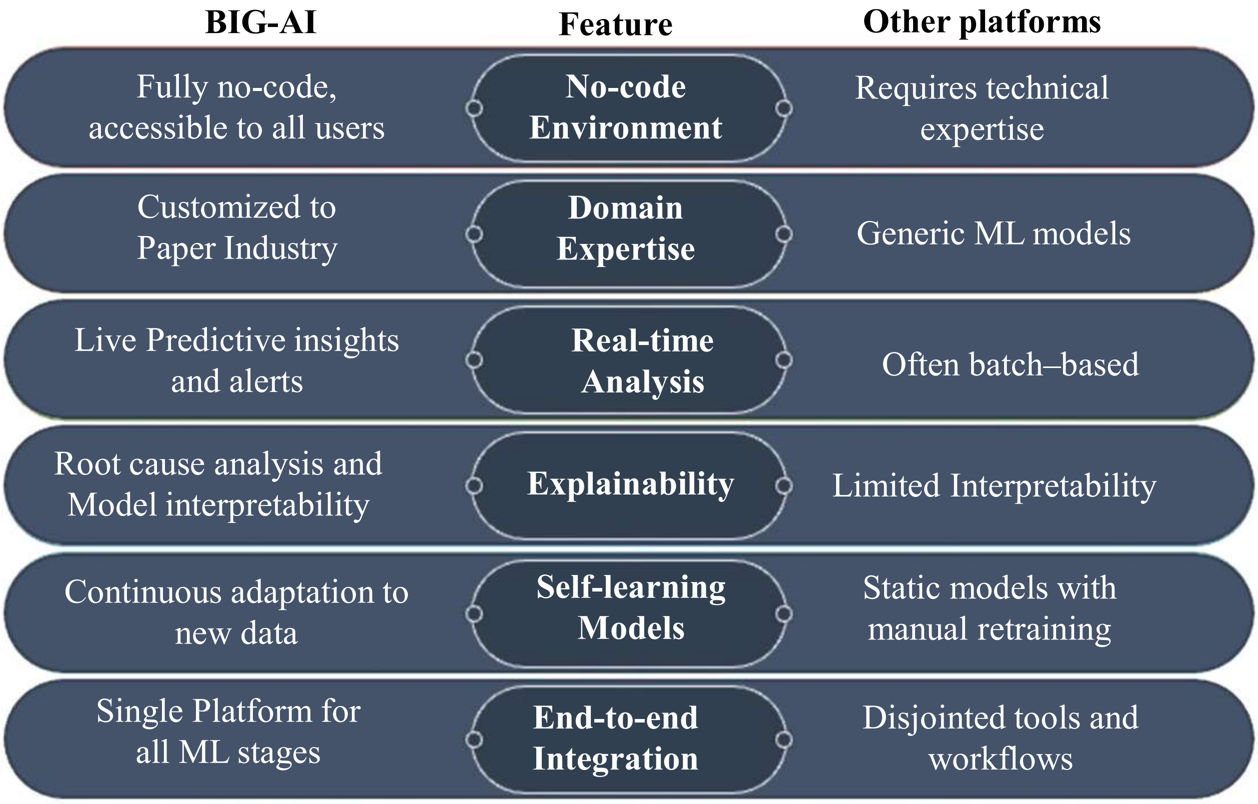

Figure 1.1: Competitive Advantages of BIG-AI

Literature Review

Sheet breaks occur due to various reasons such as poor bonding, mechanical misalignments, and environmental variables. Traditional statistical methods have proven insufficient in addressing these dynamic and high-dimensional factors (Smith et al., 2018). However, this approach is limited due to subjective human judgment and the inability to process large amount of data in real-time (Smith and Jones 2019). Statistical methods often fail in predicting sheet breaks due to dynamic data changes, limited adaptability, and difficulty capturing complex patterns (Taylor, R. et.al., 2019). The complexity of predicting sheet breaks is further increased by the interactive dynamics of machine parameters such as roll tension, speed, nip pressure; environmental conditions including humidity, temperature and variations in raw materials such as deterioration of fibre quality and changes in moisture content. These interconnected data create a highly complex problem space that traditional approaches struggle to tackle efficiently (Wang, Q., & Li, M. 2021). Machine learning (ML) and artificial intelligence (AI) have shown significant success in predictive maintenance across various industries. Techniques such as support vector machines, random forest, and deep learning enable the extraction of patterns and detection of anomalies from large datasets. In the pulp & paper industry, machines can leverage these advanced technologies to predict sheet breaks by analysing machine parameters, historical data, and environmental inputs. AI-driven solutions can map patterns, relationships, and anomalies in both past and real-time data offering early warning signs of potential operational disruptions (Zhang et al., 2020).

Implementation Methodology of BIG-AI for Sheet Break Prediction

In this section, BIG-AI employs a combination of supervised and unsupervised learning techniques to identify potential triggers and provide actionable insights. The implementation starts with comprehensive data collection from various sources.

Data Collection

The BIG-AI platform gathers data from multiple sources including Quality Control Systems (QCS), Digital Control Systems (DCS), Quality Management Systems (QMS), event logs, reel reports, lab data and equipment data. These metrics encompass tension, draw variation, vibration, speed, historical production logs, humidity and temperature. The detailed BIG-AI data collection framework is shown in Figure 3.1.

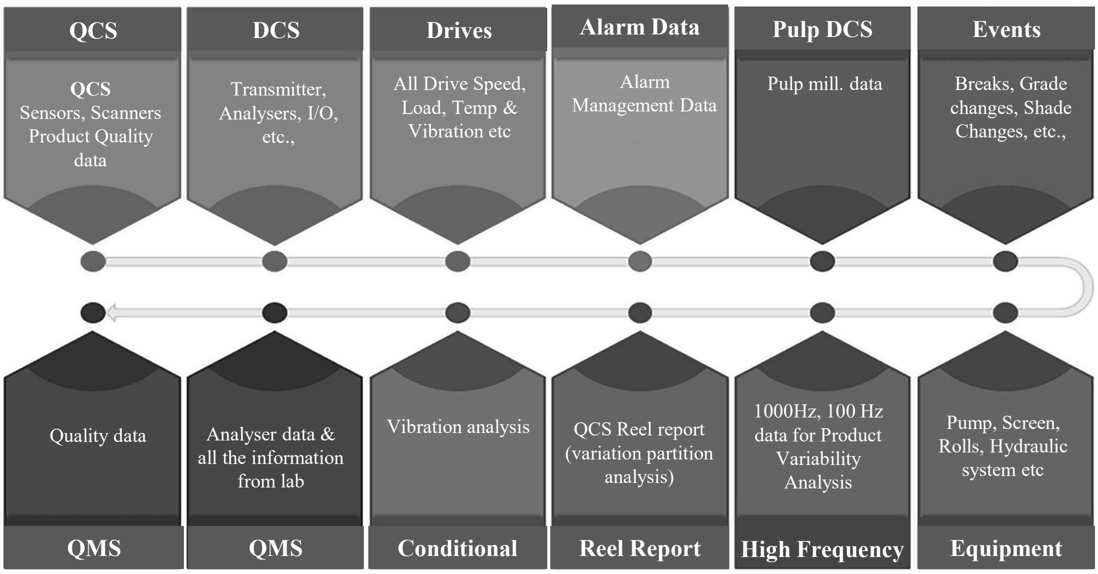

Figure 3.1: BIG-AI Data Collection Framework

Feature Engineering

Key features influencing sheet break events are identified through domain expertise and exploratory data analysis such as machine-specific parameters (e.g., roller pressure, chemical properties, dryer temperature and moisture levels). Material conditions such as pulp quality, fibber consistency, and environmental factors like conditions ambient humidity and temperature fluctuations are also included.

Predictive Modelling

The BIG-AI platform leverages advanced machine learning algorithms to build predictive models. Techniques such as gradient boosting and recurrent neural networks (RNNs) are used to capture both static and temporal patterns within the data. The Models are trained using historical data, and divided into separate datasets for training, validation and testing to ensure robust performance. Cross-validation techniques are used to validate ML models and fine-tune hyperparameters, mitigating the risk of overfitting. The summarized BIG-AI sheet break prediction process flow is shown in Figure 3.2.

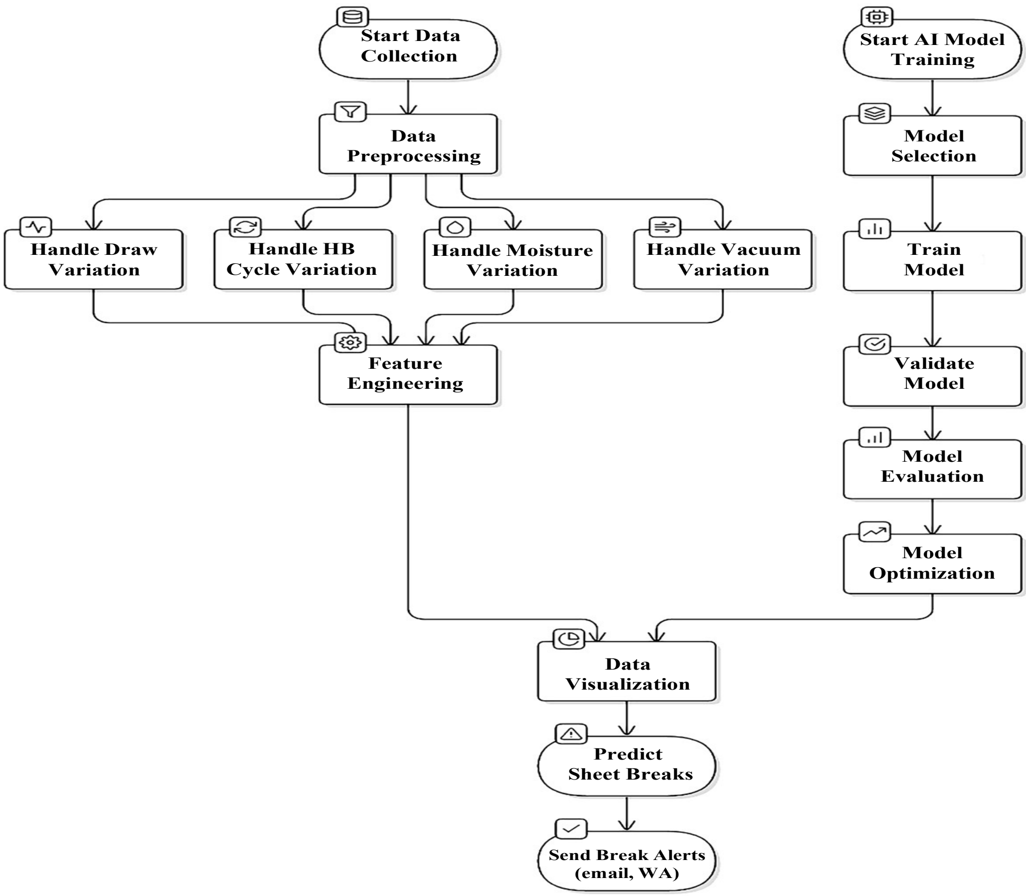

Figure 3.2: BIG-AI Sheet Break Prediction Process

Deployment and Integration

The trained model is deployed into production within the BIG-AI platform to enable real-time operation, seamlessly integrating with existing manufacturing systems. Real-time dashboards provide actionable insights to the operators, empowering them to take proactive interventions.

Evaluation Metrics

To ensure effectiveness of BIG-AI in predicting sheet breaks, the following metrics are assessed:

Accuracy: Measures the proportion of correct predictions out of the total predictions.

Precision and Recall: Evaluate the model's ability to identify true positives and minimize false negatives.

F1 Score: The harmonic mean of precision and recall, providing balanced measure of model performance.

Mean Absolute Error (MAE): Evaluates magnitude of prediction errors especially in time series data.

Area Under the Receiver Operating Characteristic Curve (AUC-ROC): Indicates the model's ability to distinguish between break and non-break scenarios.

By leveraging these metrics, The BIG-AI system ensures accurate and trustworthy predictions, significantly reducing sheet breaks and improving operational efficiency in the pulp and paper industry. With its modular structure, BIG-AI models can be operated for the most accurate and reliable prediction.

Results and Discussions

The BIG-AI was deployed on one of the paper machines at the South African Pulp and Paper Industries (SAPPI) manufacturing plant. Its performance was evaluated and benchmarked against traditional statistical models considering various operational parameters. The detailed confusion matrix and classification report are presented below.

Confusion Matrix: [[129744 181]
[272 1600]]

Classification Report:

	precision	recall	f1-score	support
0.0	0.99	0.99	0.99	129744
1.0	0.89	0.85	0.87	1600

The BIG-AI model achieved an overall predicted accuracy of 83.3% with the Recurrent Neural Network (RNN) showing the highest predicted accuracy at 87%, thanks to its ability to handle time-series data. Additionally, BIG-AI achieved a precision of 89% and a recall of 85%, highlighting its ability to accurately predict sheet breaks. The number of breaks tested at the SAPPI paper mill is presented in Table 4.1.

Table 4.1: BIG-AI predicted breaks analysis.

Description	Total
No of Days data tested	45
Actual Sheet Breaks	158
BIG-AI Predicted sheet Breaks	155
BIG-AI Correctly Predicted Breaks	141
False Negative	22
False Positive	18
Prediction Accuracy	**83.53%**

The detailed feature assessment conducted on every minute in real-time is shown in Figure 4.1.

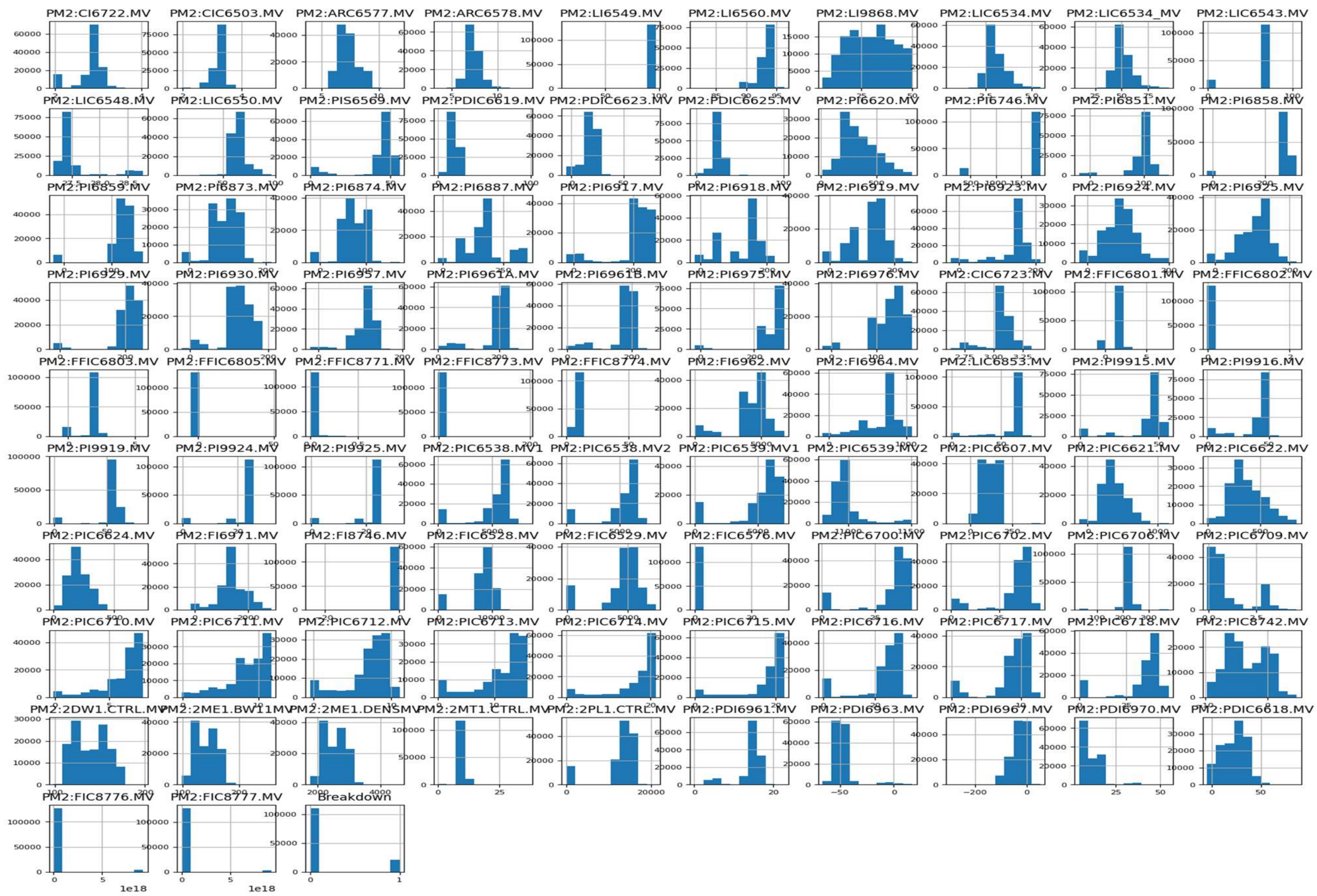

Figure 4.1: Detailed sensor analysis of highly correlated features assessment in real-time

BIG-AI processes real-time data at one-minute intervals and predicts sheet breaks 30 minutes in advance. takes all the process data in real-time with 1 minute interval and predicts sheet breaks 30 min before the breaks. The BIG-AI not only predicts sheet breaks beforehand, it also identifies the root causes of sheet breaks. The combination of root causes is shown in Figure 4.2, while individual root causes are shown in Figure 4.3.

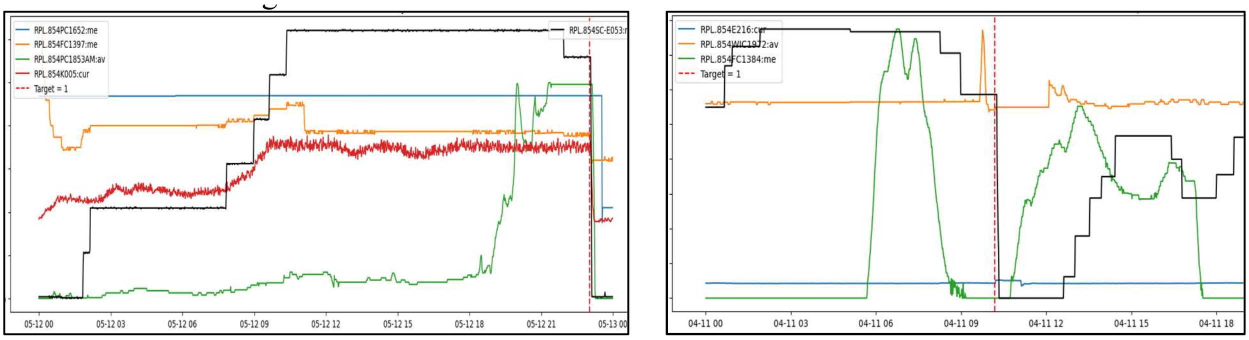

Figure 4.2: Process data variation with multiple combinations

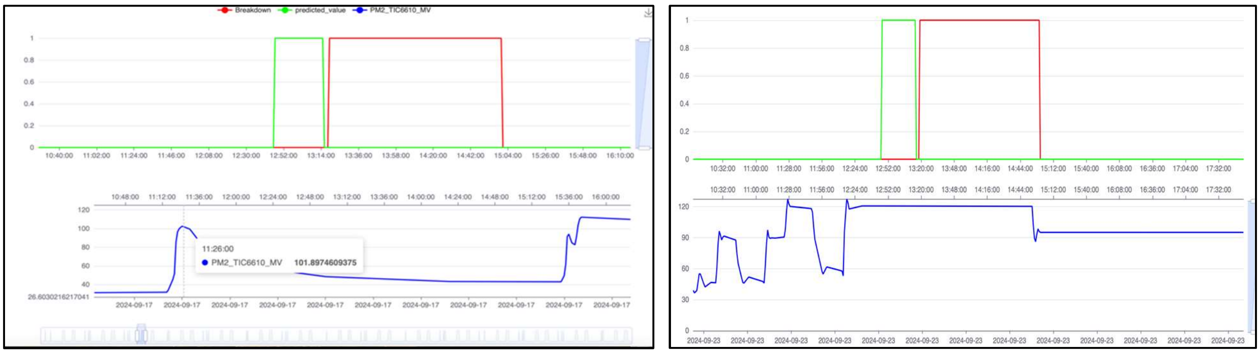

Figure 4.3: Process data variation at Dryer, Stock preparation and Steam sections

The evidence shown in Figures 4.2 and 4.3 clearly showed that, some of the process data varied at dyer section, steam section, stock preparation sections or combination of those.

Comparison with Existing Techniques

BIG-AI's performance was benchmarked against traditional and existing methodologies for sheet break prediction:

Rule-Based Systems: Traditional systems rely on predefined thresholds and lack adaptability. BIG-AI's advanced machine learning models, which adapt to shifting ambient conditions, showed a 40% gain in prediction accuracy.

Statistical System Models: Simple regression analysis struggles with multivariate interdependencies often seen in sheet break cases. BIG- AI's advanced algorithms outperformed these models, achieving a 25% increase in precision and recall.

Legacy Anomaly Detection Tools: Existing systems suffer from high false positive rates. BIG-AI's autoencoder can reduce false positives by 30% through context-aware analysis.

Quantitative Benefits

Reduction in Sheet Breaks: A 35% decrease in sheet break incidents within the first three months of commissioning.

Downtime Reduction: A 28% reduction in unscheduled downtime.

Material Waste Reduction: Achieved a 15% reduction in material wastage, directly improving production uptime.

Proactive Maintenance: Enabled by real-time monitoring, reducing unplanned downtime by 25%.

Cost Savings: Annual savings were realized through increased production, improved quality, faster recovery from sheet breaks, and more efficient grade changes.

The BIG-AI implemented on half million-tonne production paper machine showed significant savings. Figure 4.3 shows potential savings ranging from minimum to best case scenarios, achievable for any paper machine.

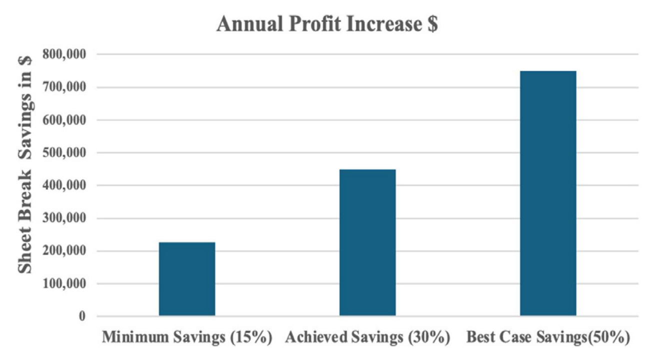

Figure 4.3: Annual Profit Increase by reducing Sheet Breaks

Conclusion and Recommendation

BIG-AI' sheet break prediction technology has proven to be far more successful than existing solutions. It elevates traditional applications to a whole new level by leveraging sophisticated machine learning models, real-time insight availability, and adaptive variability based on current operating conditions. This positions BIG-AI as a revolutionary solution for the pulp and paper industry, where enhanced production efficiency and cost savings will underscore its next-generation status.

The results achieved through BIG-AI's sheet break prediction technology have demonstrated its effectiveness, with a successful implementation on one of the paper machines at the South African Pulp and Paper Industries (SAPPI) plant. Industry experts strongly recommend adopting BIG-AI for improved outcomes and minimal disruptions. By leveraging AI-driven solutions for sheet break prediction, paper machines can reduce sheet breaks by at least 38%, lower customer complaints by 2.8%, and achieve significant cost savings with an ROI of less than one month.

Acknowledgments

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