Real-Time Cathode Voltage Drop (CVD) Analytics in Aditya Potline

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Abstract

Aditya Aluminium, a state-of-the-art AP-30 smelter with a capacity of 370 kt/a, ranks 2nd globally in metal purity among AP-30 smelters. Located in Odisha, India, the smelter emphasizes precise control over various parameters to ensure metal quality and competitiveness in the energy-intensive aluminium smelting process. Any deviations can lead to significant energy and productivity losses.

Aluminium smelting is a highly energy-intensive process, with energy consumption a major driver. Cathode voltage drop (CVD) is the voltage drop across the cathode carbon block to the end of collector bars in the pot. As CVD increases in pots, it may lead to pot voltage increase and squeezed anode-cathode distance (ACD) which decreases current efficiency. ALPSYS process control compensates CVD increase with pot voltage adder, in order to avoid ACD squeezing, which increases energy consumption. This study presents a real-time potline CVD monitoring, Analytics, and Root Cause Analysis (RCA) tool developed for Aditya Smelter, to decrease CVD and energy consumption, and increase pot life.

The proposed solution uses a data-driven approach by creation of digital thread (data pipeline), integrating real-time process monitoring, statistical analysis, and predictive analytics to identify high-CVD pots at an early stage. A five-step methodology was implemented, covering data engineering, multi-linear regression analysis for causal factor identification, and the development of an interactive analytical dashboard using open-source tools like Python NumPy [1] and Streamlit [2] Integrated Development Environment (IDE). Key influencing factors, such as cathode block type, collector bar variations, and process conditions, were analysed to determine their impact on CVD trends over different pot age groups. The deployment of this tool has led to a 30 % reduction in recurring high-CVD pots and energy savings of 78 kWh/t Al. Additionally, automation has resulted in a monthly reduction of over 15 hours of manual work

Keywords: Cathodic voltage drop, Root cause analysis, Multi-linear regression, Energy savings, Data driven decisions.

1. Introduction

In the modern aluminium production, optimizing energy consumption is a critical and continuous operational priority due to its substantial influence on overall production cost and environmental impact. Among the multitude of parameters influencing the efficiency of the aluminium smelting process, CVD stands out as a pivotal indicator. CVD is directly influenced by factors such as cathode wear and contact resistance between carbon and steel collector bars in the cathode blocks.

As aluminium is produced through an energy-intensive electrolytic process (Hall-Héroult process), any increase in electrical resistance in the cathode translates to higher DC energy consumption. A high CVD thus implies an inefficient energy profile, which not only inflates operational costs but also exacerbates cathode deterioration, accelerates pot failure, and undermines overall process sustainability.

While it is understood that CVD naturally trends upward with pot age due to gradual material degradation and thermal stresses, the occurrence of abnormally high CVD in younger pots (low-age pots) is a matter of significant concern. These sporadic and recurring high-CVD behaviours often point toward latent process inefficiencies, equipment faults, or suboptimal operational practices. If left unaddressed, such anomalies can cascade into larger systemic issues, such as premature pot failure, reduced current efficiency, and heightened maintenance frequency.

Traditionally, CVD monitoring has been conducted through periodic measurements and manual review, often after threshold violations have occurred. This reactive approach lacks precision, timeliness, and context-specific insights required to drive meaningful process interventions. Furthermore, the sheer volume and velocity of production data render manual methods both time-consuming and prone to oversight.

To overcome these challenges, this paper introduces a comprehensive, data-driven digital platform for real-time CVD monitoring and root cause analysis. The manual method of CVD measurement remained in place after the implementation of this project, typically measuring all pots once per week. Developed entirely in-house at Aditya Aluminium, Hindalco Industries, the new system integrates automated data acquisition, statistical analysis, and machine learning techniques within an intuitive Streamlit-based UI. This platform empowers plant personnel with timely alerts, historical trend visualizations, predictive insights, and actionable diagnostics, enabling faster and more informed decision-making.

The objective is not merely to detect high CVD events but to transform the way pot health is understood and managed, shifting from a reactive paradigm to a predictive and preventive approach. By embedding analytics at the core of potline operations, the solution aims to enhance energy efficiency, reduce unplanned downtime, and improve the overall performance of the smelting process.

2. Problem Statement and Objectives

2.1 Challenges

CVD trends are impacted by pot age, making it difficult to distinguish between natural and abnormal rises. Manual reports lead to delays in identifying high-risk pots and existent high CVD in some pots goes unnoticed, affecting efficiency.

2.2 Objectives

The following objectives were set at the start:

- Develop a real-time monitoring tool to track pot-wise CVD.
- Identify young pots (age < 1000 days) with abnormally high CVD.
- Compare recurring vs. non-recurring high-CVD patterns.
- Enable root cause identification and suggest corrective actions.
- Deliver insights to shop floor personnel through automated alerts and intuitive dashboards.

6. System Adoption and Sustainability

To ensure adoption and sustainability, the following steps were implemented:

- **Training sessions:** Conducted for process in-charges and technical staff.
- **Mailer integration:** Daily alert mails for quick action on anomalies.
- **Scalability:** Architecture designed to be replicated across Hindalco's other smelter locations like Mahan, Hirakud, and Renukoot.

7. Conclusions

The in-house developed real-time CVD analytics tool has demonstrated measurable benefits in energy savings, process transparency, and shop-floor responsiveness. With the integration of analytical logic and user-centric design, the system provides actionable insights, aiding timely decision-making. The platform sets a benchmark for digital transformation in energy-intensive process industries and is now a model for other smelters in Hindalco.

8. Acknowledgements

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9. References

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