

Gas Treatment Centre - Smart Filter Bags Cleaning With PLC-Based Automation at Sohar Aluminium

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Abstract

Sohar Aluminium has upgraded its Gas Treatment Centre (GTC) by implementing a cutting-edge PLC-based control system, significantly improving the filter bags cleaning process. The traditional vendor-supplied sequencers, installed 35 meters above ground, posed significant safety risks and caused prolonged downtimes. The new in-house developed PLC-based solution replaced these sequencers with a flexible SCADA-integrated system, relocating the controllers to the Motor Control Centre (MCC) for enhanced maintainability, reliability and safety. This innovative system allows operators to monitor and control the process remotely, reducing intervention time and human error. Faults are systematically correlated with specific valves, enabling targeted maintenance and minimizing downtime. The introduction of a pressure regulator with a newly developed PID control optimized the performance and enabled using the system's full potential.

The Smart GTC project has significantly improved efficiency, safety, and cost-effectiveness, positioning the operations at best practices and close to a benchmark level in process operation and industrial automation. By adopting modern automation technologies, Sohar Aluminium has demonstrated its commitment to innovation and operational excellence.

Keywords: PLC-based automation, Filter cleaning, Scada integration, Process optimization, Cost reductions.

1. Introduction

1.1 The Critical Role of Gas Treatment in Aluminium Smelting

Gas Treatment Centers (GTCs) are integral to modern aluminium production, playing a dual role in environmental stewardship and process economy. Their primary function is the capture and treatment of harmful emissions, predominantly gaseous and particulate fluorides, originating from the electrolysis process, thereby ensuring compliance with stringent environmental regulations. Furthermore, efficient GTC operation contributes to economic benefits through the recovery and reinjection of fluorine-rich alumina into the smelting pots, effectively reducing raw material consumption and associated costs.

1.2 Principles of Filter Bag Cleaning in Dry Scrubbing Systems

In dry scrubbing GTCs, fabric filters are employed to capture particulate matter, including alumina and adsorbed fluorides. The sustained efficiency of these filters depends on periodic cleaning to remove the accumulated dust cake. This is commonly achieved by introducing pulses

of compressed air in a reverse-flow manner thereby dislodging particulates from the filter media. Conventional cleaning mechanisms often utilize fixed-timer sequencers located proximally to the filter units. While providing basic functionality, these systems inherently lack adaptability to dynamic process conditions, such as variations in filter bag permeability due to aging, fluctuation in gas flow, or changes in production throughput.

1.3 Challenges with Legacy Filter Bag Cleaning Systems at Sohar Aluminium

Sohar Aluminium's legacy filter bag cleaning system, while having fulfilled the plant's operational needs for many years, presented opportunities for improvement as the system approached the end of its lifecycle. The original design, based on standalone sequencers installed atop the filter structures (baghouses), had inherent limitations in flexibility, adaptability, and integration with modern plant-wide control strategies.

With a focus on enhancing system reliability and ensuring long-term operational excellence, Sohar Aluminium identified the need to modernize the GTC filter bag cleaning system. This initiative aimed to transform the existing setup into a smart, adaptive solution that could meet current operational requirements and support future improvements.

By adopting an in-house engineering approach, the project focused on developing a robust, maintainable, and scalable system architecture. The upgraded design prioritized relocating control hardware to a protected environment, enhancing diagnostic capabilities, integrating with the existing SCADA platform, and ensuring long-term reliability through standardization and futureproofing. This strategic upgrade has modernized the filter bag cleaning process and established a foundation for ongoing performance enhancements, safety improvements, and operational efficiency.

2. System Design and Implementation of the Modernized Control Architecture

2.1 Centralized Control Hardware and Enhanced Environmental Protection

A key design decision was the relocation of all primary control hardware (PLC units) from the exposed top-of-filter environment (see Figure 1) to a climate-controlled Motor Control Center (MCC). This strategic move significantly mitigated the risk of hardware failure due to thermal stress, humidity, and particulate ingress, thereby enhancing overall system longevity and reliability. Standard industrial PLCs were selected for their robustness, processing capabilities, and programming flexibility using standard IEC 61131-3 languages.



Figure 1. Legacy system.

2.2 Comprehensive SCADA/HMI Integration for Enhanced Operability

As shown in Figure 2, the new system incorporates full integration with the plant's existing SCADA platform. This provides operators with a centralized Human-Machine Interface (HMI) at the Operator Interface Station (OIS), offering:

- **Real-time Visualization:** Dynamic mimics of the GTC filter sections, displaying individual valve status, differential pressure across filter banks, cleaning cycle progress, and alarm conditions.
- **Intuitive Operator Control:** Capabilities to remotely initiate and adjust cleaning cycle parameters (e.g., pulse duration, interval), and manually pulse individual valves or entire rows for diagnostic or specific cleaning needs.
- **Data Logging and Trending:** Continuous logging and graphical trending of critical parameters such as pressure profiles, cycle times, and alarm histories, facilitating performance analysis, pattern recognition, and informed decision-making for predictive maintenance.

This centralized interface dramatically improves operational oversight, provides at-a-glance system visibility, and critically enhances personnel safety by eliminating the routine need for high-risk manual interventions at the filter units.

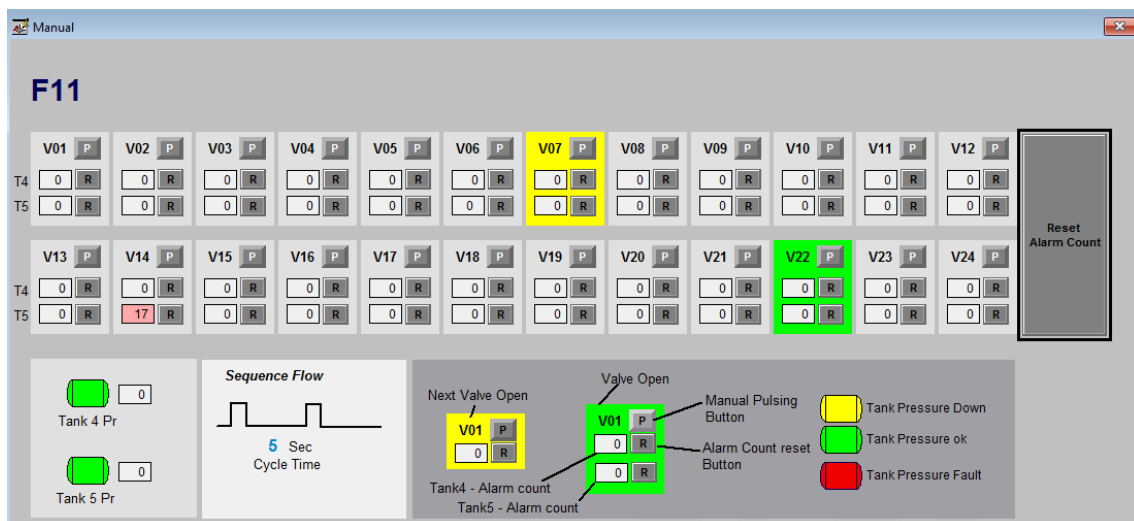


Figure 2. SCADA screen for individual filter control.

2.3 Advanced Fault Detection and Diagnostic Capabilities

A custom fault detection algorithm was developed and implemented within the PLC logic. This algorithm continuously monitors valve command signals against feedback (where available) and correlates abnormal pressure readings or valve actuation failures with specific solenoid valves or potential compressed air supply issues. The SCADA system then flags the precise location of the malfunction through alarms and on the HMI mimics. This enhanced diagnostic capability allows maintenance staff to immediately pinpoint malfunctioning components, thereby eliminating the previous time-consuming trial-and-error methods and drastically reducing the mean time to repair (MTTR).

3. Operational Enhancements and Performance Improvements

3.1 Optimized Cleaning through PID-Controlled Pressure Regulation

A Proportional-Integral-Derivative (PID) control loop was implemented within the PLC to dynamically regulate the compressed air pressure used for filter bag cleaning. This system continuously monitors the differential pressure across the filter bags – a key indicator of dust loading – and adjusts the cleaning intensity (pulse pressure and/or frequency of cleaning cycles) accordingly. This adaptive control strategy:

- Compensates for variations in filter bag permeability as they age and accumulate residual dust.
- Optimizes compressed air consumption by avoiding over-cleaning, particularly during periods of lower particulate loading (e.g., accommodating day-night operational cycles or reduced production throughput).
- Ensures consistent and effective cleaning, contributing to stable GTC performance by maintaining optimal airflow and filtration efficiency, thereby extending filter bag life.

3.2 Improved Reliability and Reduced Maintenance Interventions

The relocation of critical control hardware to the protected MCC environment has virtually eliminated the frequent failures previously attributed to harsh environmental exposure, especially the malfunction of push-button modules and display units on the sequencers during high ambient summer temperatures. The ability to monitor, adjust setpoints, optimize cleaning parameters, and diagnose faults remotely via the SCADA system has minimized the need for manual access to the filter tops. This has not only reduced the maintenance workload and associated safety risks but also allowed for proactive adjustments, preventing minor issues from escalating.

3.3 Operational Impact

The implementation of the PLC-SCADA system has drastically reduced the need for manual operator intervention (see Figure 3). Previously, operators had to climb approximately 35 meters to access the sequencer system for inspections or adjustments, averaging 9 climbs per week. With the new centralized control and remote monitoring capabilities, this has been reduced to just 1 climb per week, significantly improving safety and reducing physical strain on personnel (especially in the summertime).

3.4 Maintenance Impact

As shown in Figure 3, maintenance activities have also seen a substantial improvement. The legacy system required frequent manual fault diagnosis, averaging 6 visits per week. The new system's advanced fault detection and SCADA-based diagnostics have cut this down to almost zero visits per week. This not only reduces maintenance workload but also minimizes downtime and enhances system reliability.

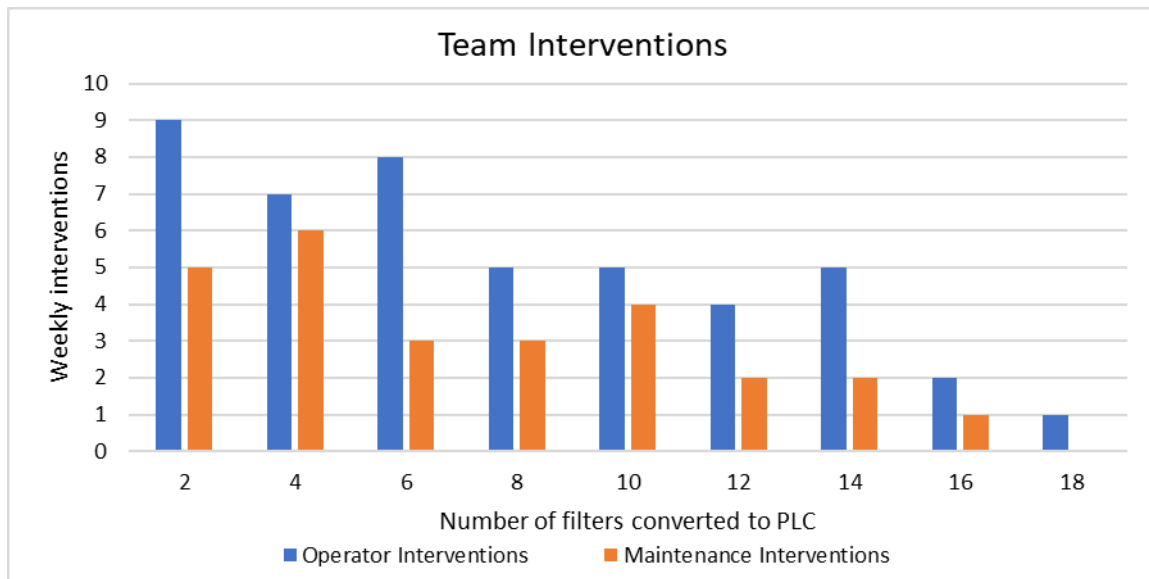


Figure 3. Maintenance impact.

4. Economic and Longevity Benefits

4.1 Reduced Capital and Operational Expenditure

The project’s successful execution by the Sohar Aluminium in-house team has been a key factor in ensuring long-term system reliability, operational resilience, and the development of critical technical competencies within the organization. By leveraging internal expertise, the project has not only delivered a solution that is tailored to the plant’s specific operational needs but has also enhanced the team’s proficiency in handling complex control systems, enabling faster and more effective responses during emergency scenarios or system faults.

This capability to independently manage, troubleshoot, and adapt the system ensures that the GTC filter bag cleaning process remains robust, efficient, and aligned with operational best practices – without relying on external support for system upgrades, modifications, or maintenance. The improved reliability of the system, combined with the team’s strengthened technical foundation, contributes to optimized compressed air consumption, reduced unplanned maintenance interventions, and extended component lifespan, thereby supporting the plant’s long-term operational goals.

4.2 Extended Filter Bag Life and Enhanced Availability

The adaptive pressure regulation and more precise, condition-based cleaning control have led to a noticeable extension in the operational lifespan of the filter bags. Gentler, demand-based cleaning reduces mechanical stress on the filter media compared to constant, aggressive timer-based pulsing. Furthermore, the improved diagnostic capabilities ensure that any developing issues, such as leaking diaphragms or faulty solenoids, are identified and addressed promptly, preventing suboptimal cleaning that could lead to premature bag blinding, damage, or increased pressure drop. This directly contributes to lower filter replacement costs and increased overall GTC availability and efficiency.

5. Legacy Sequencer vs. PLC-SCADA System: A Comparative Analysis for GTC Filter Bag Cleaning

The comparison between Legacy Sequencer and PLC-SCADA System is given in Table 1 and Figure 4.

Table 1. Comparison between the legacy system and PLC-SCADA system.

Parameter	Legacy Sequencer System	PLC-SCADA System
Filter bag life	18 to 24 months (frequent premature failures)	Extended beyond 30 months (approaching 30–36 months)
Cleaning pressure control	Fixed pulse pattern, manual coarse tuning	PID-based dynamic auto-regulation (day/night cycles)
Fault diagnosis	Manual trial-and-error, time-consuming	Automatic valve-specific fault pinpointing via SCADA
Downtime due to control failure	High, exacerbated by parts obsolescence	Significantly reduced, near-zero for control hardware
Operator safety	Required climbing 35 m for inspection/repair	Remote monitoring and diagnostics from OIS
Spare part availability	Obsolete, vendor-dependent, long lead times	Standardized components, readily sourced
System flexibility	Not configurable, fixed logic	Fully reprogrammable and scalable logic
Capital cost (upgrade)	Vendor quote for similar > 200 kUSD	120 kUSD (In-house engineered solution)

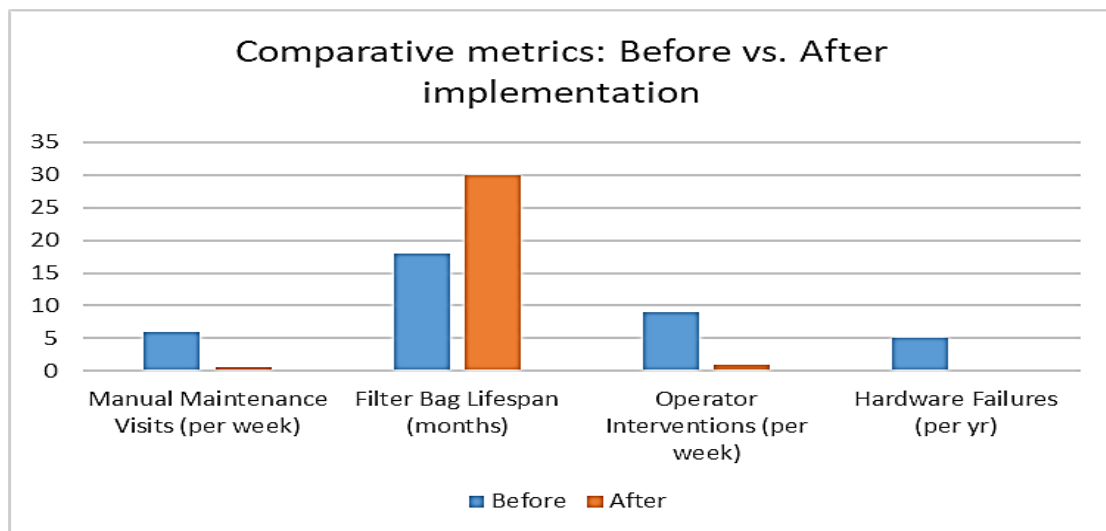


Figure 4. Comparative metrics.

6. Conclusions

The modernization of the GTC filter bag cleaning system at Sohar Aluminium, through the strategic implementation of a centralized PLC-SCADA architecture, has successfully addressed critical limitations associated with the legacy standalone sequencer system. The project has delivered tangible, measurable improvements across multiple operational dimensions, including:

- A 90 % reduction in manual maintenance visits to the filter units, with fault diagnostic requirements decreasing from 6 visits per week to nearly zero.
- A significant increase in filter bag lifespan, extending from 18 to 24 months to over 30 months, reducing filter replacement costs and minimizing system downtime.
- A drastic reduction in operator interventions, lowering the frequency of high-risk climbs to the filter tops from 9 climbs per week to 1, thereby improving personnel safety.
- Enhanced system robustness, with hardware failures previously caused by environmental factors now reduced to near-zero, thanks to the relocation of control hardware to a protected MCC environment.
- Optimized compressed air usage, supported by a PID-controlled cleaning cycle, delivering energy savings while maintaining filtration efficiency.

In addition to these operational benefits, the in-house execution of the project has elevated the technical capabilities of the Sohar Aluminium team, fostering self-reliance in system management and emergency response readiness. The project has positioned Sohar Aluminium as a leader in adopting modern, adaptive automation solutions, demonstrating a proactive approach to operational excellence and sustainability in the aluminium smelting industry.

