Upgrade and Application of Anti-Disturbance Busbar Technology in Full-Current Environments with Strong Magnetic Fields

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Abstract

For the long-running aluminium potline suffering from uneven electric field distribution in the busbar system, insufficient magnetohydrodynamic (MHD) stability, and abnormal fluctuations in cells leading to stability deterioration in upstream and downstream cells, the R&D team of Guiyang Aluminium and Magnesium Design & Research Institute (GAMI) developed an online upgrading and application technology for a novel anti-disturbance busbar in full-current environments with strong magnetic field. This technology employs an electromagnetic magnetohydrodynamic (EMHD) simulation coupling platform to model current distribution and dynamic MHD stability in the aluminium potline. The anti-disturbance busbar technology corrects the current distribution in cells, while strong magnetic welding technology enables online upgrading of the busbar system in the aluminium potline. The technology effectively mitigates the impact of transient currents on cell stability and blocks the propagation of current distribution imbalance across the aluminium potline under unstable conditions, significantly improving cell stability and interference resistance. After being applied to a 400 kA cell, this technology achieved an average voltage reduction of 31 mV and a DC power consumption decrease of 101 kWh/t Al, with significantly improved cell stability. It provides a scientifically feasible pathway for the upgrade and optimization of busbar systems in the currently operating aluminium potline.

Keywords: Aluminium electrolysis, Current distribution in cells, Anti-disturbance busbar, Strong magnetic welding technology.

1. Introduction

Aluminium, as the most important metal second only to steel in terms of global production and consumption, plays a pivotal role in modern industry. As the world's largest producer of electrolytic aluminium, China's output in 2024 reached 43.393 million tonnes (according to International Aluminium Institute statistics), accounting for 59 % of the global total, underscoring its dominant position in the global aluminium industry. However, the high energy consumption of the aluminium electrolysis process cannot be overlooked. The sector's annual electricity consumption is about 500–550 TWh, representing 7 % of the nation's total electricity usage. With the advancement of national "dual-carbon" policies and industry requirements for high-quality development, energy saving and carbon reduction in electrolytic aluminium have become the primary direction for the industry's progress [1].

In China, cells operating below 200 kA are being gradually phased out and upgraded to large-scale cells with 500–600 kA, while most cells above 240 kA are undergoing technical upgrades either through potline shutdowns or online retrofits. Currently, 240–500 kA cells account for about 50 % of the domestic total. However, these cells generally suffer from inherent issues leading to higher energy consumption. In recent years, China has widely adopted graphite cathode lining modifications, achieving some improvements in energy consumption. Yet, optimization of busbars and operational stability remains challenging, as construction under strong magnetic fields has persistently hindered advancements in busbar upgrades.

1.1 Busbar Design

The design philosophy, multi-physics coupling simulation software, and auxiliary process methods of long-running potlines lag behind current technological levels, exhibiting inherent multi-field problems. Regarding magnetic field design, the new potline's standards require the four-quadrant Bz average value to be within 4 G [2], whereas older potline generally exhibit higher Bz values. Figure 1 shows the composite Bz average distribution in one quadrant:

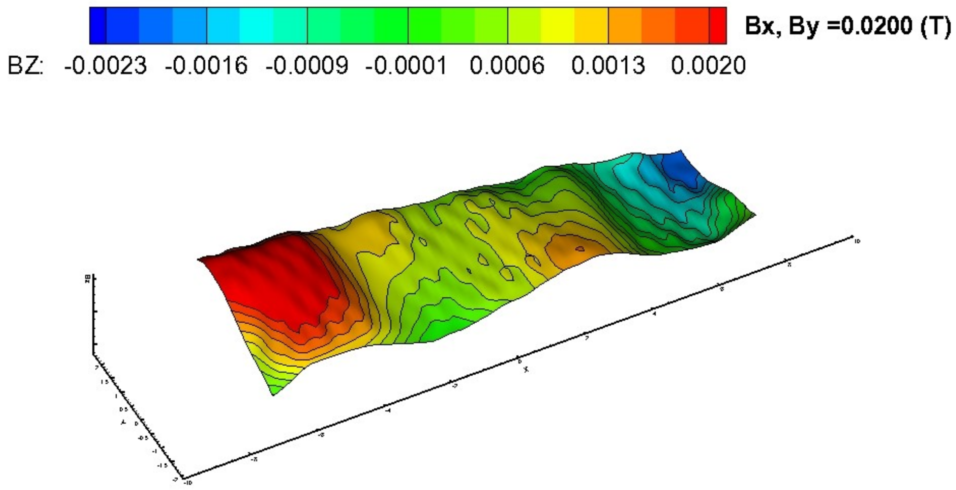

Figure 1. Vertical magnetic field (Bz) distribution of a 300 kA aluminium reduction cell (elevated mean values and gradients).

In terms of current distribution design, the older potline generally prioritized low investment with no requirements for energy consumption. This led to the widespread selection of smaller busbar cross-sections, higher current density in the busbars, and operating no-load voltages consistently higher than current design standards. Additionally, the current distribution uniformity failed to meet today's design criteria.

1.2 Fluctuation Interference Issue Between Cells

In traditional designs, to facilitate electrical balance, multiple conductive paths between the cathode flexibles and the anode risers are separated. However, in production practice, interference fluctuations between adjacent cells have persistently troubled operations, particularly in 400 kA and larger-amperage cells. The cause of interference between cells is that the potline current encounters certain resistance when transmitted through the busbar system of aluminium reduction cells. The obstructed current is forced to redistribute through the molten aluminium, leading to intensified MHD instability issues. This phenomenon becomes particularly pronounced during anode effects or the initial stage of anode replacement, when some anode carbon blocks barely conduct electricity. This results in severe uneven distribution of cathode and anode currents in the cell, which propagates to upstream and downstream cells through the busbar system, deteriorating post-tapping cell disturbances significantly decreased. Mutual interference between neighbouring cells during anode effects was effectively mitigated, with smoother curve operation and a notable reduction in anode effect occurrences. The shared voltage during anode effects also declined, contributing to a marked reduction in DC power consumption.

4. Conclusions

For operating potlines suffering from issues such as uneven current distribution, poor MHD stability, and voltage fluctuations in downstream cells caused by anode replacement or anode effects in upstream cells, affecting overall stability, our team developed an upgraded anti-disturbance busbar technology for environments with a strong magnetic field. This technology employs a cloud-based coupled EMHD simulation platform to conduct dynamic stability analysis of existing older plotlines. By implementing anti-disturbance busbar technology, interbus is installed on the cathode busbars to form multiple electrical bridges, while ensuring equipotential conditions at the branch busbar outlets. This significantly enhances the cells' anti-disturbance capability and improves operational stability. Additionally, optical-magnetic welding technology for environments with strong magnetic fields is adopted to enable online construction without shutting down the cells. The technology has been successfully applied in multiple 200–600 kA potlines. After the pilot retrofit of a 400 kA cell, the average voltage was reduced by 31 mV, with DC power consumption decreasing by 101 kWh/t Al, alongside notable improvements in operational stability. Practice has proven that this technology provides a scientifically viable approach for upgrading and optimizing busbars in currently operating potlines, offering smelters a practical solution for energy saving and carbon reduction.

5. References

Yanbin Wang, Current Status of Carbon Emissions in the Electrolytic Aluminium Industry and Pathways for Energy Conservation and Carbon Reduction, *Resources Economization & Environmental Protection*, No. 2, (2025), 14–19, https://doi.org/10.16317/j.cnki.12-1377/x.2025.02.027 (in Chinese).

Xuemin Liang, Discussion On the Busbar Design of Modern Large Aluminium Reduction Cells, *Light Metals*, No. 1, (1990), 20–26, https://doi.org/10.13662/j.cnki.qjs.1990.01.009 (in Chinese).

Xiaodong Yang, Discussion on Designing High Amperage Energy-saving Aluminium Reduction Cells - Busbar, Cathode Structure and MHD Stability, *Light Metals*, No. 10, (2016), 27–32, https://doi.org/10.13662/j.cnki.qjs.2016.10.006 (in Chinese).

Yiqing Liu, Influence of Magnetic Field on Welding and Anti-magnetic Welding in Aluminum Smelter, *Light Metals*, No. 3, (1978), 14–18, https://doi.org/10.13662/j.cnki.qjs.1978.03.004 (in Chinese)

Min Huang, Stability Analysis and Flow Field Calculation of Magnetic Fluid in Aluminium Reduction Cells, Wuhan: Huazhong University of Science and Technology, 2002 (in Chinese).

Nobuo Urata, Wave Mode Coupling and Instability in the Internal Wave in Aluminum Reduction Cells, *Light Metals*, 2005, 455–460 (in Chinese).

Yi Yang, Determination Criteria for Magneto-Hydro-Dynamics Stability of Aluminium Reduction Cells: Research Based on Arithmetic Mean Value of Bz, *Nonferrous Metals (Extractive Metallurgy)*, No. 01, (2025): 66–71, https://doi.org/10.20237/j.issn.1007-7545.2025.01.009 (in Chinese).

Xiang Nie, et al., *Electromagnetic Field and Electromagnetic Waves*, Xi'an: Xi'an Jiaotong University Press, 2022 (in Chinese).

Tingyang Zhou, Hongyan Zhang, *Electrical Network Theory*, Hangzhou: Zhejiang University Press, 1997 (in Chinese).