Discussion on Development of Intelligent Control Technology for Aluminium Reduction Cells

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Abstract

Since the invention and application of the Hall-Héroult process in 1886, aluminium electrolysis production technology has been improving cell design, production control and operation management. The industry will continue to face the challenge of low energy consumption for a long time to come in the new situation of constantly upgrading technology in combination with low-carbon and clean energy and how to make large-scale aluminium electrolytic cells operate stably and maintain good performance.

Performance indicators have become the focus of industry. In this article, the author uses the current leading large-scale aluminium electrolysis cell technology and related processes in the aluminium electrolysis industry in China and abroad to discuss intelligent cell control. With the theoretical basis as the background, the strategies and achievements of some existing intelligent control technologies are listed, and finally the future vision of technological innovation and development in this field is proposed.

Keywords: Large aluminium electrolytic cell, Low energy consumption and low carbon emissions, Intelligent cell control.

1. Introduction

Intelligent and innovative development of aluminium electrolysis that combines low energy consumption and low carbon emissions is the main development direction of the global primary aluminium industry and is also the focus of China in this field. It is the key to implementing the new development concept, cultivating new quality productivity and catching up with the world's leading level.

Recently, the research team of Academician Huang Xiaowei (led by Professor Li Jie of Central South University) published a paper, which not only affirmed the achievements made since the reform and opening up, but specifically mentions the three new normal problems that China's aluminium electrolysis industry still faces in its current development stage [1]:
1) Extreme operating conditions put the MHD stability in the cell in a difficult situation;
2) The operating conditions of large or super-large prebaked cells are complicated, and the traditional centralized and decentralized control system cannot be controlled by different zones in the cell;
3) The deterioration of aluminium smelting resources has seriously impacted the stable operation of aluminium electrolytic cell production.

The article also mentions seven key points about the greater challenges that future technological innovation will face. However, I believe that future technological challenges should be divided into two categories. In other words, research work should be accelerated in two different stages:
1) Intelligent and innovative development of traditional aluminium electrolysis process in terms of low energy consumption and low carbon emissions;

2) Research and testing of new aluminium smelting processes, such as the current research and application of large-scale inert anode cells and other technologies such as experimental research on new smelting processes, such as HaLZero.

In the future, the development and research of net zero carbon emissions in traditional aluminium electrolysis process or new aluminium smelting process still has the following problems to be solved:
1) Renewable electricity,
2) The traditional aluminium electrolysis process still needs to solve the problems:
- Emission-free alumina and anode production,
- Transportation of all materials, including alumina, by electric ships, electric trains and new energy vehicles,
- Carbon Capture, Utilization and Storage (CCUS).

3) Recycling and utilization of post-consumer aluminium waste.
4) Successfully testing and implementation of different aluminium production processes (non-consumable anodes, HaLZero).

However, for now, intelligent innovation and development of traditional aluminium electrolysis process in terms of low energy consumption and low carbon emissions is still the best choice.

In recent years, and even for a considerable period of time in the future, the existing primary aluminium production capacity in China and abroad is the priority for further development.

2. Background of Cell Technology Development

At present, the overall technology of large and super-large aluminium electrolytic cells in China and abroad is becoming more and more mature. The main characteristics of the operation of leading large aluminium electrolytic cell technologies outside China are:
1) Anode current density is high (0.90–1.0 A/cm2), the current efficiency is high (94–95 %), and specific energy consumption is typically 12.8–13.5 kWh/kg Al.
2) Leading low energy consumption is Hydro's HAL4e Ultra cell with 11.79 kWh/kg Al, with next goal of 10 kWh/t Al [2].
3) The leading design technologies of large and super-large aluminium electrolytic cells in the world outside China are HAL4e Ultra of Hydro Aluminium, AP60/APXe of Rio Tinto, DX+ Ultra and EX of Emirates Global Aluminium (EGA) and RA-550 of RUSAL.

China is now leading the design of large and super-large aluminium electrolytic cell technologies. The emergence of 300 kA electrolysis cells in China was 12 years later than that in the West, and the emergence of 500 kA cells was 10 years later. It took about 10 years for China and other countries to increase the current from 300 kA to 500 kA. It took 12 years in Pechiney to develop 600 kA cells, but only 5 years in China. Chinese ultra-large capacity cells are SAMI SY500/SY600, NEUI600, GAMI GP500/GP530 and Central South University technology CSU530. NEUI600 and SAMI600, 600 kA technology has been massively implemented in China in 20 potlines (a few still under construction).

In addition to the 38 AP60 600 kA pilot cells built by Rio Tinto in Québec, Canada, there are 92 more cells currently under construction and will start up in 2026. China’s development is much faster; there are already 20 potlines with 600 kA technology (NEUI600 and SAMI600), built in the last 10 years and many more with 500 kA technology. These are at the forefront and are the mainstream cell technologies for newly built aluminium smelters.

(2) In addition to the urgent need to upgrade the existing control hardware and software, various fixed or mobile intelligent measurement instruments and components must be implemented in the potlines.
(3) In view of increasing the proportion of renewable energy, stable operation of the cells must be considered as the primary condition. It is necessary to create better response for the dynamic control of cell energy balance. This will be achieved with future intelligent control system technology.

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8. References

1. Li Jie, Huang Xiaowei, et al., Research on the innovative development of low-carbon, clean and intelligent aluminium smelting, [J]. *Chinese Journal of Engineering Science*, 2024, 26 (5), 223-233.
2. Martin Segatz et al., Cell technology path towards specific energy consumption below 12 kWh/kg, *Light Metals* 2016, 301-305.
3. Marco A. Stam, Mark P. Taylor et al, Development of a multivariate process control strategy for aluminium reduction cells, *Light metals* 2009, 311-315.
4. Mark P. Taylor and Barry J. Welch, Improved energy management for smelters, *Eighth Australasian Aluminium Smelting Technology Conference and Workshops*, Yeppoon, Australia, 3~8 Oct. 2004.
5. Vinko Potocnik and Michel Reverdy, History of computer control of aluminium reduction cells, *Light Metals* 2021, 591-599.
6. Pierre Marcellin and Antoine Garnier, Protection against open circuit in ALPSYS pot control system, *Proceedings of 39th International ICSOBA Conference, Virtual Conference,* 22-24 November, 2021, Paper AL24, *Travaux* 50, 877-888.
7. Michel Reverdy and Abdalla Alzarooni, EGA's advanced pot control system—simple and flexible, International Aluminium Journal 1–2, February 2018, 32 and 34.
8. Steinar Kolås, Stein O. Wasbø, A Nonlinear model-based control strategy for the aluminium electrolysis process, *Light Metals* 2010, 501-505.
9. Hans Erik Vatne HE, Use of digital twins in optimization of aluminium production, *Future Aluminium Forum*, Warsaw, Poland, 22–23 May 2019.
10. Xiangwen Wang, Gary Tarcy, Eliezer Batista and Geff Wood, Active pot control using ALCOA STARprobe, *Light Metals* 2011, 491-496.
11. Jean-Pierre Gagné, Rémi St-Pierre, Pascal Côté, Pascal Lavoie and Albert Mulder, Application of multivariate statistical process control with STARprobeTM measurements in aluminium electrolysis cells, *Light Metals* 2017, 599-605.
12. Viktor Mann et al., RUSAL's digital tools for the proactive control of cells and cell lines, *Proceedings of 43rd International ICSOBA Conference,* Nanning, China, 26-31 October 2025, *Travaux No* 54 (this conference).
13. Xiaobing Yi and Quinhong Tian, Development and application of a multivariate process parameters intelligence control technology for aluminium reduction cells, *Light Metals* 2010, 523-527.
14. Xiaobing Yi and Quinhong Tian, Upgrade and innovation of (MPPIC) technology for aluminium reduction cells, Proceedings of the 36th International ICSOBA Conference, Belem, Brazil, 29 October - 1 November, 2018, *TRAVAUX No. 47*, 655-662.
15. Zhiyang Chen et al. and Xiaobing Yi, New study and application of intelligent breaking control device for aluminium reduction pot in the MPPIC technology, *Proceedings of the*

37th International ICSOBA Conference and XXV Conference «Aluminium of Siberia», Krasnoyarsk, Russia, 16 – 20 September, 2019, *TRAVAUX No.* 48,

16. Jie Li, Studies of optimization and process control of large aluminium cells, ICSOBA 2014, October 2014_Zhengzhou_China.
17. Hongliang Zhang et al., Progress in aluminium electrolysis control and future direction for smart aluminium electrolysis plant*, Journal Of Metals*, Vol 69, No2-2017, 292-300.
18. Jiaki Li et al., Construction and application of Digital Twin in aluminium electrolysis, *Light Metals* 2024, 453-463.
19. Jie Li et al., Experiments on measurement of online anode currents at anode beam in aluminium reduction cells, *Light Metals* 2015, 741-746.
20. Choon-Jie Wong et al., A Smart Individual Anode Current Measurement System and Its Applications. Light Metals 2023, 43-51.
21. Hao Xiao, Jun Tie, Dongwei Liu, Boyang Liu, Jun Lei, Application and prospects of optical fiber measurement technology for current distribution in aluminium electrolysis cells, *Proceedings of the 43rd International ICSOBA Conference*, Nanning, China, 26-31 October 2025, *Travaux No* 54 (this conference).
22. Chun Li et al., Demand-based feeding control for different zones in aluminium reduction cell to improve uniformity of alumina concentration, *Proceedings of the 43rd International ICSOBA Conference*, Nanning, China, 26-31 October 2025, *Travaux No* 54 (this conference).
23. Agnello Borim et al., STARprobeTM implementation in Sohar Aluminium potline, *Proceedings of the 41st International ICSOBA Conference*, Dubai, 5 - 9 November 2023, Travaux 41, 1273-1282.
24. Heraeus–Electro-Nite, FiberLab, https://www.heraeus.com/en/hen/products_and_solutions_hen/aluminium/aluminium.html (accessed on 31 July 2025).
25. Junfeng Wu, Application and validation of intelligent inspection robots in aluminium electrolysis, *Proceedings of the 43rd International ICSOBA Conference*, Nanning, China, 26-31 October 2025, *Travaux No* 54 (this conference).
26. Qiang Yu et al., Autonomous intelligent technology for three steel temperature measurement in cells using suspended-rail infrared thermometry, *Proceedings of the 43rd International ICSOBA Conference*, Nanning, China, 26-31 October 2025, *Travaux* No 54 (this conference).
27. Xiangquan Li et al., Design of soft-sensing model for alumina concentration based on improved Deep Belief Network, Processes 2022, 10, 2537, https://doi.org/10.3390/pr10122537.
28. Najeeba Aljabri et al., Advanced process control with smart smelter sensors at EGA, *Proceedings of the 40th International ICSOBA Conference*, Athens, 10 - 14 October 2022, *Travaux* 50, 1053-1064.