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Technological Breakthrough and Industrialization Practice of Second-Generation Iron-Chromium Flow Batteries

ESPlaza Long Duration Energy Storage Network

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From September 10-12, the 2025 3rd China Long Duration Energy Storage Conference, hosted by ESPlaza Long Duration Energy Storage Network, was held in Huzhou, Zhejiang. Dr. Liyu Li, Founder and CEO of Cougar Creek Technologies, LLC (USA), attended the meeting and delivered a keynote speech on the "Commercialization Progress and Investment Return Analysis of Second-Generation Iron-Chromium Complex Flow Batteries."

Having been deeply involved in the energy storage field for many years, he conducted long-term research on vanadium flow batteries before shifting to the research and development of iron-chromium flow batteries, leading his team to achieve several key breakthroughs. The following is the core content of his report.

1

From the Dilemma of First-Generation Iron-Chromium Batteries to the Core Breakthrough of IMABATTERY

The iron-chromium hydrochloric acid system was first invented by NASA in 1975 and has been in use for 50 years. During this period, enterprises such as Sumitomo Electric in Japan, Hubei Zhenhua, SPIC, and China Maritime Energy Storage have all attempted to commercialize the new technology at scale.

The first generation of iron-chromium batteries initially adopted a structure where "iron and chromium were placed separately on both sides of the membrane." However, due to the inability to control substance separation stably, the system was improved in 1984 by the team led by Lawrence H. Thaller, the "Father of Flow Batteries." Thaller was able to improve the existing technology into a "Mixed Symmetric System"—meaning iron and chromium exist as a mixture within the system. This concept is often misunderstood by the industry, yet it is the foundation for understanding this technology.

Dr. Li emphasized that the core dilemma of the early technology lay in the difficulty of controlling hydrogen evolution: the instability of electrochemical activity of divalent chromium ($Cr2+$) and trivalent chromium ($Cr3+$) ions. The hydrogen evolution amount per cycle was about 1%. The process of generating hydrogen gas would oxidize divalent iron ($Fe2+$) into trivalent iron ($Fe3+$), ultimately leading to system failure. For a long time, this problem lacked an effective solution.

Addressing this pain point, Dr. Li led his team to develop IMABATTERY's proprietary technology, which essentially includes two breakthroughs:

First is the "Nitrogen-Containing Complex Electrolyte System." This is the team's first authorized chemical system patent in the United States. By

converting chromium ions complexed with water in the solution into ions complexed with nitrogen-containing compounds, the activity of chromium ions is significantly enhanced, reducing the hydrogen evolution from 1% to 0.05%—a reduction of up to 20 times.

Second is the "Electrochemical-Chemical Hybrid Reduction Method." Drawing on previous experience in researching vanadium flow batteries, the team utilized the characteristic where "charging tetravalent vanadium to pentavalent vanadium decomposes water to produce hydrogen ions." In one electrochemical cell, trivalent iron is reduced to divalent iron, supplementing the hydrogen ions therein. The remaining hydrogen ions form a strong oxidant with pentavalent vanadium, which is then chemically reduced back to tetravalent vanadium using common reducing agents like fructose, achieving recycling. This process reacts quickly, and due to the low hydrogen evolution, the burden of side reactions is minimal.

Based on these two technologies, their first-generation product was launched in 2020. At that time, it had already achieved a capacity decay rate of less than 10% over 300 continuous cycles, meeting the standard of "maintaining operation on an annual basis." In 2022, the team also collaborated with Xirong Energy Storage to build a 2MWh first-generation demonstration project, laying the foundation for subsequent upgrades.

2

Second-Generation Technology Upgrade: Key Innovations and Demonstration Applications of Electrolyte and Stacks

Over the past two years, the core work of Dr. Li's team has been advancing the second-generation upgrade of IMABATTERY technology, focusing heavily on two core components–"Electrolyte" and "Stack"—to solve key obstacles to large-scale application.

Regarding the electrolyte, Dr. Li pointed out the limitations of the first-generation electrolyte: it relied on the configuration of high-purity chromium chloride and ferrous chloride. Not only was the cost high (due to strict impurity requirements), but the global production capacity of chromium trichloride crystals could only support an energy storage demand of less than 0.1 TWh per year. It also faced resource competition from the electroplating and tanning industries, making it impossible to match a "Terawatt-hour level" energy storage market.

To this end, the team broke through with the technology of "Preparing Electrolyte from Ferrochrome Alloy." Ferrochrome alloy is a common raw material for smelting stainless steel. The global annual production capacity is equivalent to an energy storage capacity exceeding 2.2 TWh, and reserves are abundant. The team first converts it into iron-chromium mixed crystals, transports them to the project site, and dissolves them in water for use. This "Solid Transport + On-site Configuration" significantly reduces raw material costs while also reducing electrolyte transportation and manufacturing expenses, solving resource and cost issues from the source.

The first-generation stack was a 960 cm^2 all-welded stack. Although it achieved the "all-welded" breakthrough, the size was small and the technology was unstable. Around 2023, Cougar Creek Technologies established a joint venture, Sichuan Weiyu Luopu Energy Co., Ltd., with Sichuan Weilide Company in Chengdu. Relying on Weilide's manufacturing capabilities, they spent nearly 10 months completing technical modifications and launched the second-generation 2800 cm^2 all-laser-welded polypropylene stack. Compared to existing stacks on the market, the new stack has a significantly reduced risk of leakage and improved performance and stability.

Currently, a 2.5 MWh demonstration project based on the second-generation technology has been running stably for over two months. The team is also designing standardized skid-mounted module products, covering specifications of

1MW/6MWh and above, with a minimum unit rated power of 1MW and a maximum power of 2MW. This is designed to adapt to the market demand for profit maximization while being equipped with a remote intelligent BMS system to reduce on-site operation and maintenance workload.

3

Scalable Value and Commercial Prospects of Iron-Chromium Flow Batteries

Regarding commercial feasibility, Dr. Li analyzed three aspects: cost, revenue, and resource logic, emphasizing the scalable value of iron-chromium flow batteries.

On the cost level, he revealed that the current project cost of the second-generation iron-chromium flow battery is conservatively estimated to reach $0.10-$0.14/Wh, making it the most cost-effective energy storage system on the market.

Regarding revenue calculation, the team based it on a total capital expenditure of $150/kWh ($50/kWh own funds, $100/kWh loan). Calculated with 50% round-trip system efficiency, annual O&M cost of $7.5/kWh, residual value of $50/kWh, 5% interest rate, 25-year lifespan, and 350 cycles per year.

In the absence of any policy subsidies, if the charging price is $0.02/kWh and the discharging price is $0.13/kWh, the full lifecycle average ROI reaches 12.9%; If the discharging price increases to $0.15/kWh, the average ROI can rise to 17.6%, yielding considerable returns.

Dr. Li particularly emphasized the resource logic behind choosing iron-chromium flow battery technology; He had researched vanadium flow batteries for a long time but found a bottleneck in global vanadium resources—90% of global vanadium production is consumed by the steel industry, leaving an amount for the energy storage industry that is far unable to match a terawatt-hour level market. In contrast, the production capacity and reserves of ferrochrome alloy can fundamentally support large-scale energy storage. This is one of the core reasons he switched to iron-chromium technology.

Finally, Dr. Li stated that the commercialization of energy storage should not only focus on cost reduction through technology, but also consider business models from the user side. If directly paired with clean energy or thermal power, purchasing electricity when it has not yet accessed the grid and not yet accrued additional fees can further reduce costs and increase profit margins. He hopes to jointly promote the large-scale development of the energy storage industry with industry peers through technology sharing and cooperation.